COOPERATIVE INSTITUTE FOR
CLIMATE and SATELLITES (CICS)

Scientific Report

VOLUME II: CICS-MD TASK REPORTS
(Part 1)

For the period:

April 1, 2013 – March 31, 2014

NOAA Grant NA09NES4400006

Dr. Fernando Miralles-Wilhelm, Executive Director

April 30, 2014

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1 PROJECTS

1.1 Data Fusion and Algorithm Development

Validation of Operational AMSR2 SSTs

Task Leader	Andy Harris
Task Code	AHAH_AMSR2_13
NOAA Sponsor	Mitch Goldberg
NOAA Office	NESDIS/JPSSPO
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: Code has been written and tested for AMSR-2 validation and datasets have been procured for a designated test period. Initial results indicate the performance of GAASP processing chain is meeting requirements. Interesting features are noted in data that illustrate the importance of understanding real SST signals from underlying geophysical processes that might be incorrectly interpreted as algorithm error.

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 which 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 scope of the work is intended to encompass both validation and feedback for algorithm improvement. Since we were only made aware of the provision of representative quality data in January 2014, and other projects had tight timelines (made even more demanding by personnel changes), and the project timeline runs July – June, only some of the intended analysis has been performed (sufficient to support NOAA's algorithm readiness review) to date. Key elements of our validation process are:

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.

Figure 1 illustrates an apparent cross-product feedback (an warm bias in retrieved SST at low wind-speeds). A potential source of the observed bias might be a deficiency in an emissivity model (explicit or implicit). However, since the bias is not observed in the nighttime data, it is much more likely that the observed biases are real, *i.e.* there is a geophysical explanation. In this case, the candidate is the phenomenon of diurnal warming.

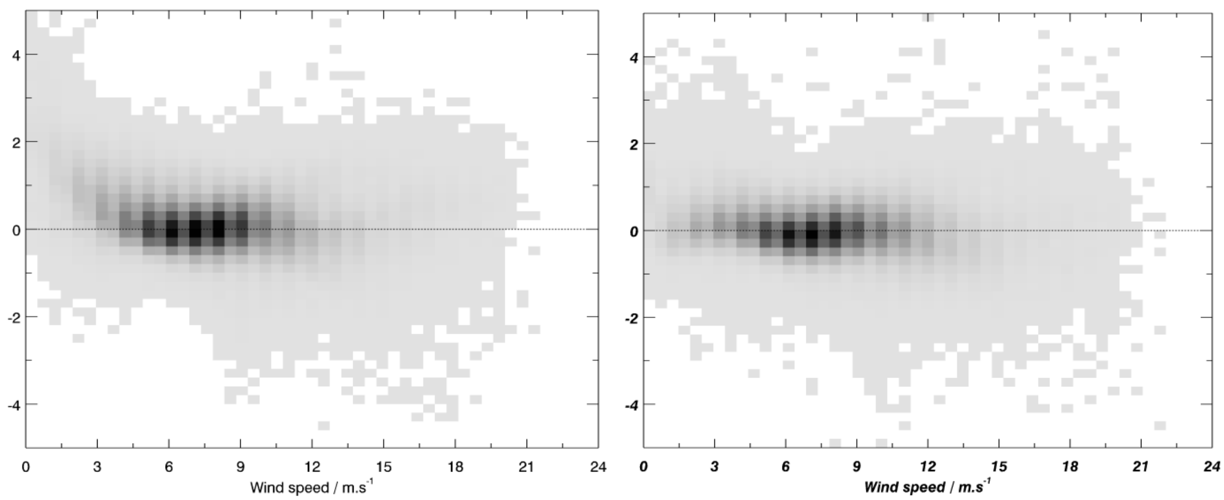

Figure 1. Bias in SST retrieved from AMSR with respect to OSTIA SST Analysis. Left panel shows bias for daytime data while right panel shows the same plot for nighttime data.

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 2014)

- Continue to refine analysis of AMSR-2 SST and BT products with the afore-mentioned tools to quantify: candidate calibration anomalies; geolocation/pointing errors; RFI contamination; inadequate rainfall flagging; and cross-product "interference"
- Comparison of anomalies with other geophysical phenomena. In particular, run our newly-developed global model of diurnal warming to account for possibility of low windspeed biases being due to geophysical differences
- Report findings to JPSS AMSR-2 project: potential areas for improvement in Level 1 & Level 2 products; and iteration on validation of Level 1 & Level 2 product accuracies
- As time permits, perform cross-comparison of AMSR-2 SSTs from Remote Sensing Systems with those from GAASP processing system, and ascertain most likely sources of product differences (retrieval algorithm, calibration differences)

PUBLICATIONS
None

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

PRESENTATIONS
None

OTHER
N/A

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

PERFORMANCE METRICS EXPLANATION
This task is only part of a major NOAA effort to produce SSTs (and other geophysical products) from AMSR-2 data. Thus, while it contributes to that effort, no products are produced explicitly as part of this task.

GOES-R Risk Reduction – Ocean Dynamics

Task Leader	Andy Harris
Task Code	AHAH_GOES_13
NOAA Sponsor	Ingrid Guch
NOAA Office	NESDIS/GOES-R3
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: The 4D-Var regional modeling and data assimilation system has been successfully ported from Oregon State University to the S4 supercomputer hosted at UW-Madison. A graduate student has been retained and is being trained in the use of the S4 and other NOAA computing systems, and in running the ocean model.

BACKGROUND

The goal of this task is to develop and evaluate alternative algorithms to satisfy the requirement for ABI Ocean Surface Currents (OSC) product generation. Although there is an Ocean Dynamics (OD) component to the GOES-R Algorithm Working Group (AWG), there have been some concerns expressed by end-user that the final product will not correctly represent the required current vectors. While the 80% AWG targets for OD accuracy were largely being met after the application of quality control measures based on a gradient strength metric, there is potential scope for improvement (see Figure 1).

During this project, collaborators at Oregon State University (OSU) have implemented and evaluated two approaches to estimate ocean surface currents, using satellite-derived sea surface temperature (SST) fields: "Feature Tracking;" and "Data Assimilation" into coastal circulation models.

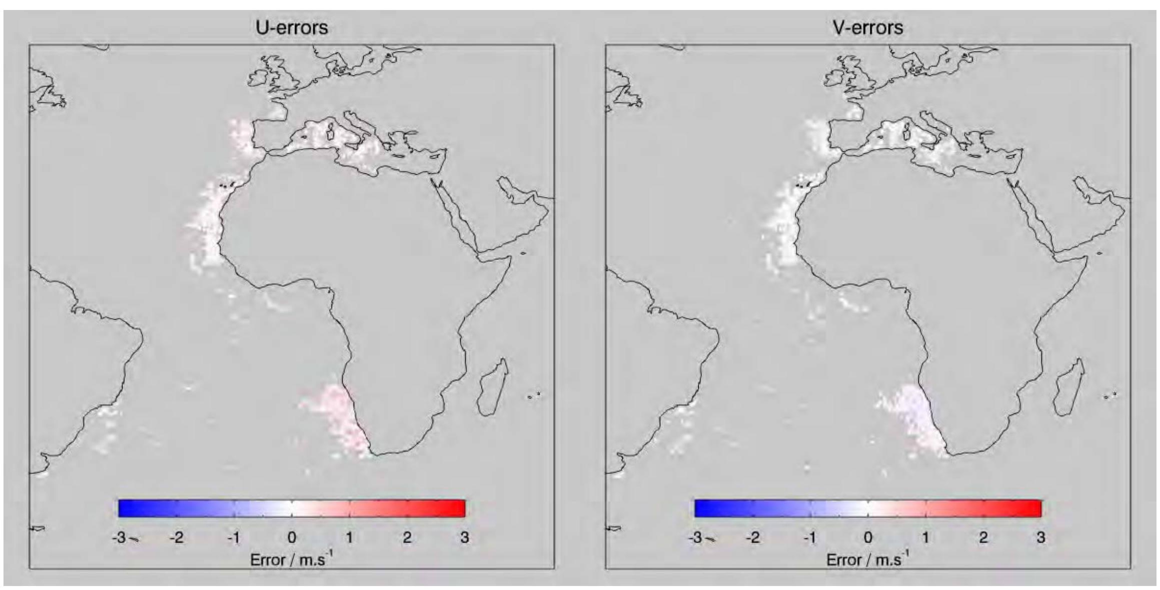

Figure 1. Locations and magnitudes of current U&V component biases w.r.t. Navy Global NCOM data. As can be seen, while the V-component shows relatively little bias, the U-component displays a significant geographical preference.

Results from the first approach, use of feature tracking methods, are consistent with previous evaluations – the methods recover velocity fields with directions of the velocities that are qualitatively reasonable but with speeds that are greatly underestimated. We are working to understand why this happens in an attempt to develop a methodology that would find only a small number of good velocities, for assimilation into ocean circulation models. Results from the second approach, data assimilation of the GOES SST fields into the dynamical ocean circulation model, are very positive, especially when multiple fields are assimilated (SST, altimeter SSH, coastal HF Radar surface velocities, etc.). The assimilation of the SST fields increases the realism of the model nowcast and forecast velocity and water property fields.

ACHIEVEMENTS

While significant results were obtained during the first two years of the project, most of these were accomplished by our partners at OSU (who received the vast majority of funding). During Year-3, residual project funds have been used to support a PhD graduate student at the University of Maryland. The student, Jeehye Han, completed her comprehensive exams and took the Data Assimilation class at UMD, in preparation for this research project. Another researcher, Dr Daniel Comarazamy (NOAA-CREST), has recently joined NOAA/STAR and has been instrumental in transferring technology from OSU to the NOAA S4 supercomputer.

Since the project is entering a enter a new educational and research phase, the goals are now more directed towards coupled modeling and data assimilation rather than the specific one of ocean currents. This has effectively been mandated by insufficient resource to enable the work to be done on the feasibility of a research-to-operations transition. To this end, substantial progress has been made on all of the intended goals:

- Familiarization with work accomplished by OSU
- Setting up student with access to modeling capability
- Procuring sample datasets for initial assimilation runs
- Results of initial tests for coupled modeling with different assimilation methods (3-d VAR, 4-d VAR, Ensemble Kalman Filter). This is only in the initial phase

PUBLICATIONS

None

DELIVERABLES

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

PRESENTATIONS

None

OTHER

N/A

PERFORMANCE METRICS

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# of invited presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	1
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

The entire budget for this project (residual funding originally intended for Year 2 but deferred to Year 3) is devoted to the support of the graduate student.

Microwave and Diurnally Corrected Blended SST

Task Leader	Andy Harris
Task Code	AHAH_JNBS_12
NOAA Sponsor	Tom Schott
NOAA Office	NESDIS/OSD/SGSP/SEID
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: Metop FRAC processing has been incorporated into operations. A state-of-the-art diurnal correction scheme including Stokes Drift parameterization has been developed and tested.

BACKGROUND

NESDIS have been in the process of developing a new high-resolution (now 0.05°×0.05°) global SST analysis 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. The other key element of the new analysis is the use of three different correlation lengths, with the final result being interpolated based on local data density. This has the effect of maximizing feature resolution where sufficient data are available without introducing excessive noise.

Figure 1 presents high-level design and data flow of the Geo-Polar SST Analysis processing system. Below are the accomplishments during this year of the project, followed by future plans for the next year.

ACCOMPLISHMENTS

High-resolution Metop FRAC SST data have been successfully been incorporated into the analysis system. The conversion of the ingest modules to C means that the processing penalty for the greatly increased data volume has been small. In addition, higher resolution has facilitated better quality control during the ingest phase since more polar data now fall within a single input grid, enabling a measure of outlier rejection to be performed. In this regard, the polar data ingest modules have been rewritten to account for the three different format types that have been generated by the ACSPO team in the recent past. The latter (GHRSST L2P) does provide some scientific benefit since pixel-based uncertainty estimates (single sensor error statistics, or SSES) are provided in a layer of the product, and the new ingest code has the facility to use or ignore such information upon request.

Most effort has been expended on the development of the diurnal correction capability of the processing system. As may be deduced from the algorithm flow diagram (Figure 1), the correction must be applied to every single incoming pixel prior to its incorporation into the gridded super-observation for that datatype. The ingestion code accesses the required correction from space-time interpolation of the output of the diurnal warming model, which is gridded on 0.5°×0.5°.

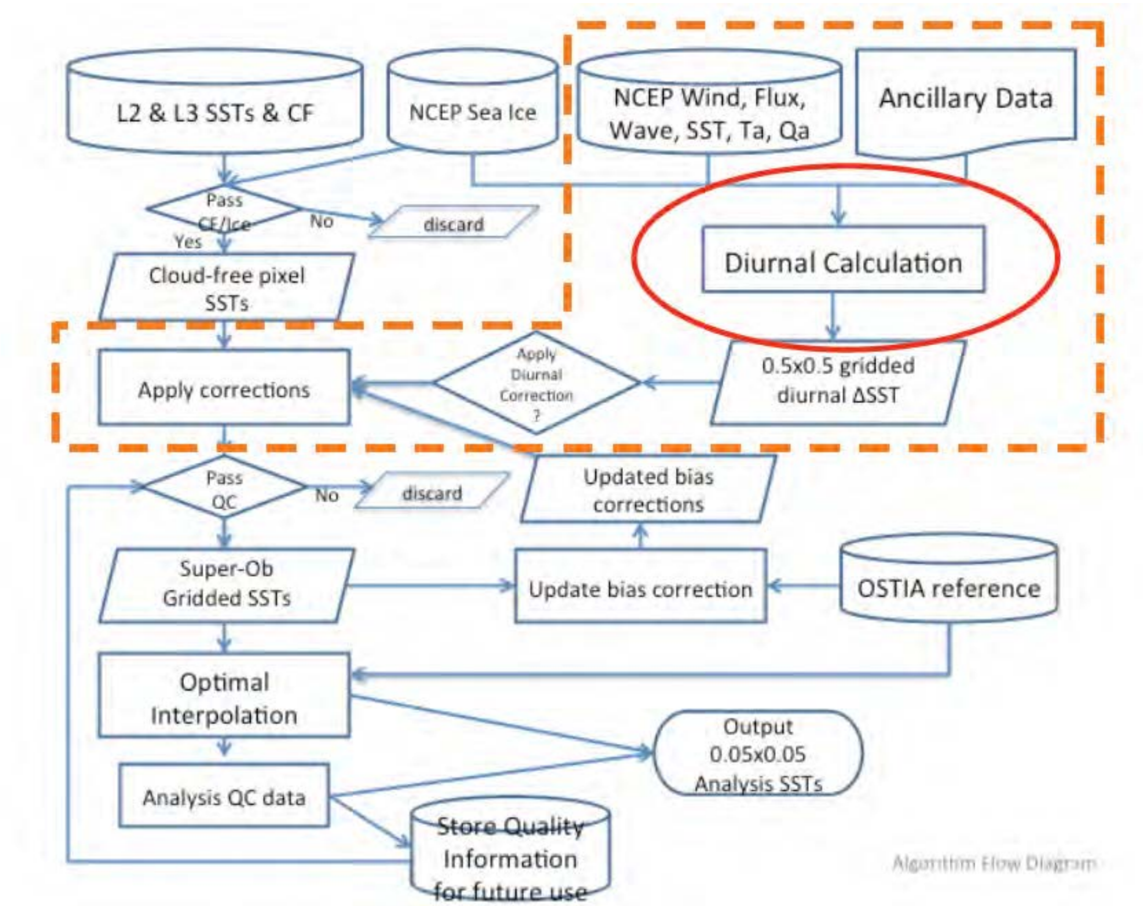


Figure 1. Geo-Polar SST Analysis processing system and data flow. The diurnal correction component is contained within the orange dashed lines

The diurnal correction module effectively runs in standalone mode prior to the data ingest phase of the main analysis. This is an inevitable consequence of needing the estimates of diurnal excursion over the full 24-hour period at the start of the analysis procedure, *i.e.* at the data ingest stage. As mentioned in last year's report, provision of wave data on an operational basis enables the prospect of incorporating additional terms into the diurnal model itself. Near surface wave processes and breaking also provide an important contribution to turbulent mixing and Kantha and Clayson enhanced their baseline model to account for these effects (Kantha and Clayson, 2004). Interactions between gravity waves and turbulent motions in the upper layers of the ocean lead to extraction of energy from waves by turbulence in the oceanic mixed layer. Neglecting these effects could lead to significant errors in the simulated diurnal warming under certain conditions. The addition is manifested most prominently where the terms containing the velocity components U and V are duplicated with the components of the wave-related Stokes Drift (U_s and V_s) in place of the mean velocities. The Stokes Drift velocities are approximated from the primary wave period and significant wave height assuming a Pierson and Moskowitz (1964) spectral shape following the approach of Webb and Fox-Kemper (2011). An example of the diurnal excursion predicted by the model is shown in Figure 2.

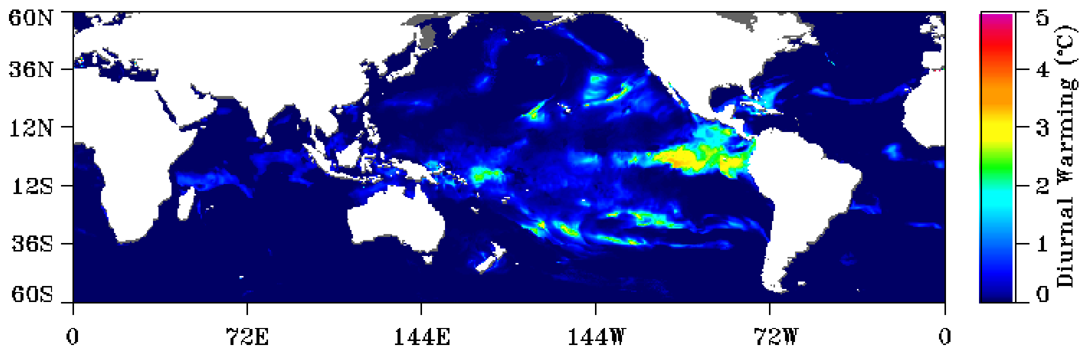


Figure 2: An example of diurnal warming (skin SST – 5 m depth) predicted by the model for 00 UTC, March 21st, 2013. The model uses NCEP GFS fluxes of heat and momentum, and wave parameters from the WaveWatch III system.

All project deliverables (documentation and software) and milestones have been accomplished. Currently, the software system is being tested and preparations are under way for the Test Readiness Review (TRR).

PLANNED WORK

- Continue work to assess the performance of the processing system
- Incorporation of AMSR-2 SSTs into the analysis once the data become available on an operational basis
- Refinement of the uncertainty estimation for the diurnal correction model, based on analysis of validation results and additional offline studies
- Incorporation of a revised bias correction scheme and preparations for Sentinel-3 SLSTR data
- Transition of diurnally corrected algorithm and microwave capability to operations

PUBLICATIONS

None

DELIVERABLES

- Updated ingest software, incorporating Metop-B FRAC;
- Documentation for new diurnally corrected analysis.

PRESENTATIONS

Maturi E., A. Harris, J. Mittaz, P. Koner, G. Wick, N. Shay, J. Sapper, D. Donahue, M. Eakin, S. Heron, W. Skirving, H. Gu, 2013: Applications of NOAA's operational Sea Surface Temperature products, *Joint AMS-EUMETSAT Meeting*, 16-20 September, 2013, Vienna, Austria.

Maturi E., A. Harris, J. Mittaz, P. Koner, G. Wick, N. Shay, J. Sapper, D. Donahue, M. Eakin, S. Heron, W. Skirving, H. Gu, 2013: Applications of NOAA's operational Sea Surface Temperature products, *NASA SST Science Team Meeting*, 29 – 31 October, 2013, Seattle, WA

OTHER

None

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	1

Assimilation of VIIRS SSTs and Radiances into Level 4 Analyses

Task Leader	Andy Harris
Task Code	AHAH_JPSS_13
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: Code has been written and tested to ingest all three variants of the ACSPO VIIRS SST data format. Trial runs have shown a significant increase in data coverage obtained from VIIRS, although biases are somewhat characteristic of previous AVHRR products. This is not surprising since the current ACSPO algorithms are essentially identical to those developed for AVHRR, *i.e.* they do not take advantage of additional channels in the retrieval.

BACKGROUND

Two major SST analysis products generated by NOAA are the Real Time Global SST (RTG) and the Geo-Polar blended. Both the RTG and Geo-Polar blended products have a wide range of users. The RTG is one of the primary SST analyses used by the National Weather Service, and of importance to both their atmospheric and ocean forecasting applications. The Geo-Polar blended product is a critical component of the Coral Reef Watch program (a program with substantial international visibility), the Oceanic Heat Content product (used in tropical storm prediction), the wide range of CoastWatch & OceanWatch users, and the NWS Ocean Prediction Center (for their high-seas forecasts).

This project involves the use of SST observations from NPP VIIRS as input to the two aforementioned analyses. Improvements are anticipated to be significant given that VIIRS is a much better characterized and less noisy sensor than those currently used in these analyses. After the VIIRS data has been incorporated into the analyses, the impact of the VIIRS data will be assessed. As part of the overall project, the improvement to the RTG is being assessed by the RTG team by comparing with their current system. If the resultant analysis is equal or superior to the current AVHRR and *in situ* data already in the system, it will be implemented as soon as possible as part of the NWS NCEP operational product suite.

ACHIEVEMENTS

Code has been written and tested for the ingestion of the three different formats of NPP VIIRS SST produced by the ACSPO team, namely HDF, netCDF and L2P. The latter is a specialized format that contains product layers specified by the Group for High Resolution SST (GHRSST), and is also in netCDF format. Once ACSPO VIIRS becomes available in L2P format, we will be able to test the extra capability of our ingestion software to take account of the single sensor error statistics (SSES) provided for each pixel.

Figure 1 shows the bias correction for the VIIRS nighttime SST product with respect to the RTG_HR_SST for day 150 of 2013. Note that these are the correction values, thus the prominent cool “bias” in the Southern Ocean is indicative of the VIIRS SST being warm *cf.* the RTG. In this instance, however, it is quite likely that the bias is in the RTG rather than the VIIRS, since bias patterns similar to this have been observed for other L4 analysis products w.r.t. the RTG.

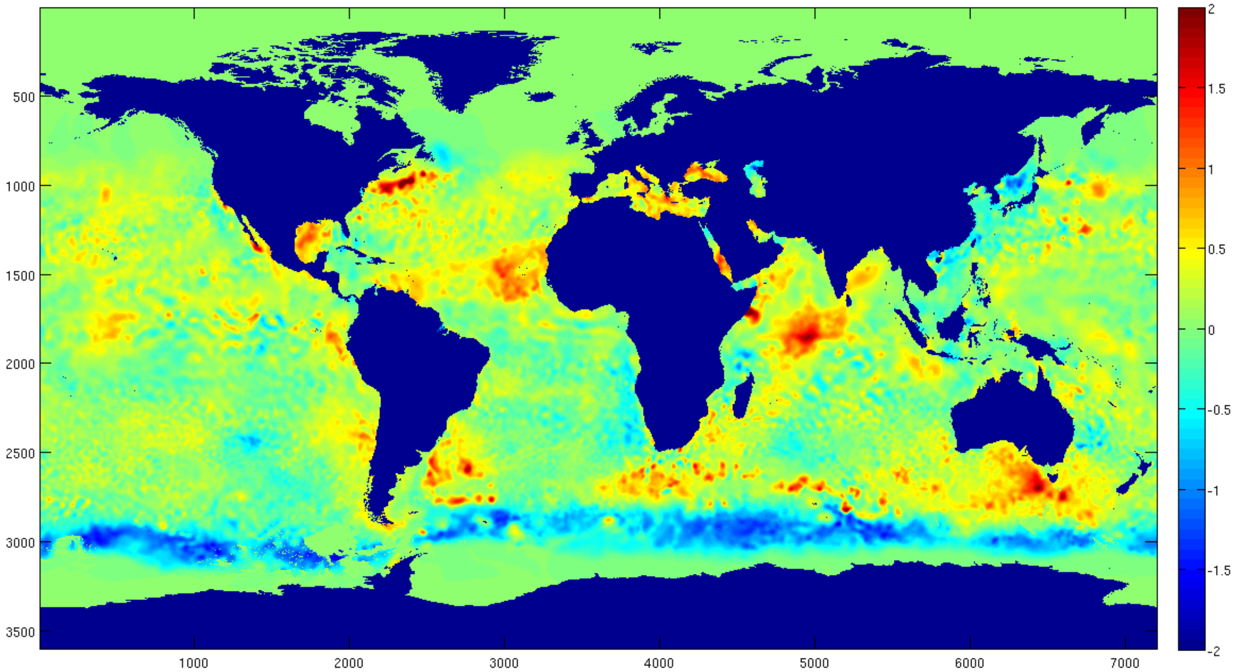


Figure 1: Bias correction for nighttime ACSPO VIIRS SST w.r.t. RTG for 2013 day 150. The cool band of negative correction in the Southern Ocean is likely to be due at least in part to a bias in the RTG.

An example of the resolution of individual SST features in the VIIRS data can be seen in Figure 2. Note that this is on the 0.05 degree input grid of the Geo-Polar SST Analysis, thus each pixel represents the quality-controlled "super-ob" of a number of VIIRS pixels, including the benefits of averaging after out-lier rejection. The feed-through to the final analysis can be discerned in Figure 3.

PLANNED WORK

- Testing of the SSES that should be provided in the GHRSST L2P version of the ACSPO product
- Continue assessment of the impact of VIIRS on RTG SST Analysis (NCEP)
- Investigate alternative bias correction estimates using VIIRS radiance data
- Transition algorithm to operations
- Assess impact of improved Geo-Polar SST analysis on Coral Reef Watch products

PUBLICATIONS

None

DELIVERABLES

- Tested VIIRS ingestion code transitioned to NOAA Operations;
- Geo-Polar SST dataset provision to NOAA Coral Reef Watch

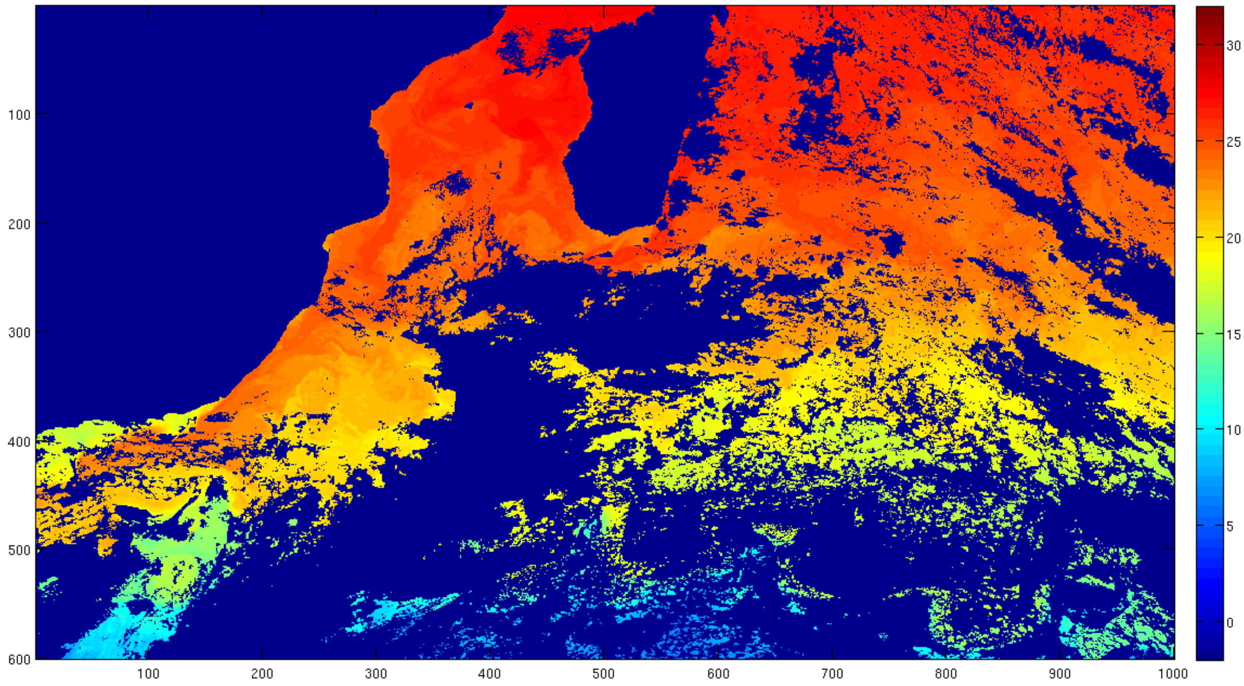


Figure 2: Nighttime ACSPO VIIRS SST after preprocessing onto the 0.05 degree grid in the vicinity of the Agulhas and Madagascar.

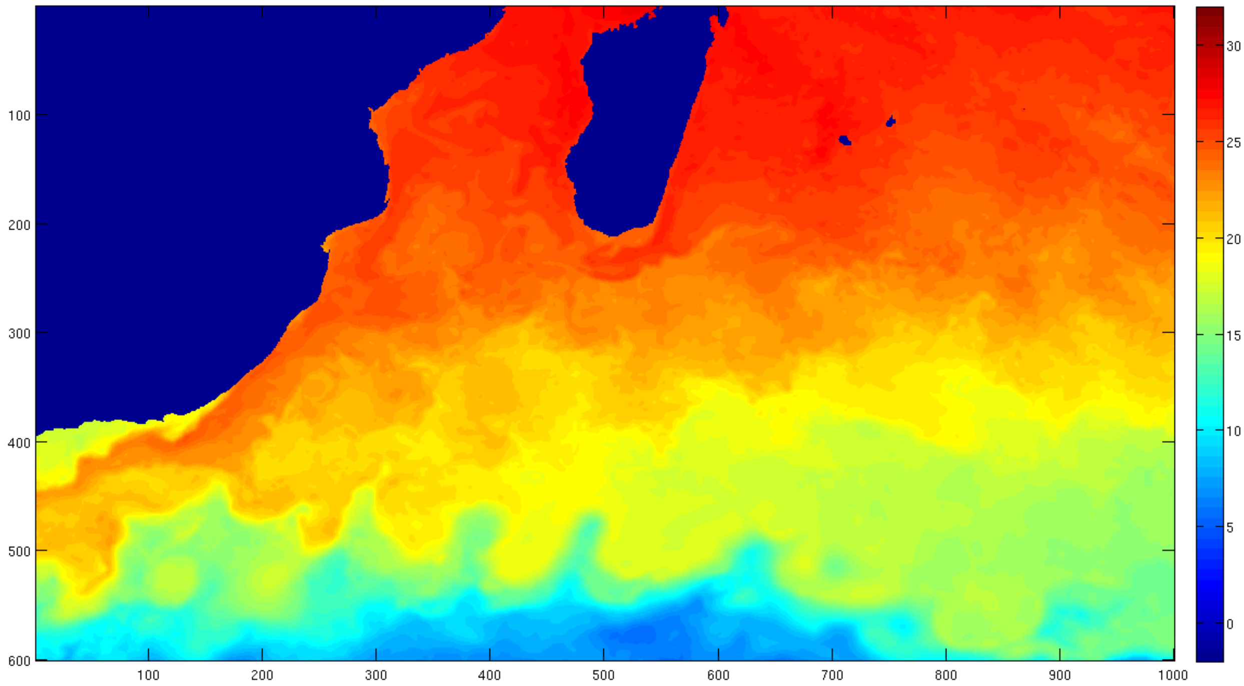


Figure 3: Final Geo-Polar SST analysis after incorporation of the VIIRS SST shown in Figure 2. Note that the high-resolution features present in the VIIRS data are generally well-retained.

PRESENTATIONS
None

OTHER
N/A

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

PERFORMANCE METRICS EXPLANATION
The budget for year 2 has been split over Years 2 & 3, so a number of results will extend into a third year, as described above.

OSU-CIOSS Support to the GOES-R Risk Reduction Program – Ocean Dynamics

Task Leaders	Alexander Kurapov/P. Ted Strub
Task Code	AKAK_GOESR_13
NOAA Sponsor	Paul DiGiacomo/Eileen Maturi
NOAA Office	NESDIS/SOCD
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 0%; Theme 3: 50%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 10%; Goal 3: 20%; Goal 4: 50%; Goal 5: 20%

Highlight: Two methods are compared to estimate surface currents from SST fields. Data Assimilation is the preferred method; but modified Feature-Tracking velocities can also be useful, if carefully evaluated.

BACKGROUND

In this and a companion GIMPAP project, we have developed and evaluated two methods that use POES and GOES SST fields to estimate surface velocities in the ocean: Feature-Tracking (FT) and Data Assimilation (DA). The original GOES-R3 Dynamics plans called for the use of FT methods between sequential GOES-R SST images to estimate surface displacements and velocities. We proposed to improve and evaluate this method and to compare its results to an alternate approach that assimilates the SST fields directly into a primitive equation ocean circulation model. That model has been developed and improved with GOES-R, GIMPAP and other funding, as reported separately (AKAK_GIMPAP_13). Here we report on the FT results and plans for comparisons.

ACCOMPLISHMENTS

In the FT method, a small region of SST pixels in one image is tested for pattern matches over a range (spatially) of subwindows in a subsequent image, using various metrics of similarity – correlations, minimum scalar differences, etc. Other methods of estimating movement of pixels include optical flow techniques and the use of neural nets. A number of these have been tested over the past three years, with our selection of the original maximum cross-correlation (MCC) FT method, after high-pass filtering the SST fields. Our innovation has been the use of more accurate statistics to determine which of the MCC correlations and displacements are statistically significant and to keep only that set to estimate surface velocities. The result is a sparse set of surface velocities instead of a complete field of velocities, but with greater certainty in each of the retained velocities. Whereas complete fields of velocities could be used directly to estimate displacements of objects (spills, debris, HABs, lost ships and bodies), the sparse fields produced by our method are more suitable for inclusion in further analysis steps, such as: (1) Assimilation into dynamical models; (2) Combination with similar sparse fields from other pairs of GOES or POES SST images; and (3) Combination with other data from satellites (altimeter surface geostrophic velocities, scatterometer surface Ekman velocities), coastal radars (surface velocities) and *in situ* sensors (surface drifter displacements, current meters on moorings, ship measurements).

We have tested the method on both model SST fields and on the clearest available SST fields from POES sensors (AVHRR, Figure 1) and present GOES sensors, as well as simulated fields with reduced spatial resolution compared to AVHRR but better signal to noise characteristics (more like AVHRR than present GOES data). This last test is meant to approximate what might be expected from the GOES-R SST fields (Figure 2). Results using the present GOES data are very poor, due to the coarse resolution and (especially) the poor quality of the SST data and are not shown.

In Figure 1, the right hand panel demonstrates the noisy field obtained from use of a constant cut-off value for the minimum correlation coefficient, r_{min}, that is used to determine significance of the correlations. In the middle panel, a regression is calculated between the original SST pixel values and those from the displaced region in the second image. Residuals from that regression are tested to determine the number of effective degrees of freedom in the fields and this is used to determine the specific value of r_{min} for that region, which is then use to accept or reject the displacement. Comparing the middle and right panels to the left panel (model velocities), the new method can be seen to eliminate most (not all) of the vectors that are inconsistent with the model velocities.

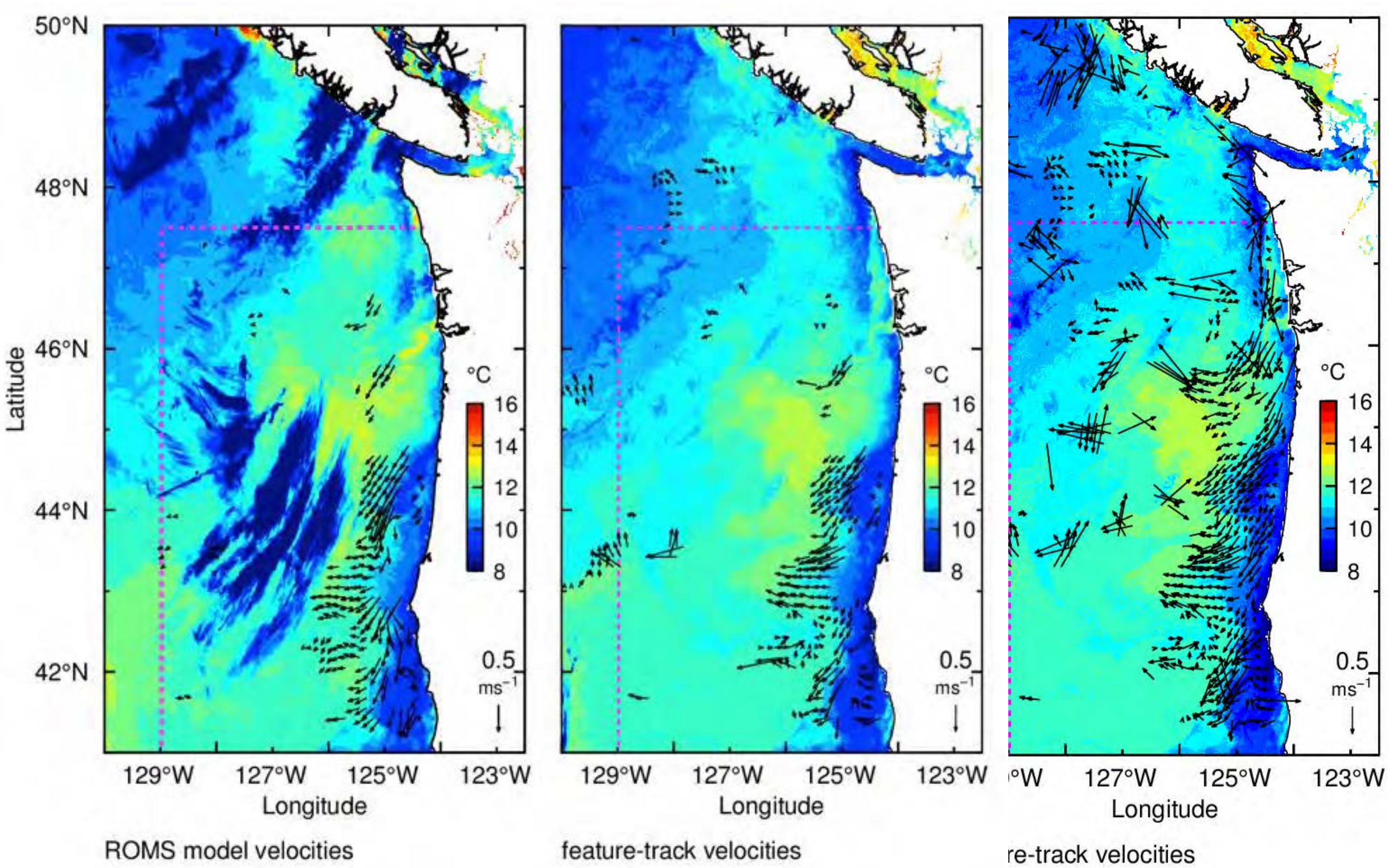


Figure 1. AVHRR images from May 4 (left) and May 5, 2013 (middle and right), separated by ~6 hours, overlaid with surface velocity vectors derived by Feature Tracking using our modified test of significance (middle) or the traditional constant r_{min} (right) and from the ROMS model from the same time (left), interpolated to the locations of the retained FT velocities from the middle panel. No data assimilation is used in the ROMS model. The limits of the model domain is shown by the purple box.

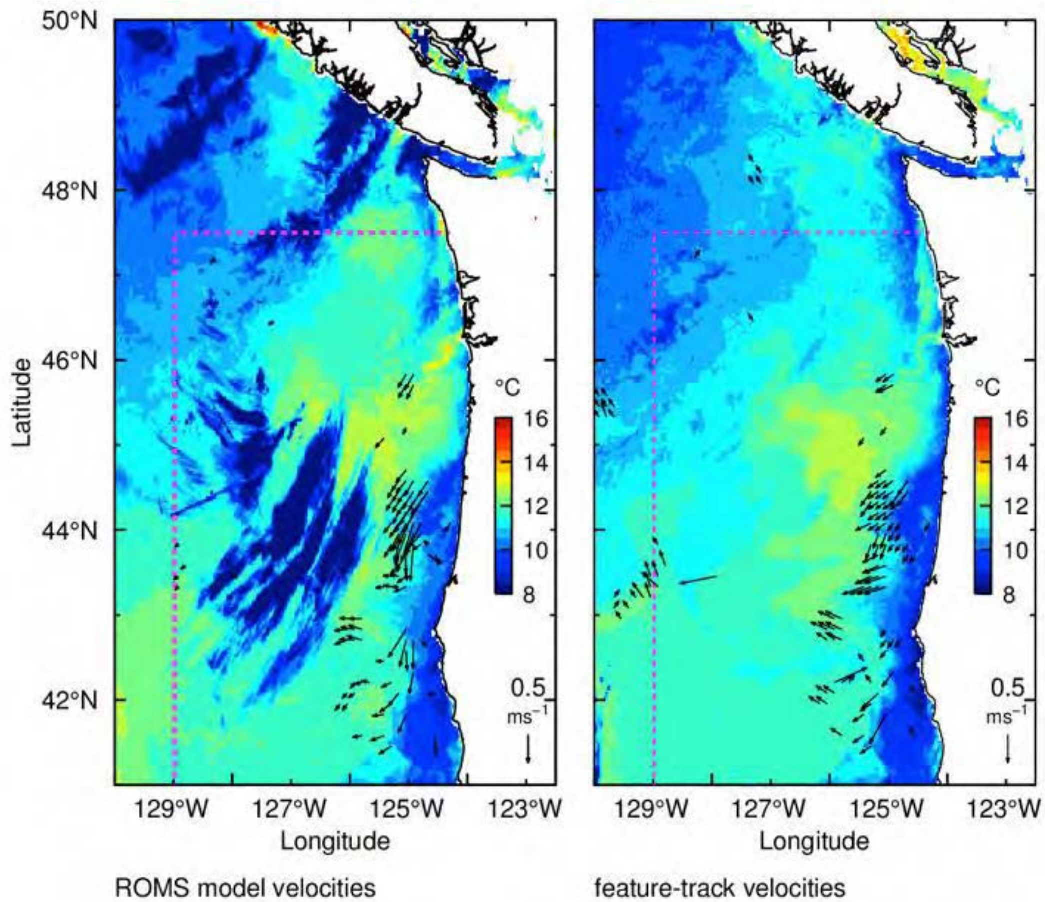


Figure 2. The same AVHRR images as in Figure 1, reduced in resolution to pixel sizes of 2-3 km to approximate GOES-R images, overlaid with surface velocity vectors derived by Feature Tracking using our modified test of significance (right) and from the ROMS model from the same time (left), interpolated to the locations of the retained FT velocities.

In Figure 2, the same modified r_{min} method is used on the reduced resolution images (approximating the GOES-R fields). The number of retained vectors is smaller than for the original AVHRR images, with 1-2 apparent "blunders". However, if there were no model or other data, the fields would still provide useful information in their regions of coverage. Given the larger number of potential pairs of images from the GOES coverage than for the POES images, the use of these methods with
GOES-R data represents a chance to combine surface velocities from multiple image pairs over short periods and create more complete coverage than possible with individual pairs of images from POES images. Note that the reduction in noise expected for GOES-R SST retrievals (compared to present GOES SST) is required to make good use of these methods.

The approach taken here is similar to that applied to the determination of cloud motion by Feature-Tracking methods. Rather than obtaining a dense field of velocities, a few clouds are identified with definite features and these are followed to produce a sparse field of relatively accurate velocities at different heights in the atmosphere, which are then assimilated (among other data) into atmospheric numerical forecast models. The sparse fields of surface ocean velocities could be assimilated similarly, when NOAA implements a more complete ocean forecast system, including data-assimilating ocean circulation models. The velocities produced by FT methods in the ocean will be most useful where SST signals are large and can serve as a tracer for motion, such as in coastal upwelling regions such as the California Current.

PLANNED WORK

- Write up the methodology in a more complete report, which will be shared with our SOCD collaborators (Eileen Maturi and Andy Harris).
- Run the ROMS ocean circulation model for the same period with the assimilation of the same SST fields, to determine the extent to which the assimilation changes the model fields.
- Write and submit a peer-reviewed paper describing the results, including a comparison of the FT fields with the fields that result from assimilation of the same SST fields into the model.

PUBLICATIONS

Pierce, S. D., P. T. Strub, and A. Kurapov, A modified feature-tracking method for estimation of surface velocities from sequences of satellite SST fields, in preparation.

DELIVERABLES

- Report on the algorithm details to allow its implementation at NOAA.

PRESENTATIONS

Strub, P. T., A. Kurapov, and D. Foley, 2013: Partnerships in the Use of GOES SST in the CONUS (poster). *NOAA 2013 SATELLITE CONFERENCE for Direct Readout, GOES/POES and GOES-R/JPSS Users,* April 9, 2013.

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	N/A
# of graduate students formally advised	1
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

This year, we developed the improved FT technique and improved the DA methodology. This is a continuation of previous work and concludes this project (a proposal to continue the work was not funded). The model development continues with other funding but the FT algorithm development will conclude with a more detailed report to our sponsors and a manuscript that will be written with the remaining 1.3 months of funding. P. T. Strub supervised an MS student during the past year; the student finished his MS degree in March 2014 and is continuing for a PhD.

Evapotranspiration and Drought Monitoring Using GOES-R Products for NIDIS

Task Leader	Dr. Christopher Hain
Task Code	CHCH_EADM_13
NOAA Sponsor	Dr. Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS 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: 40%; Goal 2: 25%; Goal 3: 10%; Goal 4: 25%

Highlight: ALEXI ET and ESI products were tested using MSG and MODIS as a proxy for current GOES-R products over Africa, Europe and CONUS. The new proxy-based products were shown to provide much higher resolution while providing similar accuracy as current GOES-based products. Findings from this project will help motivate development of operational ALEXI products in the GET-D product system as GOES-R products become available.

BACKGROUND

Monitoring evapotranspiration (ET) and the extent and severity of agricultural drought is an important component of food and water security and world crop market assessment. Agricultural systems are climate-sensitive, and conventional surface instrument networks are sparse and report with delays, therefore, satellite remote sensing and modeling play a vital role in monitoring regional water use and providing early warning of impending moisture deficits, and can be used to supplement coarser resolution data from weather and precipitation networks to assess drought conditions. Because land-surface temperature (LST) is strongly modulated by evaporation, thermal infrared (TIR) remote sensing data carry valuable information regarding surface moisture availability and therefore have been widely used to map ET, drought, and vegetation stress. Signatures of vegetation stress are manifested in the LST signal before any deterioration of vegetation cover occurs, for example as indicated in the Normalized Difference Vegetation Index (NDVI), so TIR-based drought indices can provide an effective early warning of impending agricultural drought. Evapotranspiration deficits in comparison with potential ET (PET) rates provide proxy information regarding soil moisture availability, without any need for knowledge of antecedent precipitation. In regions of dense vegetation, ET probes moisture conditions in the plant root zone, down to meter depths. Our group has spearheaded 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 demonstrating complementary value in combination with standard drought indices that reflect water supply.

Fully automated ALEXI ET and drought monitoring systems have been implemented at 10-km resolution over the continental U.S. using TIR and shortwave information from current GOES instruments. With the launch of GOES-R, our capabilities for ET and drought monitoring will be significantly enhanced due to substantial improvements in spatiotemporal resolution, radiometric accuracy, and cloud-clearing capabilities. With GOES-R, the resolution of ALEXI ESI and ET products can be improved to 2-km. This will significantly improve utility to the drought community and action agencies served by NIDIS, who are demanding drought information at increasingly higher spatial resolution to support decision making at the sub-county scale.

ACCOMPLISHMENTS

During the past year, our research group has continued the assessment of ALEXI ET and ESI products in preparation for the future GOES-R mission using MSG and MODIS as proxy datasets over Africa and Europe. We have collected and archived all necessary MSG-SEVIRI (a GOES-R proxy) input products (e.g., land surface temperature; incoming shortwave radiation; surface albedo; leaf area index) from the Land Surface Analysis Satellite Applications Facility (LSA-SAF) for the year 2013, extending our current climatology from 2007-2013. All necessary meteorological inputs for ALEXI have also been processed and archived, mainly in the form of daily WRF simulations for each day during the study period. The ALEXI evapotranspiration climatological database (2007-2013) has been processed and archived at 3 km over Europe using the aforementioned input fields. The seven-year climatology now serves as the initial period for the computation of the Evaporative Stress Index (ESI) which has been shown to be an effective drought monitoring tool over the United States. ESI over Europe has been evaluated against common drought indicators and shown to strongly represent current drought conditions over the region. Therefore, it’s been concluded that the increased spatial and spectral resolution of the future GOES-R sensor will lead to significant improvements in drought monitoring over North America, where stakeholders are currently in need of high resolution satellite-based products to supplement current drought indicators which mainly rely on observed precipitation. The impact of higher resolution products were tested using a recently developed method using high resolution MODIS thermal information from day-night LST differences (~3 km) over the CONUS. Figure 1 shows this proxy ESI product for the current 2013-2014 drought over California, compared to our current capabilities where ESI is only provided at 10 km. The future GOES-R products at 2-km will provide much finer detail of drought conditions than current capabilities.

Our research group have also extensively evaluated ALEXI surface fluxes using MSG as a proxy for GOES-R over the Nile River Basin, a region with very large spatial differences in water use. Figure 1 shows the comparison between ALEXI fluxes and fluxes from the Noah LSM. There is relatively strong agreement in energy balance fluxes as shown in b). From a model development perspective, the diagnostic assessments proved useful in evaluating irrigation sub-modules developed for Noah. The MODIS ET product did not reliably reproduce water flux estimates from either irrigation scheme, possibly due to a failure in the VPD-based constraints on soil moisture over these systems. Comparisons between Noah and ALEXI simulations also helped to identify areas for improvement in the diagnostic system, in terms of treatment of satellite inputs and modifications to modeling algorithms. Potential biases in satellite-derived insolation were identified over portions of the modeling domain, including the Ethiopian Highlands and Equatorial Lakes regions, and were spatially well correlated with discrepancies in RN forcing and H flux. A persistent wet anomaly along the south coast of the Horn was associated with incomplete cloud clearing in the LSA SAF LST product, facilitating improved screening of the morning LST time series used to create the DTRAD morning temperature rise inputs to ALEXI. Finally, ET biases over regions of high topographic relief point to the need for slope and aspect corrections to radiation inputs to ALEXI.

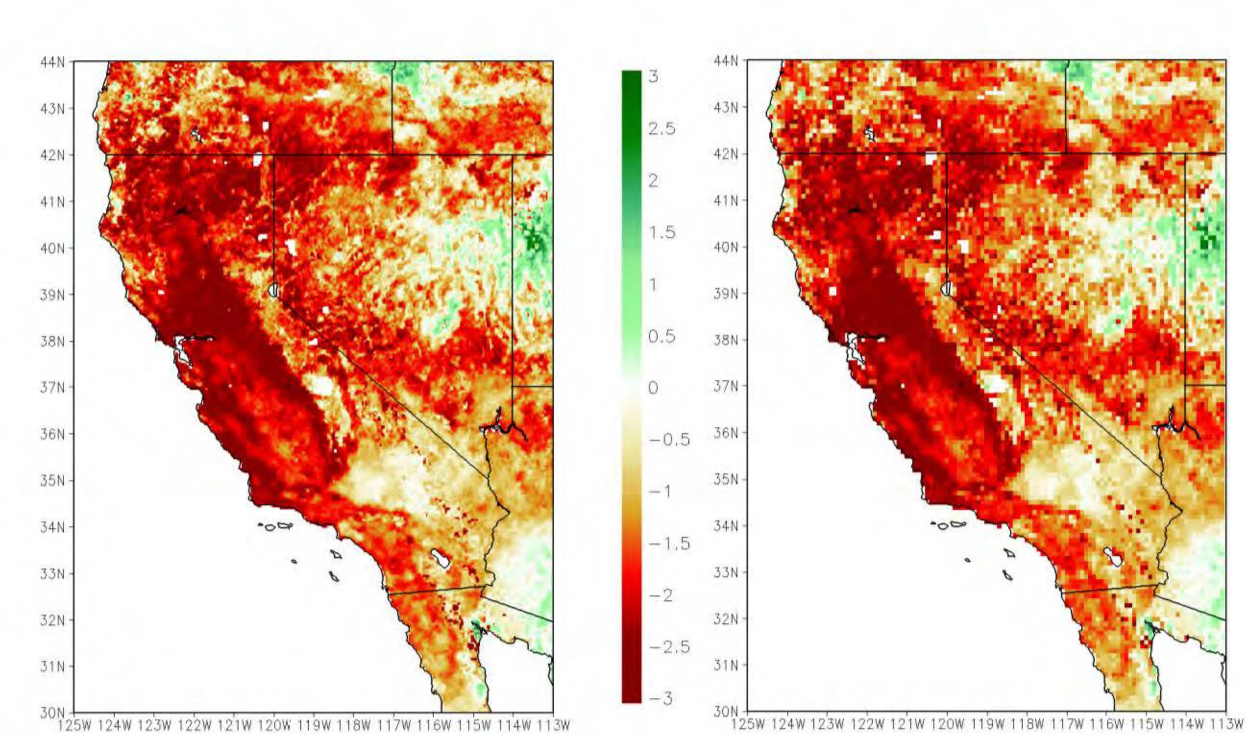


Figure 1. Example for March 27, 2014 for the GOES-R proxy (MODIS-based) ESI (left) at 2 km and the current GOES ESI capability at 10 km.

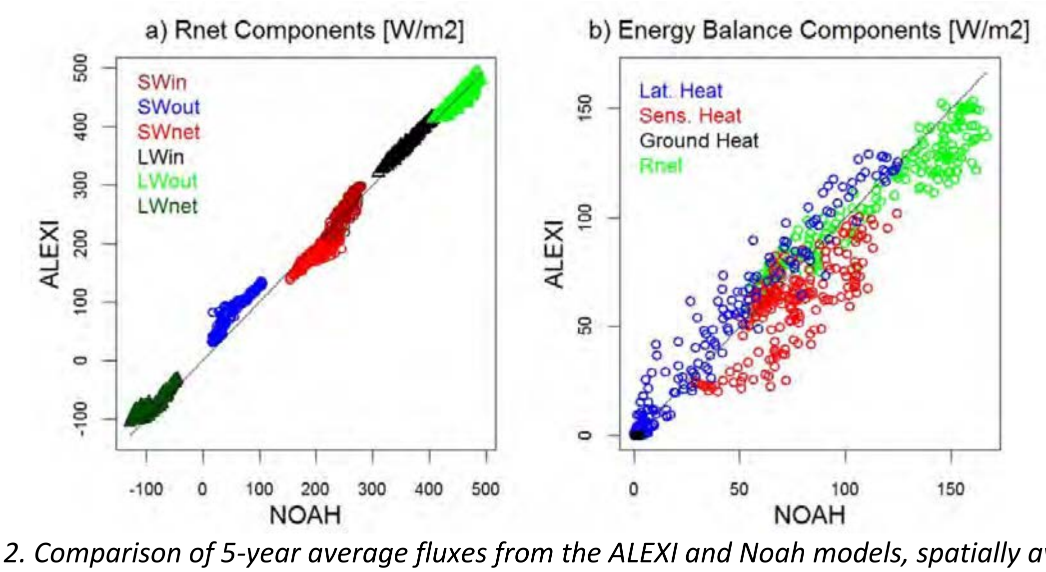


Figure 2. Comparison of 5-year average fluxes from the ALEXI and Noah models, spatially average over the Nile River Basin.

PLANNED WORK
Project ended in 2013.

PUBLICATIONS

Yilmaz, M. T., M. C. Anderson, B. Zaitchik, **C. R. Hain**, W. T. Crow, M. Ozdogan, J. A. Chun and J. Evans, 2013: Comparison of prognostic and diagnostic surface flux modeling approaches over the Nile River basin, *Water Resour. Res*., **50**, 386-408.

Parinussa, R. M., M. T. Yilmaz, M. C. Anderson, **C. R. Hain** and R. A. M. de Jeu, 2013: An intercomparison of remotely sensed soil moisture products at various spatial scales over the Iberian Peninsula, *Hydrological Processes*, In Press.

Anderson, W. B., B. Zaitchik, **C. R. Hain**, M. C. Anderson, M. T. Yilmaz, J. Mecikalski, and L. Schultz, 2012: Towards an integrated soil moisture drought monitor for East Africa, *Hydrol. Earth Syst. Sci*, **16**, 2983-2913.

DELIVERABLES
GOES-R proxy products of ALEXI ET and ESI have been evaluated and shown to perform consistent with current capabilities while providing better spatial resolution. Findings will be used to motivate future GOES-R products using ALEXI surface flux information.

PRESENTATIONS
Not yet done.

PERFORMANCE METRICS

# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	1
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	3
# 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	0

PERFORMANCE METRICS EXPLANATION

We developed and tested ALEXI ET and ESI capabilities using MSG and MODIS as a proxy for the future GOES-R sensor. Our research shows that these proxy-based products will provide significant improvements to spatial resolution of ALEXI products while providing the same level of accuracy as compared to current capabilities. Research from this project lead to three peer-reviewed papers from our research team and direct collaborators. Findings from this work will potentially be transitioned into the currently under development GET-D ET and Drought Product System at NOAA.

Enhancing Soil Moisture Data and their Applications for Agricultural and Numerical Weather Forecasts

Task Leader	Dr. Christopher Hain
Task Code	CHCH_SMDA_13
NOAA Sponsor	Dr. Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS 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: 40%; Goal 2: 25%; Goal 3: 10%; Goal 4: 25%

Highlight: As part of the NASA project team, we are tasked to provide global soil moisture data product to USDA Foreign Agricultural Service (FAS) and NOAA NWS-NCEP weather forecast models. In the past years, we continuously provided daily satellite soil moisture data product from European Space Agency's Soil Moisture Ocean Salinity (SMOS) satellite to the USDA-FAS for their world crop forecast analysts.

BACKGROUND

The primary goal of the project is to extend and enhance soil moisture data product for applications in the crop forecast and for assimilation into numerical model. In the previous years, soil moisture data products from AMSR-E on NASA's Aqua satellite, WindSat of Naval Research Lab, and SMOS satellite of European Space Agency. AMSR-E has stopped normal operation since Oct 2011. SMOS was used as a contingency data source. With the launch of JAXA's GCOM-W1 satellite, the on-board microwave sensor AMSR2 is very similar to AMSR-E. So the specific task for this FY13 project is to generate a good quality global soil moisture data product for the crop forecast applications.

ACCOMPLISHMENTS

Global soil moisture data product from NOAA-NESDIS SMOPS based on ESA SMOS satellite has been continuously integrated to the satellite data stream used by USDA-FAS Crop Explore (See Fig. 1 for SMOS daily soil moisture map from SMOPS and Fig 2 for USDA FAS satellite data feed list).

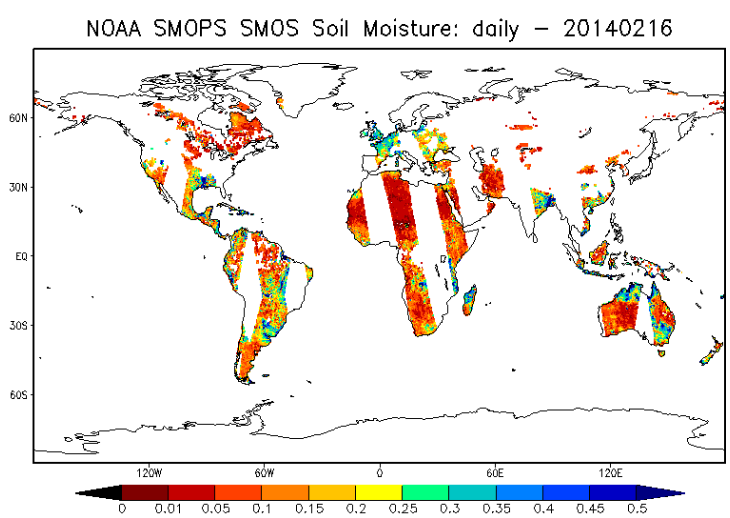


Figure 1. Global soil moisture map processed by NOAA-NESDIS SMOPS based on ESA SMOS satellite.

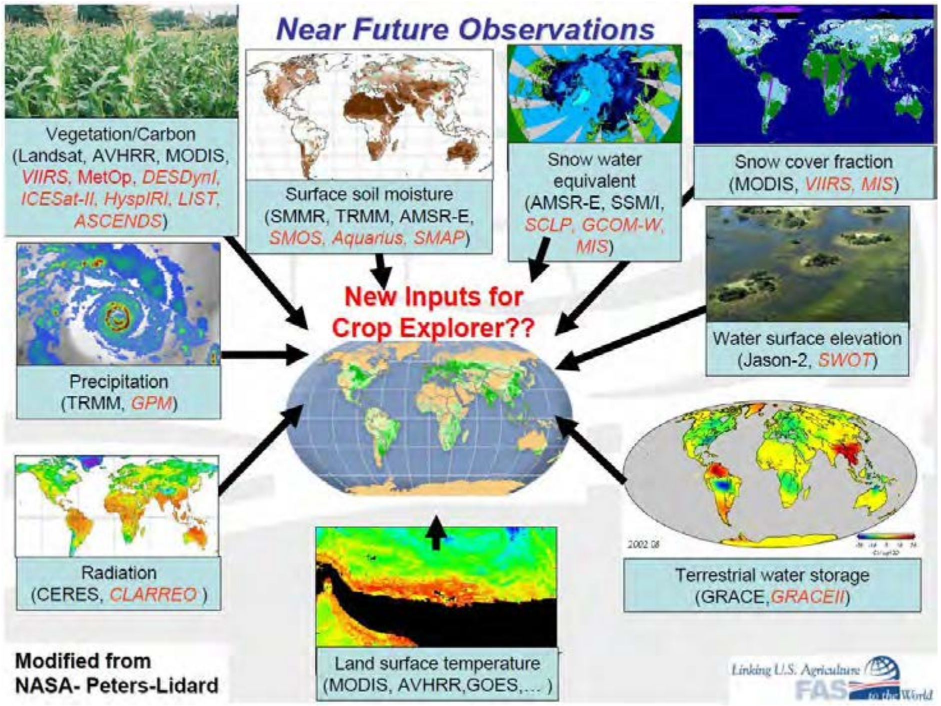


Fig. 2. Satellite data feeds for the Crop Explorer that is the database for the world crop analysts of USDA-FAS.

PLANNED WORK

- Continue to provide the global soil moisture data products to USDA with no-cost extension of the NASA funded project

PUBLICATIONS

Bolten, J. D. Crow, W. T. Zhan, X. Jackson, T. J. Reynolds, C. A. 2009. Evaluating the Utility of Remotely Sensed Soil Moisture Retrievals for Operational Agricultural Drought Monitoring. *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE*. Vol. **3**, Issue 1. pp. 57-66. DOI: 10.1109/JSTARS.2009.2037163

DELIVERABLES

Daily delivery of global soil moisture data products to USDA.

PRESENTATIONS

None for the past year.

PERFORMANCE METRICS

# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

PERFORMANCE METRICS EXPLANATION

CICS scientists (Hain/Fang/Han) ensure the global soil moisture product delivery to USDA daily while they leverage other soil moisture data generation and application projects.

Development of Global Soil Moisture Product System (SMOPS)

Task Leader	Dr. Christopher Hain
Task Code	CHCH_SMOPS_13
NOAA Sponsor	Dr. Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS 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: 40%; Goal 2: 25%; Goal 3: 10%; Goal 4: 25%

Highlight: We have upgraded SMOPS to ingest soil moisture retrievals from Metop-B ASCAT. To prepare the upgrade, Metop-B ASCAT soil moisture data are evaluated against Metop-A ASCAT data. SMOPS is the NOAA-NESDIS Global Soil Moisture Operational Product System. It provides soil moisture observations from microwave satellite for use in NWS-NCEP weather and climate prediction models.

BACKGROUND

Soil moisture status controls the sensible and latent heat exchanges between the land surface and atmosphere. These heat exchanges are among the major energy sources for atmospheric motions. Thus, reliable soil moisture data products and techniques for assimilating them into numerical weather prediction models are believed to have significant impacts for weather forecast accuracy. The Advanced Microwave Scanning Radiometer on JAXA's GCOM-W1 satellite (AMSR2) was launched on May 18, 2012. A global soil moisture environmental data record (EDR) will be generated by NOAA. NESDIS has built a Global Soil Moisture Operational Product System (SMOPS) to merge satellite retrieval data products of soil moisture from AMSR-E on NASA Aqua, WindSat of Navy NRL, ASCAT on MetOp satellite and the Soil Moisture and Ocean Salinity (SMOS) mission of European Space Agency (ESA). With the launches of MetOp-B and GCOM-W1 satellite, new soil moisture data from ASCAT and AMSR2 are becoming available. The L2 soil moisture data from SMOS has a latency of more than 12 hours. To reduce its latency and to merge the new satellite observations of soil moisture, NESDIS PSDI program supports to expand SMOPS to include MetOp-B ASCAT, AMSR2 and faster SMOS data. Details of the FY13 SMOPS project are as follows.

ACCOMPLISHMENTS

Global daily soil moisture retrievals from MetOp-B Advanced Scatterometer (ASCAT) is found to be similar to and slightly wetter than the soil moisture retrievals from MetOp-A ASCAT (See Figs. 1 and 2 below). Both MetOp-A and MetOp-B satellite fly the same polar orbit with a 10:30am/pm equator crossing time. The similarity of the two satellite sensor products will increase the reliability of the soil moisture products blended by SMOPS.

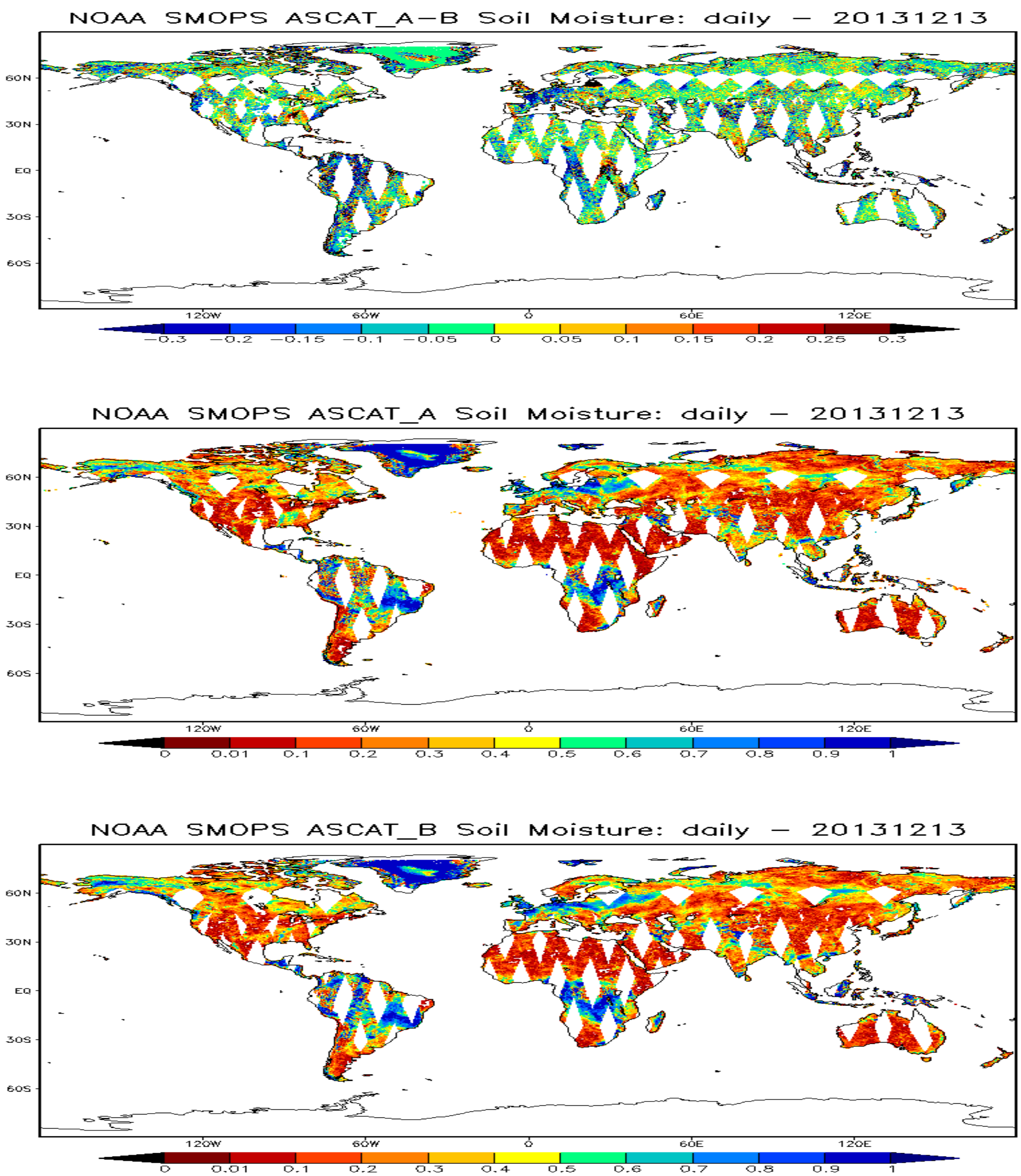


Figure 1: An example of daily Soil Moisture maps from ASCAT-MetOpA and ASCAT-MetOpB. The top map shows the difference between ASCAT-MetOpA Soil Moisture and ASCAT-MetOpB Soil Moisture on Dec 13, 2013. The middle map shows ASCAT-MetOpA Soil Moisture on Dec 13, 2013. The bottom map shows ASCAT-MetOpB Soil Moisture on Dec 13, 2013.

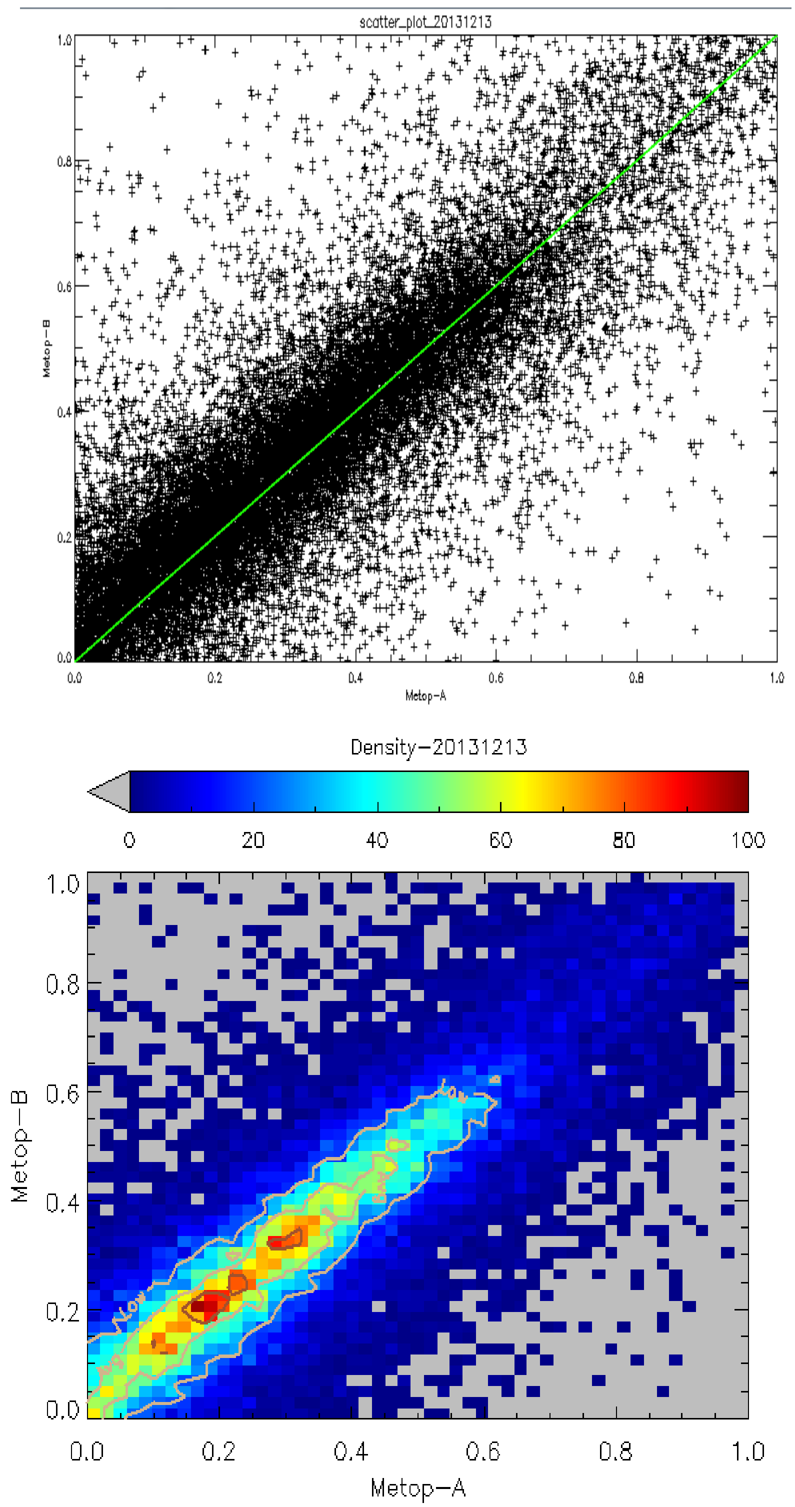


Figure2

Figure 2: The density plot between Metop-A and Metop-B soil moisture on Dec 13, 2013.

PLANNED WORK

- Work with OSPO to deliver the updated SMOPS code to OSPO.
- Work with OSPO on testing the new SMOPS system.
- Finish up all the related documents.

PUBLICATIONS

Not yet completed.

DELIVERABLES

Plan to deliver SMOPS code to OPSO in late summer of 2014.

PRESENTATIONS

Not yet done.

PERFORMANCE METRICS

# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guid-ance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	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	0

PERFORMANCE METRICS EXPLANATION

The graduate student visiting scholar began on the SMOPS project from Oct 2013 and is expected to complete the project by Sept 2014.

Development and Validation of AMSR-2 Environmental Data Records (EDR's)

Task Leaders	Patrick Meyers and Jun Park
Task Code	EBPM_AMSR2_13
NOAA Sponsor	Ralph Ferraro
NOAA Office	NESDIS/STAR/CRPD/SCSB
Main CICS Research Topic	Data Fusion and Algorithm Development
Percent contribution to CICS Themes	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 80%

Highlight: The AMSR2 EDR algorithms for precipitation and ocean retrievals were delivered to NOAA OSPO Fall 2013 and transitioned into operations. The EDRs will be operationally available in Spring 2014.

BACKGROUND

NOAA has reaffirmed its commitment to monitoring the global hydrological cycle with continued support for its latest satellite missions. In a partnership with the Japanese Aerospace Exploration Agency, the Global Change Observation Mission – Water 1 (GCOM-W1) was launched in early 2012 as part of the Joint Polar Satellite System (JPSS). GCOM-W1 is part of the A-Train constellation, crossing the equator around 1:30pm local time in a sun-synchronous orbit. GCOM-W1 is equipped with the Advanced Microwave Scanning Radiometer (AMSR2) to monitor global rainfall rates, total precipitable water (TPW), cloud liquid water (CLW), wind speed (WSPD), and sea surface temperature (SST). An accurate global record of these parameters is necessary to identify regions at risk for climatic events, such as drought or sustained inundation, and short-term hazards, including landslides, flash floods, and tropical cyclones (Kirschbaum et al. 2009; Hong et al. 2010; Kucera et al. 2013).

Algorithms developed by CICS and NOAA/STAR scientists for AMSR2 EDRs will become operational in Spring 2014 as part of the GCOM-W1 AMSR2 Algorithm Software Processor (GAASP). The rain rate retrieval follows GPROF2010V2 (Gopalan et al. 2010; Kummerow et al. 2011). The ocean EDR (TPW, CLW, WSPD, SST) employs an empirical calculation based on brightness temperature relationships to geophysical analyses (Chang et al. 2013). These algorithms have been comprehensively tested and evaluated to ensure reliable geophysical retrievals. Extensive validation was performed, comparing AMSR2 observations to various in-situ and satellite data sets. Implementation of the research algorithms and distribution of the EDRs is handled by NOAA's Office of Satellite and Product Operations (OSPO).

ACCOMPLISHMENTS

CICS scientists contributed to the creation of the AMSR2 ocean EDR algorithm. The empirical retrieval scheme accurately measures TPW, CLW, WSPD, and SST over open water. A monitoring website produces daily maps of the geophysical measurements. Daily comparisons of AMSR2 parameters to model estimates are routinely produced and will be incorporated into the monitoring website.

GPROF2010V2 was finalized as the precipitation algorithm for AMSR2. The Bayesian retrieval scheme over ocean remains the same from the previous version of GPROF. The most significant updates to GPROF pertain to the screening procedures over land to identify radiometric signals that could be misclassified as rain. In previous versions, screening procedures were applied universally over all seasons and surface types, sometimes flagging heavy summer convection as snow. Conversely, the snow detection scheme frequently failed to identify snow where it is persistently observed in winter. The updated screening procedures check a climatological snow cover database to determine whether to automatically flag a pixel for snow contamination and whether to run the heritage snow screening procedures. AMSR2 rain rates with GPROF2010V2 are being generated regularly and produce realistic rain fields, especially during extreme events (Figure 1). Precipitation observations from AMSR2 are currently undergoing testing to be incorporated into the CMORPH precipitation estimate.

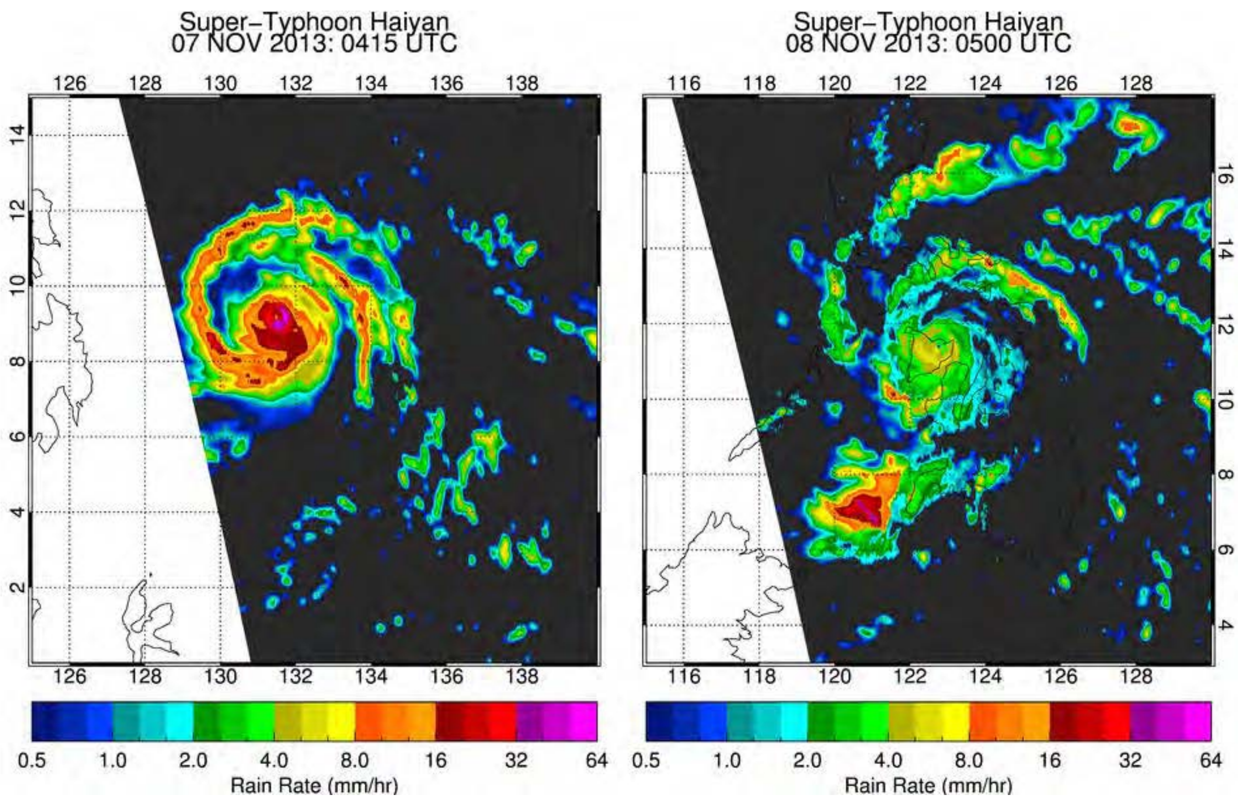


Figure 1 - Super-Typhoon Haiyan from AMSR2: The infrared and visible imagery from Super-Typhoon Haiyan showed a near-perfect annular cyclone with little azimuthal variability. Rain rate retrievals from AMSR2 show a non-uniform precipitation field spiraling out of the eye. Such imagery helps forecasters understand the organization of the storm to better predict these natural disasters.

A key component of accurate geophysical retrievals is characterizing brightness temperature calibration errors. Inter-satellite calibration between AMSR2 and TMI using the Community Radiative Transfer Model ensured consistency between satellite products. A monitoring system for AMSR2 brightness temperatures has been developed to alert developers of sensor inconsistencies (Figure 2 - top).

Over one year of AMSR2 observations provides a sufficient record for validation of the GCOM Day-1 EDRs. AMSR2 records were compared to a variety of baseline estimates, including models, rain gauges, radar, buoys, and other satellites. Thorough evaluation confirms that AMSR2 EDR retrievals meet NOAA/STAR accuracy standards (Table 1). Daily monitoring ensures a reliable record of geo-physical parameters (Figure 2 – bottom).

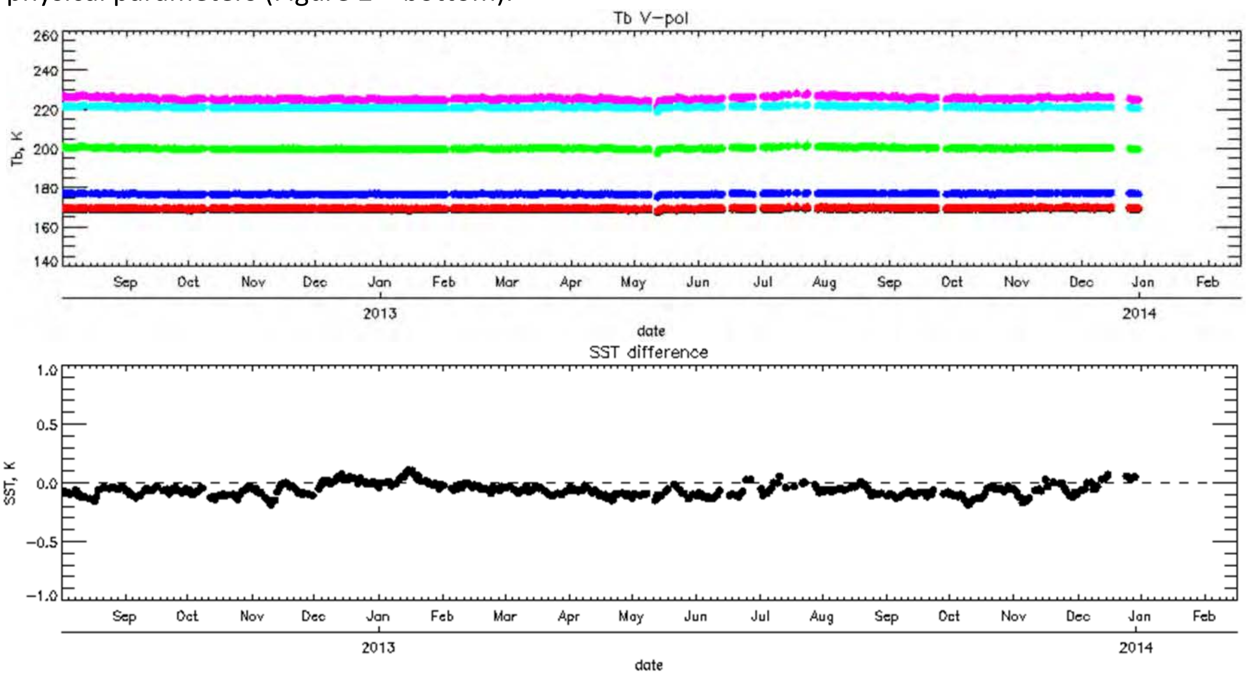


Figure 2 – AMSR2 Monitoring System: (Top) Monitoring of average daily vertically polarized brightness temperatures for AMSR2. (Bottom) Daily average difference between AMSR2 SST retrievals and Reynolds SST analysis.

Parameter	TPW	CLW	WSPD	SST	Rain (Land / Ocean)
Threshold	2 mm or 10%	0.05 mm	2 m/s or 10%	1 K	5 / 2 mm/hr
EDR Accuracy	0.9 mm	0.04 mm	1.5 m/s	1 K	3.4 / 1.5 mm/hr
Baseline	TMI	TMI	GDAS	Reynolds	TMPA 3B42

Table 1 – Performance metrics for AMSR2 Ocean and Precipitation EDRs: Thresholds of maximum allowable uncertainty are defined by JPSS Project Office Requirements. AMSR2 EDRs met all standards when compared to baseline measurements from TMI and TMPA derived estimates, Reynolds ¼° SST analysis, and the GDAS model.

The primary accomplishment of the AMSR2 task was the delivery of the ocean and precipitation algorithm to OSPO for implementation into their operational processing suite. Several milestones were reached in the process of transitioning the algorithms into operations. The Critical Design Review in May 2013 presented the algorithm theoretical basis and validation plan and gained approval from project stakeholders. The subsequent Code Test Review defined output file configuration and confirmed the research algorithms were successfully translated to meet OSPO's algorithm formatting and latency standards. An Algorithm Theoretical Basis Document (ATBD) was produced to explain the algorithm's retrieval technique and output file format. The final programmatic milestones before GAASP is operational are the Algorithm Readiness Reviews and approval from the Satellite Products and Services Review Board, scheduled for April 2014. Once GAASP is approved, this task will be completed.

PLANNED WORK (Up to 250)

- Expand collocation database for AMSR2 validation to include additional satellite and in-situ observations.
- Submit manuscript on GPROF2010V2 algorithm for peer review (in preparation)
- Develop monitoring system to ensure stability of observations and delivery system in conjunction with OSPO's Satellite Products Branch.
- Identify systematic deficiencies in the Day-1 algorithms and begin updating algorithms for the Day-2 algorithm suite.
- Introduce the AMSR2 TPW measurements into OSPO's blended TPW (bTPW) product, which merges ground-based and satellite data to create a global TPW analysis every 6 hours (Kidder and Jones 2007).
- Incorporate AMSR2 rain rate measurements into the Ensemble Tropical Rainfall Potential (eTRaP) product used to estimate total rainfall accumulation for tropical cyclones using passive microwave observations (Ebert et al. 2011).
- Complete the transition to operations by participating in the GAASP Algorithm Readiness Review and receive approval from the NOAA Satellite Product and Services Review Board.

DELIVERABLES

- Research algorithms for rain rate and ocean parameters delivered to OSPO
- ATBD for rain rate EDR

PRESENTATIONS

Meyers, P. et al.: Validation of NOAA's AMSR2 Precipitation Product, AGU Fall Meeting, December 2013, San Francisco, CA, OS44A-03.

Meyers, P., N.-Y. Wang, R. Ferraro, C. Kummerow, D. Randel, Z. Jelenak, and P. Chang: Updating the Goddard Profiling Algorithm 2010 for AMSR-E and AMSR2, EUMETSAT Meteorological Satellite Conference, September 2013, Vienna, AT.

Meyers, P., N.-Y. Wang, R. Ferraro, C. Kummerow, D. Randel, Z. Jelenak, and P. Chang: Preparation of the Goddard Profiling 2010 Rainfall Algorithm for AMSR2, CoRP Symposium, July 2013, Madison, WI.

OTHER

- Two articles were written for the ESSIC website that highlighted observations from AMSR2 for high-impact weather events.
- Demonstrated potential capabilities of merging AMSR2 data with lightning observations.
- Mentored undergraduate students interested in careers in remote sensing.

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guid-ance	2
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	1
# 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

CUNY-CREST Support for Combining JPSS with Geostationary Imager data for Fused Earth Observation Parameters: Improving JPSS data with fusion tool

Task Leader	Irina Gladkova
Task Code	IGIG_JPSS_13
NOAA Sponsor	Ingrid Guch
NOAA Office	NESDIS
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 5: 80%

Highlight: We are developing algorithms and software for fusing high spatial resolution data from the new generation of polar orbiting platforms (JPSS) with high temporal resolution data from geostationary platforms. The techniques will be applied to enhance both daily surface reflectance/emission products and derived products such as NDVI, vegetation fraction, vegetation health, LST and snow cover.

BACKGROUND

The VIIRS sensor on the JPSS-1 (NPP) is a new high-resolution tool for monitoring and weather prediction of the Earth system in the visible and infra-red spectrum. While many products will be enhanced though data available from this new high spatial resolution instrument, the benefits of VIIRS data can be greatly amplified when combined with complementary instruments. In particular, if the high spatial resolution data of a Polar orbiter like JPSS-1 can be fused with the high temporal resolution data of an imager on a geostationary satellite like the upcoming ABI, the JPSS-1 based products can be improved.

As an example, surface products like NDVI and NDSI may be unavailable at a given location and day due to occlusion by cloud cover. It is likely that the high temporal resolution of a geostationary satellite based imager will have measurements from the surface at locations occluded by clouds during the polar overpass. Therefore, we can enhance the JPSS-1 based products through fusion with geostationary imagery. We are developing the fusion algorithm at the level of radiances or reflectances, so that the result of the fusion can be used in a variety of products.

ACCOMPLISHMENTS

We developed, tested, and compared a number of algorithmic approaches to estimating high-resolution MODIS snow metrics using available low-resolution data. This experimentation allowed us to identify a core approach yielding more accurate results than other tested algorithms or baseline methods. It augments an interpolated high-resolution image using very-near-in-time known low-resolution data with an offset built from recent instances where high-resolution data was available. This offset is a weighted difference between the known historical high-resolution values and the corresponding low-resolution data from that time.

We have created a Database of test data which continues to be populated by increasing amounts of data. It currently contains one month of SEVIRI data (observations from January 2013), including reflectance data from two source formats, and cloud mask data from one, separate, source format. We have developed a method to create a composite image by finding the most recently available observation of the high-resolution instrument at every location where an estimated value is sought. This image can be found efficiently because of the indexed database.

We have developed a technique to model the changing ground conditions by creating two composite images from the low-resolution instrument: one using near-in-time observations to the above "previous high-resolution" component, the other using data which is near-in-time to the time for which an estimate is sought.

All project deliverables (documentation and software) and milestones have been accomplished as planned.

PLANNED WORK

Adapt prototype algorithms that merge Geostationary reflectance images from proxy SEVIRI with corresponding Polar MODIS images to produce merged sequence of snow products with Polar spatial resolution and temporal resolution of SEVIRI using SEVIRI data. Perform more complete evaluation. Test enhanced versions of these algorithms.

DELIVERABLES

- Develop a method to robustly merge Geostationary reflectance images from SEVIRI with corresponding MODIS images to produce merged sequence of images with MODIS spatial resolution and SEVERI temporal resolution (using clear sky pixels)
- Derive NDSI end user products from fused reflectance/emissive JPSS products to evaluate.
- Modify fusion algorithm to use VIIRS in place of MODIS to create VIIRS and SEVIRI merged reflectances.
- Develop integrated software library for fusing VIIRS and SEVIRI (with expansion to ABI).

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	1
# of undergraduate students mentored during the year	1

Enhancements for Geo-SST Products

Task Leader	Andy Harris
Task Code	JMJM_EGSP_13
NOAA Sponsor	Tom Schott
NOAA Office	NESDIS/OSD
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: Code is being written to change outputs to netCDF4. It is important to integrate this effort with the reprocessing project (JMJM_RGPB_13), which has required significant extra effort to overcome data format issues.

BACKGROUND

The current Geo-SST processing system uses some outdated procedures to both transmit information between the different programs used by the processing, as well as outputting much of the data in a simple binary format which is difficult to read and maintain. This is particularly true of the matchup database that contains many different parameters as well as the SSTs. Not only is maintenance an issue, but also the use of McIDAS files to transmit information from the main Geo-SST Bayesian code to the other codes means that there is a loss in precision since the SSTs in McIDAS format are stored in a single byte. There is also a persistent problem with missing data in the GOES-E/W merged data. Therefore in order to improve the maintainability, ease of use and accuracy and coverage we need to add in GOES full disk data and change both the output formats and infrastructure of the our processing system.

ACHIEVEMENTS

The project is focused on addressing the above-mentioned shortcomings. Code is being written and tested to change the output format of the Geo-SST Bayesian code to output all required data at full resolution to avert the irksome McIDAS format/precision issue. The merging code and scripts have being modified to utilize GOES full disk data (see Figure 1). Improved formats, based on NetCDF 4.0, are being developed for all our output data. In the case of the matchup database, a NetCDF format is being devised which is based on the GHRSST standard specified in the GDS-2.0 documentation, along with additional parameters. For the merged hourly, 3 hourly and 24 hourly data we are developing a simple NetCDF format, requesting input from the users as to what they require as additional fields. It should be noted that GHRSST have draft formats for a variety of L3 products (L3U, L3C, L3S) but the methodology for computing SSES fields in particular is not settled. A NetCDF 4.0 format for all our products enables any users to read the matchup database easily (at the moment it requires precise knowledge of the binary structure of over 1,000 variables) and merged data files as well as providing the flexibility to add in information/channels as the Geo-SST processing develops.

PLANNED WORK

- Finalize GHRSST-compliant netCDF version of matchup database record
- Complete development & testing of GHRSST L3 SSES scheme and produce GHRSST L3
- Transition code and product changes to operations

- Report on above at GHRSST Science Team meeting

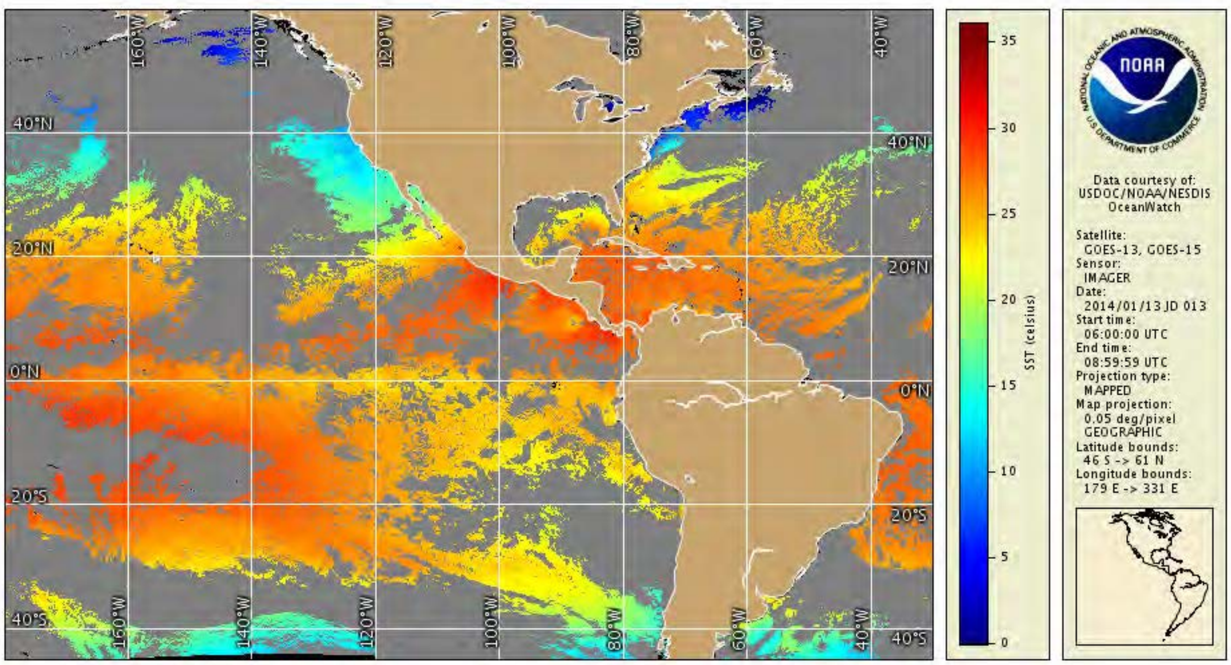


Figure 1: GOES 3-hourly composite for NOAA CoastWatch. The extra coverage afforded by the full-disk image has eliminated a previously existing triangular gap in the E Pacific.

PUBLICATIONS

None

DELIVERABLES

- Revised Geo-SST processing code to OSPO;
- Improved gridded products to NOAA CoastWatch
-

PRESENTATIONS

Maturi E., A. Harris, J. Mittaz, P. Koner, G. Wick, N. Shay, J. Sapper, D. Donahue, M. Eakin, S. Heron, W. Skirving, H. Gu, 2013: Applications of NOAA's operational Sea Surface Temperature products, *Joint AMS-EUMETSAT Meeting*, 16-20 September, 2013, Vienna, Austria.

Maturi E., A. Harris, J. Mittaz, P. Koner, G. Wick, N. Shay, J. Sapper, D. Donahue, M. Eakin, S. Heron, W. Skirving, H. Gu, 2013: Applications of NOAA's operational Sea Surface Temperature products, *NASA SST Science Team Meeting*, 29 – 31 October, 2013, Seattle, WA

OTHER

N/A

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

PERFORMANCE METRICS EXPLANATION

Improved gridded product is available to NOAA CoastWatch. Other products will be delivered to GHRSST upon completion.

Development of a Bayesian Cloud Mask

Task Leader	Andy Harris
Task Code	JMJM_GOESR2_13
NOAA Sponsor	Ingrid Guch
NOAA Office	NESDIS/GOES-R3
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: A method for rapid generation of cloudy probability distribution functions has been adapted for use over ocean surfaces. New parameter-dependent probability distribution functions are being generated for a number of different instrument parameters. Final selection of optimal parameter/channel sets will commence soon.

BACKGROUND

Many applications of geostationary satellite data require identification of cloudy radiances prior to the application of algorithms to retrieve geophysical quantities. The GOES-R project is no exception and requires an accurate and well characterized cloud mask. Currently a threshold based cloud mask is the baseline for the Advanced Baseline Imager (ABI) but studies have already show significant problems and limitations. For example, the GOES-R sea surface temperature (SST) Algorithm Working Group (AWG) has already had to add in checks to remove unidentified cloudy pixels that made it through the current GOES-R cloud mask. This project is to develop a Bayesian cloud mask methodology for GOES-R to enables a better discrimination between cloudy and clear pixels that is currently available.

ACHIEVEMENTS

In the final year of this project is focusing on development of the cloud detection over ocean. We are developing new over ocean cloudy PDFs that incorporate more channels and also more sensor information that is currently used by the NOAA Geo-SST software. This requires testing relative to the current baseline GOES-R cloud mask to show the improvements of both the land and ocean portions of the project. The sub-tasks include:

- Using the PDF generation methods developed by the University of Edinburgh to generate new cloudy PDFs/textural PDFs over ocean
- Developing methodologies to determine optimum channel combinations for cloud detection over ocean
- Testing both land and ocean masks and comparing with current GOES-R baseline

We are in the process of refining best practice methods to determine PDFs generation/Radiative transfer modeling over land and ocean that can be transitioned to GOES-R. An example of the variations in cloudy PDFs with respect to satellite view zenith angle can be seen in Figure 1.

PLANNED WORK

Refining cloudy PDFs using initializing.

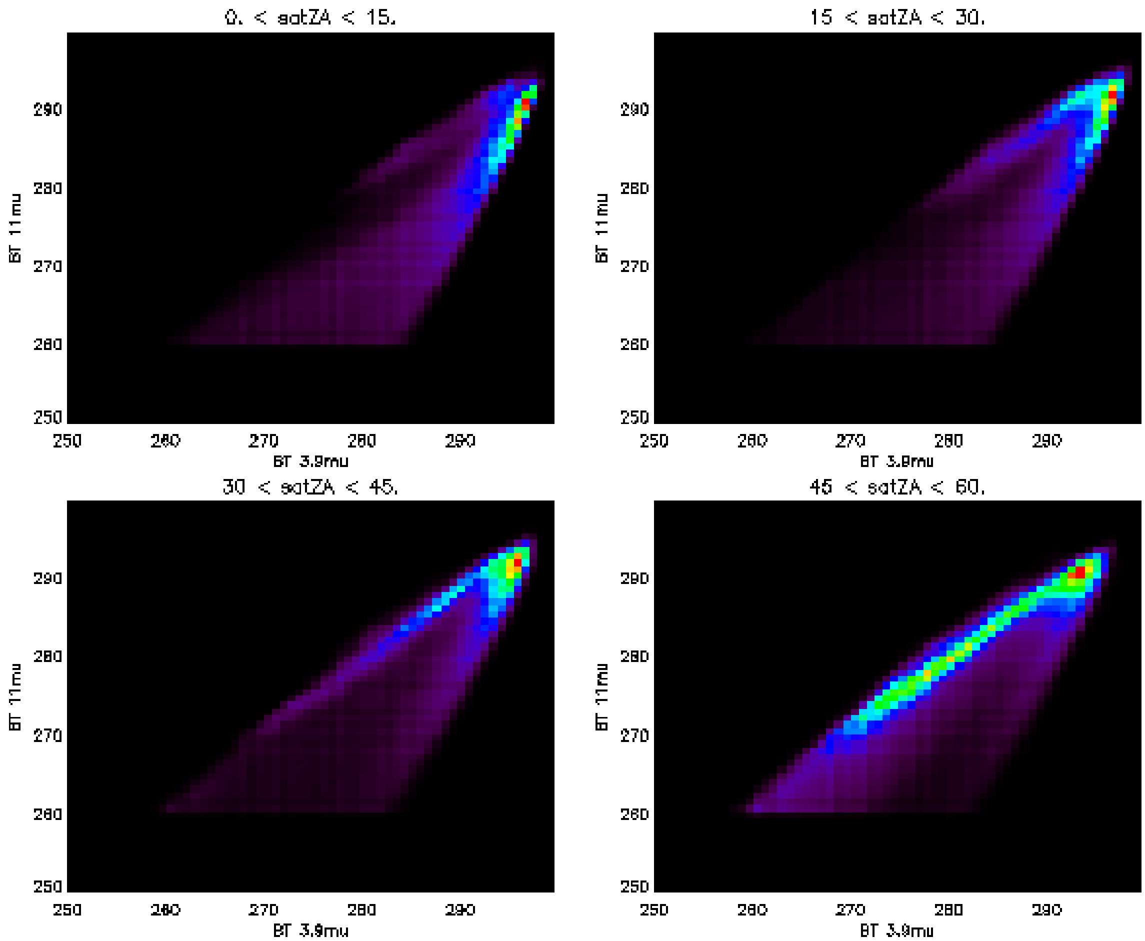


Figure 1 Example of substantial variation in MTSAT 2-d cloudy brightness temperature PDFs as a function of satellite zenith angle.

PUBLICATIONS

None

DELIVERABLES

- ATDB and test data to demonstrate the feasibility of using a Bayesian approach to cloud detection for GOES-R

PRESENTATIONS

N/A

OTHER

N/A

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	1
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

PERFORMANCE METRICS EXPLANATION

Although this improvement was proposed internally to NOAA, the impetus is definitely from outside of NOAA. However, R2O transition is a matter for NOAA after they have reviewed the ATBD.

Sea Surface Temperature Continuity for MSG

Task Leader	Andy Harris
Task Code	JMJM_MSG_13
NOAA Sponsor	Tom Schott
NOAA Office	NESDIS/OSD
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: All necessary upgrades have been made to the Geo-SST processing system and successfully transitioned to operations. New Single Sensor Error Statistics have been generated and incorporated to facilitate operational generation of GHRSST L2P SST data for Meteosat-10 (MSG-3).

BACKGROUND

The Meteosat Second Generation (MSG) satellite is a geostationary satellite which is located over 0˚,0˚ longitude and latitude and is designed to continually observe Europe, the Atlantic and Africa/western Indian ocean. Onboard is the Spinning Enhanced Visible and InfraRed Instrument (SEVIRI) which takes images every 15 minutes at a resolution of approximately 3-km. At NOAA, SEVIRI is currently used to generate Sea Surface Temperatures (SSTs) as part of standard operations, and these data are used by a range of users from CoastWatch, NMFS, NWS, Coral Reef Watch, the Navy and GHRSST (the Group for High Resolution SST). It is also a key data stream for NOAAs Geo-Polar Blended analysis and enables the blended analysis to have high data volumes over the Atlantic and western Indian oceans. As such, data from MSG/SEVIRI is of vital importance to NOAA SST products.

While the current NOAA operational chains are set up to use MSG-2 (Metosat-9), as of Jan 21st 2013 MSG-3 (Metosat-10) will become the operational satellite. If no changes are made to the current SST generation software/operational chains then the production of MSG/SEVIRI SST will fail, removing an extremely important data steam from NOAA operations.

ACHIEVEMENTS

To modify the Geo-SST operational code to be able to process MSG-3 data and generate all the current SST products including the hourly, 3-hourly, 24-hourly binary and GHRSST L2P files. In order to accomplish this, the following sub-tasks have been performed:

- Creation of new visible channel RTM coefficient files for the University of Edinburgh RTM
- Modification of operational and development codes to read in and process MSG-3 data including changes to the CRTM analysis code
- Generation of new GHRSST L2P SSES coefficient files and modification of GHRSST L2P code to output MSG-3 data in GHRSST L2P format
- Assessment the performance of the MSG-3 SSTs

An example of MSG-3 Hourly Gridded SST is shown in Figure 1

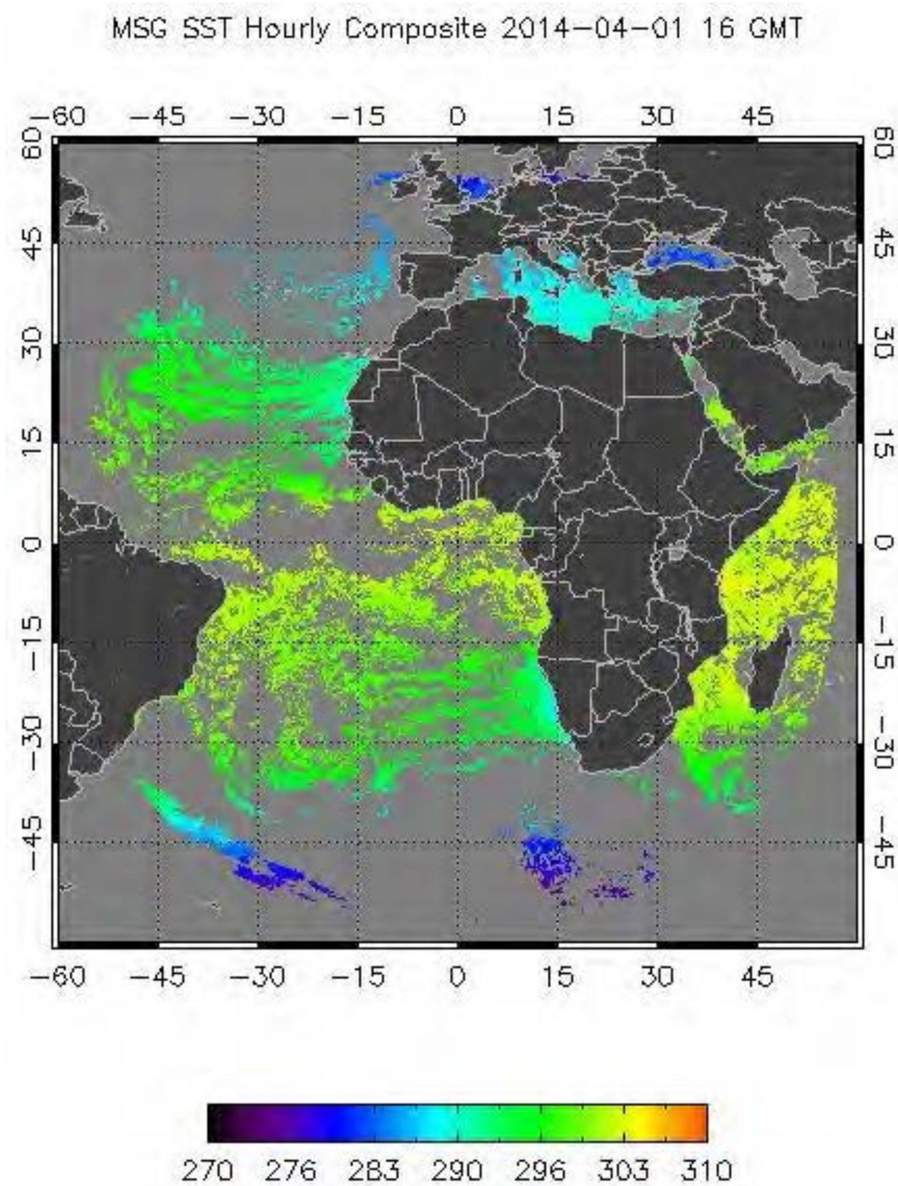


Figure 1: Example hourly gridded SST product for Meteosat-10 (MSG-3) for 16Z, 04/01/2014.

The Single Sensor Error Statistics are obtained by mapping (linear interpolation) of the quality control value to bias and standard deviation values using the information contained in Table 1. The QC value itself is the total error estimate obtained as part of our new physical retrieval methodology that was implemented on 08/01/2013.

Retrieval Type	QC value	Bias	Std. Dev.	# matches
Meteosat-10 Night	**0.11536383**	**-0.056063475**	**0.38485646**	**5401**
	0.29309112	**-0.047242705**	**0.46549090**	**8560**
	0.45332946	**-0.058804317**	**0.62359092**	**6860**
	0.55717735	**-0.23487946**	**0.88330263**	**6703**
	0.69315567	**-0.93923971**	**1.2260118**	**3527**
	1.2669497	**-2.1975732**	**1.4877082**	**1154**
Meteosat-10 Day	**0.11996787**	**-0.12103125**	**0.43307534**	**3112**
	0.29320928	**-0.11725302**	**0.49469094**	**5428**
	0.45214627	**-0.14648621**	**0.57786118**	**4212**
	0.56021188	**-0.15402645**	**0.69555655**	**4247**
	0.71262558	**-0.27195335**	**0.97821244**	**6311**
	1.2584690	**-0.89151692**	**1.3449739**	**2900**

Table 1: Tablulated mapping between QC value calculated by our physical retrieval methodology and the binned validation statistics. The stronger relationship between QC value and cool bias in the retrieval for nighttime data may be attributed to the reasonably unambiguous effect of residual cloud contamination for those conditions, whereas daytime data may experience warmer retrievals due to scattered solar radiation contributions in the 3.8 micron channel.

PLANNED WORK

None – the task is complete for this satellite.

PUBLICATIONS

None

DELIVERABLES

- Updated operational Geo-SST processing code

PRESENTATIONS

N/A

OTHER

N/A

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

PERFORMANCE METRICS EXPLANATION

Although this is listed as a single product, the task has supported multiple MSG-3 products generated operationally: hourly gridded, 3-hourly gridded, daily gridded and GHRSST L2P, as well as input to the Geo-Polar Blended SST Analysis.

Reprocessing Geo-Polar Blended SST analyses in support of NOAA Coral Reef Watch

Task Leader	Andy Harris
Task Code	JMJM_RGPB_13
NOAA Sponsor	Mark DeMaria
NOAA Office	NESDIS/OSD
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: 0%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: All required major script and code changes have been made and data procured for all geostationary sensors for 2004 – present (~150 TB). Extensive testing has been performed on a sample month (August 2013) which has had the added benefit of repopulating the archive with correct data, since the upgrade to physical retrieval within NOAA Operations contained a minor implementation bug which had caused errors in the gridded output files for that month. All code changes are being coordinated with other tasks to ensure that the reprocessing methodology is as up-to-date as possible.

BACKGROUND

Coral Reef Watch (CRW) operates the only global decision support system for tropical ocean coral reef ecosystem management, and its most critical component is the sea surface temperature (SST)-based coral bleaching thermal stress monitoring suite. This product suite serves the coral reef community by providing timely information on mass coral bleaching events that have been devastating U.S. and global coral reefs and such events are predicted to worsen in the coming decades. Currently the SST data used is relatively low resolution (50km) and to progress and provide improved information higher resolution monitoring at reef or near reef scales is required. The operational daily 5-km geo-polar day-night and nighttime only blended SST analyses provide the required high-quality SST for the new CRW coral bleaching thermal stress monitoring product suite and will allow for retirement of the heritage 50-km twice-weekly SST. The new suite will then be able to provide thermal stress information with significantly improved quality, data density, and spatial coverage for direct coral reef area applications.

In order to use the 5-km geo-polar analysis, a climatology is needed which covers a sufficient period of time and needs to have characteristics matching the geo-polar 5-km product. This is because CRW's bleaching thermal stress monitoring products are positive-only anomaly-based products which require a high-quality climatology to provide accurate and sensitive thermal stress measurements at any given time and any given location in the ocean. CRW are planning to use AVHRR Pathfinder data but this must be calibrated against an extended period of geo-polar 5-km data. Currently this is not possible as the geo-polar 5-km data is only available from 2012. Also, anomaly thresholds need to be defined against periods when major bleaching has occurred. Important periods include the global mass coral bleaching in 2010, the 2005 record-setting bleaching event in the Caribbean, and the 2006 bleaching on the Great Barrier Reef. Geo-Polar data is therefore needed from late 2004-present and requires a significant amount of Geo-SST/Geo-Polar reprocessing.

ACHIEVEMENTS

The project focus is to provide Geo-Polar blended analyses that cover the period Sept 2004-present. This date range covers a sufficient amount of time to generate a good climatology as well as covering some of the coral bleaching events defined above. This requires processing the complete set of GOES/MSG/MTSAT geostationary data through the latest operational SST generation code. These data will then be combined with the POES (ACSPO) data and run through the latest Geo-Polar analysis software to generate the complete data record. To date, the entire radiance dataset for the Geo-SST product (GOES-E/W, MSG, MTSAT) has been acquired and archived on LTO tape. Extensive testing has been performed on data for August 2013. This month coincided with the introduction of our new physical retrieval methodology into operations, which resulted in significant improvements in product accuracy (see Figure 1). However, a minor implementation bug in NESDIS Operations resulted in disabling of the cloud screening check in the generation of the hourly gridded product (other products were unaffected). So, the reprocessing has the added benefit of allowing us to replace the defective gridded SST product for that month in the archive.

In order to ensure the final output is as representative as possible of the operational Geo-Polar Blended SST product, the final reprocessing task is being coordinated with changes to the analysis software, which is currently undergoing upgrades.

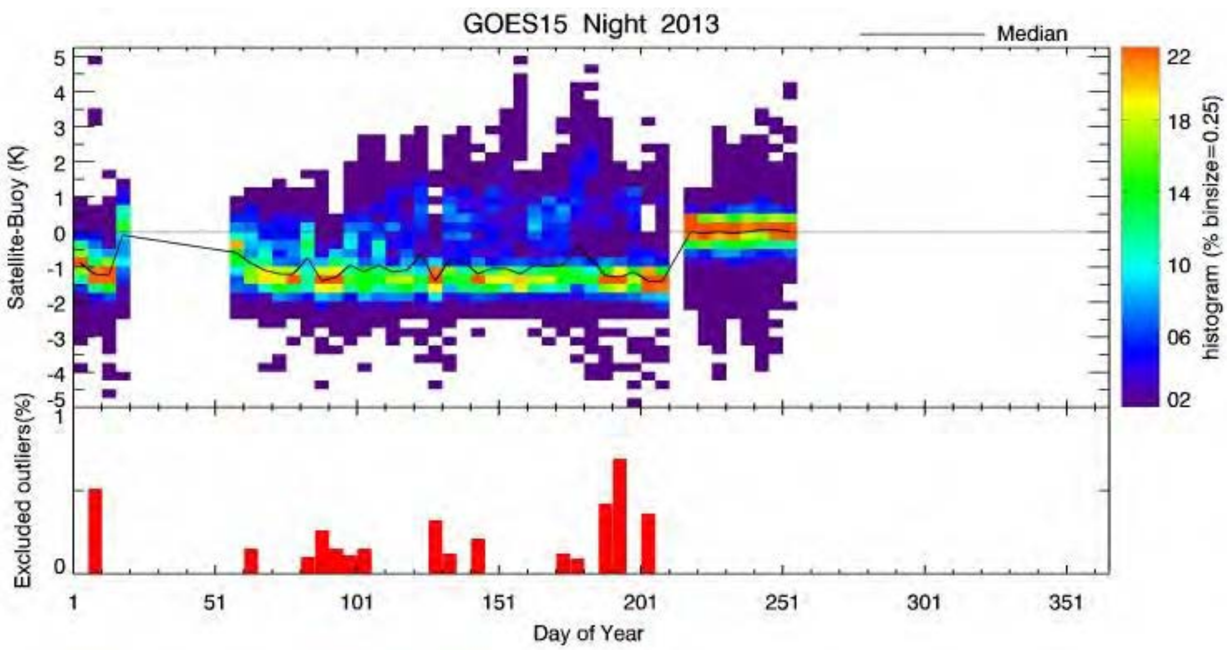


Figure 1: 2-d histogram of validation data showing example of improvement in Geo-SST product upon introduction of new physical retrieval methodology. Both bias and scatter are significantly reduced (and more stable) after the new algorithm is implemented (day-of-year 213).

PLANNED WORK

- Complete reprocessing of Geo-SST data
- Take delivery of latest version of ASCPO Polar-orbiter SST data
- Run Geo-Polar SST Analysis reprocessing
- Analyze & validate final blended SST output to check for consistency
- Deliver to NOAA Coral Reef Watch

PUBLICATIONS

None

DELIVERABLES

- Script-based offline reprocessing systems for Geo-SST and Geo-Polar Blended SST;
- Time-series of reprocessed Geo-Polar Blended SST for NOAA Coral Reef Watch

PRESENTATIONS

Maturi E., A. Harris, J. Mittaz, P. Koner, G. Wick, N. Shay, J. Sapper, D. Donahue, M. Eakin, S. Heron, W. Skirving, H. Gu, 2013: Applications of NOAA's operational Sea Surface Temperature products, *Joint AMS-EUMETSAT Meeting*, 16-20 September, 2013, Vienna, Austria.

Maturi E., A. Harris, J. Mittaz, P. Koner, G. Wick, N. Shay, J. Sapper, D. Donahue, M. Eakin, S. Heron, W. Skirving, H. Gu, 2013: Applications of NOAA's operational Sea Surface Temperature products, *NASA SST Science Team Meeting*, 29 – 31 October, 2013, Seattle, WA

OTHER

N/A

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

PERFORMANCE METRICS EXPLANATION

Replaced defective hourly gridded product for August 2013. Other products will be delivered to NOAA CRW & GHRSST upon completion. The end-result will be an improved climatology from which NOAA CRW anomaly-based products are derived. However, this task does not in itself generate improved products in NOAA operations. Procedural delays in hiring a contractor shifted the time-frame of the project several months. The McIDAS ingestion utility was found to not be able to read MSG 'native' format (in contradiction to the documentation) but the McIDAS development team at UW have been working on a correct implementation.

Contributions to the Microwave-Radar Enhanced (MW-RE) Precipitation Over Land Algorithm

Task Leader	Nai-Yu Wang
Task Code	NWNW_PMM_13
NOAA Sponsor	Ralph Ferraro
NOAA Office	NESDIS/STAR/CRPD/SCSB
Percent contribution to CICS Themes	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
CICS Research Topic:	Data Fusion & Algorithm Development
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 80%

Highlights: The before-launch GPM GPROF database for over land was constructed.

BACKGROUND

If the Global Precipitation Measurement Mission (GPM) is to meet its requirement of global 3-hourly precipitation, the use of sounders such as AMSU will likely be needed. This project utilizes the "traditional" imager channels in conjunction with high frequency observations from AMSU and SSMIS, cloud resolving models and advanced radiative transfer models to:

(1) Study the effects of hydrometeors on the 10-183 GHz radiances and utilize them to improve the current Bayesian precipitation retrieval scheme (e.g., GPROF). Focus will be on cold season precipitation systems (e.g., stratiform rain and snowfall) since the present scheme has focused only on tropical rainfall systems.

(2) Investigate the potential of incorporating microwave sounding channels (50-60 GHz and 183 GHz) to the hydrometeor profile retrieval.

(3) Improve the current GPROF "surface screening" to remove ambiguity between precipitation and other surface signatures that resemble precipitation through the use of innovative methods such as dynamic land surface data sets available from ancillary data sets (i.e., NWP assimilation fields, emerging emissivity products, etc.).

ACCOMPLISHMENTS

1. Construction of GPROF Database

This year I'm tasked to construct a before-launch GPM GPROF database for over land, an important yet tedious work. GPROF relies on a realistic database that presents the microwave radiometer observations of rainfall frequency and intensity. The decision at the GPM Algorithm Team (July 2012) was to construct the at-launch database from the empirical databases derived from TRMM PR/TMI, A-Train CloudSat/AMSR-E, SSMIS, and NOAA NMQ. In the case of over-land database which includes the conventional TRMM TMI TBs and additional high frequency channels on GPM GMI, the observed SSMIS Tbs and NOAA NMQ radar derived rain rates were be paired with CRM profiles from the GSFC MMF simulations that match both the Tb and surface rainfall. This semi-physical database would have the advantage of combining observed Tb and rain rates with CRM profiles that reproduce the right Tb and surface rain and can therefore also be used to generate the constellation databases. It is not fully physical in that there is no guarantee that the clouds extracted from the MMF simulation also match the high resolution radar vertical structure.

The overland database task can be thought of a two-step process: (1) observational database: NMQ 0.01 deg resolution (~1km) surface rain-rates averaged to SSMIS 37 GHz footprint (~27 km X 45 km)

(2) matching GSFC MMF/CRM model simulations with SSMIS/NMQ microwave brightness temperatures and surface rain-rates to get the complete vertical hydrometeor profiles for the purpose of applying the database to all constellation radiometers.

For the 1st step of attaching surface rain-rates to satellite radiometer observations, a year of SSMIS orbit TBs and NMQ rain-rates data from December 2009 to November 2010 are processed. The 1-km NMQ rain-rates are convolved to the SSMIS 37 GHz 27km by 45 km footprint based on a two-dimension Gaussian antenna beam pattern

$$g = \exp[-\left(\left(\frac{X}{FWHMX}\right)^2 + \left(\frac{Y}{FWHMY}\right)^2\right) \times 4 \times \ln 2]$$

Where FWHMX and FWHMY are the full width at half maximum at along track and cross track directions, respectively. Figure 1 shows an example of such a convolution from 1km resolution NMQ surface rain-rates to the 37 GHz footprint size of 27 km by 45 km, based on 833 km SSMIS F17 spacecraft altitude and half power beam widths. The satellite footprint averaging retains the main precipitation features from the finer resolution surface radar rain measurements, but the footprint averaging also smears out the small-scale high surface rain-rates detected by the surface radars.

Figure 1c shows the high frequency 150 GHz measurements from the same SSMIS overpass, which captures the finer details of the precipitating clouds from small ice particle scattering, relative to the 37 GHz.

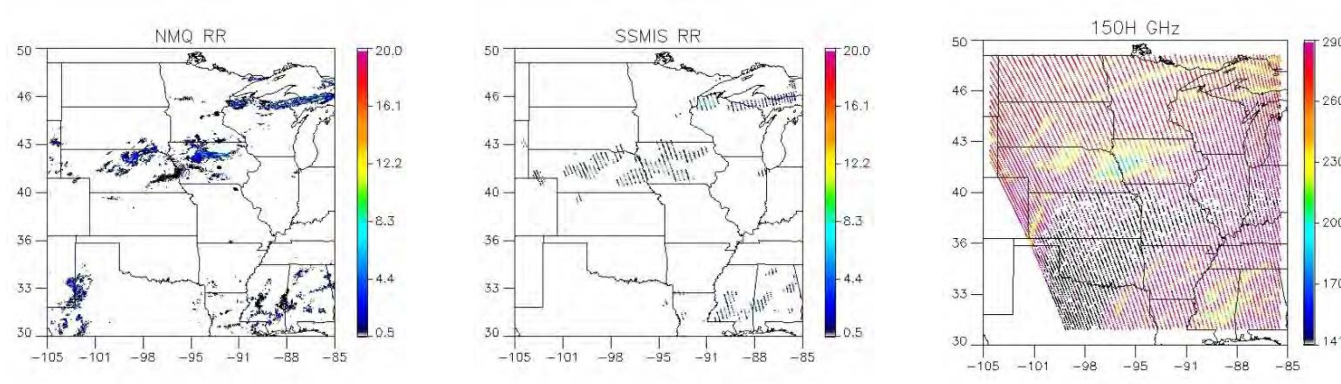


Figure 1. Surface rain-rates from June 1, 2010 from (a) NOAA radar composites NMQ at 1 km resolution (b) same NMQ rain-rates convolved to SSMIS 37 GHz footprint area at the resolution of 27 km by 45 km (c) SSMIS observations of surface rainfall at 150 GHz.

For the 2nd step of matching the SSMIS observed TBs to the CRM simulated TBs. For SSMIS/NMQ matches with the MMF profiles, we would compute a distance between the SSMIS pixel and the MMF simulation. The Total distance D^2 is

$$D^2 = D_{Tb}^2 + D_R^2 + D_{FL}^2 + D_{FOVCover}^2$$

Where the total distance D^2 is the sum of distances from Tb, rain rate, freezing level, and the fraction of FOV cover. We chose the smallest D that meets the Ts, TPW and emissivity class window. As before, The Ts, TPW, emissivity class, and T_{2m} will added to the empirical database using ECMWF and the surface classification based upon lat/lon and time. The above finds the best profile for the a-priori database for SSMIS for all Ts, TPW and emissivity classes covered by the SSMIS orbit over a year

2. **Development of a rain detection algorithm using surface characteristics and environment information**

Using this database we can explore ways to extract rain signals embedded in the highly dynamic land surface and environment background from SSMIS passive microwave (PMW) observations. The first method is the principal component analysis (PCA), which converts the correlated PMW observations to a set of linearly uncorrelated values called the principal components. Figure 2 shows the first three principal components from 11 channels SSMIS measurements from 19 to 183 GHz compared to the NOAA NMQ ground radar rain estimates. All three PCs capture the precipitation very closely to the reference NMQ ground radar rain estimates.

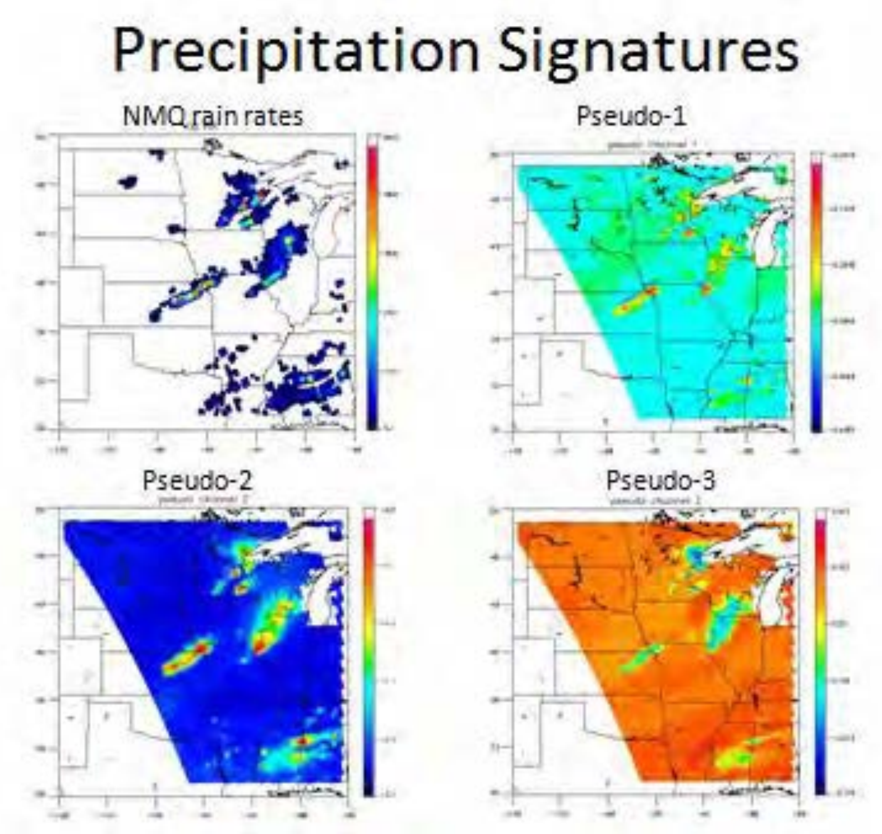


Figure 2. The first three principal components (Pseudo-1,2,3) extracted from SSMIS measurements compared to the reference NMQ ground radar rain estimates.

The second method is the Linear Discriminate Analysis (LDA). Figure 3 shows an example of rain detection from SSMIS using a single surface classes detection (middle panel) and 5 surface classes detection (3rd panel, 5 classes consist of 2 vegetation classes, 2 ice/snow classes, and one in-land water class), compared to NMQ radar rain estimates (left panel). The 5 surface classes clearly out perform a single surface class, particular at the snow-covered surface in the red circle area.

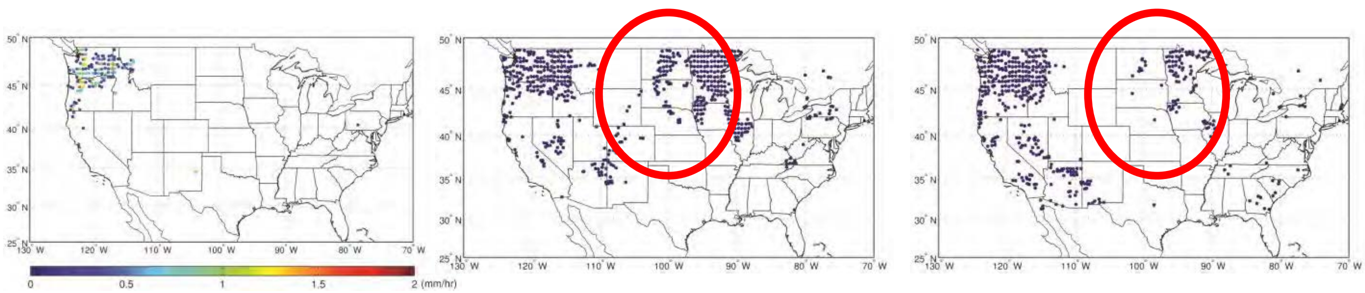


Figure 3. Single (middle) and multiple (right panel) surface class rain detection algorithms compared to NMQ rain estimates for January 7, 2010.

Figure 4 shows the overall statistics on the rain detections between a single class detection (red line on top panel) vs. multiple classes detection (blue line on top panel). The multiple classes detection clearly performs better than a single class detection. The middle panel shows the detection difference between single and multiple classes, and bottom panel shows the false alarm ratio

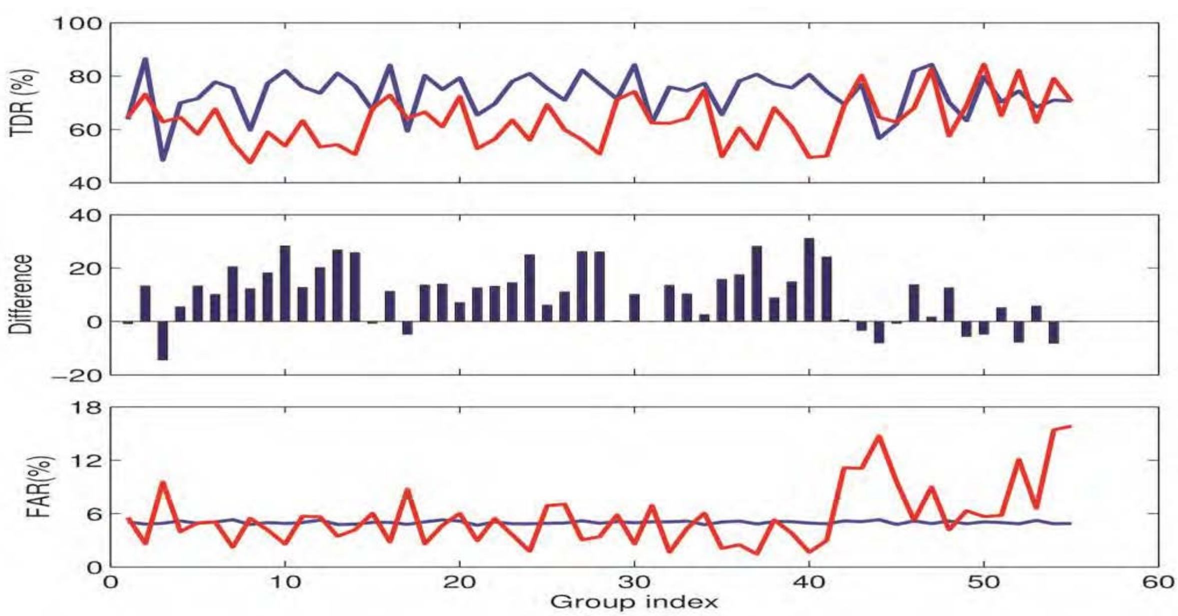


Figure 4. The difference between a single class detection and multiple classes detection methods. Top panel shows the true detection from multiple classes (blue) and a single class detection (red), middle panel shows the difference, and bottom panel shows the false alarm ratio.

PLANNED WORK

- Now the GPROF 2014 land database is built, one might ask the science questions. How do the radiometer observations depend on climate regime? For example, are there any dependence on TPW and surface temperature for each surface type? Our analysis shows that the detection performance is far better using a multiple surface classes. We're in the process of refining the detection methodology and developing rain-rate estimate methodology.
- Work on the manuscript for publication.

PRESENTATIONS

N.-Y. Wang, Y. You, and Ralph Ferraro, "Investigating Satellite Microwave Observations of Precipitation in Different Climate Regimes" in 2014 Microwave Radiometry Specialist Meeting (MicroRad), Pasadena, California, March 23-27, 2014.

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	0

Combining GLM and ABI Data for Enhanced GOES-R Rainfall Estimates

Task Leader	Robert F. Adler
Task Code	RARA_CGLM_13
NOAA Sponsor:	Ingrid Guch
NOAA Office:	NESDIS/STAR
Percent contribution to CICS Themes	Theme 1: 20%; Theme 2: 80%; Theme 3: 0%.
Main CICS Research Topic/s	Data Fusion and Algorithm Development
Percent contribution to NOAA Goals	Goal 1: 0%; Goal 2: 100%

Highlights: CICS scientists developed and tested a new satellite rainfall retrieval technique for the use with GOES-R, which uses a combination of IR data and lightning information. The new technique innovatively incorporates the lightning information and significantly reduces biases and uncertainties compared to the infrared alone technique. Comparison with the current NOAA operational technique shows large possibilities for improvement.

BACKGROUND

This project seeks to enhance precipitation estimates from the future GOES-R by combining information from the Geostationary Lightning Mapper (GLM) with the Advanced Baseline Imager (ABI) to produce a superior combined instrument product. This effort will make the GOES-R precipitation information uniquely important and provide a large step forward in improving satellite rain estimates in the coming decades. This development will provide the National Weather Service (NWS) and other users with timely, more accurate precipitation estimates from geosynchronous satellite data for use in supplementing ground-based estimates, especially in mountainous areas (e.g., western U.S.), surrounding waters, and in Mexico and Central and South America. The resulting improved rainfall estimates will be valuable for nowcasting in general, flash floods in particular, and estimation of rain potential of tropical cyclones. This type of progress will fit well into development of a system for producing an operational, integrated precipitation product for efficient use by the NWS and others.

The project examines lightning-convection-rainfall relations using TRMM data and develops an approach to integrate the lightning information into geostationary IR rain algorithms, including the ABI rainfall algorithm based on SCaMPR (Kuligowski, 2002). The resulting test product shows great benefit of the lightning data and the usefulness of the enhanced product. The remaining part of the project will be to evaluate the algorithm and compare with the current operational GOES product. This work also encompasses Nai-Yu Wang's work (coupling lightning information and microwave rainfall estimates).

ACCOMPLISHMENTS

Major accomplishments in the last year are as follows:

<u>1. Finalizing the Lightning/IR algorithm, validating it using TRMM data and publishing the result (Xu et al. 2014).</u>

The results show that lightning frequency is a good proxy to separate storms of different intensity, identify convective cores and convective rain area, and screen out false convective core signatures in areas of thick anvil debris. The lightning-cloud-rainfall relationships derived provide insights into the best approaches for rain estimation and provide the lightning-rainfall quantitative relations to potentially be used. Specifically, the lightning information has been shown to be useful to aid identification of convective cores in thick anvils missed by the IR technique, eliminate misidentified convective cores, and correctly define convective rainfall volume. These will be key uses of the lightning information as part of a geosynchronous rain estimation technique. In the last few months we have begun to incorporate these findings and relationships to improve the rainfall estimation using IR techniques, using the Convective/Stratiform Technique (CST) of Adler and Negri (1988) as a prototype approach.

A satellite rainfall estimation technique is developed to combine infrared and lightning information to estimate convective and stratiform precipitation. The algorithm is developed and tested using seven years (2002-2008) of TRMM measurements over the southern United States during the warm season. Lightning information is coupled with a modified IR-based Convective/Stratiform Technique (CST) and produces a lightning-enhanced CST (CSTL). Both the CST and CSTL are then applied to the training (2002-2004) and independent (2005-2008) datasets. In general, this study shows significant improvement over the IR rainfall estimates (rain area, intensity, and volume) by adding lightning information. The CST and CSTL display critical skill in estimating warm season precipitation and the performance is quite stable. The CST can generally catch the heavy (convective) and light rain regions, while CSTL further identifies convective areas that are missed by CST and removes convective cores that are incorrectly defined by CST (a case shown in Fig. 1). Results indicate a CSTL example much closer to the passive microwave estimate than the IR-based estimate. Specifically, the CSTL improves the convective cell detection by 5% and reduces the convective false alarm rate by more than 30%. Similarly, CSTL substantially improves the CST in the overall estimate of instantaneous rainfall rates. For example, when compared with passive microwave estimates, CSTL increases the correlation coefficient by 30%, reduces the bias by 50% and RMSE by 25%. Both CST and CSTL reproduce the rain area and volume fairly accurately over a region, although both techniques show overestimation compared to radar estimates.

2. Comparison with NOAA Operational Product.

We are also starting to compare results with the Self-Calibrating Real-Time GOES Rainfall Algorithm (SCaMPR) (Kuligowski, 2002) as part of moving toward examination of the GOES-R Baseline Rain Algorithm (BRA). In the few cases examined the CST itself and the IR-lightning technique (CSTL) show potential for improvement when compared with the SCaMPR results from GOES matched up in time with TRMM overpasses (see Fig. 2). Further comparisons will be accomplished in the near future.

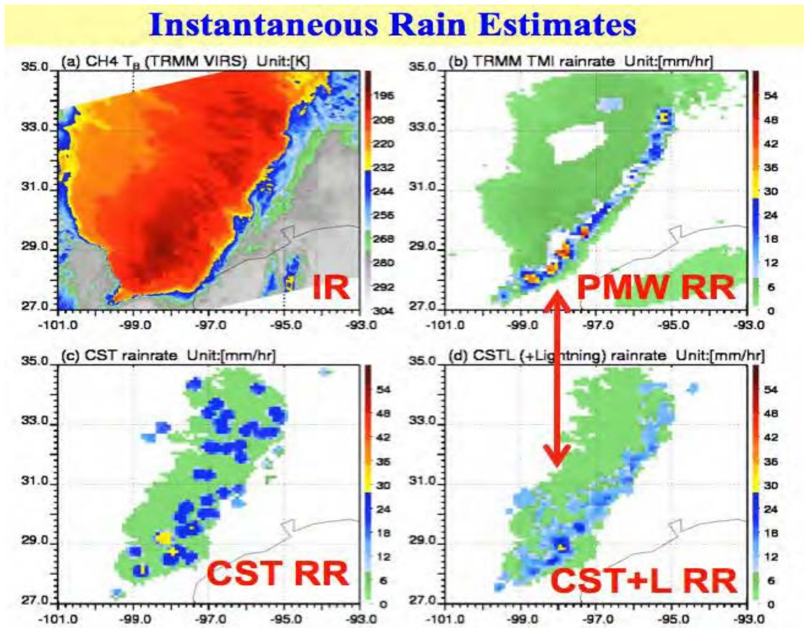


Figure 1. Instantaneous rainfall estimates (10 km resolution) of a MCS: (a) IR T_b map from TRMM VIRS (b) rainrates estimated by TMI 2A12 (c) CST rainrate estimates, and (d) CSTL rainrate estimates. Rainfall rates are indicated by the color bar with unit of mm hr^{-1}.

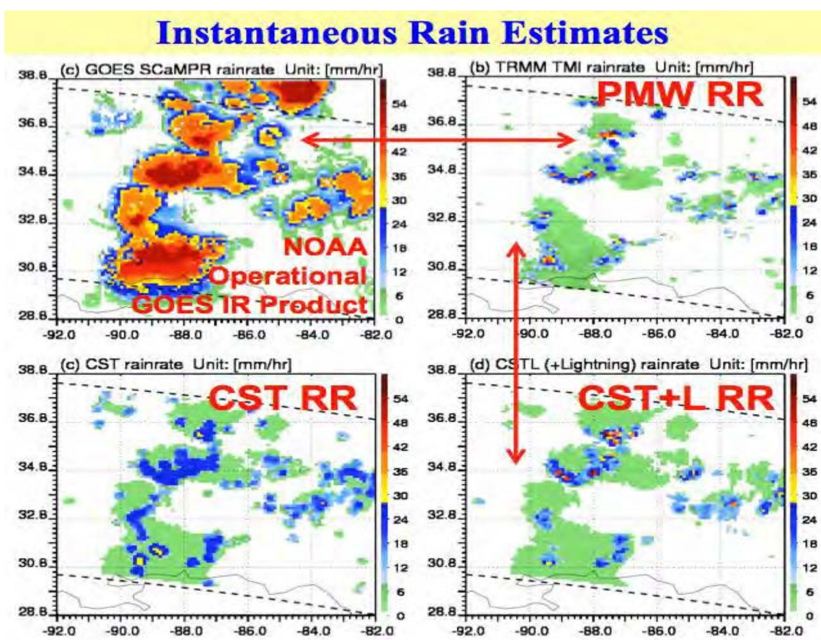


Figure 2. Example comparison of operational NOAA product with CST and CSTL. (a) SCaMPER operational estimate (b) rainrates estimated by TMI 2A12 (c) CST rainrate estimates, and (d) CSTL rainrate estimates. Rainfall rates are indicated by the color bar with unit of mm hr^{-1}.

3. Use of lightning information for improvement of convective-stratiform delineation in passive microwave rain retrievals (Wang et al., JGR).

Passive microwave rain retrievals involve determination of convective-stratiform separation, usually represented as fraction of the microwave satellite pixel area having convection. Since the GOES-R baseline IR algorithm is calibrated using low-orbit passive microwave rain retrievals, an improvement in those retrievals by using lightning information would also improve the IR-based estimates. Upon careful examination the relationships between LIS flash rate, PR reflectivity, and TMI Tb_{85V}, a new microwave convective and stratiform partitioning method that incorporates lightning information into passive microwave observations to delineate convective and stratiform precipitation has been developed as part of this project. LIS lightning occurrence and flash rates (i.e., no flash, 0-1 fl/min, 1-2 fl/min, and > 2 fl/min) are used to classify TMI Tbs into four groups of increasing convective probability. Results indicate that the improvement in microwave retrievals upon incorporating lightning information is most apparent in deep convective systems.

PLANNED WORK

With limited remaining resources we will continue to do comparisons with the NESDIS operational product.

PUBLICATIONS

Xu, W., R. F. Adler, and N.-Y. Wang, 2013: Improving Geostationary Satellite Rainfall Estimates Using Lightning Observations: Underlying Lightning-Rainfall Relationships. *J. Appl. Meteor. Climatol.,* **52,** 13-229.

Xu, W., R. Adler, Nai-Yu Wang, 2014: Combining Satellite Infrared and Lightning Information to Estimate Warm-Season Convective and Stratiform Rainfall. *J. Appl. Meteor. Climatol.*, **53**, 180–199.

Wang, N.-Y., K. Gopalan, and R. I. Albrecht, 2012: Application of lightning to passive microwave convective and stratiform partitioning in passive microwave rainfall retrieval algorithm over land from TRMM, J. Geophys. Res., **117**, D23203, doi:10.1029/2012JD017812.

PRESENTATIONS

Adler, R.F., W.Xu, and N.-Y. Wang, 2013: Combining GLM and ABI Data for Enhanced GOES-R Rainfall Estimates. NOAA Science Webinar, March 2014.

Adler, R.F., W.Xu, and N.-Y. Wang, 2013: Combining GLM and ABI Data for Enhanced GOES-R Rainfall Estimates. EUMETSAT Annual Meeting, Sep. 2013,Vienna.

Xu, W., R. F. Adler, and N.-Y. Wang, 2013: Combining GLM and ABI Data for Enhanced GOES-R Rainfall Estimates. Amer. Meteor. Soc., 93nd Annual Meeting, Jan 2012, Austin, TX.

REFERENCES

Adler, R. F., and A. J. Negri, 1998: A satellite infrared technique to estimate tropical convective and stratiform rainfall. *J. Appl. Meteor.*, **27**, 30-51.

Kuligowski, R. J., 2002: A self-calibrating real-time GOES rainfall algorithm for short-term rainfall estimates. *J. Hydrometeor*, **3**, 112–130.

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Improving GOES-R Cloud Precipitation Products Associated with Deep Convective Systems by using NEXRAD Radar Network over Continental U.S.

Task Leader	Zhanqing Li
Task Code	ZLZL_IGCP_13
NOAA Sponsor	Ingrid Guch
NOAA Office	NESDIS/STAR
Contribution to CICS 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%; Goal 4: 0%; Goal 5: 0%

Highlight: By integrating the space-borne and ground-based radar classification technique with satellite cloud property retrievals, we are developing a satellite-microphysics-based cloud classification to improve the current IR-based precipitation retrieval algorithm. Satellite-microphysics-based cloud classifications are evaluated against aircraft in situ data and ground-based retrievals, while IR-based precipitation retrievals are evaluated with ground-based radar estimates.

BACKGROUND

One of the GOES-R goals is to improve operational satellite-based cloud and precipitation products to enhance short-term heavy rainfall and flood forecasts, as well as long-term assessments concerning agriculture and water resources management. Most heavy precipitation events are associated with deep convective systems (DCSs), whose large-scale morphologic feature of a cold cloud shield at the tropopause-level and cloud microphysical properties (phase, size, IWP, etc.) near cloud top can be monitored by GOES-R satellites. It is difficult, however, to separate precipitating portions of DCSs from non-precipitating anvils using GOES-R observations, which leads to large uncertainties in satellite IR-based precipitation retrievals. This key limitation can be improved by using a newly developed automatic 3-D radar (NEXRAD) classification technique to identify the convective and stratiform rain regions (precipitation) and cirrus anvil regions (non-precipitating) from midlatitude DCSs [Feng et al. 2011]. By integrating the radar classification technique with satellite cloud property retrievals, we are developing a satellite-microphysics-based cloud classification to improve the current IR-based precipitation retrieval algorithm. Satellite-microphysics-based cloud classifications can be evaluated against aircraft in situ data, while IR-based precipitation retrievals are evaluated with ground-based radar estimates.

ACCOMPLISHMENTS

1. Used the newly developed classification technique to identify DCSs and classify them into convective cores, stratiform rain regions, mixed and ice anvils, and then to obtain their corresponding cloud and precipitation statistics from GOES-R observations over the continental U.S.,
2. Used the multi-scale, multi-sensor ground-based radars and other observations, and aircraft in situ measurements to validate satellite retrieved cloud and precipitation properties from the Mid-latitude Convective Clouds Experiment (MC3E) during the late spring/early summer of 2011 within the ARM SGP site,

3. Investigated the impact of aerosols on DCSs. Aerosols may affect the development of a DCS by delaying precipitation, enhancing latent heat release and invigorating clouds to become severe storms. It is unclear to what extent and under what conditions such effects occur. By using rich information from multiple sources of satellite data, we are investigating such effects, as a pathway for the exploitation of future GOES-R products.
4. Took advantage of new satellite and ground-based remote sensing cloud products to test, improve and develop cloud parameterization schemes used in the NCEP/GFS model. This may lay a foundation for future use of GOES-R products in operational weather applications.

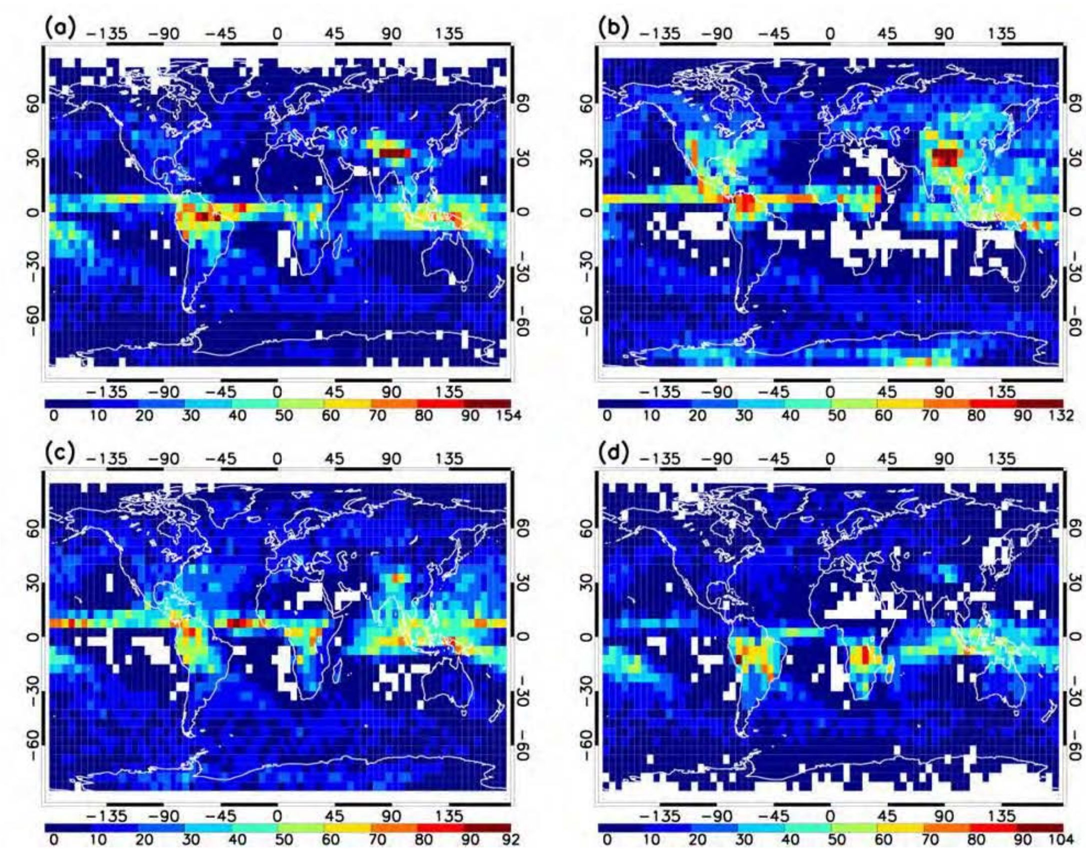


Figure 1. Total number of DCS in each 5°x5° grid box over the four-year period for (a) NH spring/SH autumn, (b) NH summer/SH winter, (c) NH autumn/SH spring, and (d) NH winter/SH summer. White grid boxes signify that no DCS were identified in that box.

All project deliverables (documentation and software) and milestones have been accomplished as planned. Currently, the software system is being tested and preparations are under way for the Test Readiness Review (TRR).

PLANNED WORK

- Continue work to assess the performance of the algorithm
- Continue work to refine the algorithm parameters and to improve its performance over high-elevation areas
- Integrate algorithm within IMS Version 3 platform
- Transition algorithm to operations

PUBLICATIONS

Fan, J., L.R. Leung, D. Rosenfeld, Q. Chen, Z. Li, J. Zhang, H. Yan, 2013, Microphysical effects determine macrophysical response for aerosol impact on deep convective clouds, *Proceedings of National Academy of Sciences (PNAS),* doi:10.1073/pnas.1316830110.

Peng, J., Z. Li, and H. Zhang, 2013: Temporal and spatial variations of global deep cloud systens based on CloudSat and CALIPSO satellite observations*, Adv. Atmos. Sci.*, in press.

Yang, X., Z. Li, 2014, Increases in thunderstorm activity and relationships with aerosol loading in Southeast China, *J. Geophys. Res.,* doi:10.1029/2013JD51155.

Yang, X., M. Ferrat, and Z. Li, 2013: New evidence of orographic precipitation suppression by aerosols in central China, *Meteorol. Atmos. Phys*., doi:10.1007/s00703-012-0221-9.

Yang, X., Z. Yao, Z. Li, 2013, Heavy air pollution suppresses summer thunderstorms in central China*, J. Atmos. & Solar-Terrestrial Phy.* 28-40, doi:10.1016/j.jastp.2012.12.023..

DELIVERABLES

We have demonstrated significant improvement over the Southern Great Plains region in the estimates of precipitation after filtering raining from non-precipitating AC regions based on both cloud optical depth and IR BT. This improved precipitation product would be a valuable asset for NWS applications. We have further improved the algorithms for detection and estimation of precipitation, and extended the region of our study from the SGP to the whole globe using A-Train satellite data. The global database of DCS can be used to study the DCS lifecyle and formation-dissipiation processes over the different continents. With the high temporal and spatial resolutions of GOES-R retrievals, the performance of rainfall detection and estimation algorithms will be markedly enhanced for these types of clouds. Furthermore, the relationship of DCS thickness and anvil size to aerosol was investigated.

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	1
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	5
# of non-peered reviewed papers	0
# of invited presentations	4
# of graduate students supported by a CICS task	1
# of graduate students formally advised	2
# of undergraduate students mentored during the year	0

1.2 Calibration and Validation

NPP/VIIRS Land Product Validation Research and Algorithm Refinement: GEOG Task 1. Surface Reflectance

Task Leader	Chris Justice
Subtask Leader	Dr. Eric Vermote
Task Code	CJEV_VIIRS_13
NOAA Sponsor	Ivan Csiszar
NOAA Office	NESDIS/STAR/SMCD/EMB
Percent contribution to CICS Themes	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Percent contribution to NOAA Goals	Goal 1: 50%; Goal 5: 50%

Highlight: CICS scientists have made great progress in the evaluation of the VIIRS cloud Mask (VCM) and VIIRS surface reflectance. The VIIRS surface reflectance has recently been promoted to provisional status on March 17, 2014 and VCM is now at validation stage 2. The methods and metrics for evaluation are well in place and a paper in press in RSE that summarized our evaluation.

BACKGROUND

This subtask support an evaluation of the accuracy of select operational algorithms for NPP/VIIRS land products. The work includes analysis of the land surface reflectance product, analysis and impact evaluation of the VIIRS SDR and VIIRS cloud mask.

ACCOMPLISHMENTS

We have developed VIIRS vicarious cross-calibration with Aqua over desert/bright sites. This method has been routinely applied to the data stream in order to provide near-real time monitoring of the VIIRS calibration focusing in the reflective domain (Figure 1). We focused in particular on the red and near-infrared bands (I1,I2 M5 and M7) which are critical for downstream products such as Vegetation indices which are used in near time for the monitoring of vegetation and agriculture area, for detecting climate induced anomaly (e.g. drought) and assessing impact on production and forecasting yields.

We have performed preliminary inter-comparison of MODIS Aqua and VIIRS surface reflectance, aerosol and cloud mask products using the Climate Modeling Grid (CMG) dataset developed for MODIS and VIIRS by our science computing facility. This activity has enabled to diagnose very rapidly issues with the VIIRS aerosol, cloud mask and reflectance algorithm on a global and continuous basis which is complementary with the detailed analysis performed on a limited amount of instrument sites (see next paragraph on the validation subset).

We have performed preliminary evaluation of VIIRS aerosol and surface reflectance products on validation subsets. This evaluation will be done by the use of the AERONET data collected at those

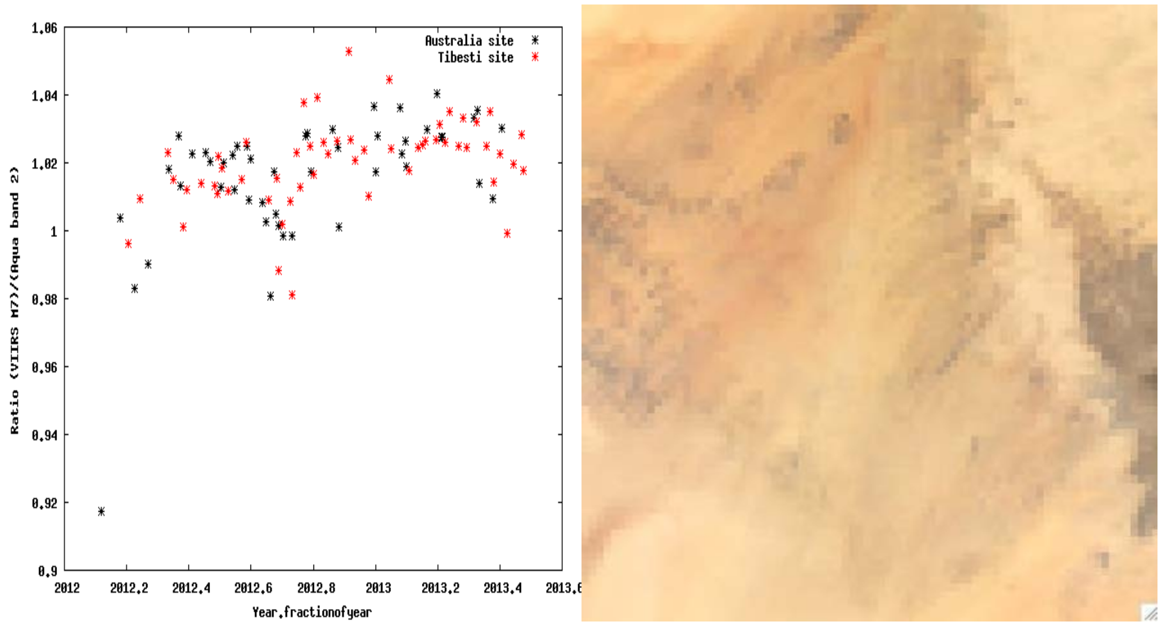


Figure 1: *Example of VIIRS continuous calibration monitoring in band M7 (Near-Infrared) over two sites, one over Australia (black symbol) and one over Tibesti (~40km x 40km) (red symbol) (left side). The true color image of the Tibesti calibration site is shown on the right side.*

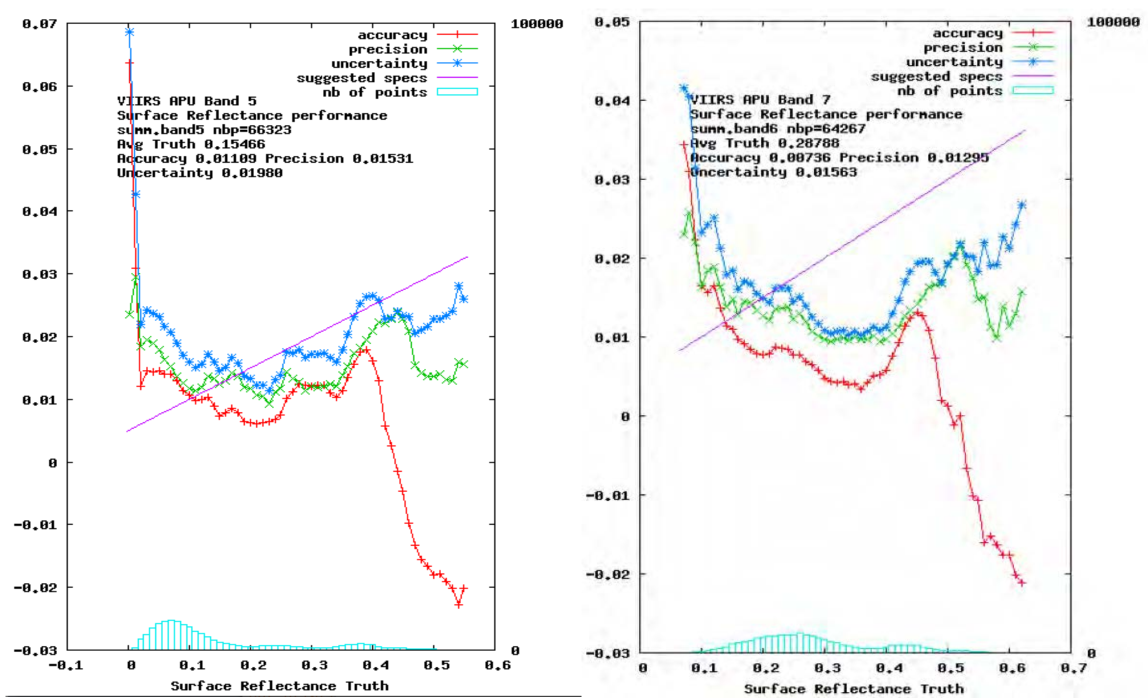


Figure 2: *Estimates of VIIRS surface reflectance Accuracy Precision and Uncertainty performances for VIIRS for band M5 (red), Left panel and M7 (Near-Infrared), Right Panel. The surface reflectance 'truth' is computed using the 6S radiative transfer code and the AERONET data for 2012.*

sites which provide with the 6S radiative transfer code an independent basis to generate surface product and assess the properties of the aerosols.

We have derived a first set of VIIRS surface reflectance product performance (accuracy, precision and uncertainty, APU). This analysis has focused primarily on the validation subset (see previous bullet) and also applied to the MODIS data (Figure 2).

We have acted as the Land Point of Contact with the VIIRS calibration and cloud mask (VCM) teams in particular attended the weekly/bi weekly teleconferences organized by those teams and reported the land perspective. We participated to calibration and cloud mask product review and contributed to the assessment of product maturity (beta, provisional, validated stage 1-3)

Performance Metrics	**FY13**
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

PLANNED WORK

Continue the Calibration monitoring and validation of the reflectance product and cloud mask over land surfaces.

PUBLICATIONS

Vermote, E.F., Justice, C.O., Csiszar, I., “Early evaluation of the VIIRS Calibration, Cloud Mask and Surface Reflectance Earth Data Records” *Remote Sensing of Environment*, (accepted)

Justice, C. O., Román, M. O., Csiszar, I., Vermote, E. F., Wolfe, R. E., Hook, S. J., Friedl M., Wang Z., Schaaf C.B., Miura T., Tschudi M., Riggs G., Hall D.K., Lyapustin A., Devadiga S., Davidson C. and Masuoka E.J. (2013). Land and cryosphere products from Suomi NPP VIIRS: Overview and status. *Journal of Geophysical Research: Atmospheres*, 118(17), 9753-9765.

PRESENTATIONS

Eric Vermote, “Land team evaluation of the Visible Infrared Imaging Radiometer Suite (VIIRS) Cloud Mask”, Suomi NPP EDR Validated 1/Provisional Readiness Review on January 7, 2014, at the NOAA Center for Weather and Climate Prediction (NCWCP)

Eric Vermote, “VIIRS Surface Reflectance Status summary”, SUOMI NPP EDR Product Review, NOOA Center for Weather and Climate Prediction, College Park, MD, August 22,2013.

A Rapid Delivery System of Enhanced VIIRS Active Fire Data for Fire Management and Fire Weather Applications

Task Leader	Evan Ellicott
Task Code	EEEE_ARDS_12
NOAA Sponsor	Ivan Csiszar
NOAA Office	NESDIS/STAR/SMCD/EMB
Percent contribution to CICS Themes	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 80%

Highlight: The VIIRS AF Proving Ground project made great strides towards our goals in 2013. Outreach continued via conference presentations, workshop training, and on-site visits to two major wildfire incidents. We enhanced our website to offer additional datasets and provide data in formats that were directly based on user feedback. Evaluation proceeded with the standard data portal (CLASS) and direct broadcast (DB) data. Webpage: http://viirsfire.geog.umd.edu/

BACKGROUND

The VIIRS Active Fire product is critical for disaster and resource management. The product is expected to be used by real-time resource and disaster management; air quality monitoring; ecosystem monitoring; climate studies, etc. The JPSS PGRR program's primary objective is to maximize the benefits and performance of SNPP data, algorithms, and products for downstream operational and research users (gateways to the public). The goals of the VIIRS AF PGRR project are product evaluation and improvement and the development of a near-real-time enhanced product delivery system to support fire management and NOAA operations.

ACCOMPLISHMENTS

The previous performance period's outcomes were varied, numerous, and successful in progressing the goals of this project and shaping future endeavors.

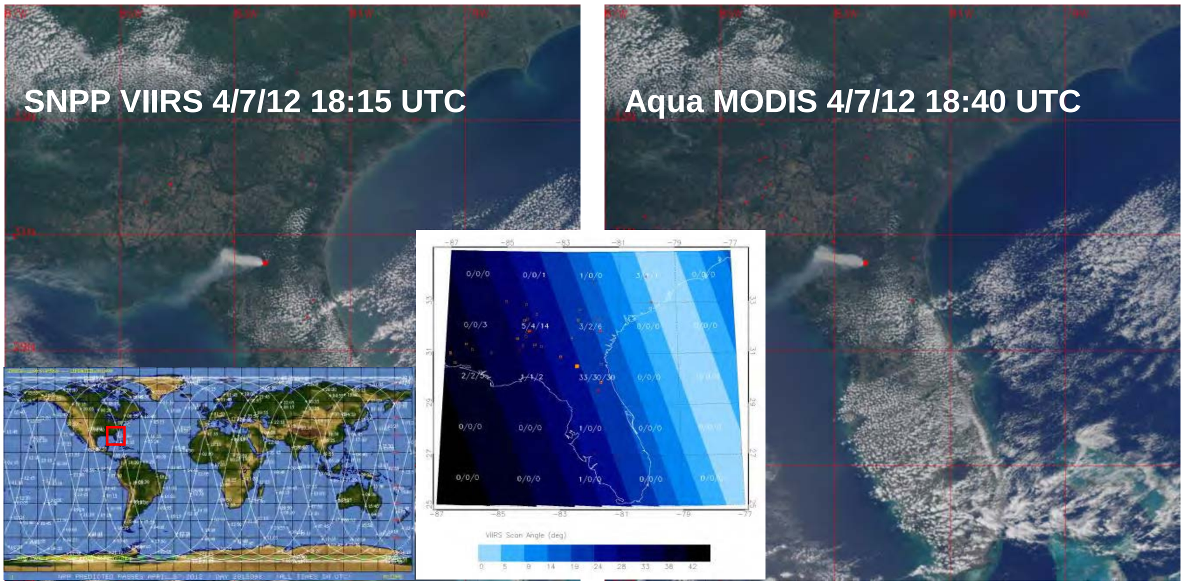
Teleconferences, user-workshop training, and meeting and conference presentations offered opportunities to engage the user community to educate them about the VIIRS AF product, hear questions and concerns, and elicit feedback as to their data needs as well as their remote sensing data experiences (pro/cons, limitations of data access, data formats, etc.). We continued to expand and improve our website to offer new data, an archive database, and user-friendly formats based on end-user feedback; http://viirsfire.geog.umd.edu (see Figure 1).

We visited two wildland fire incidents this summer for a total of approximately 8 days: the West Fork Complex fire, Colorado, in June; and the Rim fire, California, in August. We worked closely Robyn Heffernan, National Fire Weather Science and Dissemination Meteorologist and Larry Van Bussum, Operations Section Chief, both at the National Interagency Fire Center (NIFC) and National Interagency Coordination Center (NICC) in Boise, Idaho to assist in the logistics and clearance to get into the Incident Command Post (ICP) and meet with the Incident Cadre, including, but not limited

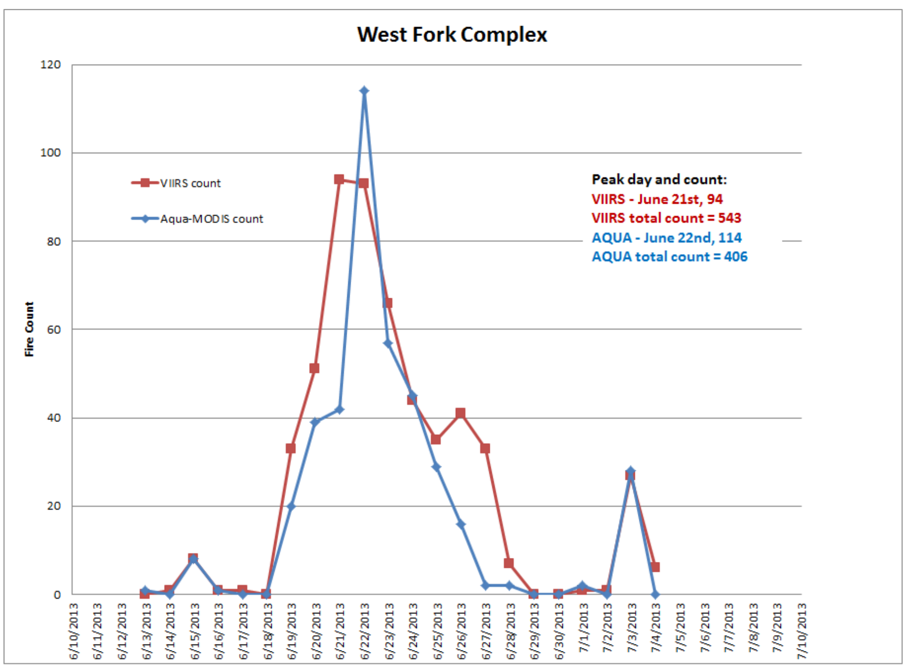
(a). (b).

(c). (d).

Figure 1: (a) VIIRS Active Fire website (http://viirsfire.geog.umd.edu) showing the home page with additional pages to learn more about the S-NPP satellite, VIIRS sensor, and AF product, as well as download data; (b) data visualization and data download page; (c) data archive and; (d) "Contact Us" page for feedback questions.



(a).



(b).

Figure 2: (a) Example of VIIRS and MODIS AF detections comparison; (a) County Line fire, Florida, April 2012. The color-coded grid plot provides a comparison of nearly coincident detections. The detections are binned in 2° x 2° cells and the color reflects the VIIRS scan angle; the darker the color, the greater the angle. The first number (N/x/x) is the VIIRS detections; the second (x/N/x) is the number of VIIRS pixels with a coincident MODIS fire detection; and the third number (x/x/N) is the MODIS-Aqua detections; (b) Comparison of fire count from VIIRS and Aqua for the West Fork Complex, Colorado, June-July, 2013.

to the Incident Meteorologists (IMET), fire behavior analysts (FBAN), LTAN (long-term analysts). The West For visit was documented in a JPSS feature article "Key Satellite Instrument Captures West Fork Complex Fire in Southern Colorado" released through the JPSS program website. The feature article is also accompanied by a more detailed discussion paper: www.jpss.noaa.gov/science_seminars/Features/Active_Fire_Detection.pdf . Simultaneously to the release of the article, an image of the West Fork fire was posted on the NESDIS Facebook page. A comment posted on the image said "I love that my tax dollars support this".

We conducted various evaluations of the standard VIIRS AF product (AVAFO). For example, a comparison with Aqua-MODIS provided a qualitative estimate of the product's performance (Figure 2).

We evaluated direct broadcast (DB) VIIRS AF data to ensure consistency with the standard VIIRS AF product (available via CLASS). For example, comparison of fire detections between the product generated by the U.S. Forest Service (USFS) Remote Sensing Applications Center (RSAC) with and AVAFO product to was performed for numerous large fire events (Figure 4). In addition, while visiting fire incidents we were able to educate users as to how to obtain fire detections from DB sources and understanding some of the nuances ranging from naming convention to nominal pixel size versus the real pixel area (a function of scan angle). Product delivery to the Direct Broad (DB) "alpha" testers provided early user feedback and evaluation of this near-real time data.

Testing of the VIIRS AF "replacement" product, as well as an experimental, higher resolution I-band fire product (Schroeder et al., 2014) was performed during the 2013 fire season (Figure 5). This product is intended to provide continuity with the MODIS AF product by offering consistency in data generated (i.e. fire characterization, FRP), as well as improve the fire detection algorithm which is currently outdated on VIIRS.

Planned Work

- Extend capabilities of the VIIRS fire evaluation portal to display global fire detections.
- Develop a strategy for coordinated, multi-satellite and multi-program interaction with operational end user communities.
- Support operational use of the IDPS product by the NOAA Hazard Mapping System
- Participate in direct interaction with end users through on-site training and through on-site visits during select fire events.
- Evaluate needs and capabilities for the inclusion of fire detection information in AWIPS II.
- Product feedback from international users to complement U.S.-based assessments
- Evaluation of the IDPS operational algorithm adjustments.
- Develop an implementation plan for coordinated, multi-satellite and multi-program initiative for operational use of satellite-based fire products.

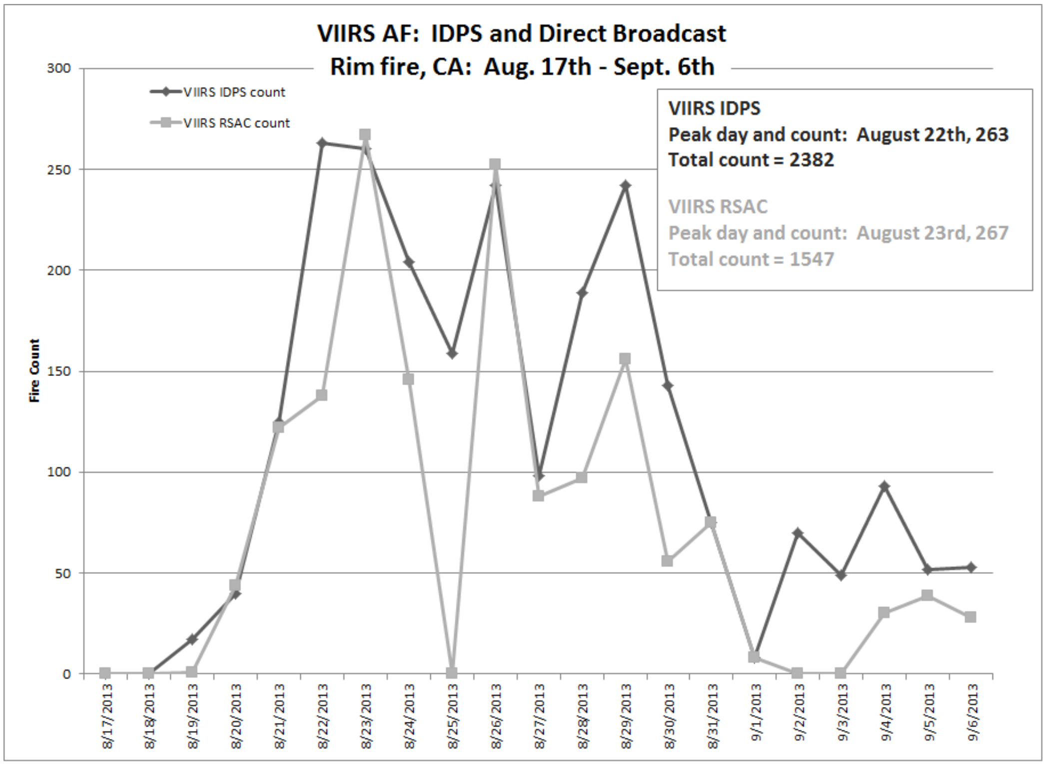


Figure 4: VIIRS IDPS product from CLASS and Direct Broadcast observed detections reported by the USFS RSAC for the Rim fire dates of 8/17/2013 – 9/6/2013.

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.

PRESENTATIONS

E. Ellicott, I. Csiszar, P. Roohr, B. Quayle, L. Giglio, W. Schroeder, K. Vadrevu, C. Justice; American Meteorological Society's Annual Meeting, February 6th, 2014, "Suomi NPP (SNPP) Visible Infrared Imaging Radiometer Suite (VIIRS) Active Fire Data for Fire Management and Fire Weather Applications".

E. Ellicott, I. Csiszar, K. Vadrevu, W. Schroeder, L. Giglio, B. Quayle, C. Justice, P. Roohr; NASA Applied Remote SEnsing Training (ARSET) November 20th, 2013, "Suomi-NPP VIIRS Active Fire: Introduction to Remote Sensing for Air Quality Applications".

E. Ellicott, K. Vadrevu, , W. Schroeder, L. Giglio, C. Justice, B. Quayle, and P. Roohr; Tactical Fire Remote Sensing Advisory Committee (TFRSAC) Spring Meeting, San Jose, CA, April 17th, 2013, "Suomi NPP VIIRS Active Fire: Proving Ground and Risk Reduction".

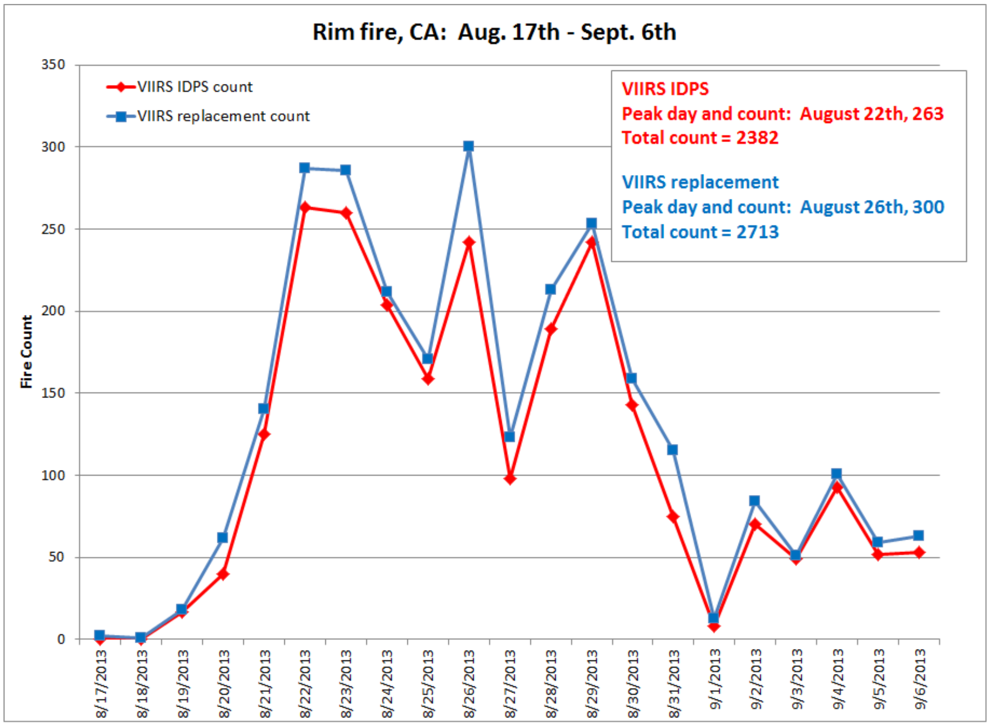


Figure 5: VIIRS IDPS product and the VIIRS replacement AF product for the Rim fire dates of 8/17/2013 – 9/6/2013.

E. Ellicott, I. Csiszar, W. Schroeder, P. Roohr, and B. Quayle, L. Giglio, and C. Justice; NOAA Satellite Conference, College Park, MD, April 9th, 2013, "Suomi NPP (SNPP) Visible Infrared Imager Radiometer Suite (VIIRS) Active Fire Data for Fire Management and Fire Weather Applications".

E. Ellicott, I. Csiszar, P. Roohr, B. Quayle, L. Giglio, W. Schroeder, K. Vadrevu, C. Justice; NWS Incident Meteorologist (IMET) training workshop, March 14th & 21st, 2013, "Suomi-NPP (SNPP) VIIRS Active Fire: Proving Ground and Risk Reduction. A rapid delivery system of enhanced VIIRS active fire data for fire management and fire weather applications".

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	3
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	1
# of invited presentations	3
# of graduate students supported by a CICS task	1
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

A Terrestrial Surface Climate Data Record for Global Change Studies

Task Leader	Eric Vermote
Task Code	EVEV_TSCDR_10 (Shadow Award)
NOAA Sponsor	Jeff Privette
NOAA Office	NESDIS/NCDC/CSMD
Percent contribution to CICS Themes	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Percent contribution to NOAA Goals	Goal 1: 100%

Highlight: A 30+ years of daily surface reflectance and vegetation index data processed in a consistent way is now available from this project. It is generated from data of several AVHRR instruments from 1981 to 2013 and of the MODIS instruments on-board Terra and Aqua from 2000 to 2013. Inter-comparison of the MODIS aqua and AVHRR for the 2000-2013 period has enable to further refine the AVHRR record. It uses state of the art algorithms for geo-location, calibration, cloud screening, atmospheric and surface directional effect correction to achieve the most consistent data record possible. This dataset is a daily global dataset at the resolution of 0.05 degree of latitude and longitude. This dataset has also been tested prior to release in practical applications of societal benefits such as forest cover change detection over the long term as well as drought monitoring or yield prediction in the context of agricultural production and food security.

BACKGROUND

The overall objective of this project is to produce, validate and distribute a global land surface climate data record (CDR) using a combination of mature and tested algorithms and the best available land imaging polar orbiting satellite data from the past to the present (1981-2013), and which will be extendable into the JPSS era. The data record consists of one fundamental climate data record (FCDR), the surface reflectance product. Two Thematic CDRs (TCDRs) are also be derived from the FCDR, the normalized difference vegetation index (NDVI) and LAI/fAPAR. These two products are used extensively for climate change research and are listed as Essential Climate Variables (ECVs) by the Global Climate Observing System (GCOS). In addition, these products are used in a number of applications of long-term societal benefit. The two TCDRs are used to assess the performance of the FCDR through a rigorous validation program and will provide feedback on the requirements for the Surface Reflectance FCDR.

ACCOMPLISHMENTS

- Release of the 30+ record (version 3)
- reprocessing and evaluation of the 2000-2013 AVHRR data (version 4 improved geolocation and gridding)
- Transition of version 4 to NOAA for official CDR status (on-going expected to finish on April 2014)

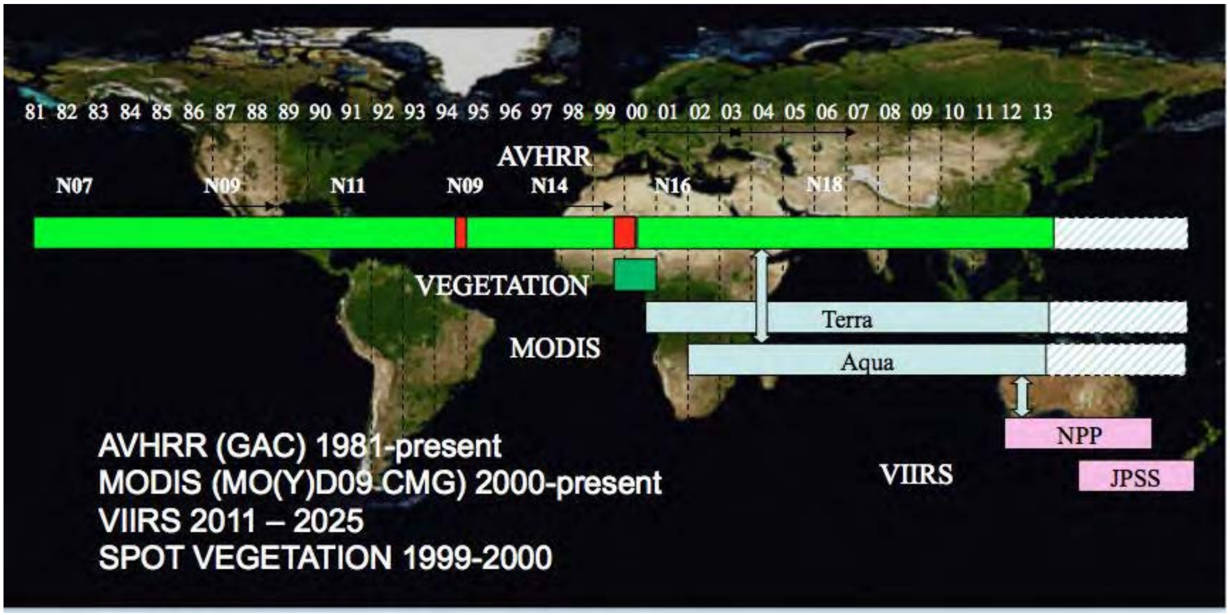


Figure 1: The generation of a Land climate data record (several decade) necessitates the use of multi instrument/multi sensor science quality data record. This record is used to quantify the trend and change in land surface parameter (e.g. Vegetation/Land Cover). A strong emphasis is put on data consistency that is achieved by careful characterization and processing of the original data rather than degrading and smoothing the dataset.

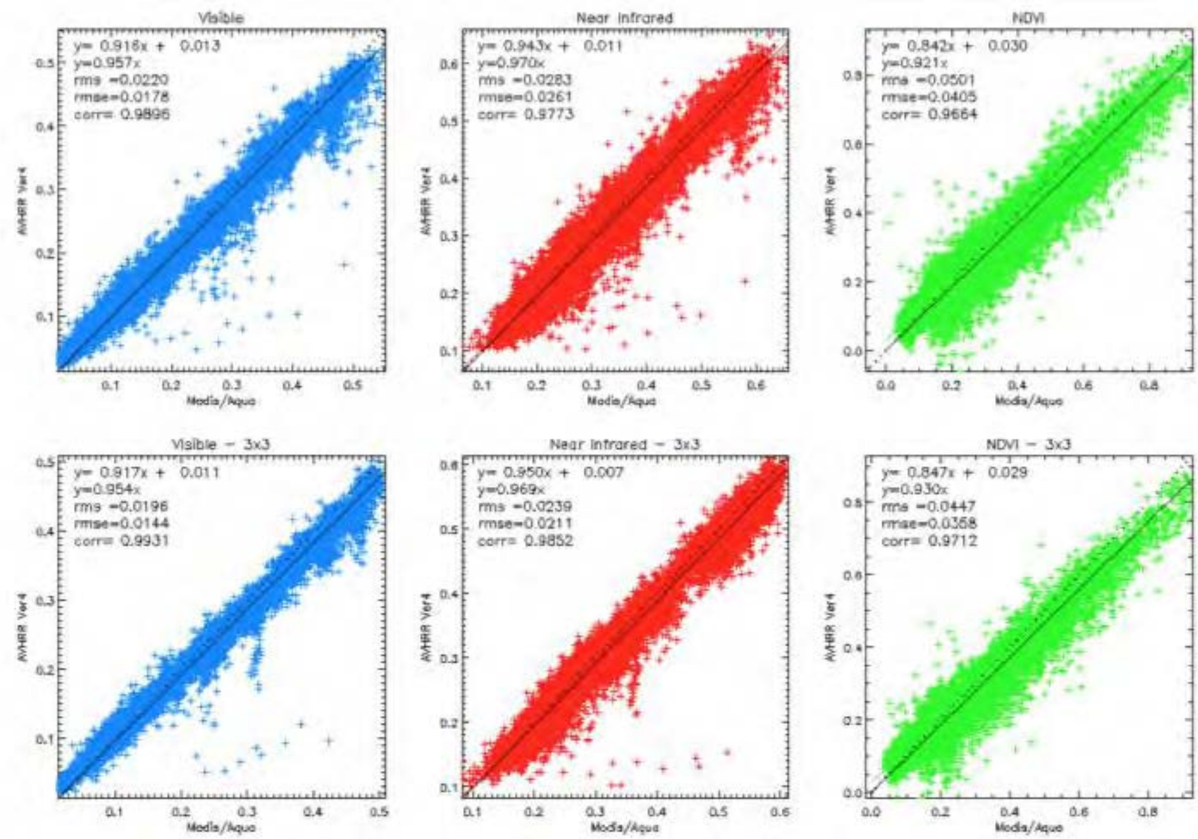


Figure 2: Inter-comparison of AVHRR LTDR Version 4 and MODIS Aqua over 400 sites for 2003.

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	3
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	5
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

PLANNED WORK

We are planning to make final improvements to the AVHRR atmospheric correction (water vapor and aerosol) that will be possible when the updated calibration of the longwave bands on AVHRR (4, 11 and 12 microns) is available.

PUBLICATIONS

Franch B., Vermote E., Sobrino J.A. and Julien Y.,"Retrieval of surface albedo on a daily basis: Application to MODIS data", *IEEE Transactions on Geoscience and Remote Sensing*, (accepted)

Claverie, M., Vermote, E. F., Weiss, M., Baret, F., Hagolle, O., & Demarez, V. (2013). Validation of coarse spatial resolution LAI and FAPAR time series over cropland in southwest France. *Remote Sensing of Environment*, 139, 216-230.

Sobrino, J.A., Franch, B., Oltra-Carrió, R., Vermote, E.F., & Fedele, E. (2013). Evaluation of the MODIS Albedo product over a heterogeneous agricultural area. *International Journal of Remote Sensing*, 34, 5530-5540;DOI 10.1080/01431161.2013.792968

Verger, A., Baret, F., Weiss, M., Kandasamy, S., & Vermote, E. (2013). The CACAO Method for Smoothing, Gap Filling, and Characterizing Seasonal Anomalies in Satellite Time Series. **IEEE** *Transactions on Geoscience and Remote Sensing*, 51, 1963-1972, DOI: 10.1109/TGRS.2012.2228653.

B. Franch, E.F. Vermote, J.A. Sobrino, E. Fédèle, (2013) Analysis of directional effects on atmospheric correction, *Remote Sensing of Environment*, Volume 128, Pages 276-288 http://dx.doi.org/10.1016/j.rse.2012.10.018.

PRESENTATIONS

E. Vermote, lecture on "Best practises over land using optical sensors (MODIS, LANDSAT)", Committee on Space Research (COSPAR) Capacity Building Workshop on "Atmospheric Correction of Earth Observation Data for Environmental Monitoring: Theory and Best Practices" GISTDA Training Facility, Bangkok,Thailand, November 4 -8 , 2013

E. Vermote, "A Terrestrial Surface Climate Data Record for Global Change Studies", NOAA's Climate Data Record Annual Meeting, National Climate Data Center, Asheville, NC, July 30-31,August 1, 2013

Evaluation of Megha-Tropiques (M-T) Products

Task Leader	Isaac Moradi
Task Code	IMIM_EMTP_13
NOAA Sponsor	Ralph Ferraro
NOAA Office	NESDIS/STAR/CRPD/SCSB
Contribution to CICS Themes (%)	Theme 1: 25%; Theme 2: 70%; Theme 3: 5%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA Goals (%)	Goal 1: 80%; Goal 2: 20%

Highlight: This research evaluated quality of the observations from SAPHIR instruments aboard Megha-Tropiques satellite versus ATMS onboard S-NPP as well as in-situ measurements.

BACKGROUND

The hydrological cycle of the Earth is perhaps one of the most complex global feedback mechanisms that impact all living forms on the planet. An accurate description of the global precipitation patterns over an extended period of time is critical to determining any changes in the hydrological cycle. These pattern changes include the frequency, areal extent and duration of extreme weather events (e.g., flash floods, drought, extreme events, etc.) as well as long term shifts of the global rainfall distribution. Such changes have a dramatic impact on the quality of life for all inhabitants on the Earth.

Measurements from low earth orbiting (LEO) satellites, in particular, microwave sensors, offer a unique dataset to develop global precipitation retrievals. This project focuses on a new satellite – Megha-Tropiques (M-T) – a joint research mission between India and France (launched in October 2011), and the evaluation of hydrological products generated at NESDIS from the M-T sensors (Brogniez et al. 2012). M-T operates in an orbit very similar to TRMM and covers a latitude band spanning from almost 30° S to 30° N. In particular, a series of products generated through the Microwave Integrated Retrieval System (MiRS; Boukabara et al. 2011).

ACCOMPLISHMENTS

Figure 1 shows the results for the comparison between different channels of ATMS and SAPHIR instruments. As is shown, in most cases the difference is less than 2 K but it should be noted that this difference is mainly introduced by the frequency difference between SAPHIR and ATMS. SAPHIR and ATMS channels operate at slightly different frequencies which causes some systematic bias between the channels that needs to be removed from the comparison. This systematic difference was estimated using radiative transfer calculations and is shown in Table 1. Therefore the actual bias between ATMS and SAPHIR is estimated using a double difference as Bias = Obs – Sim, where Obs indicates the difference between SAPHIR and ATMS observations and Sim indicates the difference between simulated SAPHIR and ATMS brightness temperatures. As is shown in Table 1, the actual difference between ATMS and SAPHIR observations is less than 0.5 K in most cases.

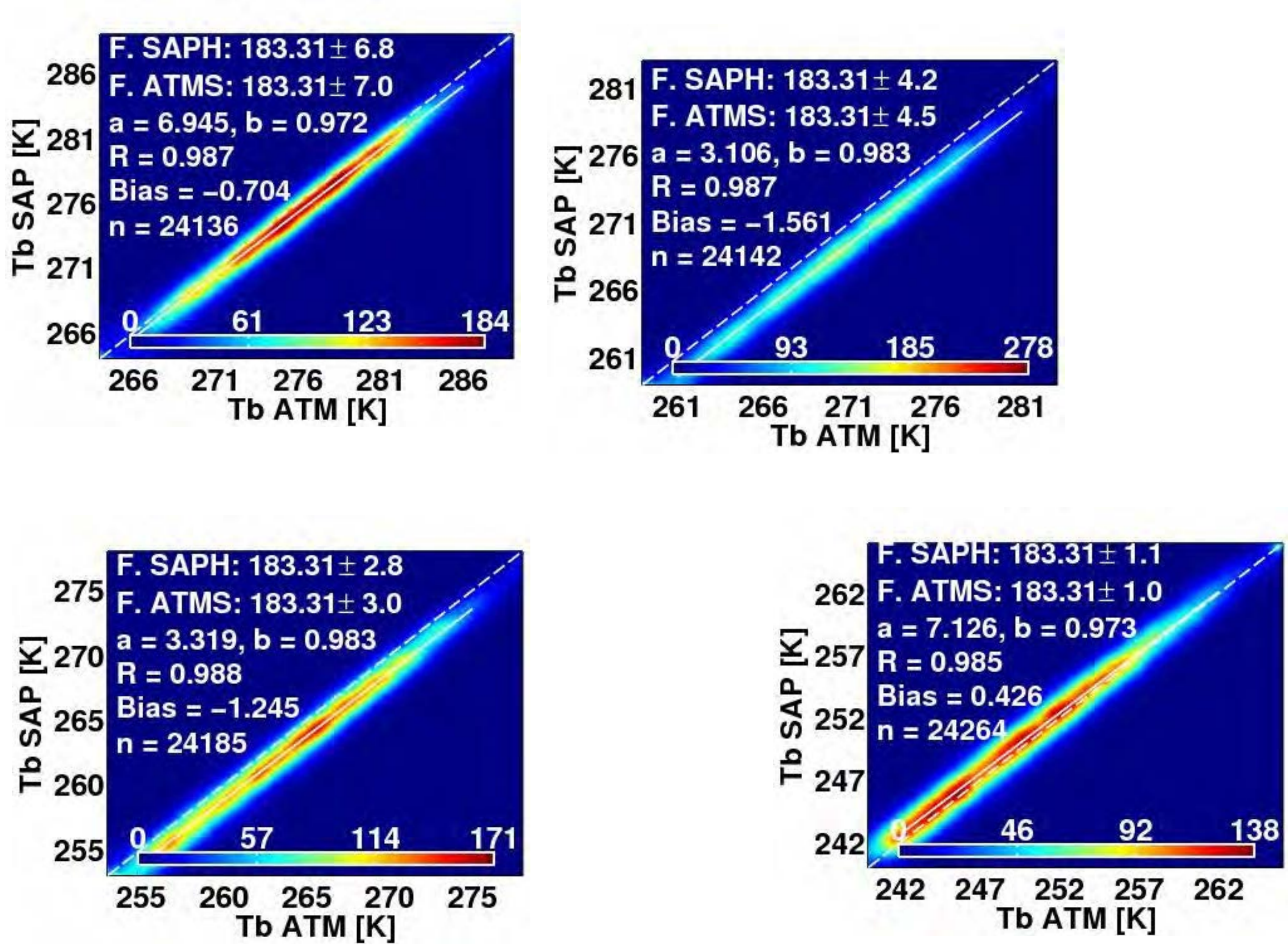


Figure 1: Comparison between SAPHIR and ATMS observations. F indicates the frequency, R correlation coefficient, a and b are intercept and slope of the fitted line and n indicates number of observations.

We also compared SAPHIR observations versus simulated brightness temperatures using ARM radiosonde data. The results for this comparison are shown in Figure 2. In this case, the bias slightly increase from Channel 1 to Channel 6. It should be noted that about 1 K of the bias is related to error in radiosonde data, temporal and spatial mismatch, and error in radiative transfer calculations. So the actual bias is expected to be less than 1 K.

PLANNED WORK

- Publish results in peer-reviewed journals.

Table 1: Systematic bias between observed and simulated ATMS and SAPHIR brightness temperatures.

F ATMS	F SAPHIR	Bias (Obs)	Bias (Sim)	Obs - Sim
183±7.0	183±6.8	-0.70	-0.42	-0.28
183±4.5	183±4.2	-1.56	-0.91	-0.65
183±3.0	183±2.8	-1.25	-0.93	-0.32
183±1.0	183±1.1	+0.43	+0.90	-0.47

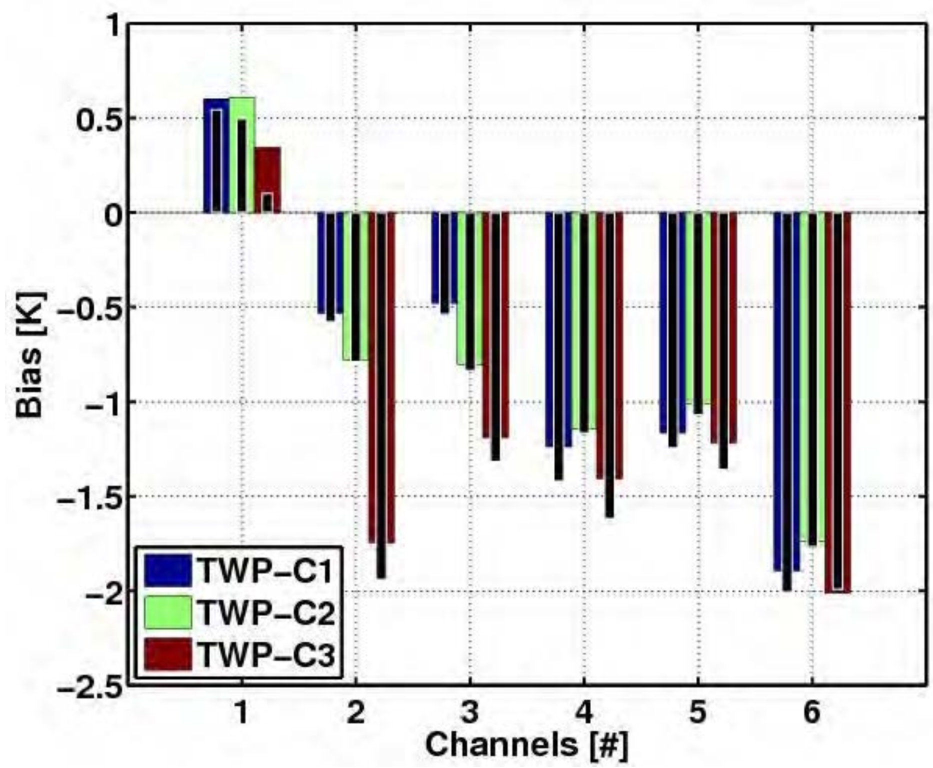


Figure 2: Difference between observed and simulated SAPHIR brightness temperatures using ARM radiosonde profiles. The bars show the bias with respect to different stations and black bars show the corresponding bias for the simulations conducted using land emissivity.

PUBLICATIONS

I. Moradi and R. Ferraro. Intercalibration and valiadation of observations from modern spaceborne microwave instruments*. IEEE Trans. Geoscience and Remote Sensing*, in preparation.

I. Moradi, R. Ferraro, B. Soden, and P. Eriksson. Retrieving layer-averaged tropospheric humidity from Advanced Technology Microwave Sounder (ATMS) water vapor channels. *IEEE Transactions on Geoscience and Remote Sensing*, 99: Paper No. TGRS–2014–00141,2014. Submitted.

I. Moradi and R. Ferraro. Evaluating tropospheric humidity observations from modern space-borne microwave instruments. In AGU Fall Meeting, San Francisco, CA, USA, December 9–13 2013.

I. Moradi and R. Ferraro. Inter-calibrating observations from microwave humidity sounders (saphir, atms, mhs). In GPM Applications Workshop, NOAA Center for Weather and Climate Prediction (NCWCP), College Park, MD 20740, November 12–13 2013.

DELIVERABLES

- Inter-calibration of SAPHIR and ATMS;
- Evaluation of SAPHIR observations versus simulated brightness temperatures using radiosonde profiles
- Peer-reviewed and conference publications

PRESENTATIONS

I. Moradi and R. Ferraro. Microwave Satellite Data and Products: Bias Correction and Applications, The Cooperative Remote Sensing Science and Technology Center (CREST), City University of New York (CUNY), New York, NY, USA, 2013.

I. Moradi and R. Ferraro. Inter-calibration and validation of observations from modern satellite microwave humidity sounders. In The 13th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment, Pasadena, CA, USA, March 24–27 2014.

I. Moradi and R. Ferraro. Validation, inter-calibration, and application of observations from space-borne microwave instruments. In Second Annual CICS-MD Science Meeting, University of Maryland, College Park, MD 20740, November 6–7 2013.

OTHER (e.g., awards; outreach…

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	2
# of non-peered reviewed papers	2
# of invited presentations	3
# of graduate students supported by a CICS task	N/A
# of graduate students formally advised	N/A
# of undergraduate students mentored during the year	N/A

PERFORMANCE METRICS EXPLANATION

This research supported the transition of Megha-Tropiques SAPHIR products in term of inter-calibration and validation of observations versus similar space-borne instruments as well as reference in-situ data. The results are documented in a peer-reviewed paper which is in preparation to be submitted to IEEE TGRS journal. The results have also been presented in national conferences as well as in a few invited talks. This project supported and led the transition of SAPHIR products to operation.

Satellite Calibration and Validation (Cal/Val) efforts for STAR Precipitation Products

Task Leader	Jian-Jian Wang
Task Code	JWJW_SCAV_13
NOAA Sponsor	Ingrid Guch
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 30%; Theme 2: 70%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA Goals (%)	Goal 1: 25%; Goal 2: 75%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Daily and seasonal validations of several operational rainfall products generated by NESDIS are conducted over the contiguous United States, and the results are disseminated via a CICS web page.

BACKGROUND

The NOAA/NESDIS/Center for Satellite Applications and Research (STAR) is responsible for the calibration and validation (Cal/Val) of remotely-sensed products produced by NESDIS. Various projects are helping to insure both the quality of satellite radiance data and satellite-derived products. Also included in STAR's Cal/Val effort is the WMO based Global Space-based Inter-Calibration System (GSICS), for which STAR is the international leader. During the past year, CICS has embarked on two projects that are contributing to STAR's Cal/Val effort. This proposal is for the continued support of the rainfall product validation.

ACCOMPLISHMENTS

Seasonal validation efforts of several operational rainfall products (i.e., SCaMPR (US only), MiRS, MSPPS, and the HydroEstimator) generated by NESDIS (and originally by STAR algorithm developers) were conducted for the Mar-May, Jun-Aug, Sep-Nov 2013 seasons. Results were disseminated within a month after the end of each season.

These NESDIS rainfall products also were validated on a daily basis. For comparison, this validation also was extended to CMORPH, Merged Microwave, GPI (CPC), TRMM (NASA), NRL Blended, PERSIANN (UC Irvine), and GSMAP (JAXA).

The validation procedures were modified to incorporate precipitation estimates from the ATMS instrument. In addition, considerable effort was expended to streamline and document these procedures.

Times series and histograms were created to compare GPROF2014 rain rates with the Stage IV radar data for January and July 2013. This work was requested by Ralph Ferraro (STAR) to assist algorithm development by his group.

Two student interns investigated annual and seasonal composites of the satellite products relative to the rain gauge and radar products. A manuscript describing their findings is being prepared.

PLANNED WORK

- Seasonal rainfall validation for the upcoming 2014-2015 seasons will be conducted routinely during this performance period and the new results will posted on the rainfall validation web page within one month of the end of each season. The results will be discussed at the PREPOP, if requested, and modifications or additions of new statistics or the manner in which they are portrayed will be conducted as requested by STAR researchers or the PREPOP.
- We plan to expand our Cal/Val efforts to several exciting new rainfall estimates including JPSS GCOM AMSR-2, ATMS MiRS, NESDIS bRR, Environmental Data Records (EDR) rain rate from SSMI/S, and the products from newly launched GPM. We will work with STAR researchers to add these new estimates into the validation system and to develop any new metrics that might be useful for algorithm assessment.
- The current suite of validation activities focuses on the validation of rainfall products, and largely excludes validation of snowfall estimates. Several snow products are routinely produced by STAR scientists, and validation of these products is required in order to both benchmark current performance and to identify areas for improvement. During the upcoming performance period, we will begin assessing potential sources of reliable snow validation data that can be used to routinely validate snowfall estimates from satellites and incorporated into our validation activities.
- We are planning to do some areal statistics for target areas with Western Gulf RFC, the HMT-W and HMT-SE areas, and Alaska as our candidates. This validation effort would contribute to future NOAA Proving Ground activities related to precipitation, and will be conducted in collaboration with other NOAA scientists in those areas.

DELIVERABLES

- Daily validation for various satellite precipitation estimates;
- Seasonal validation of several operational rainfall products (i.e., SCaMPR, MiRS, MSPPS, and the HydroEstimator) generated by NESDIS; and
- Documentation for the validation procedures.

PRESENTATIONS

Wang, J.-J., 2013: Satellite Calibration and Validation (Cal/Val) efforts for STAR Precipitation Products, *2nd Annual CICS-MD Science Meeting*, 6-7 November, 2013, College Park, Maryland.

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	1

PERFORMANCE METRICS EXPLANATION

This year, we have conducted daily and seasonal validations for several operational rainfall products generated by NESDIS.

Development of the Satellite Sea-Surface Salinity Quality Monitor System

Task Leader	Li Ren
Task Code	LRLR_SSS_13
NOAA Sponsor	Eric Bayler
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 30%; Theme 2: 70%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA Goals (%)	Goal 1: 25%; Goal 2: 0%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%

Highlight: We are developing the Satellite Sea Surface Salinity Quality Monitor (4SQM) system. In this system, satellite data will be monitored for self- and cross-platform consistency, as well as consistency with *in situ* data.

BACKGROUND

This report summarizes the year-1 work of the development of the Satellite Sea Surface Salinity Quality Monitor (4SQM) system. The NOAA Center for Satellite Applications and Research (STAR) is leading the NOAA effort to evaluate sea-surface salinity (SSS) data and products from the recently-launched Aquarius and SMOS satellite missions for their potential to provide NOAA with information that would improve NOAA objectives, such as ocean forecasting and ocean resource management.

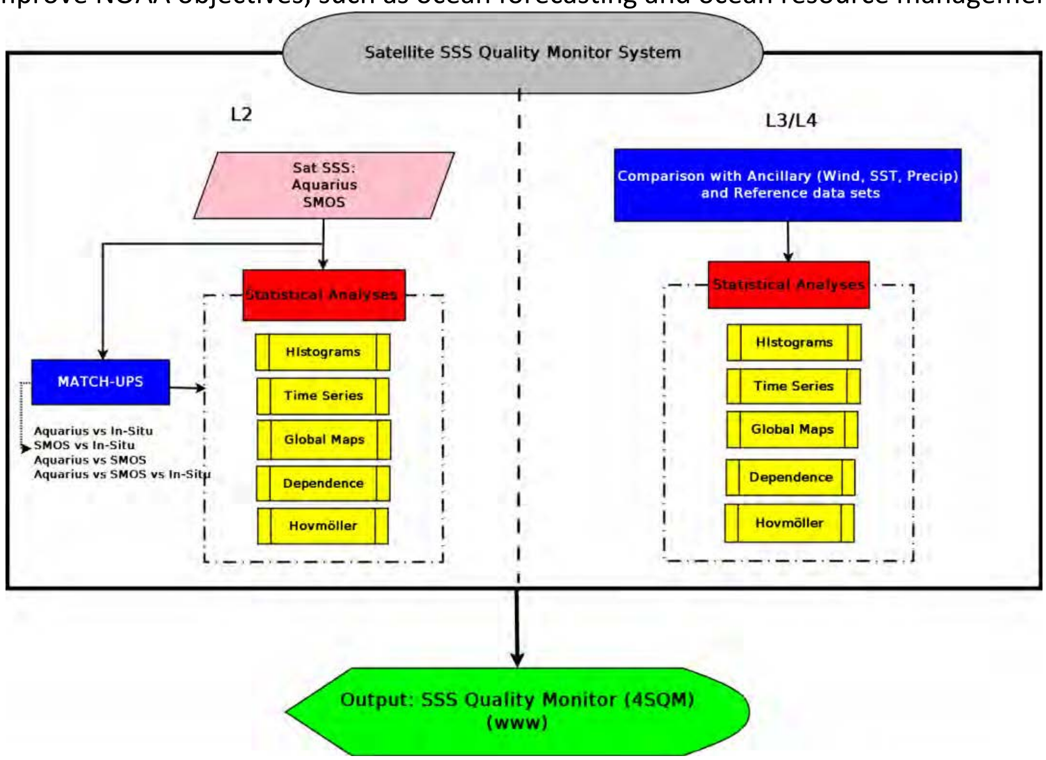


Figure 1. Satellite Sea Surface Salinity Quality Monitor system and data flow.

These products will be used on an evaluation basis by a wide group of users throughout NOAA. The Sea-Surface Salinity (SSS) Science Team within the NOAA/NESDIS/STAR is developing systematic quality monitoring and assessment of satellite SSS observations and *in situ* salinity observations. Figure 1 presents the high-level design and data flow of the 4SQM system. Below are the accomplishments during the first year of the project, followed by future plans for the second year.

ACCOMPLISHMENTS

During the year-1 from the period 07/01/2013-03/31/2014, we have accomplished the following tasks.

- Established the data flows of Satellite SSS data: Level-2 data of SMOS (ESA) and Aquarius (NASA/JPL), Level 3 data of SMOS Barcelona Center (BEC), Aquarius (NASA) CAP and V2.0;
- Performed global QC and statistical analysis on the self-consistency of Level-2 satellite SSS of SMOS (ESA) and Aquarius (NASA, both CAP and V2.0), including maps, Hovmöller diagrams, and time series;

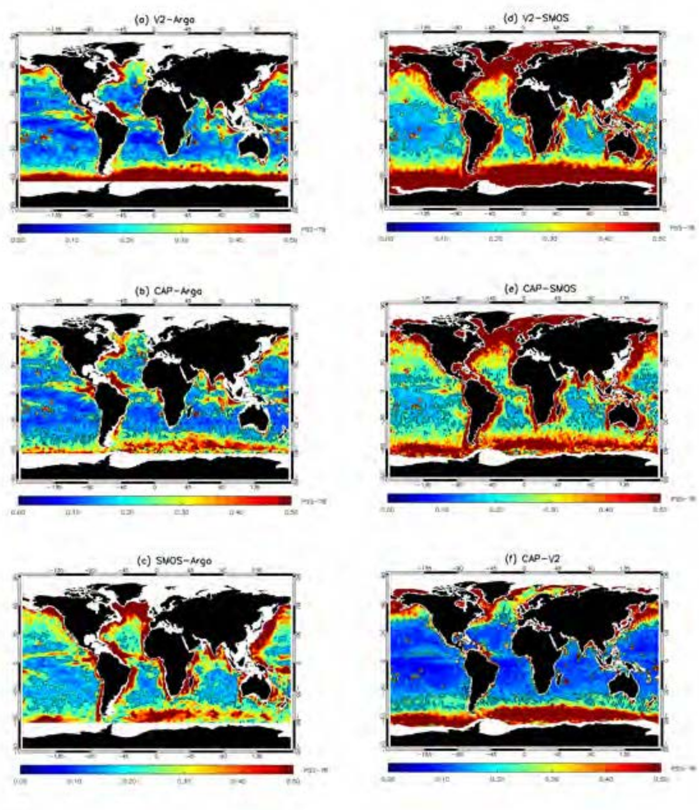


Figure 2: : Root Mean Square differences during the time period September 2011 to October 2013 between (a) Aquarius V2.0 and Argo; (b) Aquarius CAP and Argo; (c) SMOS and Argo; (d) Aquarius V2.0 and SMOS; (e) Aquarius CAP and SMOS; (f) Aquarius CAP and V2.0. The contour in black represents 0.2 pss.

- Performed global QC and statistical analysis on the cross and self-consistency of Level-3 satellite SSS of SMOS (BEC), Aquarius (NASA, both CAP and V2.0) and gridded Argo salinity data, including maps, Hovmöller diagrams, time series, zonal averages (preparing a journal paper with this content);

- Developed the web pages for the Satellite Sea Surface Salinity Quality Monitor System, including maps, histograms, time series, dependencies and Hovmöller diagrams of Level-2 and Level-3 data and products, as well as user-selected comparisons and plots.

Figure 2 presents the global Root Mean Square Differences of the inter-comparison of satellite sea surface salinity observation with reference to *in-situ* near surface salinity. Figure 3 presents the annual mean zonal mean of the bias/differences among satellite and *in-situ observations*.

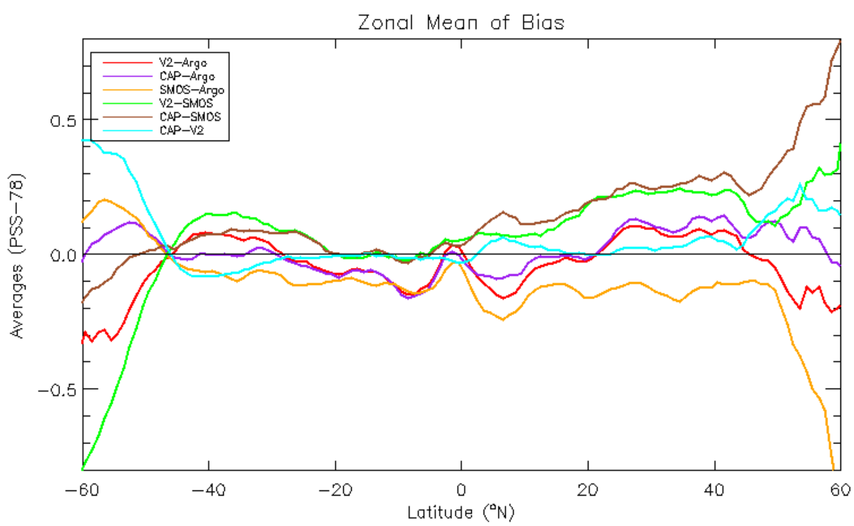


Figure 3: Annual mean zonal median of the bias/difference of Aquarius V2.0 minus Argo (red), Aquarius CAP minus Argo (purple), SMOS minus Argo (orange), Aquarius V2.0 minus SMOS (green), Aquarius CAP minus SMOS (brown) and Aquarius CAP minus V2.0 (cyan). The annual mean is calculated during the time period September 2011 to August 2013.

PLANNED WORK

- Continue to establish data flows for reference data sets and dependency parameters
- Perform global QC and statistical checks for cross-consistency
- Document the Satellite Sea Surface Salinity Quality Monitor System (4SQM))
- Operationalize the web pages;

PUBLICATIONS

Ren, L. and E. Bayler, 2014: Inter-comparison of global satellite sea surface salinity observations with reference to Argo near-surface salinity, to be submitted to *Journal of Geophysical Research-Oceans*, Special Issue of Ocean Salinity.

Performance Metrics	**FY13**
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# 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	0

Extension of Global Space-based Inter-Calibration System (GSICS) Framework using CrIS Sensor DataRecords (SDR)

Task Leader	Likun Wang
Task Code	LWLW_EGSB_12
NOAA Sponsor	Fuzhong Weng
NOAA Office	NESDIS/STAR
Percent contribution to CICS Themes	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 80%

Highlight: CICS scientists have developed a novel method of employing inter-sensor comparison to evaluate and improve radiometric, spectral, and geolocation accuracy of Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR), which are fundamental for Global Space-based Inter-Calibration System (GSICS) Framework.

BACKGROUND

This work is part of the project "Support for NPP/JPSS Global Space-Based Inter-Calibration System (GSICS)" but emphasizes more on NPP/JPSS Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR). The goal of this project is to extend the GSICS framework by using CrIS hyperspectral radiance measurements from NPP and JPSS as a benchmark reference for assessing the calibration accuracy and preciseness of operational broad- and narrow-band instruments. To achieve this goal, the first step is to well understand, characterize, and document the data quality of CrIS SDR.

The major methods are to use inter-sensor calibration techniques to evaluating spectral, radiometric, and geolocation calibration accuracy of CrIS SDR and to improve and ensure the data quality of CrIS SDR, including 1) geolocation assessment using collocated Visible Infrared Imager Radiometer Suite (VIIRS) infrared channels; 2) radiometric evaluation through inter-sensor comparison with Atmospheric Infrared Sounder (AIRS), Infrared Atmospheric Sounding Interferometer (IASI), and VIIRS infrared (IR) channels; 3) data processing quality assurance involving in discovering SDR data processing anomalies, investigating root causes, and providing solutions to CrIS SDR team; and 4) understanding the instrument measurements based on the sensor physics through the simulation.

ACCOMPLISHMENTS

Hyperspectral radiance measurements from CrIS can serve as a reference to independently assess the radiance measurements of broad- or narrow-band instruments that share the same spectral region, such as VIIRS, HIRS, AVHRR, and GOES imagers. Therefore, the stability and accuracy of CrIS is essential for the above inter-calibration efforts. More importantly, the newly-launched CrIS on Suomi NPP, combined with AIRS on Aqua and IASI on MetOp-A and -B, provide the first-ever inter-calibration opportunity because three hyperspectral IR sounders simultaneously coexist together. It is important to to evaluate long-term radiometric and spectral consistency among AIRS, IASI, and CrIS using the

SNO and double difference methods at both relatively large wavelength intervals and the finest spectral scale. The radiometric and spectral differences among AIRS, CrIS, and IASI will be identified and provided for the GSICS community. In addition, the team will extend and enhance current GSICS framework by introducing CrIS on Suomi NPP and JPSS. The current GSICS framework uses the AIRS on Aqua and IASI on MetOp-A as reference instruments for inter-calibration of geostationary imager infrared (IR) channels. These activities have greatly improved the calibration accuracy of geostationary instruments from each agency. Given the fact that AIRS is gradually degrading after seven years' operation, it is a high priority to use CrIS from Suomi NPP and JPSS to replace AIRS and continue serving as a benchmark reference for assessing the calibration accuracy and preciseness of operational broad- and narrow-band instruments. Therefore, the team will bridge the "gap" from the AIRS-IASI age to the new IASI-CrIS era and create a consistent and seamless inter-calibration system for the GSICS community.

In year 2013, we have compared CrIS hyperspectral radiance measurements with AIRS on *Aqua* and IASI on *Metop-A* to examine spectral and radiometric consistency and difference among three hyperspectral IR sounders using newly updated calibration parameters. Specifically, the most significant changes of CrIS calibration is the release of engineering package V36, which includes new non-linear (a2) and instrument line shape (ILS) coefficients. With new calibration parameters, the differences between CrIS and IASI/AIRS are reduced as shown in Figure 1.

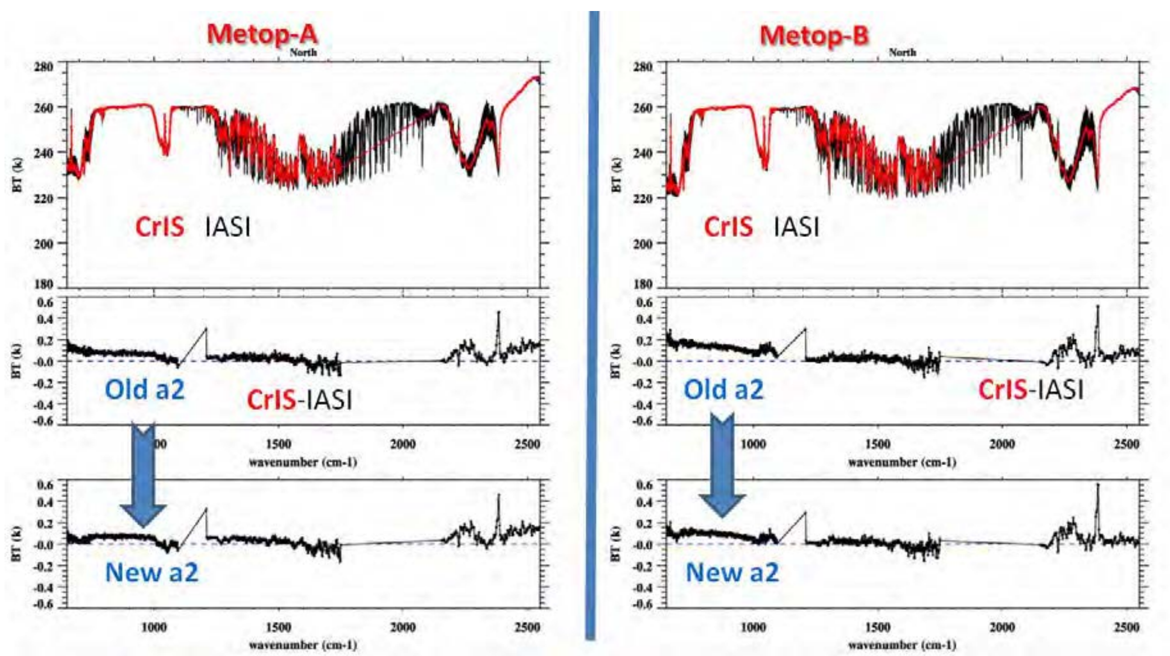


Figure 1 CrIS-IASI radiances differences with old a2 and new a2 values for MetOp-A (left) and MetOp-B (right).

In the second part of the inter-comparison of CrIS with other sensors, we also examined how newly-updated calibration coefficients effect on the inter-calibration results. There are four VIIRS IR channels that are fully covered by CrIS, i.e. M13, M15, M16, and I5. The out-of-band spectral response from VIIRS has been carefully addressed to reduce to comparison uncertainties due to the limited

CrIS spectral range. The CrIS-VIIRS BT radiance difference is thus examined along with view angles, orbit, scene temperatures, and different FOVs. More important, the third sensor - IASI - is introduced to compare with VIIRS to investigate the root causes of the differences. The scene-dependent feature has been identified for CrIS-VIIRS for VIIRS M15 in the previous studies. Overall, it is found that, with newly updated calibration coefficients, the radiances differences between CrIS and VIIRS at M15 bands at cold scenes have been reduced; however, the scene-dependent features still can be seen.

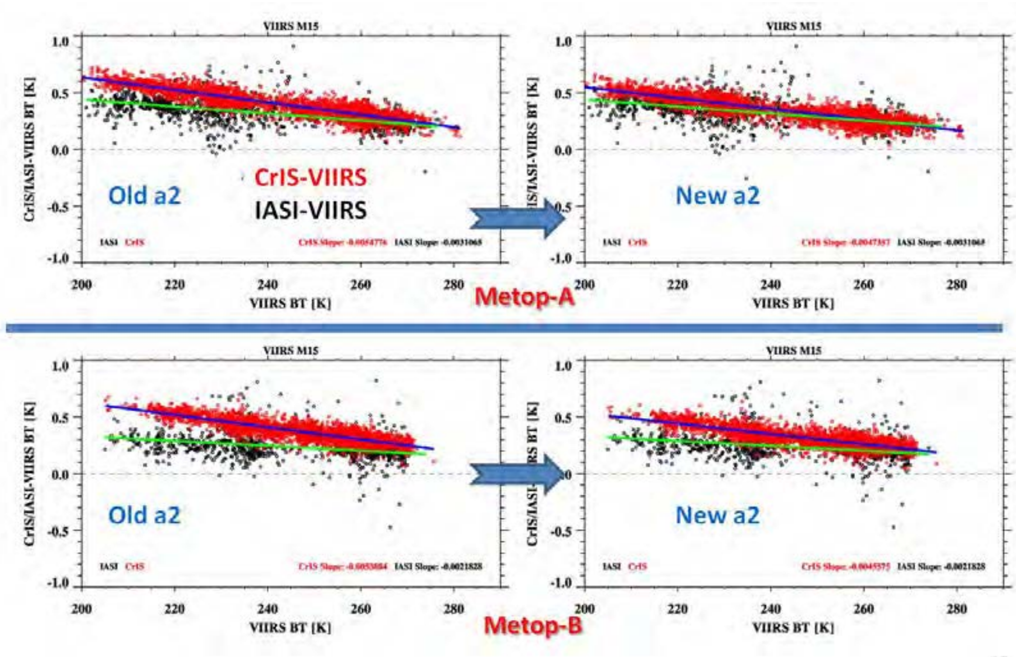
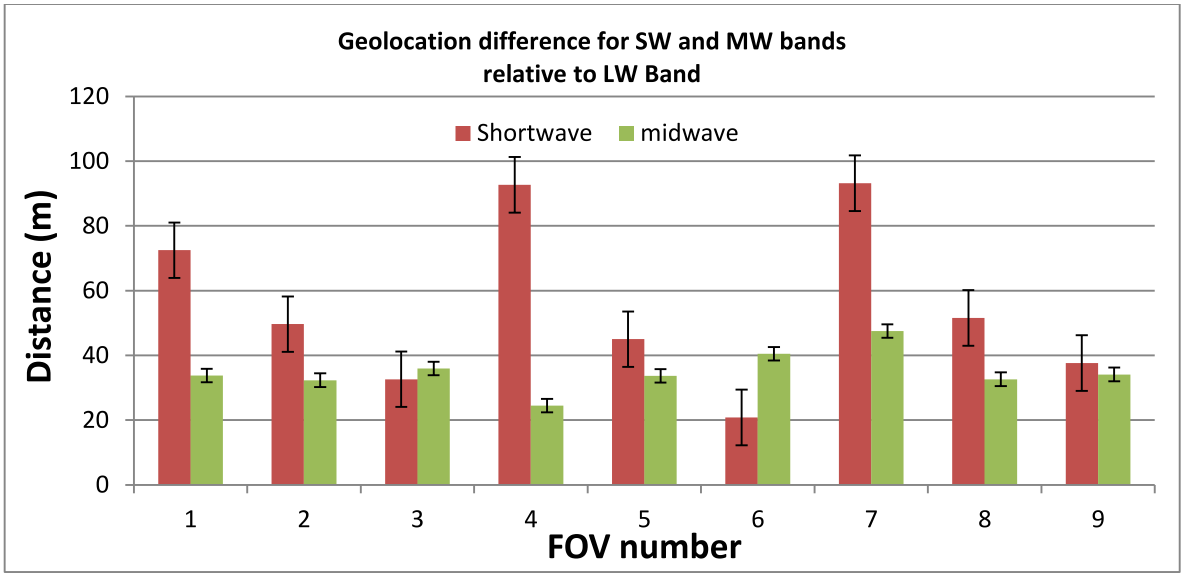


Figure 2 CrIS-VIIRS and CrIS-IASI radiances differences with old a2 and new a2 values for MetOp-A (top) and MetOp-B (bottom).

The accomplishments of year 2013 also include assessment of CrIS band-to-band co-registration. CrIS has three bands and each band has a focal plane. Only the detector position angles from the LWIR band are used for geolocation computation. The radial offsets of all 27 CrIS detectors from the interferometer axis are determined using the relative spectral calibration of these FOVs. The spatial offsets of focal plane detectors between the LWIR and the MWIR/SWIR bands derived from relative frequency calibration can be used to connect the LW geolocation to the other two focal planes. The detector coregistration difference between the LWIR and either the MWIR or SWIR focal planes is less than 0.7% (100m) of the FOV, which is well within the 1.4% (196m) coregistration specification for CrIS focal planes.

In year 2013, four peer reviewed papers have been published or under review, and two conference proceedings have been published.



Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	6
# of non-peered reviewed papers	0
# of invited presentations	7
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PLANNED WORK

- Develop a system to long-term monitoring CrIS SDR stability through inter-sensor calibration.
- Evaluate long-term radiometric and spectral consistency among AIRS, IASI, and CrIS.
- Demonstrate that the CrIS SDR data from NPP and JPSS can serve as a long-term reference benchmark for inter-calibration and climate-related study.
- Drafted two papers on CrIS/AIRS/IASI and CrIS-VIIRS collocation.

PUBLICATIONS

Han, Y., H. Revercomb, M. Cromp, D. Gu, D. Johnson, D. Mooney, D. Scott, Larrabee Strow, Gail Bingham, Lori Borg, Yong Chen, Daniel DeSlover, Mark Esplin, Denise Hagan, Xin Jin, Robert Knuteson, Howard Motteler, Joe Predina, Lawrence Suwinski, Joe Taylor, David Tobin, Denis Tremblay, Chunming Wang, Lihong Wang, **L. Wang**, and Vladimir Zavyalov (2013), Suomi NPP CrIS measurements, sensor data record algorithm, calibration and validation activities, and record data quality, *Journal of Geophysical Research.*, **118**, doi:10.1002/2013JD020344.

Wang, L., D. A. Tremblay, Y. Han, M. Esplin, D. E. Hagan, J. Predina, L. Suwinski, X. Jin, and Y. Chen, 2013: Geolocation assessment for CrIS sensor data records, *Journal of Geophysical Research*, **118**, doi:10.1002/2013JD020376.

Tobin, D. H. Revercomb, R. Knuteson, J. Taylor, F. Best, L. Borg, D. DeSlover, G. Martin, H. Buijs, M. Esplin, R. Glumb, Y. Han, D. Mooney, J. Predina, L. Strow, L. Suwinski, and **L. Wang**, 2013: Suomi-Npp Cris Radiometric Calibration Uncertainty, *Journal of Geophysical Research - Atmospheres,* **118**, 10,589-10,600, doi:10.1002/jgrd.50809

Wang, L., and Cheng-Zhi, Zou, 2013: Inter-comparison of SSU Temperature Data Records with Lidar, GPS RO, and MLS Observations. *Journal of Geophysical Research,* **118***,* 1747–1759, doi:10.1002/jgrd.50162.

Wang, L., X. Wu, F. Weng and M. Goldberg, 2013: Effects of Ice Decontamination on GOES-12 Imager Calibration, ***IEEE Transactions*** *on Geoscience and* ***Remote Sensing, 51, 1224-1230, DOI:*** 10.1109/TGRS.2012.2225839**.**

Zou, C.-Z. , H. Qian , W. Wang , **L. Wang**, C. Long, 2013: Recalibration and Decomposition of SSU Observations for Stratospheric Temperature Trend Studies. *Journal of Geophysical Research - Atmospheres* (Submitted).

PRESENTATIONS (First Author Only)

Wang, L. Y. Han, F. Weng et al., 2013: **Inter-Comparison of NPP/CrIS Radiances with AIRS and IASI**, AMS 93rd Annual Meeting/9th Annual Symposium on Future Operational Environmental Satellite Systems, January 5-10 2013, Austin, Texas.

Wang, L. Y. Han, F. Weng et al., 2013: *Assessment of CrIS Geolocation Accuracy using VIIRS*, AMS 93rd Annual Meeting/9th Annual Symposium on Future Operational Environmental Satellite Systems, January 5-10 2013, Austin, Texas.

Wang, L., Y. Han, D. Tremblay, Y. Chen, and X. Jin, 2013: Inter-Comparison of NPP CrIS with MetOp-A IASI. 3rd IASI International Conference, Hyères, France, 4-8 February, 2013

Wang, L., Y. Han, D. Tremblay, Y. Chen, and X. Jin, 2013: CrIS Inter-comparison with other sensors.2013 GSICS Data & Research Working Groups Meeting, Williamsburg, Virginia, USA. 4-8 March 2013.

Wang, L., Y. Chen, Y. Han, D. Tremblay, and X. Jin, 2013: Radiometric and Spectral Consistency of Hyperspectral Infrared Sounders. 2013 Conference on Characterization and Radiometric Calibration for Remote Sensing, 19-22 August 2013, Logan. UT.

Wang, L., Y. Han, D. Tremblay, Y. Chen, and X. Jin, 2013: Suomi NPP CrIS Sensor Data Record Quality Assessment toward the Validated Product Maturity Level. 4th Asia-Oceania Meteorological Satellite Users Conference. 9-11 October 2013, Melbourne, Australia.

Wang L., Y. Han; Y. Chen; X. Jin; D. A. Tremblay, 2013: Inter-Comparison of Suomi NPP CrIS Radiances with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements. 2013 AGU Annual Conference, 9-13 December 2013, San Francisco, CA.

OTHER (e.g., awards; outreach; deliverables…)

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

Task Leader	
Task Scientists	Jingfeng Huang, Ho-Chun Huang
Task Code	SKSK_SMSN_13
NOAA Sponsor	Shobha Kondragunta, Istvan Laszlo
NOAA Office	NESDIS/STAR/SMCD
Percent contribution to CICS Themes	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 80%

Highlight: CICS scientists at NOAA NESDIS STAR (Drs. Jingfeng Huang and Ho-Chun Huang) maintained, evaluated, and improved the current operational Suomi-National Polar-orbiting Partnership (S-NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) aerosol products. The Intensive Calibration and Validation (ICV) of the products were conducted through closely monitoring global aerosol observations and evaluating data maturity against ground measurements. New aerosol retrieval and quality assurance schemes were developed and implemented to improve global aerosol retrievals. Data usage support to research and application communities were provided.

BACKGROUND

The VIIRS launched aboard the S-NPP satellite in October 2011 is 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 are important components for the NOAA/NASA's JPSS program that is dedicated to provide long term continuous comprehensive spaceborne remote sensing capability to monitor global atmosphere, land and ocean environment, and advance weather, climate, environmental and oceanographic sciences. As a continuation to a task started in June 2012, this work is part of the NOAA/NASA S-NPP operational project "Global Aerosol Environmental Data Record (EDR) from S-NPP Visible Infrared Imaging Radiometer Suite (VIIRS)" under the NOAA NESDIS JPSS program.

The S-NPP VIIRS provides three aerosol EDRs including aerosol optical thickness (AOT), aerosol particle size parameter (APSP), and suspended matter (SM). The work covered the Intense Calibration and Validation (ICV) period of the VIIRS aerosol products, representing a continuation and enhancement of previous early orbit calibration/validation activities after NPP's successful launch in October 2011. The research and development in this task supports scientific investigations to improve the VIIRS global aerosol EDR data quality, and sustains data management to support scientific and operational data users worldwide in weather forecasting, air quality monitoring and forecasting, climate mitigation studies, and satellite remote sensing.

This particular task is focused on numerous topics related to the development of the VIIRS aerosol products. Through this task, calibration and validation activities of the *VIIRS Aerosol Environmental Data Record (EDR) Products* are conducted by comparing the VIIRS aerosol products to the heritage satellite aerosol products (such as MODIS, MISR, CALIPSO, etc.) and the Aerosol Robotic Network (AERONET) and the

Marine Aerosol Network (MAN) in-situ measurements. The task maintains and improves the VIIRS operational aerosol algorithms schemes through research and operational activities by conducting research on anomalous behaviors of global aerosol retrievals, investigating causes and providing code fix to the operational code, and reprocessing aerosol retrievals using the Algorithm Development Library (ADL) for code change and retrieval performance evaluations. The task also supports evaluations of the VIIRS aerosol products for reaching various stages of product maturity (beta, provisional, validated) to meet the JPSS program requirements. Data quality and aerosol event monitoring are also conducted on daily basis in this task to ensure product quality assurance, data delivery and archiving, anomaly discovery, and performance stability etc. CICS scientists from this task also provide any necessary operational services to global data user community to support their scientific and operational use of the VIIRS aerosol products.

ACCOMPLISHMENTS
The main goal of this task is to support the NOAA STAR scientists in conducting calibration and validation of 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 the user communities.

Through the Intensive Calibration and Validation (ICV) phase of the VIIRS aerosol products, VIIRS AOT and AE products reached ***Provisional*** maturity status on 01/23/2013 and the datasets are publicly accessible since 05/02/2012. The VIIRS Suspended Matter product reached *beta* version on 01/23/2013 with more in-depth evaluation still needed. The CICS Scientists are supporting the NOAA STAR VIIRS Aerosol team to further evaluate the VIIRS aerosol products to reach *Validated Stage I* maturity status that is planned in 2014.

Supported by the task, an automated data archiving and processing system was developed and implemented to automatically fetch, process, and archive VIIRS aerosol EDR datasets on local disk storage. This system supports the daily activities of data visualization, event monitoring, data reprocessing, and calibration/validation currently performed by members of NOAA STAR VIIRS aerosol team. The CICS scientists also performed the large array data management for the entire VIIRS aerosol team by monitoring and reorganizing the structure of data storage. The archived datasets and any other special requested datasets were used to support other team members for their scientific and operational needs.

Besides data management, CICS scientists also conducted research on new aerosol retrieval and internal testing schemes to further improve the aerosol products. For a better quality assurance on aerosol retrievals over unfavorable conditions such as snow surface and cloudy scenes, a new snow detection scheme based on normalized difference snow index and a spatial filter based on spatial variability of deep blue band reflectance were proposed and the implementation testing is underway.

Operational procedures were established to systematically compare VIIRS aerosol products, i.e., AOT, ASAP, and SM, to those of other satellites or in-situ observations, e.g., MODIS, AERONET, and MAN. The results from the comparison were used to evaluate the performance of the VIIRS aerosol products and determine their maturity levels. The evaluation results helped determine the provisional-maturity review of VIIRS AOT and AE products and more evaluation with longer data coverage period will contribute to the upcoming Validated Stage I review (**Improved Product #1**). The results from the VIIRS-AERONET L2.0 measurements, that are critical for VIIRS aerosol products for data maturity evaluation, are shown in the following Figure 1 and Figure 2, in time series and scatterplots respectively.

(a)

(b)

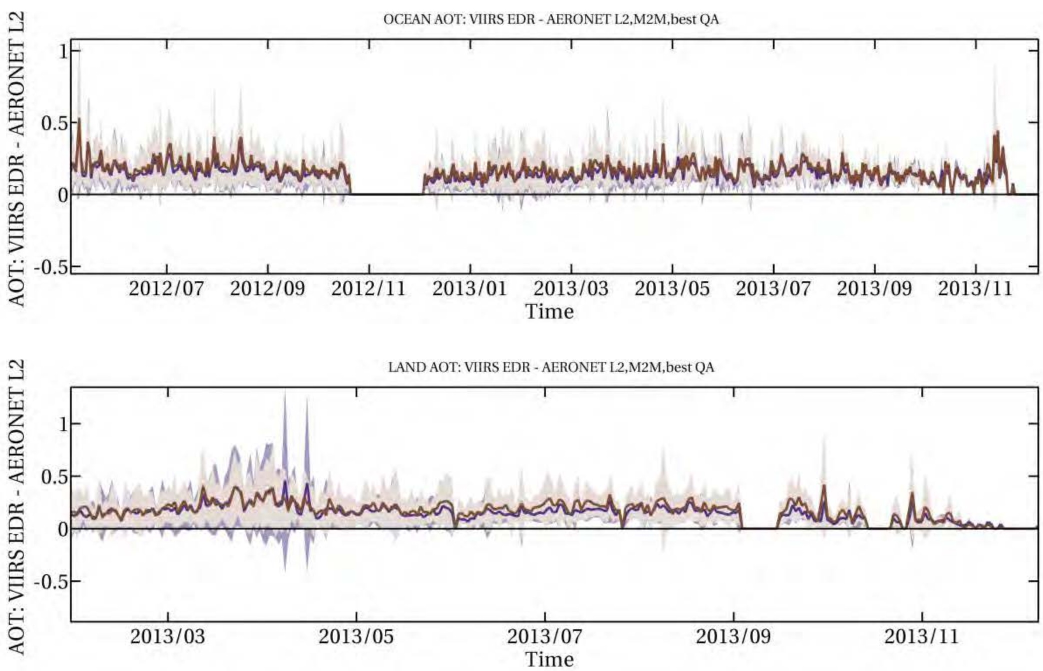


Figure 2. (a) Time series of daily mean VIIRS ocean AOT EDR best QA and daily mean AERONET AOT L2.0 over land sites; (b) time series of daily mean VIIRS land AOT EDR best QA and daily mean AERONET AOT L2.0 over coastal sites.

(a) (b)

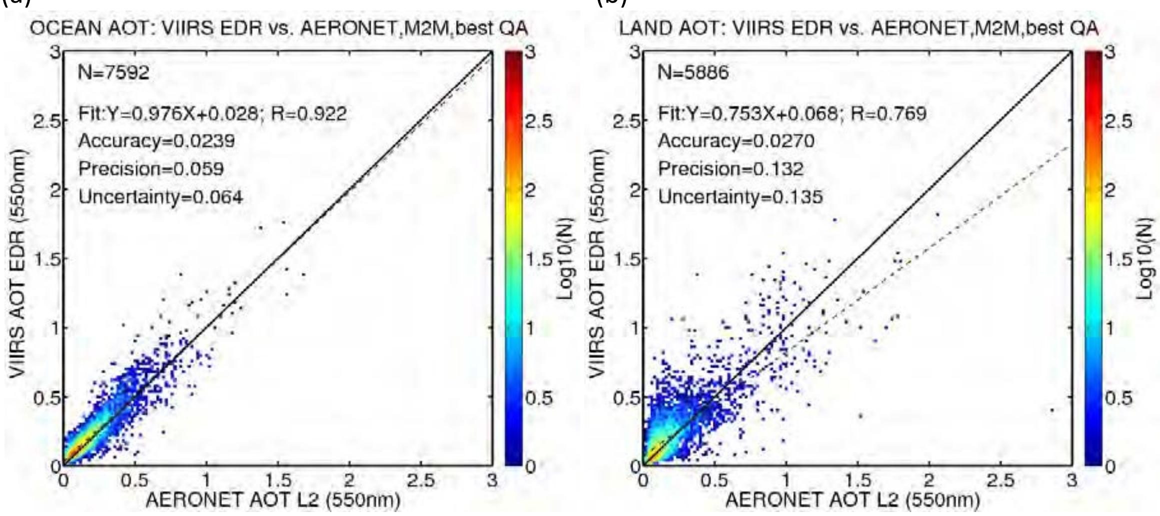


Figure 3. (a) ***Scatterplots of VIIRS Aerosol AOT against AERONET: (a) ocean retrievals vs. AERONET L2.0 over coastal sites; (b) land retrievals vs. AERONET AOT over land sites.***

To ensure correct implementation of code changes in the VIIRS aerosol algorithm and the upstream data products such as VIIRS Cloud Mask, the Factory Baseline Tests (FBT) through NPP algorithm Mx7.2 to Mx8.3 were conducted. With the learned experience on operational version of the ADL, the task also provided assistance to develop a standalone science version of the ADL code that can run locally at NOAA STAR. Algorithm testing in both operational and science version of the ADL were conducted to support Discrepancy Report (DR), Problem Change Request (PCR) and Configuration Change Request (CCR) submissions. The ADL testing was used to assess the impacts from future code improvements, such as LUT and PCT updates, ocean model update and snow detection scheme update etc. Facilitated by the science version of the local ADL, the near real time VIIRS aerosol observations developed by the VIIRS aerosol team are now available at NOAA Infusing Satellite Data into Environmental Applications (IDEA) website.

To meet the user needs from global climate modelers, the gridded VIIRS aerosol 0.25°X0.25° resolution products were developed and provided through NOAA STAR website (**research to ops #1**). This dataset is valuable for climate modelers to use the VIIRS aerosol products on their research on air quality prediction, global aerosol and climate modeling as well as climatic impacts of aerosols.

The NOAA STAR VIIRS aerosol team had summarized the details of the VIIRS aerosol algorithm in both journal paper (Jackson *et al.*, 2013, JGR) and the Algorithm Theoretical Basis Document (ATBD). Preliminary evaluation results were also reported in JGR (Liu et al., 2014). Some significant scientific results were presented at AGU Fall Meeting 2013.

Performance Metrics	**FY13**
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	6
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PLANNED WORK

- Continue the Intensive Calibration/Validation activities to further improve the VIIRS aerosol products.
- Conduct Validated Stage I maturity evaluation of the VIIRS aerosol products.
- Publish and report scientific significant results in journals and at conferences.

PUBLICATIONS

Jackson, J., H. Liu, I. Laszlo, S. Kondragunta, L.A. Remer, **J. Huang**, H. Huang, (**2013**), Suomi-NPP VIIRS aerosol algorithms and data products, *J. Geophys. Res. Atmos.*, 118, 12,673–12,689, doi:10.1002/2013JD020449.

Liu, H., L.A. Remer, **J. Huang**, H. Huang, S. Kondragunta, I. Laszlo, M. Oo, J. Jackson, Validation of Suomi-NPP VIIRS Aerosol Optical Thickness, *J. Geophys. Res. Atmos.*, **2013, in press.**

DELIVERABLES

The VIIRS Aerosol Science and Operational Users Workshop was successfully held at the NOAA NCWCP on November 21-22, 2013.

VIIRS Aerosol Products README file http://www.class.ncdc.noaa.gov/notification/pdfs/VIIRSAerosolAOT_APSPEDRProvisionalReleaseReadme_Final.docx. The document provides information on the official VIIRS aerosol products at the current maturity level.

VIIRS 0.25×0.25 degree gridded AOT EDR README file ftp://ftp.star.nesdis.noaa.gov/pub/smcd/hhuang/npp.viirs.aerosol.data/edraot550/1README.txt. The document provides information on the 0.25×0.25 degree gridded VIIRS AOT EDR products that are available at http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/products_gridded.php.

VIIRS Aerosol Products User's Guide http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/documents/Aerosol_Product_Users_Guide_V2.0.1.pdf. The User's Guide provides general introduction to the VIIRS instrument, aerosol data products, format and contents, and the essential documentation for accessing and using the VIIRS aerosol data products.

VIIRS Aerosol AOT and APSP Algorithm Theoretical Basis Document (ATBD), the Post-Launch Revised Version (http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/documents/VIIRS_Aerosol_ATBD_2013_11_28(Draft).pdf)

PRESENTATIONS

Huang, J., H. Huang, I. Laszlo, S. Kondragunta, H. Liu, L. Remer, H. Zhang, Introduction of the New VIIRS Aerosol Algorithm and Products, CICS-MD Science Meeting, Nov 6-7, **2013**

Huang, H., **J. Huang,** S. Kondragunta, I. Laszlo, H. Liu, L. Remer, H. Zhang, Validation of the VIIRS Aerosol Products, CICS-MD Science Meeting, Nov 6-7, 2013

Lorraine A. Remer; Leigh A. Munchak; **Jingfeng Huang;** Robert C. Levy; Shana Mattoo, Resolving mesoscale variation in aerosol fields from satellite: Is fine resolution worth the hassle? *(Invited)* AGU, 94, Fall Meet. Suppl., Abstract A24C-03, San Francisco, 9-13 December 2013.

S. Kondragunta, I. Laszlo, H. Liu, H. Zhang, **J. Huang**, L. Remer, P. Ciren, H-C. Huang, Current status of Suomi NPP VIIRS aerosol products, AGU, 94, Fall Meet. Suppl., Abstract A43D-0284, San Francisco, 9-13 December 2013.

Smirnov, A., B.N.Holben, A.M.Sayer, S.Kinne, T.D.Toth, M.L.Witek, R.A.Kahn, N.C.Hsu, R.C. Levy, J.Zhang, J.S.Reid, M.J.Garay, D.J.Diner, S.Mattoo, L.Munchak, L.A.Remer, R.G.Kleidman, **J. Huang**, H. Huang**,** Maritime Aerosol Network (MAN) as a component of AERONET – a useful validation tool for remote sensing applications, Marine aerosol Workshop, Galway, September 2013

Laszlo, I., and the SNPP/VIIRS Aerosol Cal/Val Team, 2013: Aerosol retrieval from SNPP/VIIRS: Analysis of technique and data quality, EGU General Assembly 2013, Vienna, Austria, 7–12 April, 2013

NPP/VIIRS Land Surface Albedo Validation Research and Algorithm Refinement

Task Leader	Shunlin Liang
Task Code	SLSL_VIIRS_13
Main CICS Research Topic	Calibration and Validation
Percent contribution to CICS Themes	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%.
Percent contribution to NOAA Goals	Goal 1: 60%; Goal 2: 40%

Highlight: We evaluated the quality of the current surface albedo EDR data and compare them with the existing products. We updated the BPSA LUT, and the new LUT generated better results. We investigated the angular dependency of BPSA retrievals and proposed methods to reduce the temporal variations.

BACKGROUND

This work is part of the project "NPP/VIIRS Land Product Validation Research and Algorithm Refinement" and particularly focused on the validation and refinement of the NPP/VIIRS land surface albedo algorithm. Land surface albedo (LSA), together with ice surface albedo and ocean surface albedo, are combined into one final product --VIIRS surface albedo EDR. LSA is generated from two types of algorithms: Dark Pixel Sub Algorithm (DPSA) and Bright Pixel Sub Algorithm (BPSA). DPSA uses the Bi-directional Reflectance Distribution Function (BRDF) information from the 16-day gridded albedo IP to first calculate spectral albedo and then convert spectral albedo to broadband albedo using empirical models. BPSA directly estimate broadband albedo from VIIRS TOA radiance. In addition to land pixels, surface albedo over sea ice pixels is also calculated from a similar direct estimation approach.

ACCOMPLISHMENTS

1. Updating BRDF LUTs

The original BPSA uses a spectral library as the input for atmospheric radiative transfer simulation. An assumption of a Lambertian surface is implied in the process. It has been found that this simplification of surface reflectance will result in retrieval uncertainties and lead to angular dependence in some cases. For example, temporal variations are manifest in LSA retrievals with the Lambertian assumption for some stable surfaces. To address this issue, a new LUT that considers the anisotropy of surface reflectance was established.

A band construction method is used to obtain a BRDF database in VIIRS bands from MODIS BRDF data, where VIIRS reflectance is expressed as the linear combination of MODIS spectral reflectances. VIIRS has 22 bands, and 9 bands (1–5, 7, 8, 10, 11) are initially used to estimate LSA. There are three VIIRS bands in the blue region of the visible spectrum. A strong correlation exists among the BRFs of the three bands, because these are converted from MODIS BRDF data, which have only one blue band. Such multicollinearity in linear regression will lead to instability of the prediction results. Thus, Bands 2 and 3 of VIIRS are excluded from the construction of the BRDF LUT, so only seven bands (1, 4, 5, 7, 8, 10, 11) are used.

Including the aerosol and surface types, there are ten LUTs available (five aerosol cases and two surface cases). The accuracy of the LUTs is dependent on viewing geometry. Figure 1 shows the RMSE of the generic BRDF LUT at two SZAs (10˚ and 60˚). Regression results are better for near-nadir observations. Smaller SZA and VZA usually lead to higher accuracy. In the case of the SZA of 60˚, the prediction uncertainties increase quickly as the VZA increases, especially for the observations from the forward scattering direction.

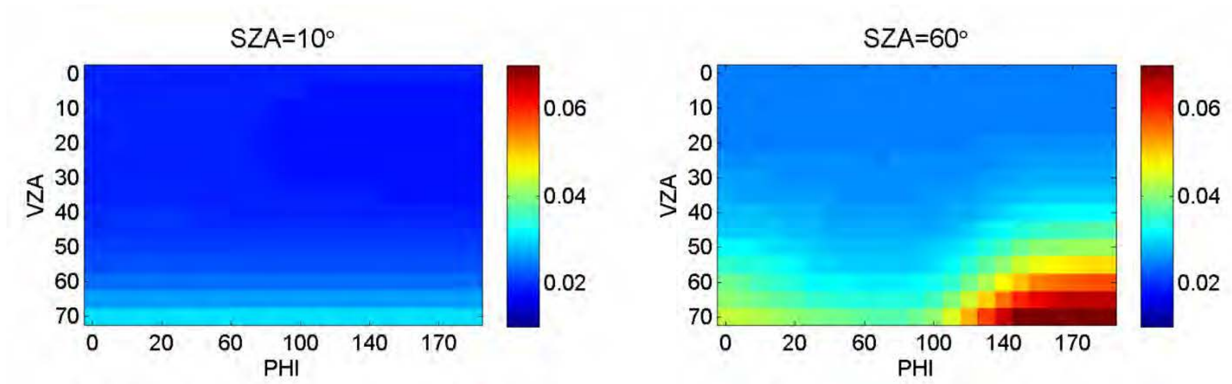


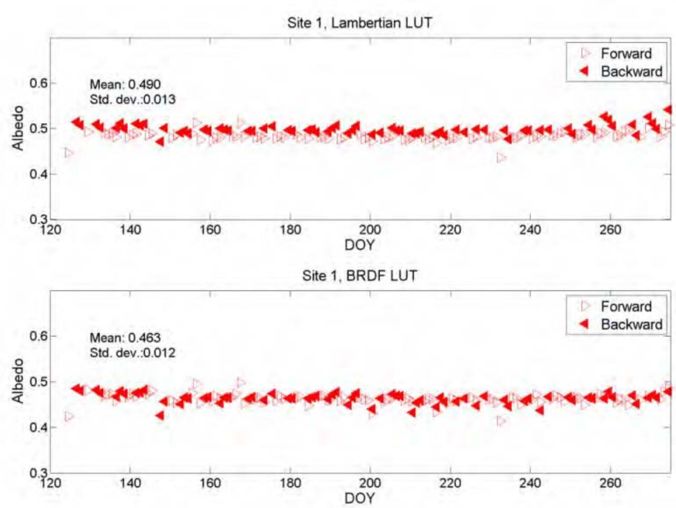
Figure 1. Predictability (in terms of RMSE) of the regression models varies with viewing geometry. Results shown here are from the generic BRDF LUT at two solar zenith angles (10˚ and 60˚).

2. Validating results of BRDF LUT

2.1 Evaluate temporal variability

2.1.1 Over stable surfaces (e.g., desert)

The LSA retrievals over two Libyan desert sites are used to illustrate the improvement. Site 1 is 24.42˚N 13.35˚E and Site 2 is 26.45˚N 14.08˚E. Five months of data (May–September, 2012) are analyzed. The use of the BRDF LUT significantly reduces the angular dependence. The pattern of larger backward retrievals is not seen in the new retrievals with the BRDF LUT.



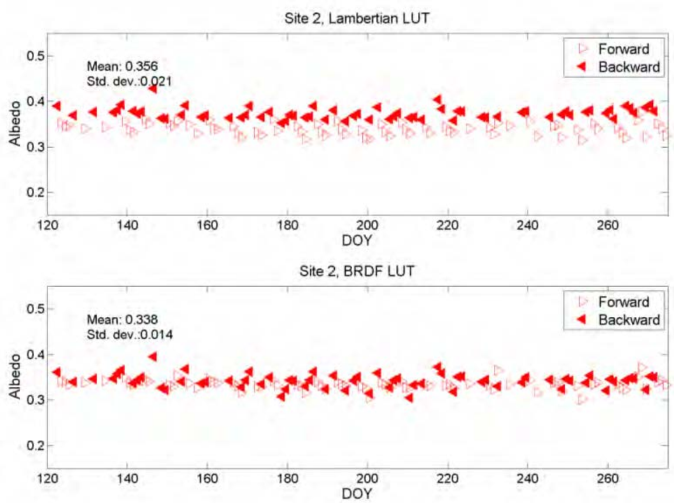
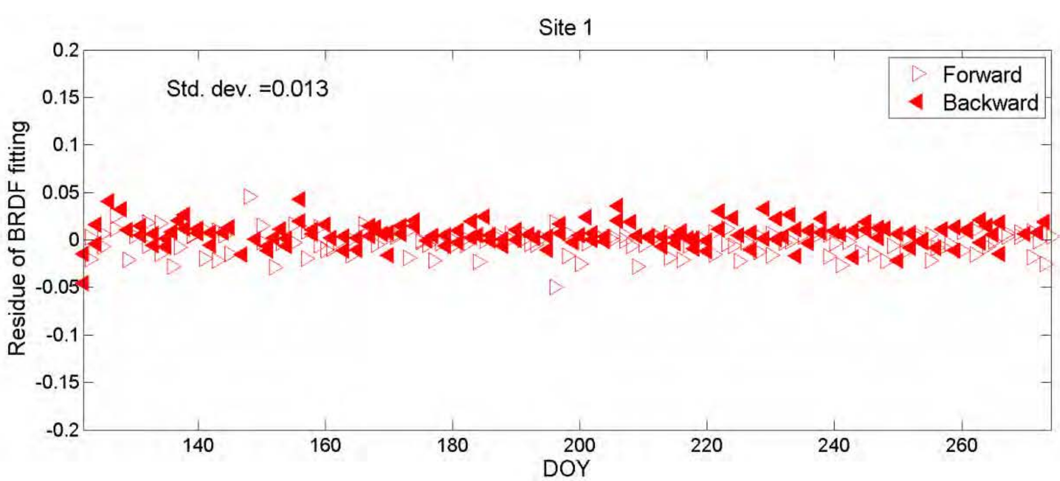


Figure 2. LSA retrieved from two LUT (Lambertian and BRDF LUT) at two desert sites. The spurious retrievals caused by undetected cloud and cloud shadow are excluded with the threshold of mean ± 0.05. "Forward" means pixels with relative azimuth angle >90° and "backword" means those with relative azimuth angle <90°.

2.1.2 Comparing with variability from other methods (e.g. BRDF fitting)

The temporal variations of BPSA retrievals can have many contributing factors, such as sub-pixel cloud or shadow, changes in solar illumination, and variations in surface features. Though the 16-day albedo retrievals from MODIS are relatively smooth, a similar scale of temporal variations is implied in the retrieval process for MODIS albedo. Here, the fitting residual is calculated as the difference between the atmospherically corrected surface reflectance from MODIS (MOD09GA and MYD09GA) and the BRF predicted from MODIS BRDF modeling (MCD43A2). For a better comparison with broadband albedo, spectral residuals are converted to broadband residuals using the narrow-to-broad band conversion coefficients derived by Liang [2001]. When calculating the standard deviation of a time series of residuals, the absolute values greater than 0.05 are excluded for a fair comparison. The variation of fitting residual is similar to that of VIIRS LSA



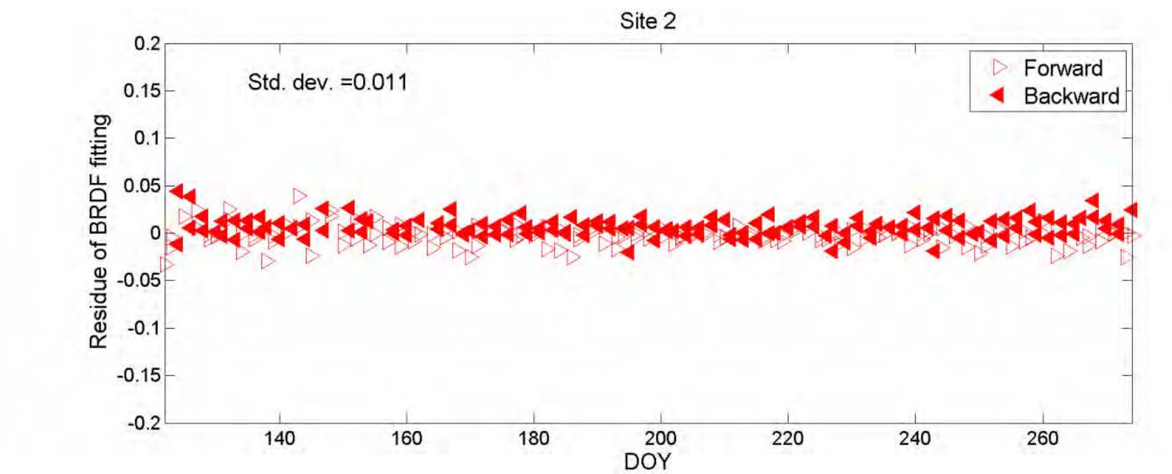


Figure 3. Residue of BRDF fitting, calculated as the difference between MODIS surface reflectance and BRF predicted from MODIS BRDF. The narrow-to-broadband conversion coefficients are used to covert spectral residues to broadband residue.

2.2 Validation against ground truth data

2.2.1 Direct validation of daily albedo

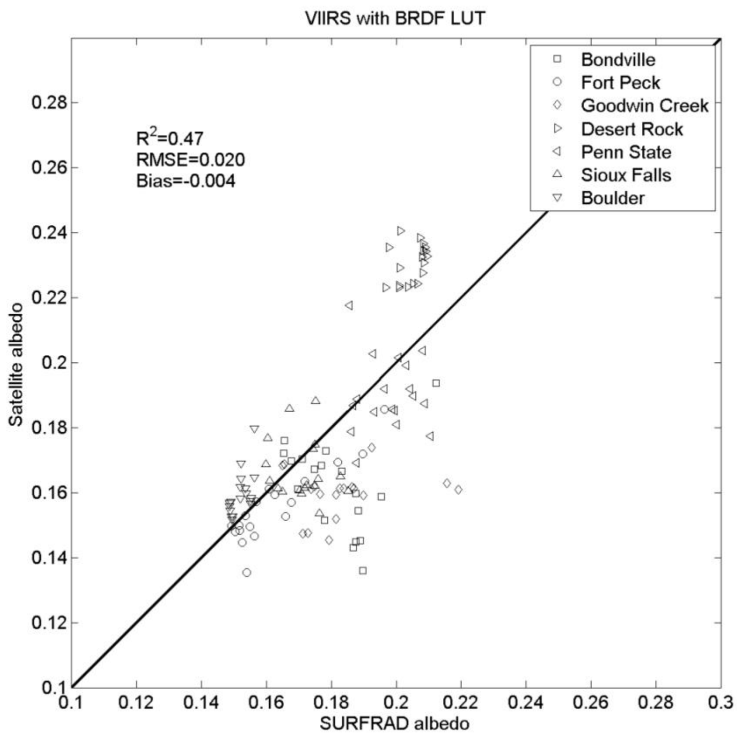
VIIRS data collected from February to December in 2012 over seven Surface Radiation (SURFRAD) Network sites are used for direct comparison with field measurements. The validation clearly demonstrates that by using the BRDF LUT the LSA is estimated reliably for all sites, with an overall RMSE of 0.049 and a slight negative bias of 0.004 (Table 3 and Figure 5). Generally, the Lambertian LUT has results worse than those of the BRDF LUT, with smaller correlation R2 as well as larger RMSE and bias. The results vary between sites. For the sites with both snow and other albedos, R2 is much larger. Among the seven sites, Boulder has the smallest RMSE of 0.029, while Bondville and Fort Peck have the largest error of 0.070. MODIS products have results slightly worse than VIIRS LSA from the BRDF LUT, with an overall RMSE of 0.052 and a negative bias of 0.026. The MODIS results are better than the VIIRS retrievals for Desert Rock, which is a desert site with relatively stable LSA.

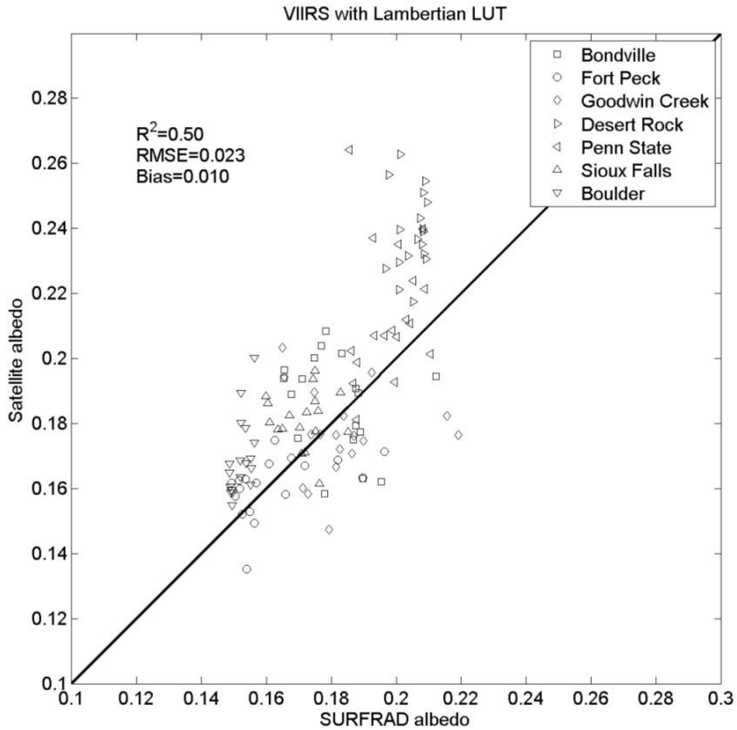
Table 1. Summary of validation results at seven SURFRAD sites. Three satellite albedo data (VIIRS LSA from the Lambertian LUT, VIIRS LSA from the BRDF LUT and MODIS albedo) are validated against field measurements.

Site	VIIRS (BRDF LUT)			VIIRS (Lambertian LUT)			MODIS		
	R^2	RMSE	Bias	R^2	RMSE	Bias	R^2	RMSE	Bias
Bondville	0.50	0.070	-0.048	0.15	0.081	-0.038	0.57	0.071	-0.052
Fort Peck	0.89	0.070	0.001	0.87	0.073	-0.005	0.98	0.043	-0.020
Goodwin Creek	0.01	0.040	-0.033	0.15	0.051	-0.031	0.11	0.051	-0.048
Desert Rock	0.10	0.032	0.026	0.02	0.045	0.020	0.02	0.025	-0.023
Penn State	0.60	0.040	-0.020	0.27	0.054	-0.011	0.02	0.079	-0.054
Sioux Falls	0.89	0.064	0.004	0.82	0.066	0.007	0.87	0.059	-0.001
Boulder	0.96	0.029	0.011	0.91	0.034	0.012	0.79	0.047	0.002
Overall	0.80	0.049	-0.004	0.71	0.057	-0.003	0.78	0.052	-0.026

2.2.2 Comparison of 16-day mean albedo

To evaluate the effects of temporal aggregation on retrieval accuracy, a comparison of temporally aggregated albedo is also carried out. For the snow-free season (May–September, 2012), 16-day data on VIIRS LSA is averaged to obtain the mean albedo with an interval of 8 days, corresponding to the temporal step of the MODIS albedo. To remove the effects of undetected cloud, the VIIRS retrievals greater than 0.7 are excluded. In terms of 16-day mean, the VIIRS albedo from the BRDF LUT also performs better than the MODIS albedo, with larger R2 and smaller error (Figure 4). The correlation between MODIS data and field measurements is much smaller than that between VIIRS retrievals and field data. One possible explanation is that the aggregation feature of the MODIS algorithm reduces some dynamic variations in albedo estimates. Similar to the results for instantaneous LSA, the VIIRS data have a slight negative bias of 0.004 and the MODIS albedo is underestimated with a much larger negative bias of 0.01.




VIIRS with Lambertian LUT
Bondville
Fort Peck
Goodwin Creek
Desert Rock
Penn State
Sioux Falls
Boulder
R2=0.50
RMSE=0.023
Bias=0.010
Satellite albedo
SURFRAD albedo

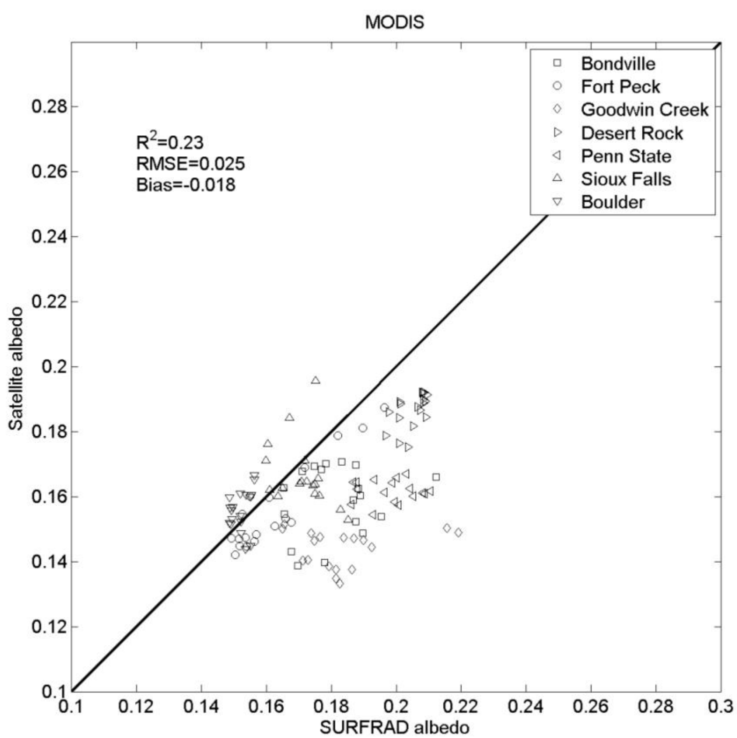

MODIS
Bondville
Fort Peck
Goodwin Creek
Desert Rock
Penn State
Sioux Falls
Boulder
R2=0.23
RMSE=0.025
Bias=-0.018
Satellite albedo
SURFRAD albedo

Figure 4. Validation results of 16-day mean albedo from a) VIIRS BRDF LUT, b) VIIRS Lambertian LUT and c) MODIS, using data from 2012 non-snow seasons (May-September) at seven SURFRAD sites.

2.3 Inter-comparison with MODIS albedo products

Figure 5 makes a pixel-to-pixel comparison between the VIIRS maps and the MODIS map. Undetected cloud and cloud shadow cause large errors in BPSA retrievals. To reduce such effects, only the pixels where clear-sky conditions prevail more than half the time (pixels with more than eight valid data) are used in the comparison. The LSA data from the two sensors agree with each other very well. The VIIRS albedo is slightly larger than the MODIS albedo. Note that the VIIRS retrievals using the Lambertian LUT are better correlated with the MODIS data. Moreover, comparisons with field measurements reveal that the VIIRS LSA from the BRDF LUT is more accurate than either the VIIRS LSA from the Lambertian LUT or the MODIS LSA.

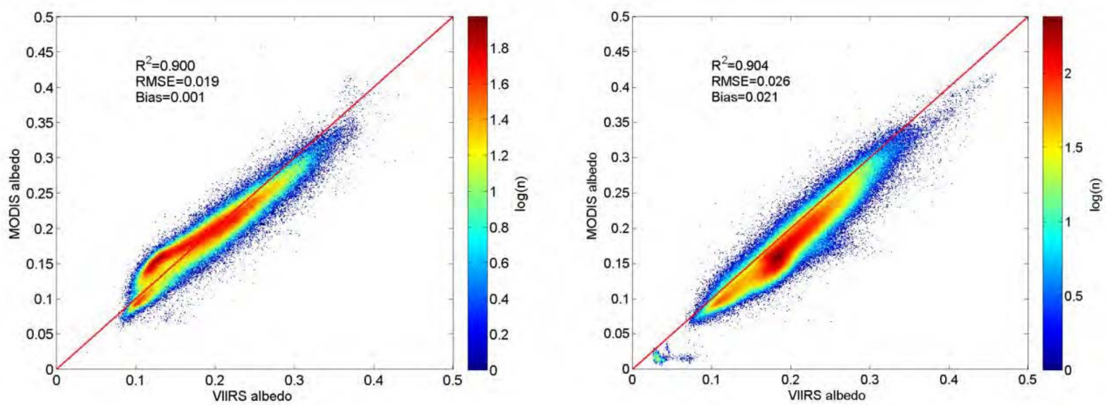


Figure 5. Comparing 16-day mean VIIRS albedo from a) BRDF LUT and b) Lambertian LUT with MODIS blue-sky albedo. Data are limited to those with at least 8 clear-day observations during the composite period of 16 days.

PLANNED WORK

* Continuing to validate the albedo product;
* Updating LUT for sea ice surface albedo;
* Developing post-processing filters.

PUBLICATIONS

Dongdong Wang, Shunlin Liang, Tao He, Yunyue Yu. 2013. Direct estimation of land surface albedo from VIIRS data: algorithm and preliminary validation. JGR-Atmosphere. 118, 12,577–12,586, doi:10.1002/2013JD020417.

OTHER

A new BPSA LUT was developed.

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

In terms of Performance Metrics, we developed and delivered a new BPSA LUT, which improves the retrieval accuracy of land surface albedo. Please find details on the publication and presentation in the following sections.

GOES-R Calibration Working Group (CWG) Support at the University of Maryland

Task Leader	Shunlin Liang and Xi Shao
Task Code	XSSL_GCWG_12
NOAA Sponsor	Changyong Cao
NOAA Office	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%

Highlight: CICS scientists support Calibration and Validation work for GOES-R Advanced Baseline Imager (ABI) instrument through lunar calibration, long-term monitoring of radiometric parameters at desert areas and field measurement.

BACKGROUND

This work supports the calibration and validation of GOES-R Advanced Baseline Imager (ABI) instrument. The sensor performance of ABI sensor is subject to degradation caused by various post-launch influences, which requires independent calibration and validation activities to satisfy required uncertainty criteria. We support GOES-R ABI cal/val work and assessment of sensor variability through onboard solar diffuser monitoring, vicarious and lunar calibration, and homogeneous surface on the Earth such as long-term monitoring of desert areas.

Photometric stability of the lunar surface and its smooth reflectance spectrum makes the moon an ideal target for calibrating satellite-based hyper/multi-band visible and infrared imagers. Therefore, lunar calibration for solar bands is an important part of the GOES-R ABI Cal/Val plan. Long-term performance monitoring of ABI instrument using Moon can reveal the degradation of instruments. It can also be used as a framework to compare GOES-R radiometer performance relative to similar radiometers flown on different satellite platforms.

For calibration using desert surface, we focused on the characterization of the atmosphere and surface variability of the Sonoran Desert in Mexico. The Sonoran Desert is one of the best pseudo-invariant sites available in North America which can be observed both from GOES-West and -East. To fully exploit the top-of-atmospheric radiance/reflectance measured at the sensor, understanding of the variability in the surface and the atmosphere above the desert areas is essential.

ACCOMPLISHMENTS

1. **Developed schemes of assessing long-term sensor radiometric degradation using time series data from vicarious sites at desert**

The monitoring of top-of-atmosphere (TOA) reflectance time series provides useful information regarding the long-term degradation of satellite sensors such as GOES-R ABI. For a precise assessment of sensor degradation, the TOA reflectance time series is usually corrected for surface and atmospheric anisotropy by using bidirectional reflectance models so that the angular effects do not compromise the trend estimates. However, the models sometimes fail to correct the angular effects, particularly for spectral bands that exhibit a large seasonal oscillation due to atmospheric variability. We investigated the use of time series algorithms to identify both the angular effects and the atmospheric variability simultaneously in the time domain using their periodical patterns within the time series. Two nonstationary time series algorithms were tested with the Landsat 5 Thematic Mapper time series data acquired over two pseudo-invariant desert sites, the Sonoran and Libyan Deserts, to compute a precise long-term trend of the time series by removing the seasonal variability. The time series results showed an effective removal of seasonal oscillation, caused by angular and atmospheric effects, producing trending results that have a higher statistical significance than other approaches.

2. **Conducted field measurement activities (June 3-6, 2013) to Support GOES-R ABI vicarious calibration**

Characterizing ground radiometric reflectance properties and determining atmospheric effect on radiation transfer are essential to support post-launch vicarious calibration activities for GOES-R ABI. We participated in the field measurements organized by University of Maryland in support of the NASA HYSPIRI mission to collect ground spectral reflectance and aerosol data near Los Angles with ASD spectrometer and sun photometer provided by NOAA/NESDIS/STAR. The team performed measurements for about 20 types of ground covers at ~ 30 locations near Los Angles (Figure 1). These ground spectral reflectance and aerosol data will be used to calibrate over-flight remote sensing measurements.

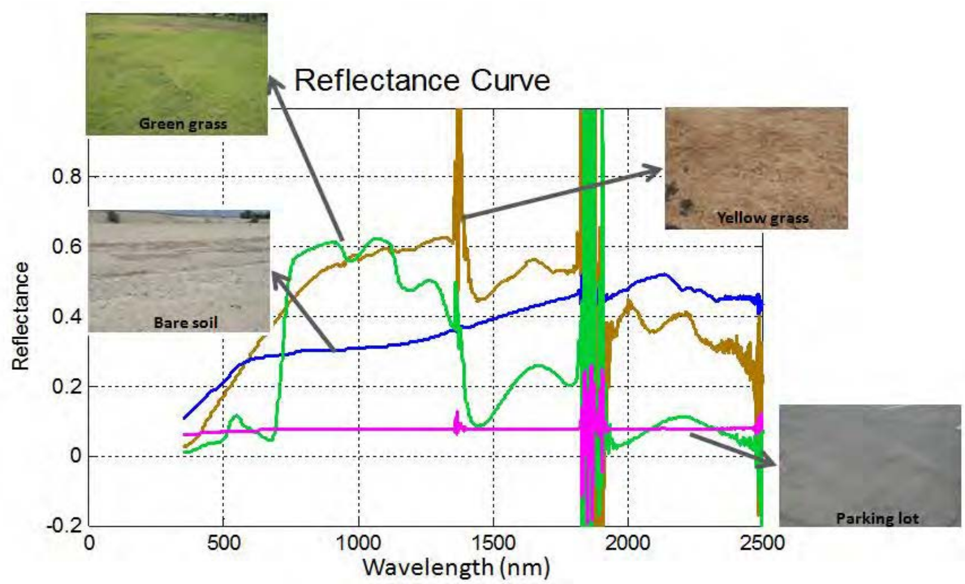


Figure 1: Measured Reflectance for Several Types of Ground Cover (from June 3-6, 2013 field campaign)

3. **Performed assessment of exclusion zone occurrence for GOES-R ABI**

For GOES-R ABI, severe stray light will be observed on ABI when the sun is <3° of the line of sight. Therefore, ABI scan system will scan around the exclusion zone during normal operations. We performed modeling of the occurrence of the exclusion zones using orbital tracking codes and found that they occur in the two months around spring and autumn equinox, respectively. Analysis is able to assess the time, location, and duration of exclusion zone occurrence for GOES-R ABI. We also determined the exclusion-zone occurrence duration as a function of day of year and N/S angle of Sun w.r.t. GOES-R ABI.

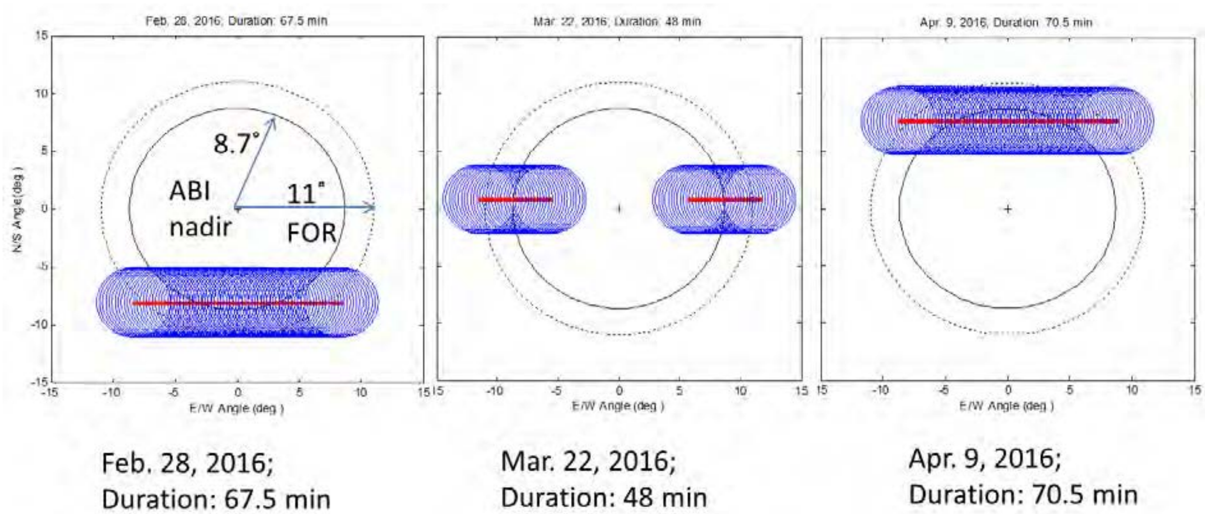


Figure 2: Examples of exclusion zone occurrence around spring equinox for GOES-R ABI in 2016.

4. **Performed comparison study of the radiometric calibration algorithm for solar reflective band between GOES-R ABI, NPP VIIRS and MODIS**. We investigated the differences and similarities in choice of solar radiance model, form of polynomials for converting DN to radiance, and the use of solar diffuser for on-board calibration. We worked on calibration theory and algorithm for on-board radiometric calibration of reflective solar band using solar diffuser and calibration of thermal emissive band using blackbody. We delivered a report on the radiometric calibration algorithm comparison for solar reflective band among GOES-R ABI, NPP VIIRS, and MODIS.
5. **Lunar Calibration Support for GOES-R ABI**
    a. Performed comparison between lunar observation by GOES and model to benchmark lunar irradiance model.
    b. We assessed the uncertainties due to lunar phases of the moon in lunar radiance models through comparison between ROLO and Miller Turner 2009 model.
    c. Performed assessment of lunar appearance opportunities in GOES-R ABI field of view during Apr-May, 2016 to assist evaluation of the proposed idea of using moon as light source for calibrating the uniformity of ABI detectors.
6. **Worked on cross-calibration** between GOES and POES satellite using past satellite data and assessed the radiometric propagation loss due to the difference in viewing angle.
7. **Developed and populated publication tracking database** to support GOES-R CWG: http://spp.astro.umd.edu/papers/interface.php

PLANNED WORK:

- Characterization of BRDF of the vicarious sites using current GOES data, airborne hyperspectral data and field measurements.
- Continue to work on cross-calibration between GOES and POES satellite using past satellite data and assessed the radiometric propagation loss due to the difference in viewing angle.
- Supports lunar calibration of GOES ABI through lunar irradiance model and observation comparison and lunar appearance prediction in the field of view GOES-R ABI.
- Evaluate and refine radiometric calibration algorithm of GOES-R ABI for solar reflective and thermal emissive band.

PUBLICATIONS:

Wonkook Kim; Tao He; Dongdong Wang; Changyong Cao; Shunlin Liang, "Assessment of Long-Term Sensor Radiometric Degradation Using Time Series Analysis," *Geoscience and Remote Sensing, IEEE Transactions on* , vol.52, no.5, pp.2960,2976, May 2014, doi: 10.1109/TGRS.2013.2268161.

PRESENTATIONS:

None

DELIVERABLES:

- GOES-R ABI publication tracking database: http://spp.astro.umd.edu/papers/interface.php

PERFORMANCE METRICS

Performance Metrics	**FY13**
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

Developing Calibration Data Quality Monitoring Tools for GOES-R Advanced Baseline Imager (ABI) L1B in support of the Calibration Working Group

Task Leader	Xi Shao
Task Code	XSXS_ABI_13
NOAA Sponsor	Changyong Cao
NOAA Office	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%

Highlight: CICS scientists are developing calibration data quality monitoring tool to support Calibration and Validation work for GOES-R Advanced Baseline Imager (ABI) instrument, to facilitate the diagnosis of instrument problems, and to better serve the user community.

BACKGROUND

The Advanced Baseline Imager (ABI) is the primary instrument on GOES-R for imaging Earth's weather, climate, and environment. ABI will be able to view the Earth with 16 different spectral bands, including two visible channels, four near-infrared channels, and ten infrared channels. It is designed to observe the western hemisphere in various time intervals at 0.5, 1, and 2 km spatial resolutions in visible, near-infrared (IR), and IR wavelengths, respectively. 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 ABI will be calibrated to an accuracy of 3% (1 σ) radiance 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. However, due to the feature of such ongoing working units, instruments always present some degree of variations, which possibly show fairly different patterns over different space locations or during different period of time. Therefore, it is essential to continuously monitor the performance of GOES-R ABI instrument and quality of measured radiances in near-real time for direct radiance assimilation in numerical weather prediction, for retrievals of various geophysical parameters, and for climate monitoring and reanalysis.

To ensure that the requirements for GOES-R ABI are met, we are developing L1B Data Quality and Instrument Performance Monitoring system to support the calibration and validation work for GOES-R ABI, to facilitate the diagnosis of instrument problems, and to better serve the user community. The system focuses on the on-orbit verification and near real-time/long-term monitoring of instrument performance, and inter-calibration of operational satellite radiometers using techniques such as the simultaneous nadir overpass (SNO) method.

ACCOMPLISHMENTS

1. Developing software for GOES-R ABI instrument performance monitoring and imagery product browsing on mobile platform. The system being developed for monitoring ABI instrument status can explicitly provide users the information regarding the satellite data quality. It also enables browsing of most up-to-date imagery data and short-interval animation of imagery products from ABI for different spectral channels. Imagery products and instrument performance monitoring plots from current GOES and NPP-VIIRS have been used to test the software. Applications are developed for both Android and Iphone mobile platform.

2. We also supported the development of monitoring tool for space weather instrument performance and observation on GOES.

3. We participated development of validation site time series services to support and archive vicarious calibrations. This supports post-launch calibration work of GOES-R ABI. The prototype web-based tools can archive and facilitate the ABI sensor radiometric calibration using vicarious targets such as views of deserts and polar region. It is available at https://cs.star.nesdis.noaa.gov/NCC/VSTS.

4. Developed the on-line calculator of Planck function, NEDT, NEDN to support Thermal Emissive Band calibration for GOES-R ABI. It is available at http://ncc.nesdis.noaa.gov/data/planck.html.

5. Supporting inter-satellite and inter-platform calibration of radiances using the SNO and extended SNO (SNOx) methods. We developed web-based tools to support inter-satellite calibration between GOES and POES, MetOP, and Suomi-NPP using SNOs and SNOx methods. Using SNO/SNOx methods, the observations from different satellites are precisely collocated and coincidental. The tool assists reducing the number of factors in inter-satellite calibration and identifying the root cause of the biases. The tool also allows us to evaluate the relative performance of the radiometers and to establish the onboard calibration traceability between satellites with little ambiguity. Tools are developed to automate the prediction inter-satellite SNO/SNOx time series and to facilitate radiometric data collections. This tool will make the radiances highly traceable between GOES-R and a constellation of global satellites in both geostationary and polar orbits. The predictions of SNO between GOES and polar orbiting satellites are available at https://cs.star.nesdis.noaa.gov/GOESRCWG/SNOPredictions. Figure 1 shows an example of the prediction of overpasses of POES satellite at nadir of GOES satellite.

6. We are also developing tools to perform lunar appearance prediction and lunar radiance calibration for GOES-R ABI. Lunar irradiance model derived from ROLO and Miller-Turner 2009 for GOES-R ABI bands will be used to calibrate ABI.

Table of predicted SNOs for the next 14.0 days since TLE Epoch: 3/20/2014

Index	Date	Time (GOES-15)	GOES-15 Lat,Lon	NPP Lat,Lon	Distance(km)	Time Diff (sec)
1	03/20/2014	22:25:28	0.02,-134.88	0.10,-134.47	46.77	80
2	03/23/2014	10:31:19	-0.02,-134.98	0.04,-135.23	28.56	80
3	03/24/2014	10:09:57	-0.02,-135.00	-1.00,-130.71	490.22	80
4	03/25/2014	22:34:37	0.01,-135.04	-0.19,-136.02	111.37	80
5	03/26/2014	22:13:15	0.01,-135.06	0.80,-131.49	407.40	80
6	03/28/2014	10:37:47	-0.01,-135.12	0.37,-136.77	187.96	80
7	03/29/2014	10:16:26	-0.01,-135.14	-0.67,-132.25	330.37	80
8	03/30/2014	22:41:06	0.01,-135.17	-0.50,-137.56	272.17	80
9	03/31/2014	22:19:44	0.01,-135.19	0.48,-133.03	246.14	80
10	04/02/2014	10:44:16	-0.01,-135.24	0.68,-138.31	349.76	80
11	04/03/2014	10:22:54	-0.01,-135.26	-0.37,-133.79	168.06	80

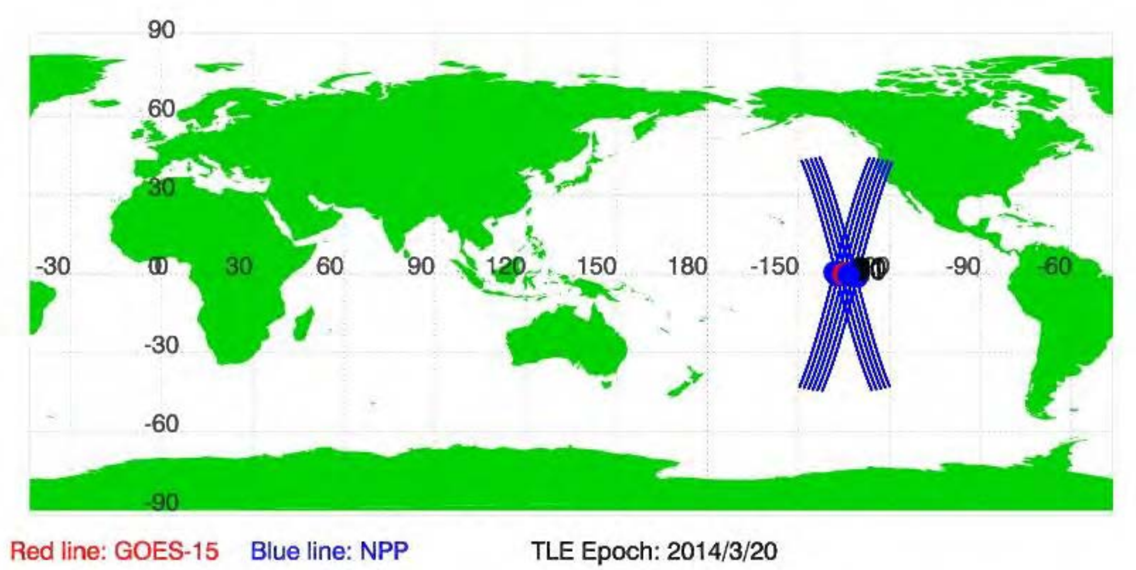


Figure 1: Outputs from the online SNO prediction tool for GOES-15 and Suomi-NPP observing the same nadir location in tabular and graphic form.

PLANNED WORK

- Continue to develop integrated tools for near real-time and long-term monitoring of ABI L1B data quality and instrument performance
- Continue to develop tools to support and archive vicarious calibrations for GOES-R ABI
- Continue to develop tools to perform lunar appearance prediction and lunar radiance calibration for GOES-R ABI
- Continue to support inter-satellite and inter-platform calibration of radiances using the SNO and extended SNO (SNOx) methods

PUBLICATIONS:

None

PRESENTATIONS:

None

DELIVERABLES:

Web-based products have been developed

http://ncc.nesdis.noaa.gov/data/planck.html (On-line Plank-Calculator)

https://cs.star.nesdis.noaa.gov/GOESRCWG/SNOPredictions (SNO prediction)

PERFORMANCE METRICS

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

Analyzing AVIRIS Data to Support GOES-R Calibration Working Group (CWG)

Task Leader	Xi Shao (Scott Ozog)
Task Code	XSXS_AVIRIS_13
NOAA Sponsor	Steven Goodman
NOAA Office	NESDIS/GEOSPO
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%

Highlight: A graduate student, Scott Ozog, from Department of Atmospheric and Oceanic Science of UMD is supported to develop tools to perform accurate retrieval of surface reflectance in AVIRIS scene and validation and calibration of the reflectance products with ground measurements. This supports the post-launch vicarious calibration of GOES-R ABI instrument.

BACKGROUND

The Geostationary Operational Environmental Satellite-R Series (GOES-R) satellite will provide continuous imagery and atmospheric measurements of Earth's western hemisphere. GOES-R ABI will generate a suite of atmosphere and land surface products and the requirement for the reflective solar band calibration drift is < 1.5% during the mission life, with the L1b calibration accuracy of 3%. 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 make use of vicarious target such as views of deserts by Airborne Visible InfraRed Imaging Spectrometer (**AVIRIS**). AVIRIS is a premier instrument in the realm of Earth Remote Sensing. It is a unique optical sensor that delivers calibrated images of the upwelling spectral radiance in 224 contiguous spectral channels (also called bands) with wavelengths from 400 to 2500 nanometers (nm). The signals received by AVIRIS sensor contain spectral information from both the atmosphere and the earth surface, which makes it difficult to differentiate changes in surface reflectance from large variation in the incoming signals. Accurate retrieval of "actual" surface reflectance in AVIRIS scenes is essential for the radiometric calibration of the airborne sensor.

This work trains a graduate student to develop tools to perform accurate retrieval of surface reflectance in AVIRIS scene and develop a reliable surface reflectance product from AVIRIS data through validation and calibration of the reflectance product using ground measurements.

ACCOMPLISHMENTS

1. A graduate student, Scott Ozog, from Department of Atmospheric and Oceanic Science of UMD is supported by this grant. The student works closely on analyzing AVIRIS data with Bob Iacovazzi and Dr. Steven Goodman of GOES-R Calibration Working Group from NASA and team member from National Calibration Center of NOAA/NESDIS/STAR.
2. The student acquired the necessary background knowledge of Airborne Visible Infrared Imaging Spectrometer **(**AVIRIS) data (its data acquisition, archiving and access), radiometric calibration

process for satellite sensor instruments using vicarious sites, concept of bidrectional reflectance distribution function (BRDF), cross-calibration of sensor performance from airborne and ground measurements, and atmospheric absorption correction through atmospheric radiation transport modeling.
3. The student also learned the knowledge for carrying out the task on estimating the surface spectral reflectance by removing the effects of aerosols, thin clouds, and cloud shadows; the two major steps of performing atmospheric correction such as parameter estimation and surface reflectance retrieval.
4. The student has been trained to acquire AVIRIS data, visualize geo-location of flight path from AVIRIS data and apply software tool to analyze and visualize AVIRIS data.
5. Vicarious sites of interest such as Sonoran desert have been identified to support radiometric calibration of GOES-R ABI. Sonoran desert is among the few vicarious targets within the field of view of GOES-R ABI.
6. The student is developing IDL programs and image analysis techniques to facilitate the analysis of AVIRIS data and performing radiometric calibration and verification of AVIRIS data.

PLANNED WORK:
Second year assistantship for the student to continue the work has been applied. The student will analyze large volume of hyperspectral data from field experiments with **AVIRIS** and ground measurements performed at desert sites. In particular, the surface reflectance/albedo properties, bidrectional reflectance distribution function (BRDF) for the desert sites, and atmospheric absorption effects will be characterized. The following work will be performed:

- Analyze AVIRIS data and determine Top-of-Atmosphere (TOP) reflectance.
- Perform site radiative transfer modeling and estimation of atmospheric effects. Variability in atmospheric conditions such as water vapor and aerosol amount will be estimated through a radiative transfer models and further be related to the time series variability for the long-term stability analysis of the area.
- Determine surface reflectance from analyzing AVIRIS data and performing atmospheric radiation transport correction.
- Comparison of the ground based and airborne measurements (ASD, and AVIRIS)
- Investigate factors such as atmospheric water vapor, surface vegetation, and surface roughness affecting the surface reflectance at desert sites , in particular at Sonoran desert which among the few vicarious targets within the field of view of GOES-R.

PUBLICATIONS:
None

PRESENTATIONS:
None

DELIVERABLES:
None

PERFORMANCE METRICS

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

HIRS Calibration: Developing HIRS adjusted spectral response functions (ASRFs) for satellites NOAA 6, 7 and 8

Task Leader	Xi Shao
Task Code	XSXS_HIRS_13
NOAA Sponsor	Changyong Cao
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Calibration and Validation; Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%

Highlight: Calibration methods such as double differencing, global mean and SNO are used process radiance data over land/ocean sites and those from GOES 6, to calculate inter-satellite bias for HIRS channel 4,5,7 of NOAA -6, -7,-8 and -9.

BACKGROUND

The proposed work supports development and provision of the HIRS recalibrated SRFs, for satellites NOAA-6, -7 and -8 to support the development of the Cloud Top Pressure Property CDR and the Total Precipitable Water Vapor CDR.

The WMO's Global Climate Observing System (GCOS) (2011) defines the requirements for the Essential Climate Variables, which include Cloud Top Pressure (CTP). Our study uses CTP to demonstrate the impact of the HIRS spectral recalibrations on the long term cloud trends. The goal of our SRF recalibration is to reduce the mean inter-satellite HIRS biases toward zero with the residual uncertainty less than 1%, meeting the GCOS requirements.

Based on the inter-satellite SNO radiance comparisons, Chen et al. (2013) recalibrated the SRFs of HIRS long-wave CO2 channels for NOAA satellites from NOAA-9 to NOAA-19. However, the HIRS SRFs for NOAA-6, -7, and -8 have not been recalibrated in their study because there are no SNO events between NOAA -8 (or -7) and NOAA-9. There is around one month's gap for data records between NOAA-7 and NOAA -9, even longer gap between NOAA -8 and NOAA -9.

Alternative methods other than SNO are proposed to bridge the temporal gap between NOAA-7 and NOAA-9, including global mean method, vicarious site calibration methods and double differencing method. The site and global mean methods assume there is little change in the climate signal across NOAA-7 and NOAA-9 time so that inter-satellite bias can be assumed by analyzing data from two satellites but at different time. GOES -6 has overlapping time periods with both NOAA-7 and NOAA - 9 at different times, so a double differencing method can be applied for inter-satellite calibration.

ACCOMPLISHMENTS

1. Inter-satellite bias determined using global mean dataset

We compared the radiance time series over a monthly global mean of HIRS channel 4, 5, 7 of NOAA 07 and NOAA 09 for inter-satellite comparison. The method is similar to the one in Jackson and Soden (2007). First we averaged the radiance data monthly onto a global 2.5°grids for NOAA -7 and NOAA -9, respectively. And the monthly radiance data are averaged globally over all valid grids. A global seasonal cycle is then fitted from both NOAA -7 and NOAA -9 data and is removed by dividing it from the monthly time series. Inter-satellite difference between NOAA -7 and NOAA -9 can be seen clearly from the final data set (Fig. 1) for each channel.

2. Inter-satellite bias determined at different land/ocean sites.

We used radiance data in several land/ocean sites to look at the inter-satellite difference between NOAA -7 and NOAA -9. We analyzed the radiance variance over the grids in the global mean method and selected those with smallest variance. We have selected several ocean sites, South Atlantic

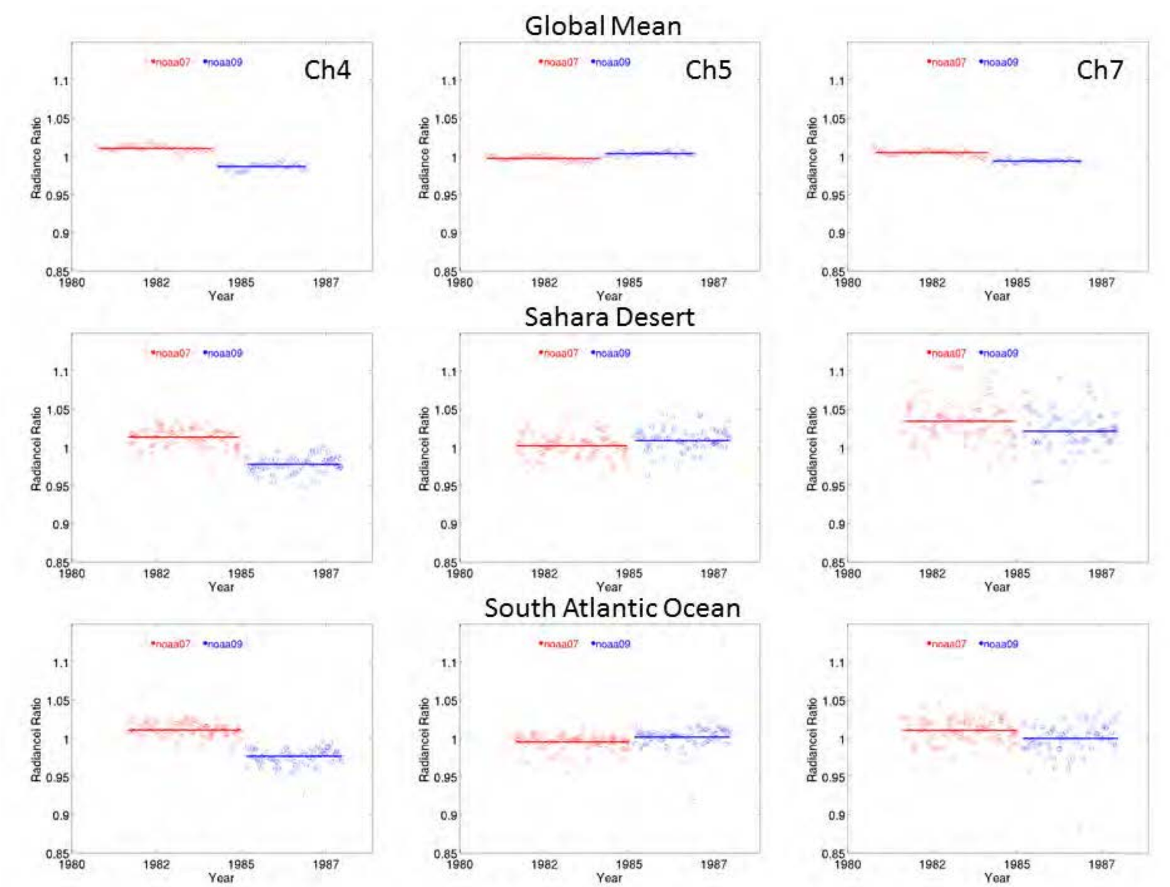


Figure 4 Comparison of the radiance ratio (to the fitted seasonal cycle) for NOAA -7 and NOAA -9 using global mean method (Upper), at land site (Sahara Desert) and at ocean site (South Atlantic Ocean). From left to right are channel 4, 5 and 7.

Ocean, Mediterranean Sea and one land site in Sahara Dessert, as well as some traditional calibration sites, such as Dome-C and Southern Great Plains. The nadir pixels in 50 km radius of the site are located and the radiance data are averaged over a 10 by 10 pixels centered at that nadir pixel to form time series for NOAA-6, NOAA-7, NOAA-8 and NOAA-9. Cloud screening method is applied for the data to remove cloud contaminated data. A seasonal cycle with diurnal cycle are then fitted and removed from the time series. The difference between NOAA-7 and NOAA -9 are shown in Fig. 1 for selected site. For the land site, the diurnal cycle is much stronger than in ocean site, and in the tropical region, the seasonal cycle becomes weaker than polar region. The Dome-C site has much noise possibly due to cloud screening not working there and most of data at SGP site are screened out due to high cloud coverage.

3. Using GOES-6 VAS to bridge the data gap between NOAA -9 and NOAA -8.

We have used the VISSR atmospheric sounder (VAS) measurements from GOES-6 to bridge the data gap between NOAA -9 and NOAA -7. Comparisons are being made between VAS and HIRS for similar channels, which are VAS channel 3 .vs. HIRS channel 4, VAS channel 4 .vs. HIRS channel 5, and VAS channel 5 .vs. HIRS channel 7. The GOES-6 VAS measurements are compared with NOAA-7 HIRS using data from year 1983, and with NOAA-9 HIRS using data from year 1985. Double differencing method is applied to the comparison results to get the time series of inter-satellite HIRS radiance difference between NOAA-7 and NOAA-9.

4. SNO for inter-satellite calibration for NOAA -6, NOAA -7 and NOAA -8

SNO method is applied for inter-satellite bias calculation for pair NOAA -6/NOAA -7,NOAA -7/NOAA -8. Obvious inter-satellite discrepancies can be identified (Figure2).

PLANNED WORK:

We will continue to perform the following work

- Compare the results from using vicarious sites, global mean and double differencing methods.
- IASI hyper-spectral data will be used to simulate HIRS observations.
- The inter-satellite difference of SRF (including pre-launched difference and uncertainties) will be determined using least square fitting between the simulated and actual HIRS observations.
- Documentation for the algorithm and process to determine the ASRFs
- Summarize results and submit paper to conference and journals for publication.

PUBLICATIONS:

None

PRESENTATIONS:

- Delivered two presentations to Dr. Paul Menzel of the University of Wisconsin – Madison on the project progress.

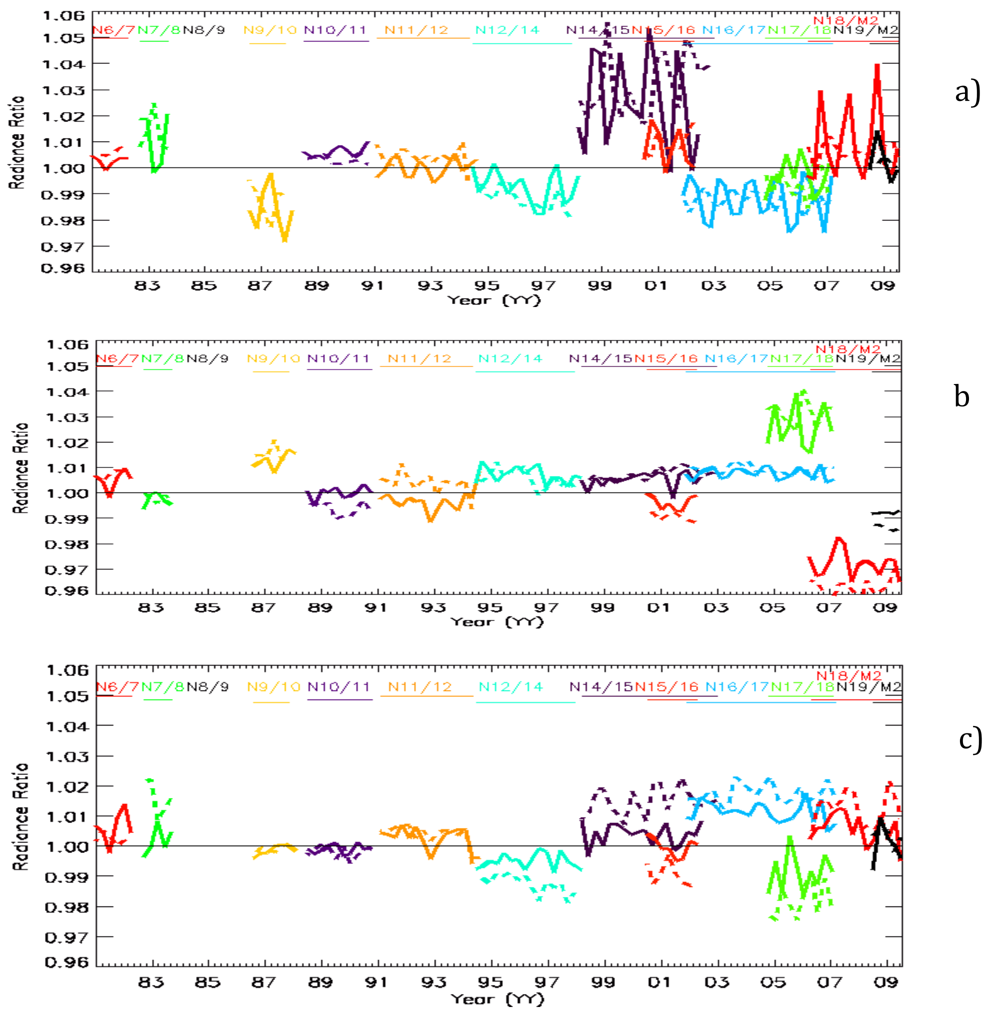


Figure 2. Time series of inter-satellite biases of HIRS long-wave CO2 channels for NOAA-6 to -19. Solid lines represent SNO comparisons in the south polar region; dashed lines represent SNO comparisons in the north polar region. a) channel 4; b) channel 5; c) channel 7.

DELIVERABLES:

- Implementation Plan for Developing HIRS adjusted spectral response functions (ASRFs) for satellites NOAA 6, 7 and 8

PERFORMANCE METRICS

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

NPP VIIRS Cal/Val Support at the University of Maryland

Task Leader	Xi Shao
Task Code	XSXS_NPPV_12
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%

Highlight: CICS scientists support calibration and validation work for NPP VIIRS instrument through developing routine SNO/lunar appearance/vicarious sites overpassing predictions web services, performing sensor data record verification, validation, and long-term performance monitoring with lunar, vicarious and deep convective cloud calibration.

BACKGROUND

VIIRS (Visible Infrared Imager Radiometer Suite) onboard the Suomi-NPP satellite primarily focuses on clouds and Earth surface variables. VIIRS is designed to provide moderate-resolution, radiometrically accurate images of the globe twice daily. It is a wide-swath (3,040 km) scanning radiometer with spatial resolutions of 370 and 740 m at nadir for I and M bands, respectively. It has 22 spectral bands covering the spectrum between 0.412 µm and 12.01 µm, including 9 reflective solar bands (RSB), 12 thermal emissive bands (TEB), and 1 day-night band (DNB). For the reflective solar bands, the calibration uncertainty in spectral reflectance for a scene at typical radiance is expected to be less than 2%. This performance has been demonstrated in prelaunch testing in the laboratory, but on-orbit performance requires additional efforts in calibration by using the onboard solar diffuser (SD), lunar observations and vicarious methods, as well as inter-comparisons with other instruments.

Our work focuses on providing support to the calibration of RSB, TEB and DNB bands of VIIRS to ensure that the mission requirements are met and the production of high quality radiometrically and geometrically corrected sensor data records for VIIRS.

ACCOMPLISHMENTS

We supported the VIIRS calibration in a broad scope by

1. Participated Suomi NPP VIIRS sensor data record verification, validation, and long-term performance monitoring and publish one paper in Journal of Geophysical Research.
2. Performed detection of light outages after severe storms Using the S-NPP/VIIRS Day/Night Band Radiances
3. Participated radiometric intercomparison between Suomi-NPP VIIRS and Aqua MODIS Reflective Solar Bands using simultaneous Nadir overpass in the low latitudes and publish one paper in Journal of Atmospheric & Oceanic Technology.
4. Investigated the Deep Convective Clouds (DCC) radiometric sensitivity to spatial resolution, cluster size, and LWIR DCC technique and Suomi NPP VIIRS observations (Figure 1). An manuscript based on the results from this study was submitted to JTECH for peer review. The method and

source code developed in this study can be readily applied for long-term VIIRS RSB calibration monitoring.

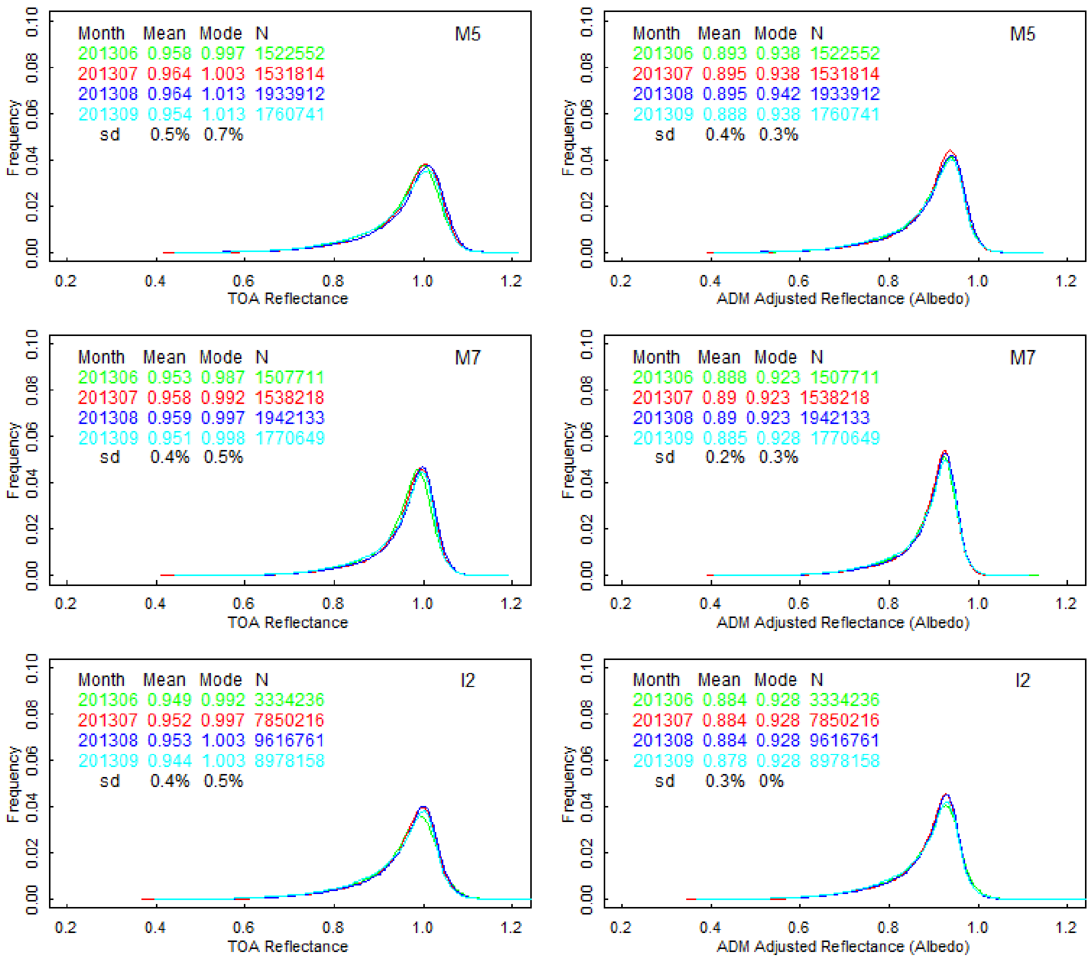


Figure 1: Monthly probability distribution functions of VIIRS DCC reflectance for before (left panel) and after (right panel) the correction of the anisotropic effects.

5. Provided in-depth supports to the NOAA/NESDIS/STAR VIIRS post-launch cal/val activities through visualizing and analyzing the dependencies of Response versus Scan (RVS) on wavelength (band), detector, scan angle (frame position), and HAM side.
6. Completed the evaluation of the DNB straylight correction package, including analyzing source code and testing the look-up table (LUT) using the NPP ADL4.2 tool and assessing the performance straylight removal.
7. Investigated the inconsistency in the VIIRS bands I4 and I5 radiance and BT limits and found that similar inconsistency also exist in bands M12, and M14-M15.
8. Studied the VIIRS EBBT LUT and developed detector level EBBT LUTs. Detector level LUTs indicated that band M15 detectors 1-2 are significantly different from other detectors, which may cause the observed stripping in the VIIRS SST EDR product.

9. Completed VIIRS bow-tie removal experiment using average of the values from the previous and after good scanlines.
10. Developed and refined satellite orbit tracking software to provide web-services of predicting SNO and SNOx events, vicarious site overpass, lunar appearance, and solar diffuser illumination.
11. Performed vicarious calibration for VIIRS DNB band with moon light.

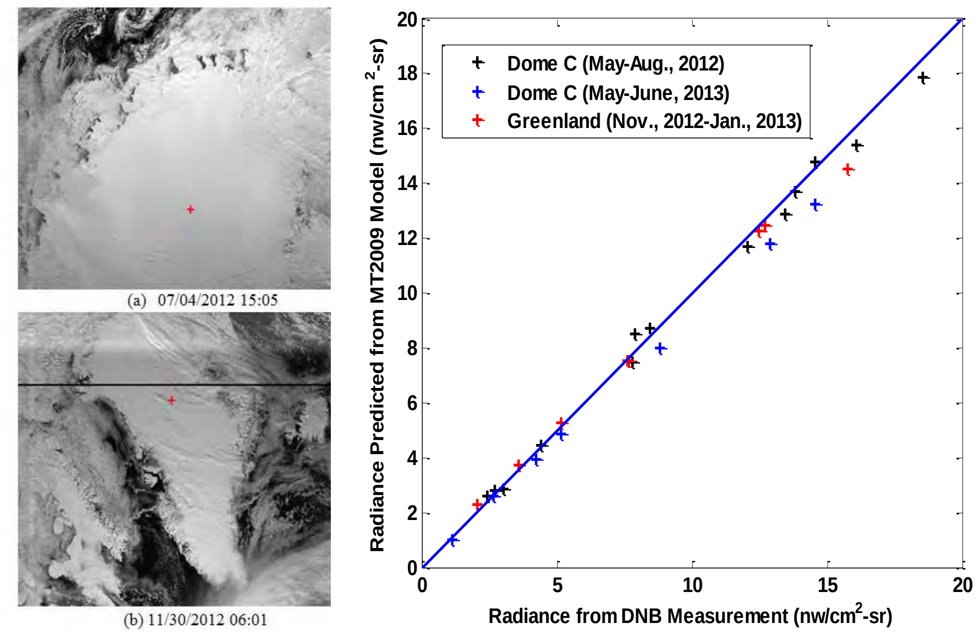


Figure 2: Left: (a, b) DNB observations of Dome C and Greenland, respectively, at night under lunar illumination. Red '+' mark the centers of the vicarious sites used in this study. Right: Scatter plot of radiances observed by DNB vs. radiance predicted from Miller and Turner, 2009 (MT2009) model.

12. Monitoring VIIRS stability through vicarious calibration over desert, sea, and Dome C sites using SNO and SNOx techniques.
13. Performed correlational analysis of orbital variation of blackbody thermistor temperature and assessment of its effects on the thermal emissive band calibration.
14. Refine radiometric calibration algorithm and support VIIRS radiometric calibration ATBD document development.
15. Evaluated radiometric consistency between Suomi NPP VIIRS and NOAA-19 AVHRR using extended simultaneous nadir overpass in the low latitudes

PLANNED WORK:

- Continue to provide support to the vicarious calibration of VIIRS RSB and TEB bands.
- Perform vicarious calibration of VIIRS day-night band (DNB) with lunar illumination events.
- Continue to support SNOs and SNOx, vicarious site overpass, lunar appearance prediction web services development for NPP.
- Continue to monitor VIIRS stability through vicarious calibration over desert, sea, and Dome C sites and inter-satellite calibration using SNO and SNOx techniques.

- Continue to support calibration of VIIRS using scheduled moon and moon-in-space view observations

PUBLICATIONS:

Cao, C., J. Xiong, S. Blonski, Q. Liu, S. Uprety, Shao X., Bai Y., and Weng F., Suomi NPP VIIRS sensor data record verification, validation, and long-term performance monitoring, J. Geophys. Res. Atmos., 118, doi: 10.1002/2013JD020418, 2013.

Cao, C.; Shao, X.; Uprety, S., Detecting Light Outages after Severe Storms Using the S-NPP/VIIRS Day/Night Band Radiances, Geoscience and Remote Sensing Letters, IEEE, vol.10, no.6, pp.1582-1586, doi: 10.1109/LGRS.2013.2262258, 2013.

S Uprety, C Cao, X Xiong, S Blonski, A Wu, X Shao Radiometric Intercomparison between Suomi-NPP VIIRS and Aqua MODIS Reflective Solar Bands Using Simultaneous Nadir Overpass in the Low Latitudes, Journal of Atmospheric & Oceanic Technology, Dec2013, Vol. 30 Issue 12, p2720-2736. 17p. 2013.

Shao, X., C. Cao, and S. Uprety, Vicarious calibration of S-NPP/VIIRS day-night band, SPIE Proceedings Vol. 8866, Earth Observing Systems XVIII, James J. Butler; Xiaoxiong (Jack) Xiong; Xingfa Gu, Editors, 88661S, DOI: 10.1117/12.2023412, 2013.

S Uprety, C Cao, S Blonski, X Shao, Evaluating radiometric consistency between Suomi NPP VIIRS and NOAA-19 AVHRR using extended simultaneous nadir overpass in the low latitudes, Proc. SPIE 8866, Earth Observing Systems XVIII, 88660L (September 23, 2013); doi:10.1117/12.2023335.

Xin Jing, Xi Shao, Changyong Cao, Xiaodong Fu, Lei Yan, Comparison between Suomi-NPP Day-Night Band and DMSP-OLS in Correlating with Regional Socio-economic Variables, submitted to Remote Sensing of Environment, 2014.

PRESENTATIONS:

Wang. W. and C. Cao (2013), Suomi NPP VIIRS Observations of DCC Radiometric Sensitivity to Spatial Sampling, Cluster Size, and LWIR Calibration Bias, CICS Science Meeting, November 6-7, 2013, College Park, MD (poster presentation).

Quanhua (Mark) Liu, C. Cao, S. blonski, X. shao, and S. Uprety, SUOMI NPP VIIRS CALIBRATION/VALIDATION PROGRESS UPDATE, American Meteorological Society annual meeting, 4 February 2014.

Slawomir Blonski, Changyong Cao, Sirish Uprety, Xi Shao,Inter-comparison of Terra and Aqua MODIS Reflective Solar Bands using Suomi NPP VIIRS, Conference on Characterization and Radiometric Calibration for Remote Sensing (Calcon), Logan, Utah, Aug. 2013.

Sirish Uprety, Changyong Cao, Slawomir Blonski, Xi Shao, Frank Padula, Tracking On-orbit Radiometric Stability and Accuracy of Suomi NPP VIIRS Using Extended Low Latitude SNOs, Conference on Characterization and Radiometric Calibration for Remote Sensing (Calcon), Logan, Utah, Aug. 2013.

Xi Shao, Changyong Cao, Sirish Uprety, Calibration/Validation of S-NPP/VIIRS Day-Night Band using Moon Light, CICS-MD Science Meeting, November 6-7, 2013, College Park, MD.

Xin Jing, Xi Shao, ,Changyong Cao, Xiaodong Fu, Comparison between DMSP-OLS and S-NPP Day-Night Band in Correlating with Regional Socio-economic Variables, CICS-MD Science Meeting, November 6-7, 2013, College Park, MD.

Slawomir Blonski, Changyong Cao, Sirish Uprety, and Xi Shao, Inter-comparison of Terra and Aqua MODIS reflective solar bands using Suomi NPP VIIRS, CICS-MD Science Meeting, November 6-7, 2013, College Park, MD.

Orbital Variation of Blackbody Platinum Resistance Thermometer Temperature for S-NPP VIIRS Thermal Emissive Band Calibration, Xi Shao, Slawomir Blonski, Quanhua Liu, Changyong Cao, Conference on Characterization and Radiometric Calibration for Remote Sensing (Calcon), Logan, Utah, Aug. 2013.

Invited Talk: X. Shao and Changyong Cao, NOAA Cal/Val Progress Update, The 36th CEOS Working Group on Calibration and Validation Plenary (WGCV-36), Shanghai, China, May 13-17, 2013.

Xi Shao; Changyong Cao; Sirish Uprety, Calibration/Validation of S-NPP/VIIRS Day-Night Band using Moon Light, A23A-0198 , Fall meeting of American Geophysical Union, 2013.

Xin Jing; Xi Shao; Changyong Cao; Xiaodong Fu, Comparison between DMSP-OLS and S-NPP Day-Night Band in Correlating with Regional Socio-economic Variables, A23A-0214,Fall meeting of American Geophysical Union, 2013.

Sirish Uprety, Changyong Cao, Slawomir Blonski and Xi Shao, "Radiometric Comparison between Suomi NPP VIIRS and AQUA MODIS using Extended Simultaneous Nadir Overpass in the Low Latitudes", NOAA Satellite Conference, College Park MD, 2013.

Slawomir Blonski, Changyong Cao, Sirish Uprety, and Xi Shao, Continuity of VIIRS/MODIS Radiometric Measurements: Simultaneous Nadir Overpass and Pseudo-Invariant Site Comparisons for Reflective Solar Bands, ASPRS 2013 Annual Conference, March 24-28, 2013, Baltimore, Maryland, USA.

Changyong Cao, Xi Shao, Sirish Uprety, Quantifying Power Outages after Severe Storms using the S-NPP/VIIRS Day Night Band Radiances, NOAA Satellite Conference, College Park MD, 2013.

Slawomir Blonski, Changyong Cao, Sirish Uprety, and Xi Shao, Continuity of VIIRS/MODIS Radiometric Measurements: Simultaneous Nadir Overpass Comparisons for Reflective Solar Bands, NOAA Satellite Conference, College Park MD, 2013.

DELIVERABLES:

Five web service products to support VIIRS calibration have been developed

- Satellite Simultaneous Nadir Overpass (SNO) Prediction Service for National Calibration Center of NOAA: http://ncc.nesdis.noaa.gov/SNO/SNOs//NCC_SNOs_prediction_service.html
- Suomi-NPP VIIRS instrument event log database: http://spp.astro.umd.edu/NPP/interface.php
- Suomi-NPP VIIRS publication tracking database: http://spp.astro.umd.edu/papers/interface.php
- Prediction service of Moon in Space View of VIIRS: http://ncc.nesdis.noaa.gov/SNO/SNOs/NPP_moon/cur_NPP_moon.html
- Suomi-NPP VIIRS vicarious sites overpass prediction: https://cs.star.nesdis.noaa.gov/NCC/NPPCalValSites

PERFORMANCE METRICS

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	5
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	4
# of non-peered reviewed papers	2
# of presentations	15
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

The Ozone Mapping and Profiler Suite (OMPS) Sensor Data Record (SDR) Calibration and Validation

Task Leader:	Fred Wu
Task Code:	ZLZL_JPIC11
NOAA Sponsor:	Fuzhong Weng
NOAA Office:	NESDIS/STAR
Percent Contribution to CICS Themes:	Theme 1: 20%; Theme 2: 70%; Theme 3: 10% (estimated)
Main CICS Research Topic:	Calibration and Validation; Scientific support for the JPSS Mission; Future Satellite Programs and Earth System Monitoring from Satellites.
Contribution to NOAA goals:	Goal 1: 70%; Goal 2: 20%; Goal 5: 10%

Highlight: CICS Scientist CHunhui Pan have developed new comprehensive data analysis algorithms to evaluate entire sensor orbital performance in accordance to the NASA newly established calibration measurement sequences. The algorithms have been used by me to have performed sensor end-to-end data analysis to evaluate sensor orbital performance and calibration results, as well as to validate SDR products. Sensor anomalies are identified based on my results and solutions were proposed. I presented a comprehensive sensor performance review to the JPSS program in SNPP Products Review on Dec. 19, 2014.

Report of Chunhui Pan

BACKGROUND

This report summarizes the year-2 work of the ongoing NOAA project entitled "The Ozone Mapping and Profiler Suite (OMPS) Sensor Data Record (SDR) Calibration". A new comprehensive sensor performance analysis has been developed and is being used to evaluate, monitor and validate sensor comprehensive orbital performance, including electronic, spectral, wavelength and radiometric calibration and validation. The algorithm framework is an optimal implementation of the newly established calibration measurement sequences. The analysis results that I provided determine the mature level of the sensor data records (SDRs) for the SNPP/JPSS program. Below are the accomplishments during the second year of the project, followed by future plans for third year.

ACCOMPLISHMENTS

The following are three examples of my major accomplishments that are critical performance parameters and issues in the current OMPS operation.

1. Radiometric Stability

Solar irradiance measurement determines sensor radiometric stability through a trending of orbital change of the sensor throughput. One challenge in the irradiance calibration is the diffuser feature presents spectral and spatial non-uniformity in the observed signals. By modifying the pre-planned calibration sequence, the measurement extends from a signal one orbit to 3 orbits. The collected data shows 5% improvement on the interference structure. The data analysis algorithm was redeveloped to adopt to the changes in the orbital measurement sequences.

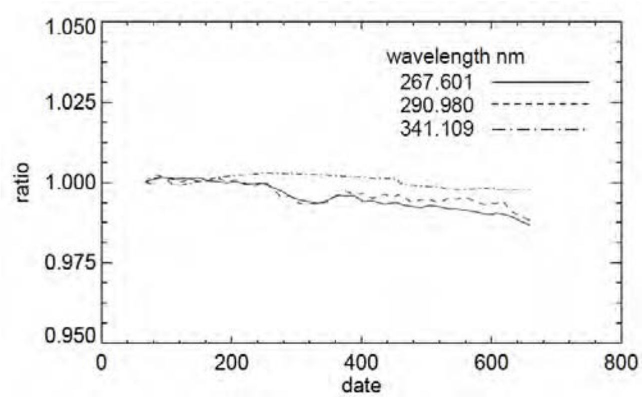


Figure 5: Time dependent changes in NP and NM optics throughput from the working and reference diffusers for four different channels.

2. Wavelength shift from ground to orbit

Figure 2 verifies there is wavelength shift from ground to orbit by showing the comparison result of the solar irradiance based on the same orbital wavelength table. The predicted synthetic solar flux is computed by convolving the band center with the prelaunch defined slit function and a high resolution solar reference flux. A noticeable discrepancy of up to 12% observed in the NP and NM spectral overlap region 300-310 nm significantly higher than elsewhere indicates a dichroic shift of 0.15 nm occurred when sensor transitioned from ground to orbit.

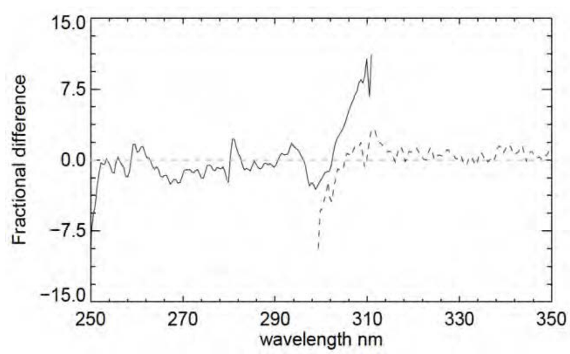


Figure 2 12% percent difference between observed solar flux and the predicted solar flux based on the orbital wavelengths occurred in spectral range 300-310 nm, elsewhere indicates a dichroic shift of 0.15 nm occurred when sensor transitioned from ground to orbit.

3. Cross-track position variation

OMPS NM sensor exhibits wavelength dependent difference in the cross-track position. Such a feature presents in both the observed solar flux and the earth radiance. Fig. 3 compares solar flux of the measured to the predicted synthetic data for 2 different cross-track position relative to the nadir view position 17. The difference is computed by. The difference reach a maximum 0f 2.5% at the two edge position on the NM CCD.

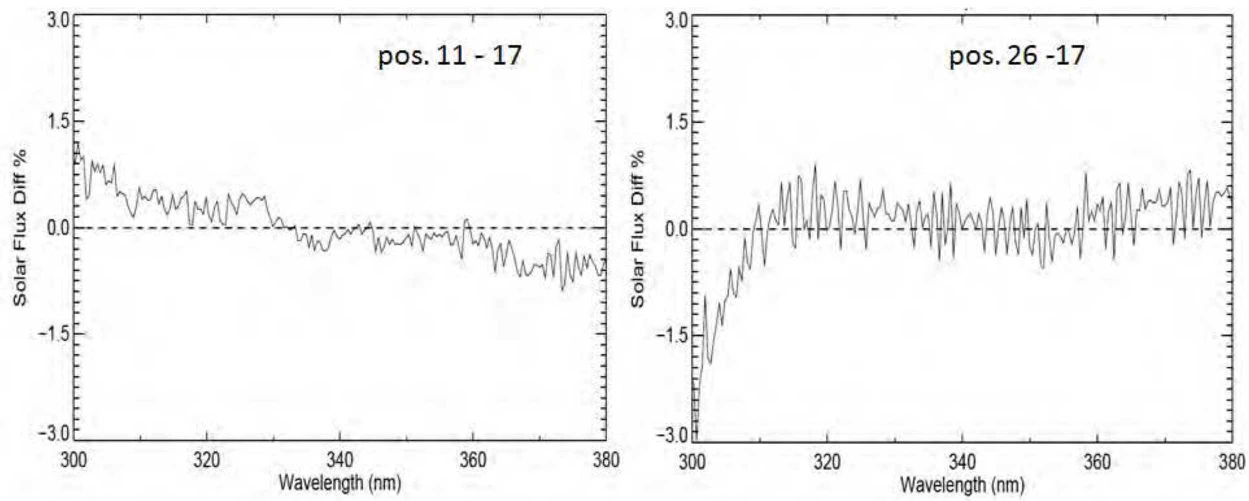


Figure 3 Cross-track position flux ratio difference for position 11 and 26 relative to nadir view of position 17, which introduces noticeable error of 2.5% in the radiance retrieval.

Sensor Performance Summary

Parameters	Specification/Prediction Value	On-Orbit Performance
Non-linearity	< 2% full well	< 0.46%
Non-linearity Accuracy	< 0.2%	±0.2%
On-orbit Wavelength Calibration	< 0.01 nm	~ 0.02 nm
Stray Light NM Out-of-Band + Out-of-Field Response	For NM ≤ 2	average < 2%
Intra-Orbit Wavelength Stability	Allocation (flow down from EDR error budget) = 0.02 nm	~ 0.025 nm
SNR	1000	> 1000
Inter-Orbital Thermal Wavelength Shift	Allocation (flow down from EDR error budget) = 0.02 nm	~0.025 nm
CCD Read Noise	60 –e RMS	< 25 –e RMS
Detector Gain	43 (for NP) 46 (for NM)	47 (for NP) 51 (for NM)
Absolute Irradiance Calibration Accuracy	< 7%	< 7% in 300-310 nm: up to ~10 % for both NM and NP
Absolute Radiance Calibration Accuracy	< 8%	< 8%
Normalized radiance Calibration Accuracy	< 2%	< 1%

Work Summary

All project deliverables (documentation and software) and milestones have been accomplished as planned. Additionally, I have reviewed NASA sensor calibration tools and results, and successfully duplicated dark calibration operation from NASA to the NOAA STAR facility. Currently, the stray light algorithm, data analysis and orbital calibration are under way for both SNPP and J1 projects.

PLANNED WORK

- Continue work to assess and evaluate the comprehensive performance of the OMPS sensor suite
- Continue work to refine the stray light algorithm parameters and to improve its performance over orbit
- Continue work to monitoring SNPP-OMPS sensor orbital performance
- Support Calibration SDR transition from NASA to GRAVITE.
- Work on J1 OMPS prelaunch calibration.

PUBLICATIONS

Journal Articles

Published

C. Pan, M. Kowalewski, R. Buss, L. Flynn, X. Wu, M. Caponi, and F. Weng, Performance and Calibration of the Suomi-NPP Ozone Mapping Profiler Suite From Early-Orbit Images, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Volume 6, Issue 3. DOI: 10.1109/JSTARS.2013.2259144, May 13, 2013

Accepted:

C. Pan, L. Flynn, R. Buss, C. Softer, X. Wu, W. Yu and M. Grotenhuis; Performance Monitoring of the S-NPP Ozone Mapper Profiler Suite's Sensor Data Records, IEEE Transactions, Jan. 2014

L. Flynn, C. Long, X. Wu, R. Evans, C.T. Beck, I. Petropavlovskikh, G. McConville, W. Yu, Z. Zhang, J. Niu, E. Beach, Y. Hao, C. Pan, B. Sen, M. Novicki, S. Zhou, C. Seftor; Performance of the ozone mapping and profiler suite (OMPS) products, J. of Geophysical Research Special Issue of the Suomi National Polar- Orbiting Partnership Satellite Calibration, Validation and Applications Dec. 2013

X. Wu, Q. Liu, J. Zeng, M. Grotenhuis, H. Qian, M. Caponi, L. Flynn, G. Jaross, B. Sen, R. Buss Jr., W. Johnsen, S. Janz, C. Pan, J. Niu, T. Beck, E. Beach, W. Yu, R. Kovilakom, D. Stuhmer, D. Cumpton, C. Owen and W. Li, Evaluation of the Sensor Data Record from the Nadir Instruments of the Ozone Mapping Profiler Suite (OMPS), J. of Geophysical Research Special Issue of the Suomi National Polar- Orbiting Partnership Satellite Calibration, Validation and Applications, Dec. 2013

Conference Papers

C Pan, X. Wu, L. Flynn and M. Grotenhuis; S-NPP Zone Mapping and profiler Suite Provisional Operations Performance. Geoscience and Remote Sensing Symposium (IGARSS), July, 2013 IEEE International

C. Pan, X. Wu and M. Grotenhuis; Ozone Mapper Profiler Suite Early Orbit Linearity Performance Evaluation. Geoscience and Remote Sensing Symposium (IGARSS), July 2013 IEEE International.

DELIVERABLES

- Automated dark look up table generation for sensor weekly calibration;
- Delivered a comprehensive analysis package of sensor performance review for validated mature level of SDR products; and
- Documentation for algorithms and data analyses.

PRESENTATIONS

C. Pan, X. Wu, L. Flynn and F. Weng; S-NPP Ozone Mapping and Profiler Suite (OMPS) Performance and Calibration [Poster], *2nd Annual CICS-MD Science Meeting*, College Park, MD (Nov. 6-7 2013), http://cicsmd.umd.edu/assets/1/7/P3_Pan_ab.pdf.

C. Pan, X. Wu and L. Flynn; Ozone Mapping and Profiler Suite (OMPS) Instrument Performance Evaluation, AGU 2013.

C Pan, X. Wu, L. Flynn and M. Grotenhuis; S-NPP Zone Mapping and profiler Suite Provisional Operations Performance. IGARSS, July, 2013 IEEE International

C. Pan, X. Wu and M. Grotenhuis; Ozone Mapper Profiler Suite Early Orbit Linearity Performance Evaluation. IGARSS, July 2013 IEEE International.

C. Pan, X. Wu and L. Flynn; S-NPP Ozone Mapper Profiler Suite Nadir Sensor Performance, SUOMI NPP SDR Science and Validated Product Maturity Review. December 18-20, 2013, College Park, MD 20740

C. Pan, X. Wu, L. Flynn and F. Weng; On the Provisional S-NPP Ozone Mapping and Profiler Suite Performance, NOAA Satellite Conference, April 8-12, 2013, NOAA Center for Weather and Climate Prediction (NCWCP), College Park, MD20740

OTHER

Invited and provided proposal consult to Science Systems and Application, Inc. for VIIRS/MODIS project re-competition.

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	1
# of products or techniques transitioned from research to ops without NOAA guidance	1
# of peer reviewed papers	4
# of non-peered reviewed papers	2
# of invited presentations	6
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

This year, I have developed a new sensor data analysis package that provides a comprehensive sensor orbital performance evaluation, includes wavelength calibration, dark, nonlinearity, electronic bias, smears, sensor optics degradation, straylight evaluation and validation, radiometric calibration and spectral calibration. This development involved transfer sensor orbital characterization to operation product delivery. One of dark calibration techniques transitioned from research to ops. One journal paper on the comprehensive sensor performance related to the project has been published, 3 are accepted and one is submitted. While another journal publication on the algorithm is under preparation. Four presentations summarizing the algorithm and the results have been made.

1.3 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
Task Code	BDBD_GCOS_13
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCDC
Contribution to CICS Themes (%)	Theme 2: 70%; Theme 1: 30%; Theme 3: 0%.
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 90%; Goal 3: 0%; Goal 4: 0%; Goal 5: 10%

Highlight: NPP-Satellite overpass coordinated upper air sonde and ground based remote sensing profile data collection as part of the GRUAN network has continued. Evaluation and analysis of collected data and comparison of suite of instruments with satellites is in progress.

BACKGROUND

This report summarizes the activities undertaken under the NOAA project entitled “Howard University Support of NOAA's commitment to the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN)”.

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 Beltsville Center for Climate System Observation (see http://bccso.howard.edu/ and http://ncas.howard.edu/) and the NOAA Center for Atmospheric Studies (NCAS) is one of these sites (http://gruan.org) which is making measurements of upper air radiosondes during the NPP overpass times and archiving the data sets for validation purposes and to estimate Site Atmospheric State Best Estimate (SASBE). The proposed project (1) will facilitate the activities at Howard University Beltsville Campus that pertain to satisfying the GRUAN station measurement requirements; (2) processing dedicated observations at Suomi-NPP overpass to serve as basis to develop “recipe(s)” of GRUAN ancillary and radiosonde measurements to calculate SASBE with focus on atmospheric temperature and moisture for NPP satellite FTIR/MW products validation..

NPP-Satellite overpass coordinated upper air sonde and ground based remote sensing data collection has continued. Evaluation and analysis of data comparison from selected cases has also commenced. Examples are given below. Coordination with the GRUAN processing is in progress. RSLAUNCH software has been tested at the site and pre-flight RS92-calibration unit has been ordered.

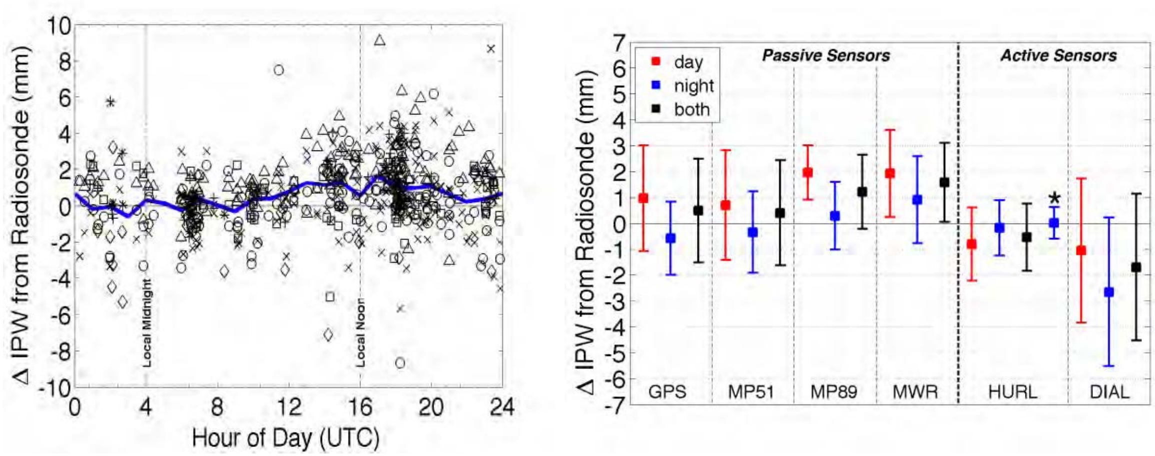


Figure 1: A figure comparing many ground sensors in relation to the RS-92 sonde – shown in earlier report but expanded here. Comparison of a multi-instrument derived Integrated Perceptible Water Vapor (IPW): RS92 radio sonde is used as the "truth" and compared to GPS, Lidar (DIAL and HURL), and microwave radiometer derived data. We plan to include the lidar derived similar quantities in such a comparison. The RS92 data has not gone through any special processing except factory DigiCore software. The data have been segregated to day-night to show any diurnal variation in instrument response. This work is being performed by Mr. Lorenzo Cooper, as part of his PhD. Dissertation.

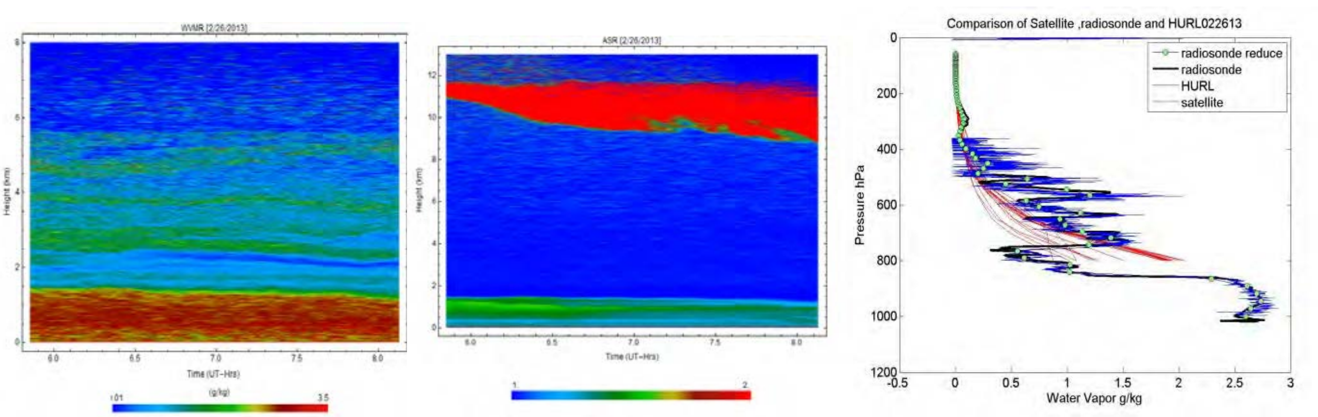


Figure 2: A case study of Raman lidar data showing the time-height variability of water vapor mixing ratio and aerosol on 02262013: Note the aerosol image (Middle) shows a thin cirrus cloud near the troposphere. A comparison of the lidar-satelite-sonde is also shown: The method of Nalli et al 2014 and Adam et al 2010 is used for processing the sonde profile data into layer averages (Green dots). The satellite-provided curves represent profiles near the ground station – plotted to show the pixel-to-pixel variability. This work is in progress for publication by Dr. Walker.

ACCOMPLISHMENTS

A satellite-coordinated radio sonde data archive has been created and is being shared with NESDIS/STAR scientists. The same data is also being processed through the RSLaunch GRUAN software and corrected with an error estimate for each data point. A paper (Fasso et al 2013) that discusses the collocation mismatch of observations and estimating the statistical errors associated was submitted for journal publication. Several students and a postdoc are using the data as a basis for their work and training.

All project deliverables (sonde data) and milestones have been accomplished as planned.

PLANNED WORK

- Continue data collection and algorithm development;
- Continue collaboration with GRUAN;
- Continue working on part two - sonde-satellite data comparison collocation error analysis;
- Continue collaboration with STAR personnel for validation of the EDRs;
- Continued launches of the monthly and weekly launches of RS92 and CFH data product and integration of the data into the GRUAN data stream.

PUBLICATIONS

Fasso, A.; R. Ignaccolo, F. Madonna, B. B. Demoz, and M. Franco-Villoria Statistical modeling of collocation uncertainty in atmospheric thermodynamic profiles, accepted *Atmos Meas Tech* 2014

DELIVERABLES

- Satellite coordinated weekly radio sounding launches.

PERFORMANCE METRICS	**FY13**
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	4
# of undergraduate students mentored during the year	1

PERFORMANCE METRICS EXPLANATION

Training of graduate students is an integral part of the work under this grant and any work that goes on at the Howard University Beltsville Campus. As such, the radiosonde data is used by all the graduate students in their thesis and journal publication work. Two examples that have utilized the data the most are the following. A publication was submitted. And, the Team leader is advising 4 students, mentoring an undergraduate student

Assessment of Global Oceanic Net Freshwater Flux Products Using Argo Salinity Observations

Task Leader Li Ren
Task Code N/A
NOAA Sponsor: N/A
NOAA Office: N/A
Main CICS Research Topic: Surface Observation Networks
Percent contribution to CICS Themes Theme 1: 20%; Theme 2: 60%; Theme 3: 20%.
Percent contribution to NOAA Goals Goal 1: 20%; Goal 2: 0%; Goal 3: 70%; Goal 4: 10%; Goal 5: 0%

Highlight: We attempted to evaluate ten E-P sets employing the ocean rain gauge as a valid reference. For the annual mean spatial distribution, the combination of E-P from OAFlux/TRMM has the best agreement with the indirect estimate of E-P according to their spatial pattern correlations and the RMSD. Thus, we recommend this combination for ocean modeling studies. The zonal averaged analysis indicates that direct estimate products likely overestimate in their high value regions. This NSF-funded project was completed this year.

BACKGROUND

Evaporation and precipitation are major components of the global hydrological cycle as well as among the most important components of the climate system, with 86% of global evaporation and 78% of global precipitation occurring over the oceans. However, even in the age of satellite observations, measurements of both evaporation and precipitation are still unsatisfactory. In-situ observations of sea surface evaporation and indirect retrievals of evaporation from satellite information are both subject to errors and uncertainties . Oceanic precipitation can be estimated from satellite observations, but the values are subject to significant uncertainties due to the scarcity of calibrating observations and the physical limitations involved.

With the rapidly growing number of ocean salinity measurements in recent years, the concept of “ocean rain gauge” has gained increasing attention. With the expanding salinity measurements by new satellite instruments and in situ technologies our understanding of the global water cycle would be improved. At present there are more than 3200 active Argo floats providing near real time temperature and salinity profiles of the world ocean. Additionally, the NASA Aquarius mission, which was launched in June 2011, is providing global Sea Surface Salinity (SSS) with 150-Km spatial resolution on a 30-day time scale with measurement error estimate to be less than 0.2 psu. This mission, along with the European Soil Moisture/Ocean Salinity (SMOS), provides an unprecedented view of global SSS.

The oceanic salinity budget links salinity to forcing at the ocean-atmosphere interface in the form of E (evaporation) - P (precipitation). However, upper ocean salinity variation is a rather complex process, being additionally influenced by factors including horizontal advection, entrainment, lateral diffusion and mixing. In this study, we take advantage of the rich salinity data employing the “ocean rain gauge” concept according to the ocean salinity budget, to validate the oceanic precipitation and evaporation.

ACCOMPLISHMENTS

Ten sets of E-P (Table 1, direct estimate) have been evaluated with the reference to the E-P estimated from the salinity (indirect estimate). The spatial correlations of the direct estimate and the indirect estimate indicates that the set of OAFlux/TRMM yields the highest correlation (0.55), while the second highest is provided by the GSSTF3/TRMM pair. The Root Mean Square Difference (RMSD) between the direct and indirect methods indicates that OAFlux/TRMM and IFREMER/TRMM have the smallest RMSD (2.30 m $year^{-1}$). The evaporation and precipitation from RSS has the highest RMSD among the net freshwater products. Therefore, annual mean E-P from OAFlux/TRMM agrees best with the E-P estimated from the ocean salinity budget based on this simple assessment of its high spatial correlation and low RMSD.

Name	Organization	Resolution	Data Access
GPCP (P)	NASA	2.5°×2.5°	http://precip.gsfc.nasa.gov/
CMAP (P)	NOAA CPC	2.5°×2.5	http://www.esrl.noaa.gov/psd/data/grid-ded/data.cmap.html
TRMM (P)	NASA	1°×1°	http://disc.sci.gsfc.nasa.gov/daac-bin/DataHold-ings.pl
OAFlux (E)	WHOI	1°×1°	http://oaflux.whoi.edu
GSSTF3 (E)	NASA	1.5°×1.5°	http://disc.sci.gsfc.nasa.gov/datareleases/gsstf-version-3
IFREMER (E)	IFREMER	1°×1°	ftp://ftp.ifremer.fr/ifremer/cersat/products/grid-ded/flux-merged/data/
NEWS (E,P)	RSS	0.25°×0.25°	ftp://ftp.remss.com/water_cycle/

Table 1: List of freshwater flux products includes Evaporation (E) and Precipitation (P).

The zonal averages of the annual mean E-P products and the E-P from salinity show similar latitude distributions (Figure 1). In the tropics, where precipitation peaks, the E-P all have negative numbers representing precipitation exceeding evaporation. However, most of the E-P products are lower than the E-P from salinity. Also, the local minimums of the E-P products are offset slightly north of the E-P from salinity. North of 40°N and south of 40°S, where the secondary precipitation maximum (storm track) appears, the E-P from salinity and the E-P products all have negative numbers. Most of the E-P products are lower than the E-P from salinity. In the Northern hemisphere subtropics, the E-P from salinity is lower than most of the E-P products except OAFlux/CMAP. The E-P from salinity is almost identical to OAFlux/GPCP in these regions. In the Southern Hemisphere subtropics, local maximums of E-P products are offset to the north of the E-P from salinity. In summary, the E-P products are lower than the E-P from salinity in the heavy rain zones possibly due to overestimation of the precipitation and/or underestimation of the evaporation in these products. In the high evaporation zones, the E-P products are greater than the E-P from salinity possibly due to the overestimation of evaporation and/or underestimation of precipitation in these products.

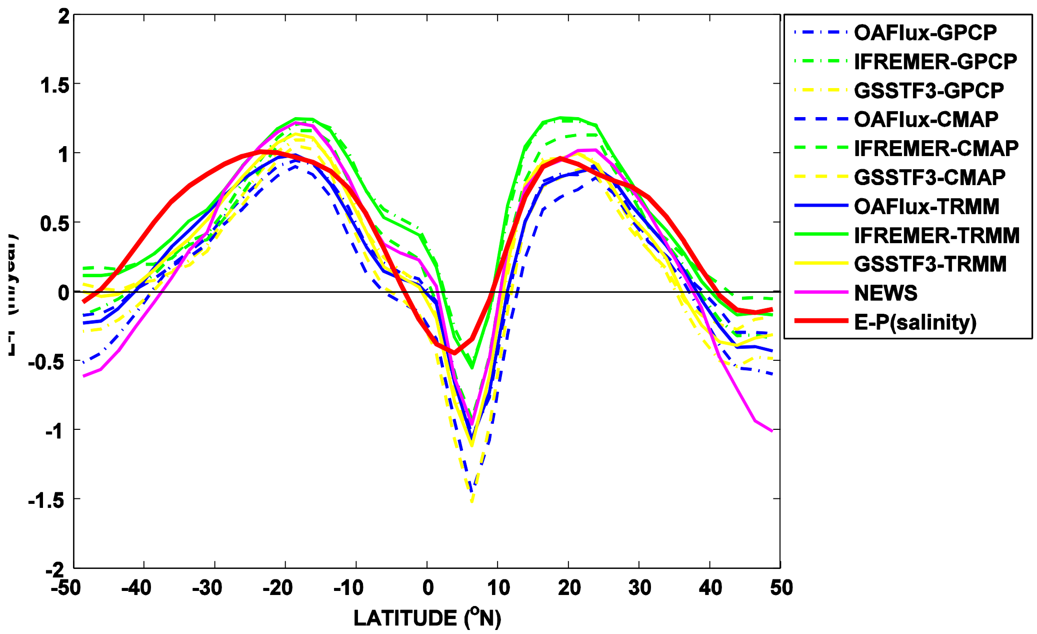


Figure 1: Zonal averages of the annual mean E-P from both the direct (ten sets) and indirect estimates.

The manuscript based on these results was submitted to the *Journal of Geophysical Research* and it is under revision.

PRESENTATIONS

Ren, L., E. Hackert, A. J. Busalacchi, and P.A. Arkin, Assessment of Global Oceanic Net Freshwater Flux Products Using Argo Salinity Observations, AGU Fall Meeting 2012, San Francisco, 12/2012

PEER-REVIEWED PAPER

Ren, L., E. Hackert, P. Arkin. A. J. Busalacchi (2014), Assessment of Global Oceanic Net Freshwater Flux Products Using Argo Salinity Observations, *Journal of Geophysical Research-Oceans*, under revision.

1.4 Future Satellite Programs

Year 3 GOES-R/JPSS Visiting Scientist Program

Task Leader: Michael J. Folmer
Task Code: EBMF_GOES-R_13
NOAA Sponsor Steven Goodman/Mitch Goldberg
NOAA Office NESDIS/GEOSPO & JPSSPO
Percent contribution to CICS Themes: Theme 1: 20%; Theme 2: 80%; Theme 3: 0%.
Main CICS Research Topics: Future Satellite Programs (GOES-R and JPSS)
Percent contribution to NOAA Goals: Goal 2: 50%; Goal 5: 50%

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 for the last three years. 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-orbiting Satellite Services (JPSS) Proving Grounds are a collaborative effort among the GOES-R Program Office, JPSS Program Office, cooperative institutes, weather forecast offices, National Centers for Environmental Prediction (NCEP) National Centers, and National Oceanic and Atmospheric Administration (NOAA) Testbeds across the country. The Proving Ground is a project in which simulated GOES-R and JPSS products can be tested and evaluated before the GOES-R series of satellites are launched into space. The simulated GOES-R products are generated using combinations of currently available GOES data, along with higher-resolution data provided by instruments on polar-orbiting satellites such as the Moderate Resolution Imaging Spectroradiometer (MODIS) on National Aeronautic and Space Administration's (NASA) Aqua and Terra satellites, the Visible Infrared Imaging Radiometer Suite (VIIRS) on the new Suomi-National Polar-orbiting Partnership (S-NPP), and model synthetic satellite data.

The GOES-R Proving Ground 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 National Environmental Satellite, Data, and Information Service (NESDIS) Satellite Analysis Branch (SAB) in Camp Springs, Maryland requires a full-time CICS VS to coordinate the evaluation effort, help facilitate product availability, generate combined reports in a timely manner, interact with forecasters directly to help train them on the application of products, and provide valuable feedback to product developers. The VS has also introduced these new satellite products to scientists and forecasters participating in the NASA Hurricane and Severe Storm Sentinel (HS3) Field Campaign.

ACCOMPLISHMENTS

The 2013 GOES-R Proving Ground activities at WPC, OPC, TAFB, and SAB focused on observing and analyzing convection for heavy rainfall and high wind events from land to sea. The new products that were introduced included the WRF and NAM simulated imagery, the overshooting top detection (OTD), and Vaisala GLD-360 Lightning Density products. Approximately 72 forecasters and analysts were trained on the products between 1st June and 31st October and a survey was conducted to collect their feedback. Forecasters found the simulated imagery useful in identifying areas that might be impacted by heavy rainfall, especially when considering organization of mesoscale convective systems (MCS). The OTD and lightning density products proved useful in identifying areas of most intense convection and for trend monitoring.

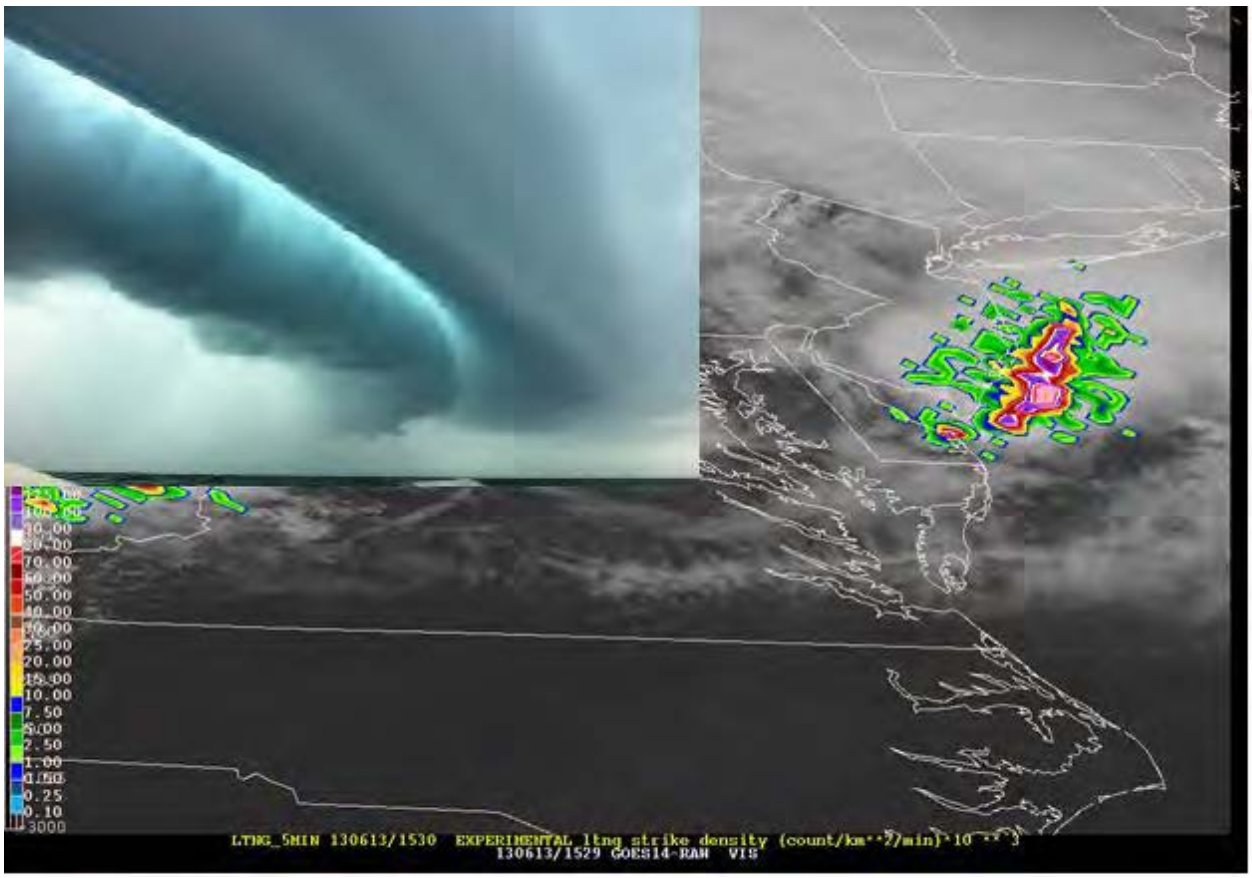


Figure 1: The GOES-14 Super Rapid Scan Operations for GOES-R (SRSOR) in June 2013 gave forecasters the opportunity to look at high temporal resolution imagery with other products overlaid. In this image, the new GLD-360 Lightning Density product is overlaid at a 5-min increment with values that exceed the upper-bounds of the density scale. The picture in the upper-left was taken from a sailboat 60-nautical miles east of Little Egg Harbor, NJ around the time of the image.

A few forecasters even mentioned the products a few times in the respective center text products issued to the public. Two times in 2013, GOES-14 was taken out of storage for backup of GOES-13 and for science testing. The GOES-R Program Office and NESDIS made Super Rapid Scan Operations

(SRSO) available to the forecasters through the Cooperative Institute for Meteorological Satellite Studies (CIMSS) for a glimpse of the capabilities that will be provided by GOES-R. The imagery was available in 1-minute increments at 1-km resolution, making mesoscale boundaries more prominent and allowing forecasters and analysts the opportunity to monitor convective or forest fire trends. Forecasters and analysts were treated to the SRSOR during a low-end derecho event in mid-June that provided an exciting opportunity to match up the 1-min imagery with the new lightning density product and the image below shows the moment the MCS moved off of the New Jersey coastline. The lightning activity increased substantially and the forecasters at each center were treated to a first glimpse at GOES-R era technologies that are available now, though in proxy form.

The second year of the Proving Ground included a second year of involvement in the NASA HS3 Field Campaign that was run out of the NASA Wallops Flight Facility in Chincoteague, VA. The CICS VS met with forecasters for the experiment to train them on the products and answer any questions. Approximately 20 forecasters were trained on products that included the RGB Dust and Pseudo-Natural Color products to monitor the Saharan Air Layer, Tropical Overshooting Tops, even some first glimpses at the GLD-360 lightning density product near developing tropical cyclones. There are plans in the works for continued involvement during the 2014 experiment.

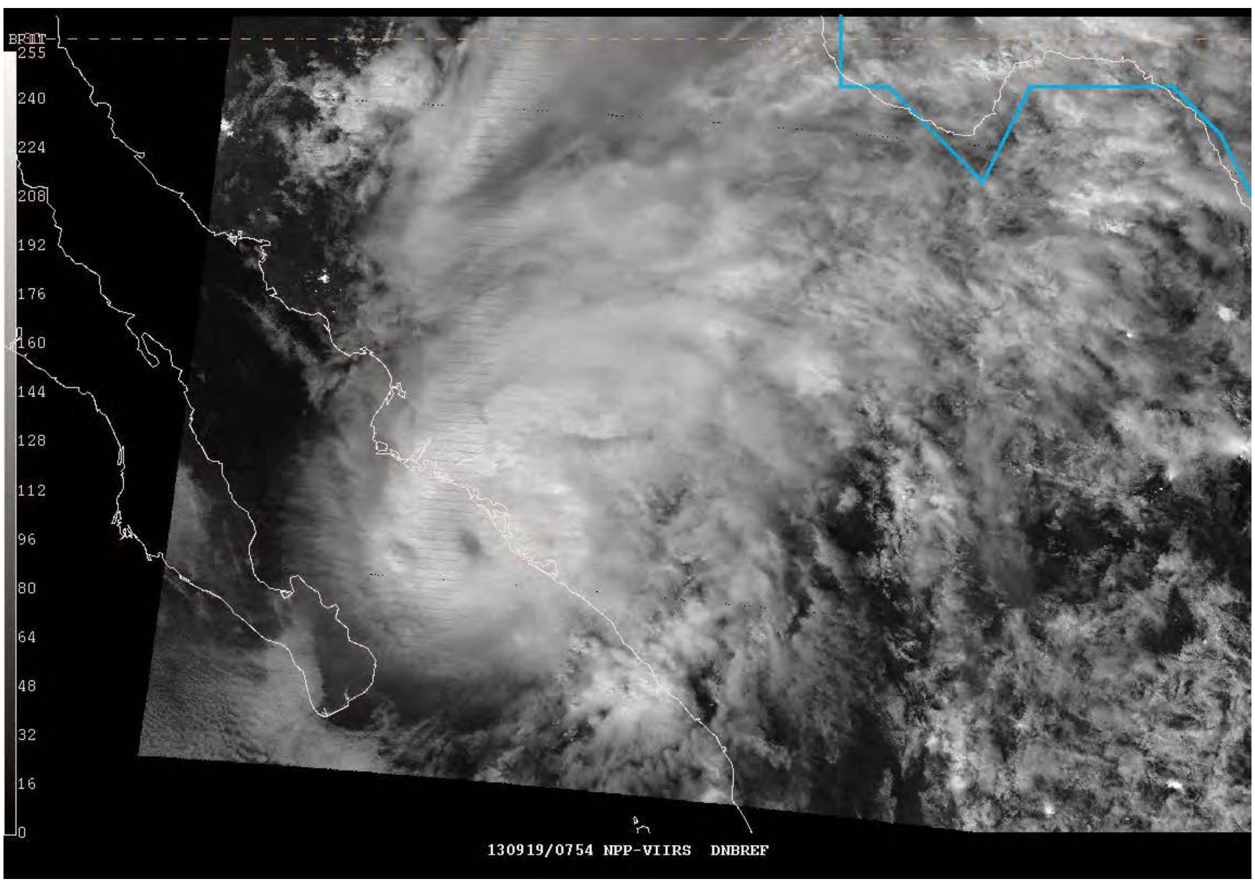


Figure 2: The first Day-Night Band image from the VIIRS instrument on the S-NPP satellite made its debut at NHC in mid-September, in time to capture Hurricane Manuel making landfall in western Mexico.

As part of the PG activities, the CICS VS was able to shed light on some satellite display problems at WPC and OPC. In accordance with keeping the theme of GOES-R and JPSS in providing higher quality imagery (temporally and spatially), the CICS VS met with WPC, OPC, NESDIS, and NCEP Central Operations (NCO) representatives to discuss changing the current satellite viewing paradigm at the centers to the highest resolution possible with the current, legacy GOES-13 and GOES-15. The first JPSS products from the S-NPP satellite and from NASA's Aqua and Terra satellite made their debut at all of the centers. The Day-Night band from the VIIRS instrument on S-NPP became available in the NCWCP early in the year and made its debut at NHC in time to capture an image of Hurricane Manuel making landfall in Mexico. Other imagery products were made available during the GOES-13 anomaly in late spring 2013 and are now available routinely in the N-AWIPS terminals at WPC, OPC, and SAB. The CICS VS has developed a robust archive of current and proxy satellite products to assist forecasters and scientists in case study development. This has led to multiple collaborations including internships from a Coast Guard Cadet and a University of Maryland student, a thesis topic for a Masters student at Saint Louis University, a peer-reviewed paper on RGB Air Mass and AIRS Total Column Ozone Retrievals for use in an operational setting, and a paper in development that highlights satellite usage during Hurricane Sandy. Work has also begun on getting some of the products into AWIPS II by the end of 2014 in collaboration with NCO and NASA SPoRT which will compliment a Visiting Scientist proposal through GOES-R Risk in summer 2014.

PLANNED WORK

- The 2014 Winter Demonstrations runs from 01/15/14-04/15/14 for the following products:
  - RGB Air Mass
  - AIRS Ozone Products
  - GLD-360 Lightning Density Product
  - OTD
  - Hybrid Imagery
  - Fog and Low Stratus
- The 2014 Summer Demonstration runs from 05/15/14-08/31/14 for the following products:
  - OTD
  - Lightning Density
  - Convective Initiation
  - Nearcast
  - RGB products
- JPSS products from S-NPP VIIRS will be introduced through the year
  - Day-Night Band
  - Longwave IR, Visible
  - CrIS/ATMS products
- Work with AWIPS-II experts to display GOES-R/JPSS products
- Participate in the 2014 HS3 field experiment
- Continue research collaborations with CICS scientists and other academic partners

PUBLICATIONS

Zavodsky, B. T., A. L. Molthan, and M. J. Folmer, 2013: Multispectral imagery for detecting stratospheric air intrusions associated with mid-latitude cyclones. *J. Operational Meteor.*, **1**(7), 71–83.

PRESENTATIONS

Folmer, M.J., D. Novak, J. Sienkiewicz, H. Cobb, and J. Kibler, 2014: GOES-R and JPSS Proving Ground Activities at WPC, OPC, SAB, and TAFB. Satellite Liaison Meeting at CIMSS, Madison, WI.

Folmer, M.J., A. Stinner, J.M. Sienkiewicz, C. Schultz, and S. Rudlosky, 2014: Danger at Sea: Diagnosing and Communicating the Threat for Strong Maritime Thunderstorms. 94th AMS Annual Meeting, Atlanta, GA.

Terborg, A., M.J. Folmer, and W. Line, 2014: The GOES-R/JPSS Proving Ground: A National Centers Perspective. 94th AMS Annual Meeting, Atlanta, GA.

Folmer, M.J., D. Novak, J. Sienkiewicz, H. Cobb, and J. Kibler, 2013: GOES-R and JPSS Proving Ground Activities at WPC, OPC, SAB, and TAFB. Satellite Liaison Meeting at SPoRT, Huntsville, AL.

Folmer, M.J., D. Novak, A. Orrison, J. Sienkiewicz, H. Cobb, and J. Kibler, 2013: GOES-R and JPSS Demonstrations at WPC, OPC, SAB, TAFB: 2013 Convective Demonstrations. 38th NWA Annual Meeting, Charleston, SC.

Folmer, M., J. Beven, M. Brennan, H. Cobb, M. DeMaria, J. Knaff, C. Velden, J. Dunion, G.Jedlovec, and K. Fuell, 2013: The 2013 Satellite Proving Ground at the National Hurricane Center. 38th NWA Annual Meeting, Charleston, SC.

Folmer, M.J., D. Novak, J. Sienkiewicz, H. Cobb, and J. Kibler, 2013: GOES-R and JPSSDemonstrations at WPC, OPC, SAB, TAFB: OCONUS Perspective. OCONUS Meeting, Anchorage and Fairbanks, AK.

Folmer, M.J., 2013: S-NPP Data at WPC/OPC/TAFB/SAB: How do you introduce new polar-orbiting data into operations? *JPSS Science Seminar*, Greenbelt, MD.

Folmer, M.J., 2013: Hurricane to Superstorm Sandy: How did satellites track Sandy? *Maryland Day*, College Park, MD.

Folmer, M.J., 2013: New GOES-R Satellite Technique for Diagnosing and Forecasting High Impact Events. *Virtual Presentation to Alaska Region*.

Folmer, M.J., 2013: Satellite Techniques for Marine, Precipitation, and Hazardous Weather Applications. *NOAA Satellite Conference*, College Park, MD.

Folmer, M.J., 2013: New GOES-R Satellite Technique for Diagnosing and Forecasting High Impact Events. *Satellite Science Week Virtual Meeting.*

Folmer, M., J. Beven, M. Brennan, H. Cobb, M. DeMaria, J. Knaff, C. Velden, J. Dunion, G. Jedlovec, and K. Fuell, 2013: The 2012 Satellite Proving Ground at the National Hurricane Center. *67th Interdepartmental Hurricane Conference*, College Park, MD.

Kibler, J. and M.J. Folmer, 2013: The Satellite Analysis Branch Hazard Mitigation Programs and Preparing for GOES-R/JPSS. *2nd NWS/Eastern Region Virtual Satellite Workshop.*

Folmer, M.J., K. Mozer, S. Goodman, J.M. Sienkiewicz, D.R. Novak, H.D. Cobb, and J. Kibler, 2013: GOES-R Convective Product Demonstrations at HPC, OPC, TAFB, and SAB. *AMS 93rd Annual Meeting*, Austin, TX.

Folmer, M.J., K. Mozer, S. Goodman, M. Goldberg, J.M. Sienkiewicz, D.R. Novak, H.D. Cobb, and J. Kibler, 2013: The 2012 HPC/OPC/TAFB/SAB GOES-R/JPSS Proving Ground Demonstrations. *AMS 93rd Annual Meeting*, Austin, TX.

OUTREACH

- Mesonet development project with the Marine Academy of Technology and Environmental Sciences
- Co-mentoring a Masters Degree student at Saint Louis University (SLU)
- Co-mentoring a Coast Guard Cadet Intern at OPC
- Co-mentoring a University of Maryland Intern at OPC

Performance Metrics	**FY13**
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	7
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	7
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

1.4a Scientific Support for the GOES-R Mission

Application of the GOES-R Land Surface Temperature Product for Snowmelt Mapping

Task Leader	Cezar Kongoli
Task Code	CKCK_AGLS_13
NOAA Sponsor	Ingrid Guch
NOAA Office	NESDIS/STAR
Percent contribution to CICS Themes	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Future Satellites: Scientific support for the GOES-R Mission
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 80%

Highlight: A snowmelt detection technique for the future GOES-R ABI sensor has been developed using GOES-13 and VIIRS data as proxy. The NOAA's Snow Data Assimilation System (SNOWDAS) was used as reference to develop and test the algorithm.

BACKGROUND

This report summarizes the year-3 work for the GOES-R3 project entitled "Application of the GOES-R Land Surface Temperature Product for Snowmelt mapping". Land Surface Temperature (LST) derived from the operational GOES-13 algorithm was used as proxy and initially evaluated for its ability to accurately retrieve LST. Figure 1 presents an inter-comparison example. Shown is a scatter-plot of GOES-13 retrieved LST versus ground truth LST, the latter estimated from surface radiation data at an AMERIFLUX forested site. As shown, GOES LST performs reasonably well in the surface temperature range between -5 and +5 ^{0}C that is most relevant for wet snow detection. Next, empirically established thresholds were applied to LST for wet-dry snow discrimination of synoptic weather events associated with snowmelt.

ACCOMPLISHMENTS

A technique has been developed that flags the melting snow component of the GOES pixel using empirically established LST thresholds. GOES-13 data were collected for weather events over CONUS associated with snowmelt. In addition, VIIRS LST and optical measurements were also collected and examined for their potential to improve day-time snow melt detection. Specifically, VIIRS Normalized Snow Difference Index (NSDI) computed from comparable MODIS bands 4 and 6 was examined in concert with VIIRS derived LST. The NOAA's Snow Data Assimilation System (SNOWDAS) was used as reference to develop and test the algorithm (Figure 2).

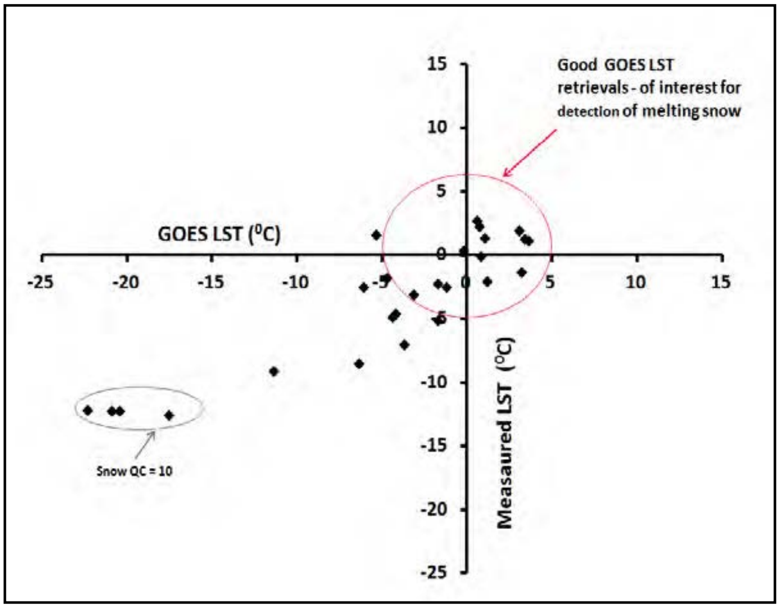


Figure 1. An example of GOES-13 retrieved LST and measured LST (computed from flux radiation data) at an AMERIFLUX site in Michigan during 2012 snow season. The surface type is deciduous broadleaf forest. Surface emissivity is assumed 0.98 for LST calculations. GOES LST performs reasonably well over the surface temperature range between -5 and +5 ^{0}C that is most relevant for wet snow detection.

PLANNED WORK

- Leverage a remote-sensing land surface energy balance modeling system called TSEB/ALEXI to estimate surface energy balance components including melt occurrence and rates.

PRESENTATIONS

Kongoli, C. Y. Liu, and Y. Ju, “Use of GOES-R proxy data for snowmelt detection” (poster), Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 93rd American Meteorological Society Annual Meeting, 6-10 January, 2013.

Liu Y., Y. Yu, C. Kongoli, Zh. Wang, and P.Yu “Validation of S-NPP VIIRS Provisional Land Surface Temperature Product”, 2014 (oral) Tenth Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS 94th Annual Meeting, 2-6 February 2014 in Atlanta, GA

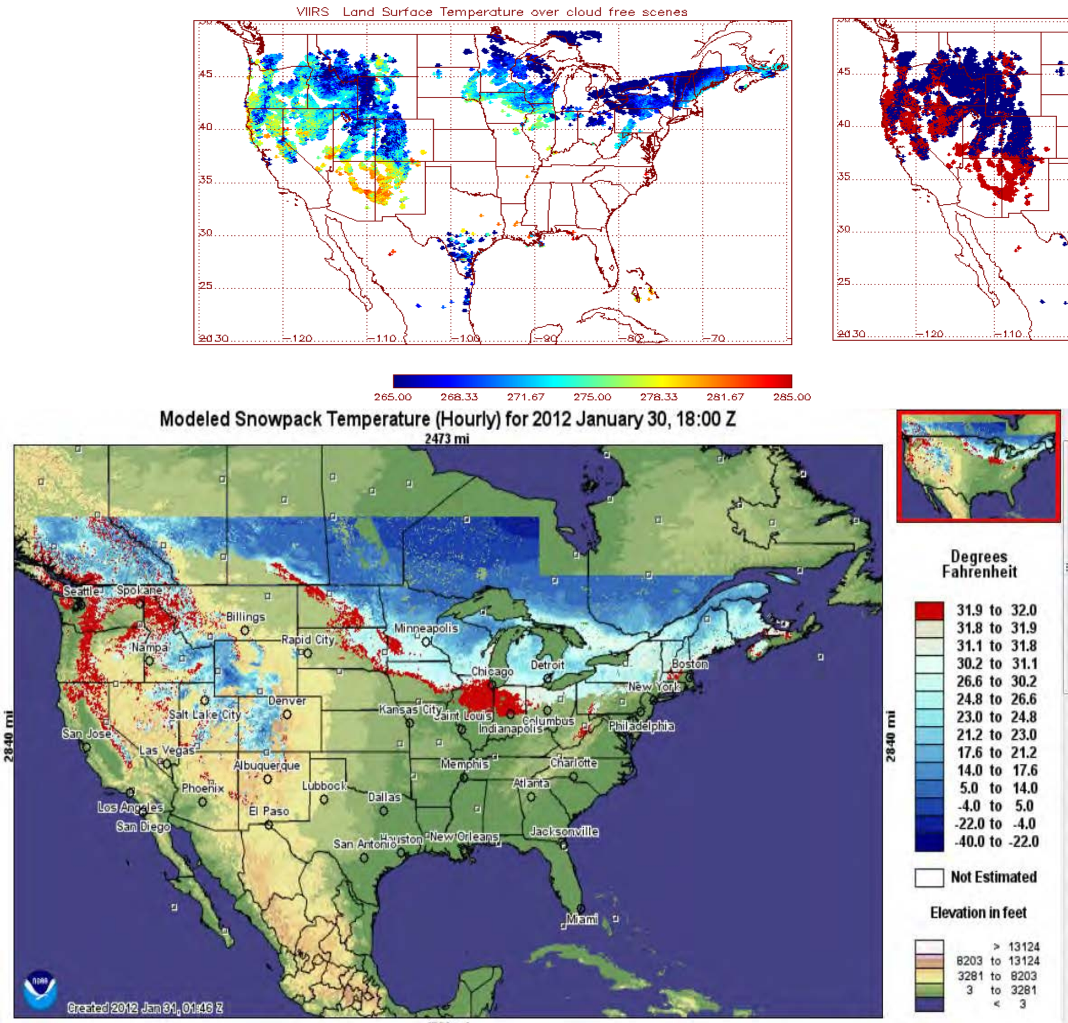


Figure 2. VIIRS LST in Kelvin over clear- and snow-identified scenes (top panel left) and wet/dry snow areas (top panel right) in red and blue, respectively, based on an established LST threshold of 274 Kelvin. Closest-in-time modeled surface snowpack temperature in Fahrenheit over US on January 30, 2012 (bottom), obtained from the 1-km Snow Data Assimilation System (SNOWDAS) of NOAA's National Operational Hydrological Remote Sensing Center (NOHRSC). Note that SNOWDAS reports the modeled snowpack temperature, which refers to the surface temperature of the snow component of the (mixed) surface, not the LST of that particular surface. On the other hand, VIIRS LST refers to the skin temperature of the (mixed) surface. Inconsistencies between the dynamic snow mask applied by SNOWDAS (on an hourly basis) and the rather static snow mask applied to the VIIRS LST (on a daily basis) can be seen, e.g., no-snow areas by SNOWDAS that are flagged as snow by VIIRS.

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Science and Management Support for GOES-R ABI Land Surface Temperature Algorithm and Validation

Task Leader	E. Hugo Berbery/Peng Yu
Task Code	EBPY_SMS_13
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR/SMCD
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Scientific support for the GOES-R Mission
Contribution to NOAA Goals (%)	Goal 1: 25%; Goal 2: 25%; Goal 3: 0%; Goal 4: 25%; Goal 5: 25%

Highlight: We have developed a new validation tool for GOES-R LST product. It validates the ABI LST split-window retrieval algorithm with SURFRAD ground networks and multiple ABI proxy sensors.

BACKGROUND

This report summarizes the ongoing NOAA project entitled "Science and management support for GOES-R ABI land surface temperature algorithm and validation". A new validation tool for GOES-R LST product has been developed. The tool uses different satellite sensors as the ABI proxy sensors.

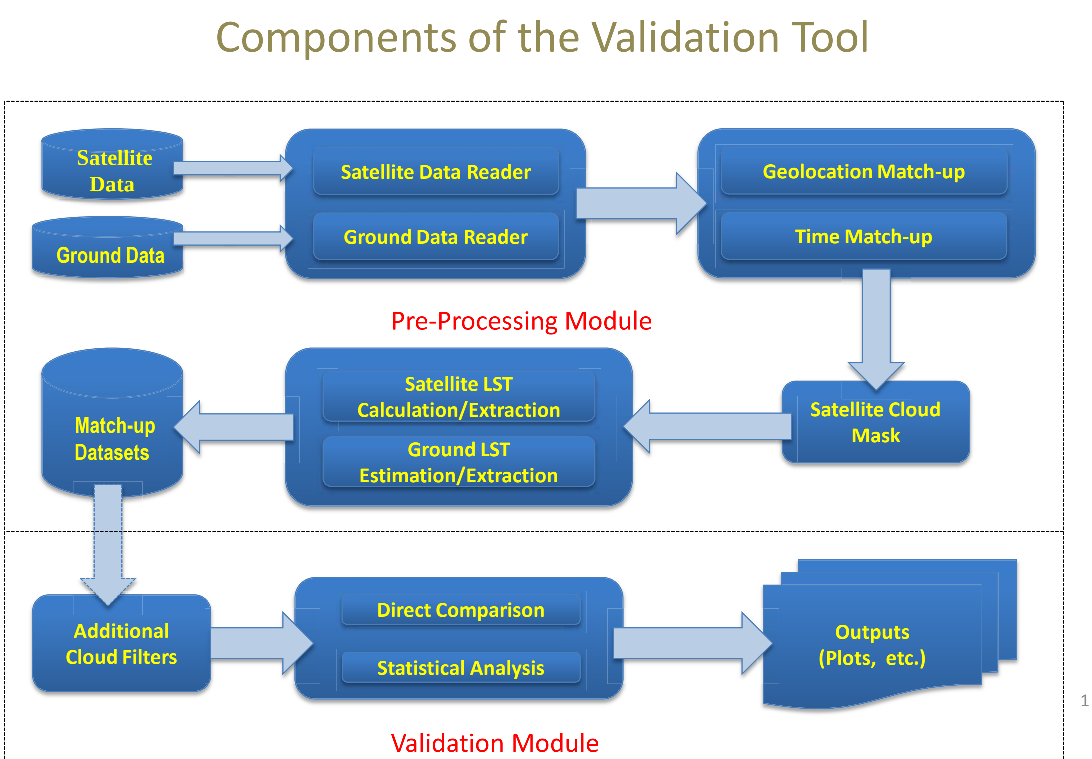


Figure 1. Components of the GOES-R LST validation tool.

Different algorithm coefficients for each proxy sensor were generated separately due to the slightly different central wavelengths and spectral response functions of each proxy split window channels. The validation tool is used to validate the ABI LST with observations from ground observing systems.

Tool development for systematic LST validation is crucial to process and analyze large amount of satellite and ground data. This LST validation tool development with visualization is targeted to apply standard algorithms and standard validation procedures in an integrated software package. All processing procedures are designed to realize full or partial automation for future operational use. The landval validation system carries out routine validation for GOES-R LST product and serves as a basic research tool for the ABI algorithm improvement, the study of the impact by the up-scaling model, etc. A dual-module design (Figure 1) is adopted during the implementation phase of the tool, which allows better flexibility, easier software maintenance, and lower I/O cost for huge amount of datasets.

ACCOMPLISHMENTS

A validation tool for GOES-R Land Surface Temperature (LST) has been developed to access the accuracy of the ABI LST retrieval algorithm. It matches the retrieved satellite LST to that from ground stations, *e.g.*, the Surface Radiation Network (SURFRAD). Since the GOES-R ABI data are not available during the development phase, we used data from other satellite sensors as proxies: the Spinning Enhanced Visible and Infra-red Imager (SEVIRI) onboard the European Meteosat Second Generation (MSG) satellite, the Moderate Resolution Imaging Spectroradiometer (MODIS) on both the Terra and Aqua satellites, and the Visible Infrared Imaging Radiometer Suite (VIIRS) of the Suomi National Polar-orbiting Partnership (NPP) satellite. The data from these satellite sensors are considered as good proxies of ABI since they have Thermal Infrared (TIR) split window channels as the ABI does.

The algorithm coefficients applied for different proxy sensor inputs are different because the central wavelengths and spectral response functions of the proxy split window channels are slightly different from those of GOES-R ABI window channels. To obtain the coefficients for different proxy sensors, a large complicated dataset was generated from MODTRAN 5.1.2 simulations, based on 60 daytime and 66 nighttime atmospheric profiles with 8 satellite view zenith angles, flexible surface temperature range, thermal infrared bands, and emissivity range. Regression method was then applied given different spectral response function from each proxy sensor. To minimize the impact from cloud, the validation uses its own stringent cloud filter schemes in addition to the satellite cloud product if available. The tool was designed in a two-module fashion, rendering a good balance between the performance and the flexibility. It serves as both the routine validation software and the basic research tool. The tool has by far been successfully used to validate LST retrieved from multiple GOES-R proxies with ground sites' LST observations from SURFRAD and two African sites, Gobabeb and Heimat. Figure 2 presents the interface of the validation tool and an example of the validation results produced by the tool.

Large amount of data from satellites and ground stations have been collected to validate the ABI algorithm, including one and a half years' MODIS TERRA and AQUA data (2012/01/01 – 2013/06/30), one month of MSG SEVIRI data (2012/03/01 – 2012/03/31), one year of VIIRS data (2012/04/01 – 2013/03/28), and the corresponding observations from ground observing systems, *e.g.*, SURFRAD, CRN, and other data from international collaborations. Satellite data from different proxy sensors include all variables required for the ABI LST retrieval. The corresponding auxiliary data, the emissivity data from the CIMSS baseline fit emissivity database and total precipitable water (TPW) data from the NCEP analysis and forecast water vapor dataset, have also been collected. These datasets are the key to the GOES-R prelaunch test of the ABI LST retrieval algorithm.

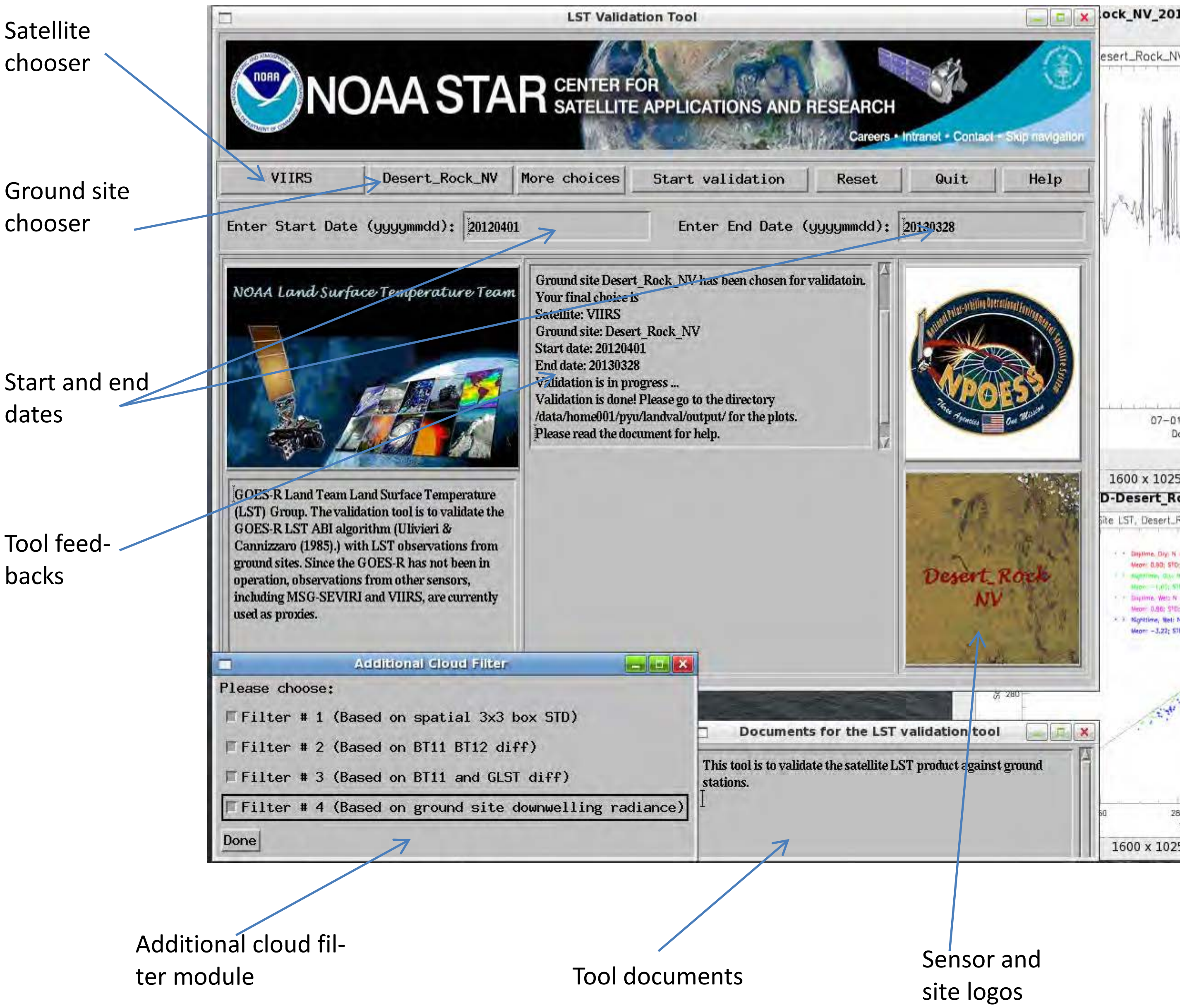


Figure 2: The interface of the GUI based LST validation tool and an example of its validation results.

During this period of time, we have continued to closely collaborate with the AIT group for algorithm improvement and update and test of the simulated LST products. Potential problems of the data generation and quality flags have been addressed and resolved.

All project deliverables (documentation and software) and milestones have been accomplished as planned. Currently, the software system is being tested and applied to different scenes for further improvement of the algorithm.

PLANNED WORK

- Continue to develop the routine validation tool with effective satellite to ground data match-up system and use it for selected case studies
- Continue the satellite and *in situ* data collection for global data coverage and compare them with LSTs from the ABI proxy sensors
- Continue work to evaluate and improve the performance of the ABI LST retrieval algorithm
- Continue the development of a compensation model/table for the satellite to ground LST comparison from the LST initial site characterization model development
- Work closely with industrial contractors (the vender) for validating and maintaining the LST package that has been delivered to the vender
- A new geostationary satellite from the Japanese Meteorological Agency (JMA), Himawari-8, is expected to be launched in late 2014. Its 16 spectral bands are very similar to those of the GOES-R ABI and can act as a very good proxy for GOES-R. The software to compare the ground data to the Himawari-8 Advanced Himawari Imager (AHI) data will be ready and the comparison will be performed if the required data are available
- Work on a stand-alone tool which routinely monitors LST products from VIIRS, AHI, and the future GOES-R
- Continue to work on different validation techniques, including the simultaneous multiple measurements technique recently studied
- Update corresponding documents related to the above tasks

PUBLICATIONS

None.

DELIVERABLES

- Software package for the GOES-R LST validation tool;
- Validation results using four satellite sensors as ABI proxies and SURFRAD ground stations' observations;
- LST algorithm maintenance and update; and
- Documentation for the GOES-R LST validation tool.

PRESENTATIONS

Liu, Y., Y. Yu, Z. Wang, and P. Yu, 2013: Evaluation of the Suomi NPP VIIRS Land Surface Temperature Product (poster), *CICS Science Meeting*, 5-6 November, 2013, College Park, Maryland.

Wang, Z., Y. Yu, Y. Liu, and P. Yu, 2014: Using the model simulation to improve the Land Surface Temperature retrieval for JPSS and GOES-R Missions (poster), AMS Annual Meeting, 2-6 February, 2014, Atlanta, Georgia

Yu, Y., I. Csiszar, Y. Liu, P. Yu, Z. Wang, J. Privette, and P. Guillevic, 2014: JPSS S-NPP Land Surface Temperature Product: Beta and Provisional Release Status (poster), AMS Annual Meeting, 2-6 February, 2014, Atlanta, Georgia

Liu, Y., Y. Yu, Z. Wang, and P. Yu, 2014: Validation of S-NPP VIIRS Provisional Land Surface Temperature Product (poster), AMS Annual Meeting, 2-6 February, 2014, Atlanta, Georgia

OTHER (e.g., awards; outreach…

Nominee of STAR Certificate of Appreciation for outstanding performance and lasting contributions to the Satellite Instrument Calibration and Product Developments, Awarded date: May 29, 2014

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	4
# of graduate students supported by a CICS task	N/A
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

This year, we developed a new validation tool for GOES-R LST product (1). Its development involved new design of the tool package, using different satellite sensors, *e.g.*, MODIS TERRA and AQUA, MSG-SEVIRI, NPP_VIIRS, as ABI proxies, and generating the retrieval coefficients for each sensor (1). Four presentations summarizing improvement and validation of the related satellite LST products have been made (4).

Land Surface Temperature Diurnal Analysis to Validate the Performance of GOES-R Advance Baseline Imager

Task Leader	Konstantin Vinnikov
Task Code	KVKV_LSTD_13
NOAA Sponsor:	Jaime Daniels
NOAA Office:	NESDIS/STAR/SMCD/OPDB
Contribution to CICS Themes	Theme 1: 75%; Theme 2: 25%
Main CICS Research Topic	Future Satellites: Scientific Support for GOES-R Mission
Contribution to NOAA Goals	Goal 1: 30%; Goal 2: 70%

Highlights: Two journal articles were published on angular anisotropy of satellite observed land surface temperature and a presentation was given at the NOAA 2013 Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users.

BACKGROUND

CICS Annual Reports 2011-2012 and 2012-2013 contain main research results on this task. The goals of this Task were: to statistically evaluate angular anisotropy of LST (Land Surface Temperature) using available simultaneous land based and satellite, GOES-EAST and GOES-WEST, at locations of SURFRAD stations; to develop algorithm for correcting GOES-R retrieved clear sky LST for angular anisotropy of LST field; to take into account angular anisotropy of LST in validation of GOES-R observed LST.

There were only a few related modeling and case study type previous investigations on this subject, which includes empirical evaluation of "Anisotropy in the land surface temperature as observed with two geostationary satellites" by Peter Romanov and Dan Tarpley. They concluded that "at least 2-3 K temperature change may be caused by changing the relative solar-satellite azimuth from backscatter to approximately 90º. The difference between temperatures observed in the backscatter and forward scatter may be higher. The major reason for the temperature differences is the effect of shadows".

The climatological approach is applied here. The main requirement to the angular correction algorithm is to convert satellite observed directional LST, $T(z,zs,az)$, that depends on satellite viewing angle z, sun zenith angle zs, and azimuth az into the scalar, unbiased, energy effective value of LST, ϑ, that can be used in land surface energy balance computation.

ACCOMPLISHMENTS

The results of work are summarized in the paper by Konstantin Vinnikov, Yunyue Yu, Mitchell Goldberg, Dan Tarpley, Peter Romanov, Istvan Laszlo, Ming Chen "Angular Anisotropy of Satellite Observations of Land Surface Temperature", published in Geophysical Research Letters. In this paper, we evaluated the angular anisotropy of LST using one full year of simultaneous observations by two Geostationary Operational Environment Satellites, GOES-EAST and GOES-WEST, at the locations of five surface radiation (SURFRAD) stations. We developed a technique to convert directionally observed LST into direction-independent equivalent physical temperature of the land surface. The anisotropy model consists of an isotropic kernel, an emissivity kernel (LST dependence on viewing angle), and a solar kernel (effect of directional inhomogeneity of observed temperature). Application of this model reduces differences of LST observed from two satellites and between the satellites and surface ground truth - SURFRAD station observed LST. This model should be considered as the first prototype algorithm for angular correction of GOES-R retrieved LST.

The proposed statistical model to approximate angular dependence of satellite observed LST can be expressed by the next simple equation:

$$T(z,zs,az)/T(0) = 1+A\cdot\phi(z)+D\cdot\psi(z,zs\leq 90º,az), \quad (1)$$

where: T(0) is LST in the nadir direction at z=0; ϕ(z) is "infrared kernel" (related to angular anisotropy of infrared radiation near land surface); ·ψ(z,zs≤90º,az) is "solar kernel" (related to angular anisotropy in solar radiation near land surface), ψ(z,zs≥90º,az)≡0; A and D are the coefficients that should be estimated from observations. These coefficients depend on land cover structure. The equations applied to estimate A and D from instantaneous LST observations of two satellites, GOES-EAST (W) and GOES-WEST (W), at the same location are the next:

$$TE-TW \approx BW+A*(TW+BW)\cdot\phi(ZE)-TE\cdot\phi(ZW). \quad (2)$$

$$TE\cdot[1+A\cdot\phi(ZW)]-(TW+BW)\cdot[1+A\cdot\phi(ZE)]\approx D\cdot[(TW+BW)\cdot\psi(ZE,ZS,AZE)-TE\cdot \psi(ZW,ZS,AZW)]. \quad (3)$$

BW is constant bias of GOES-WEST retrieved LST compared to GOES-EAST retrieved temperature which is assumed to be unbiased one. First step: Ordinary least squared with a few iterations (to resolve weak nonlinearity) are applied to the nighttime observations to estimate BW and A from (2). Second step: ordinary least squares technique and daytime observation are used to estimate D in the equation (3). Different analytical expressions of kernel functions have been tested. θ - An unbiased, angular corrected, energy effective, value of LST can be estimated from the next equation:

$$\theta = \frac{T(Z,ZS,AZ)}{1+\varphi(Z)+\psi(Z,ZS,AZ)}\left(\pi^{-1}\int_0^{2\pi}\int_0^{\frac{\pi}{2}}[1+\varphi(z')+\psi(z',sz,\beta)]^4\sin(z')\cos(z')\,dz'd\beta\right)^{0.25}. \quad (4)$$

The double integral in the right side of expression (4) is constant for the most of reasonable analytical approximations of ϕ and ψ.

For independent verification of the model, we also used nighttime LST data for CONUS area retrieved from GOES-11 and GOES-13 satellites for year 2011 using single channel LST retrieval technique (PATMOS-x data provided by Andrew Heidinger). This is one channel retrieved LST. Using this data, we obtained the next empirical estimates of the A=-0.0070 coefficient for land surface in the emissivity kernel ϕ(Z)=A(1-cos(Z)), where Z-satellite viewing zenith angle. This estimate is twice smaller compared to the estimated earlier A=-0.0138 K-1 for split-windows technique retrieved LST. This means that angular anisotropy of satellite retrieved LST may be different for different LST retrieval algorithms.

GOES-11 and GOES-13 retrieved LST are based on single channel technique. Instead of the second channel brightness temperature observations, the technique uses NCEP Forecast Reanalysis System output which is the same for GOES-E and GOES-W and does not provide hourly data. This feature of single channel technique artificially decreases differences between LST retrieved at the same times and locations from GOES-11 and GOES-13 and makes it impossible, at this stage, to obtain realistic information on angular anisotropy of LST that can be recommended for GOES-R algorithm. Coefficient anisotropy D for solar kernel in (1) estimated for split-windows retrieved LST is found to be different dependent on land surface smoothness. It is much larger, from D=0.013 1/K to D=0.017 1/K, for the pixels with stations Desert Rock, NV, Boulder, CO, and Goodwin Creek, MS, the pixels with complicated topography and rough land cover compared to much smaller this coefficient D values from 0.007 to 0.010 1/K for pixels with stations Fort Peck, MT and Bondville, IL, the pixels with very smoothes and flat surfaces. There is no opportunity to improve GOES-R angular correction algorithm using GOES-E and GOES-W LST data retrieved with single-channel technique. We studied statistical distribution of differences between GOES-11 and GOES-13 LST data and found that application of the angular correction by algorithm developed for GOES-R does not decrease these differences. This means that blending of GOES-11 and GOES-13 LST data is useless and should not be recommended. It looks as if diurnal cycle in the GSIP LST data artificially modulated by using reanalysis generated atmospheric information.

Nevertheless, using LST data at five SURFRAD stations during one year as ground truth, we found that angular correction noticeable decreases random errors of satellite retrieved LST based on GOES-R spit window algorithm. Root mean squared differences between satellite observed angular adjusted and surface observed LST are in the range from 1.0 to 1.6 K.

The main obstacle in using satellite retrieved LST is that it is LST for clear sky conditions, only. Users do not know how to interpret such temperature. Climatological technique is applied here to evaluate mean difference between LST for Clear and Overcast sky conditions at six SURFRAD stations. This technique is based on approximation of observed seasonal and diurnal variation of meteorological variable with simple mathematical expression. Such expression can be obtained from the theory of amplitude modulation of radio waves assuming that diurnal cycle of meteorological variable can be approximated by a sum of K first Fourier harmonics of diurnal period modulated by seasonal cycle signal approximated by a sum of N first Fourier harmonics of annual period [Vinnikov and Grody, 2003; Vinnikov et al., 2004]:

$$F(t) = \sum_{k=-K}^{K} \sum_{n=-N}^{N} a_{kn} e^{i2\pi t(\frac{n}{T}+\frac{k}{H})}. \tag{5}$$

Here F(t) is time dependent value of observed variable f(t), H=1day, T=365.25 day, akn are (2K+1)(2N+1) unknown coefficients that can be estimated from the least squares condition

$$\overline{(f(t)-F(t))^2} = \min. \tag{6}$$

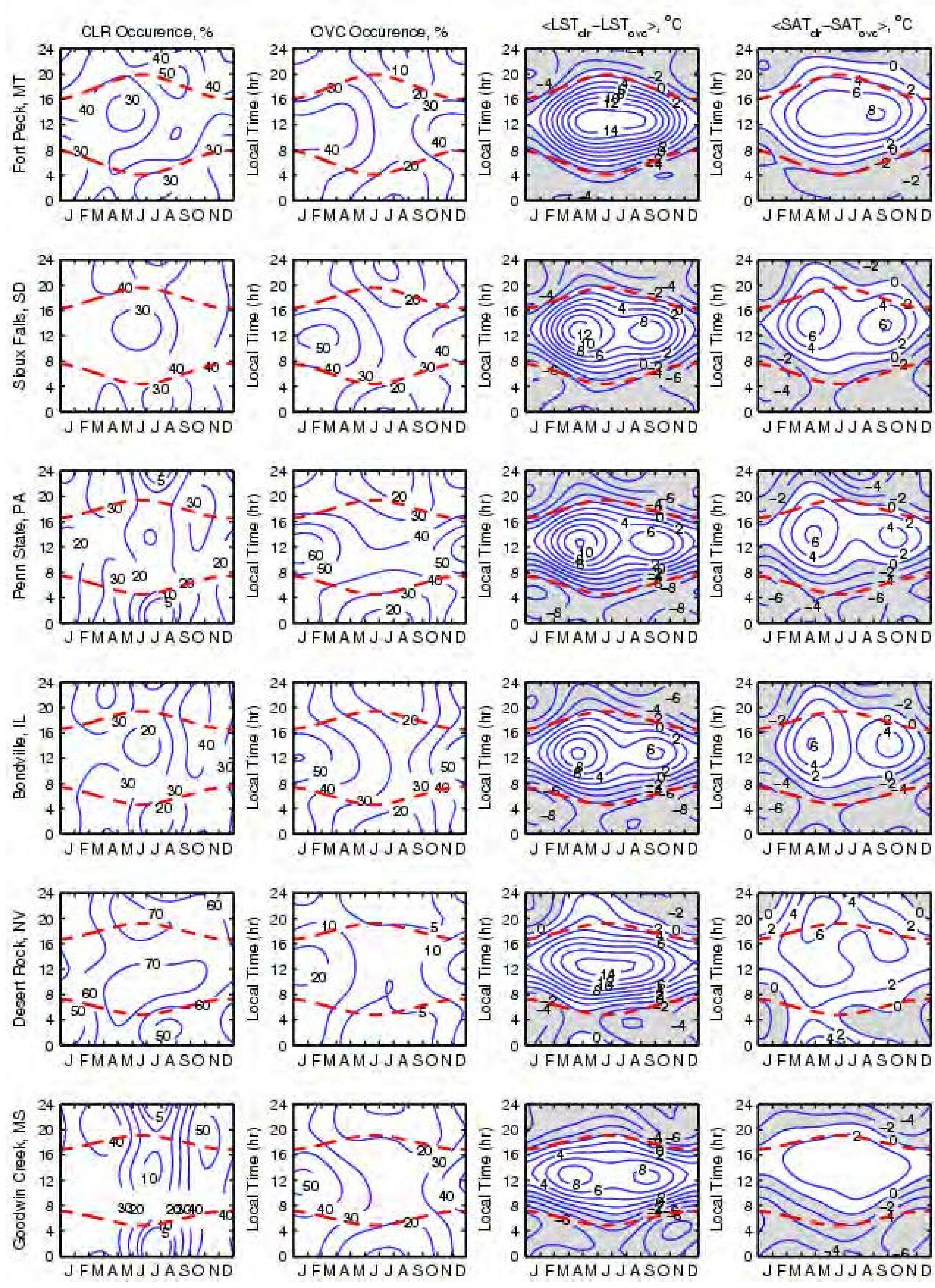


Figure 1. SURFRAD stations climatology: Occurrence of CLR and OVC skies and mean differences<LSTclr>-<LSTovc> and <SATclr>-<SATovc>. Approximation: 2 diurnal and 2 annual harmonics.

For computation, F(t) can be expressed through trigonometric functions, for example, as the next:

$$F(t)=\sum_{k=0}^{K}\sum_{n=0}^{N}\alpha_{kn}\cos(2\pi n/T)\cos(2\pi k/H)+\sum_{k=-K}^{-1}\sum_{n=-N}^{-1}\alpha_{kn}\sin(2\pi n/T)\sin(2\pi k/H)+$$
$$\sum_{k=-K}^{-1}\sum_{n=0}^{N}\alpha_{kn}\cos(2\pi n/T)\sin(2\pi k/H)+\sum_{k=0}^{K}\sum_{n=-N}^{-1}\alpha_{kn}\sin(2\pi n/T)\cos(2\pi k/H). \quad (7)$$

The more data is available, the larger number of diurnal and seasonal harmonics can be used for approximation and more accurately diurnal/seasonal cycles in the observed records will be estimated. This technique has been successfully applied for studying diurnal/seasonal variations of climatic variables and their trends [Vinnikov and Grody, 2003; Vinnikov et al., 2004, 2006, 2008, 2010; Bloomer et al., 2010]. It will be used here as it is described in [Vinnikov et al., 2004] but without the term for climatic trend. The availability of very large number of observation permits us to use up to four, K=4) harmonics of diurnal period and four (N=4) harmonics of annual period to approximate diurnal/seasonal variations in expected value of observed variables and their variances. Below are the estimates obtained for smaller numbers of harmonics, K=2 and N=2. LST, SAT (Surface Air Temperature) and Sky Condition data used here are provided by Chuck Long for time interval from beginning observations (1994-2003, depending on station) to 2008.

We can see that mean difference between LST at CLR and OVC sky conditions is very large, up to 10-15°C. Without using microwave radiometers, LST for OVC sky conditions cannot be obtained. Surface air temperature (SAT) available from observation of surface meteorological stations should be considered as a surrogate of LST at OVC sky conditions.

PLANNED WORK

Further publication of the obtained materials is desirable. This should be accomplished without additional funding.

PUBLICATIONS

Yunyue Yu, Dan Tarpley, Jeffrey L. Privette, Lawrence E. Flynn, Hui Xu, Ming Chen, Konstantin Y. Vinnikov, Donglian Sun, and Yuhong Tian, 2012: Validation of GOES-R Satellite Land Surface Temperature Algorithm Using SURFRAD Ground Measurements and Statistical Estimates of Error Properties. *IEEE Trans. on Geosci. Remote Sens*. 50 (3), 704-713.

Konstantin Y. Vinnikov Yunyue Yu, Mitchell D. Goldberg, Dan Tarpley, Peter Romanov, Istvan Laszlo, and Ming Chen (2012), Angular anisotropy of satellite observations of land surface temperature, *Geophys. Res. Lett*., 39, L23802, doi:10.1029/2012GL054059.

PRESENTATIONS

Konstantin Y. Vinnikov Yunyue Yu, Mitchell D. Goldberg, Dan Tarpley, Peter Romanov, Istvan Laszlo, and Ming Chen, Angular anisotropy of satellite observed land surface temperature, NOAA 2013 *Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users.*

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	0
# of peer reviewed papers	2
# 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	0

Development of Algorithms for Shortwave Radiation Budget from GOES-R

Task Leader Rachel Pinker
Task Code RPRP_DASR_13
NOAA Sponsor: Jaime Daniels
NOAA Office: NESDIS/STAR/SMCD/OPDB
Contribution to CICS Themes: Theme 2: 100%
Main CICS Research Topic: Scientific support for the GOES-R Mission
Contribution to NOAA Goals: Goal 1: 100%

Highlight: This year's effort has focused on making refinements to the original delivery of the narrow-to-broadband (NTB) transformation coefficients used in the indirect path shortwave radiative flux algorithm. Additional simulations of radiative transfer based on the Atmospheric Infrared Sounder (AIRS) are being used to increase the robustness of cases used to calculate the coefficients. New spectral response functions for ABI are now available, and the coefficients are being reprocessed with these inputs as well.

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 the 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. The NTB transformations are based on theoretical radiative transfer simulations with MODTRAN-3.7 using 14 land use classifications based on the International Geosphere-Biosphere Programme (IGBP). This represents an improvement over currently available NTB transformations that consider only 4 land use categories. The ADMs are a combination of MODTRAN-3.7 simulations and the Clouds and the Earth's Radiant Energy System (CERES) *(Loeb et al., 2005)* observed ADMs. The radiative transfer simulations provide information that fills in gaps in the CERES ADMs. The NTB transformations and ADMs have been tested using proxy data from multiple satellites to simulate ABI observations. Initial algorithms were delivered in 2010. The current focus is on validation and improvement.

ACCOMPLISHMENTS

1. Improved simulation database

We are creating additional simulations of radiative transfer to increase the robustness of the database used to create the NTB coefficients. We have downloaded profiles from the Atmospheric Infrared Sounder (AIRS) and we are extracting the temperature, moisture, and ozone observations that are required inputs to the MODTRAN radiative transfer code.

2. Updated NTB coefficients using ABI spectral response functions

We have received the new spectral response functions (SRFs) for ABI and have been generating the NTB coefficients using the new information. This process must be accomplished for clear-sky, ice cloud, and water cloud cases for multiple surface types and, where applicable, either 5 or 11 cloud optical depths (CODs). The following summarizes our progress:

- Step 1 (obtain TOA directional spectral radiance): We have completed this step **for all cloud cases**.

- Step 2 (Apply satellite sensor SRF): We have completed this step **for all cloud types and all CODs**.

- Step 3 (Calculate top-of-atmosphere narrowband and broadband albedos): We have completed this step **for all cloud types and all CODs**.

- Step 4 (Select channels for the NTB conversion): We have selected channels 1 - 6 as these correspond to the wavelengths with which we obtained the best accuracy for the MODIS NTB coefficients. After all of the NTB coefficients have been processed, we will need to conduct testing to see if this selection should be refined.

- Step 5 (Establish NTB conversion relationships): We have completed this step pending further refinements based on test results.

- Step 6 (Obtain NTB conversion coefficients): We are currently working on this step for all cloud types.

3. Manuscript preparation

We are preparing a manuscript detailing the work we have done to prepare for the new Advanced Baseline Imager (ABI). In the manuscript we are reporting on the performance of the NTB transformations using a "Deep Dive" approach by implementing the coefficients using a well-established shortwave radiative flux algorithm. The testing is done over the Meteosat 8/9 domain with the NTB coefficients we produced using SEVIRI observations as proxy data for ABI. *Figure 1* shows daily average surface shortwave downward flux for July 1, 2004. Evaluation of the shortwave radiative fluxes is shown in Figure 2.

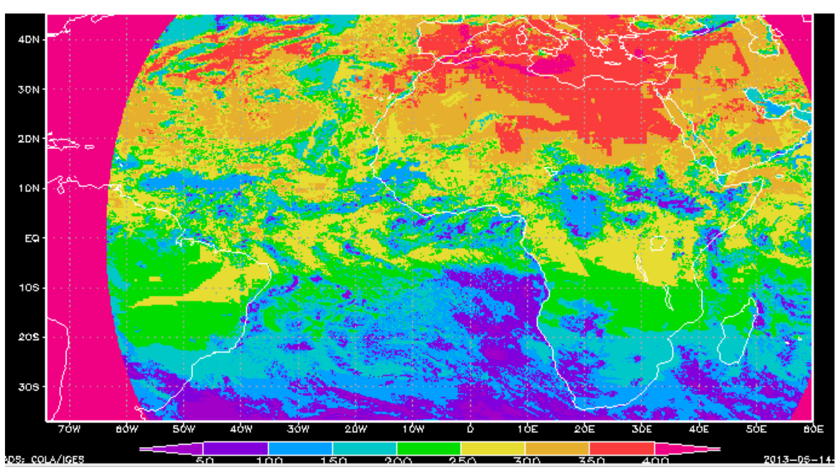


Figure 1.Daily average surface SW downward flux (Wm-2) for 7/1/04 produced with SEVIRI proxy data.

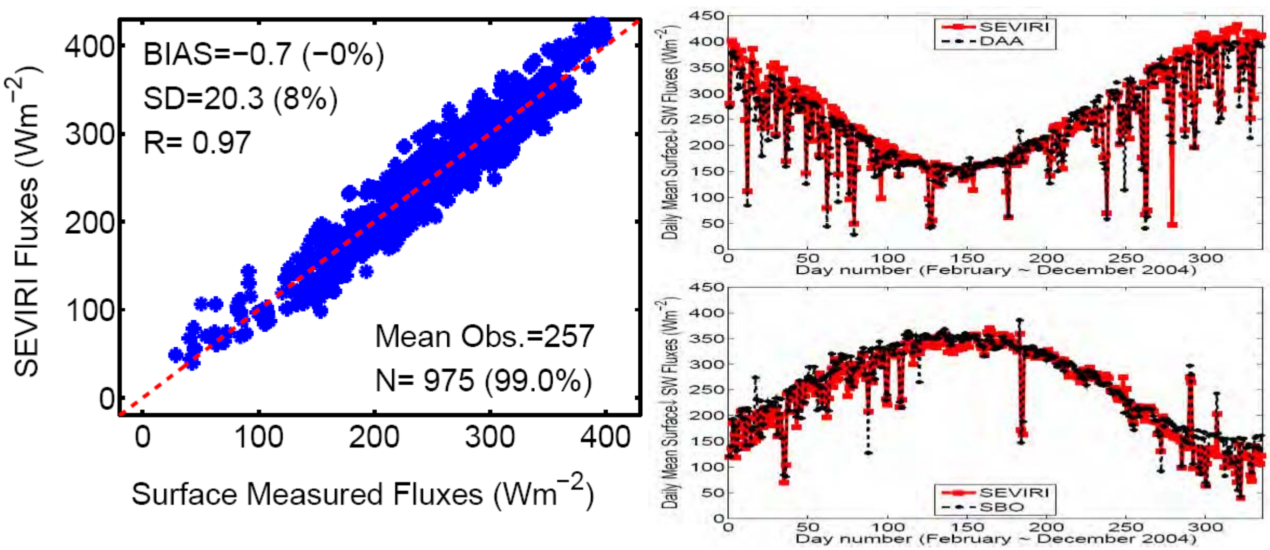


Figure 2. Left: Evaluation of estimated daily mean surface downward SW fluxes against surface observations from 3 BSRN sites for 11 months (February-December) 2004 (cases eliminated 1.0%). Right: Daily mean surface downward SW flux time series (red solid line) against BSRN surface observations (black dashed line) at DAA (30.67°S, 23.99°E, top right) and SBO (30.91°N, 34.78°E, bottom right).

PLANNED WORK

- Complete the process of calculating the NTB coefficients using the updated SRFs for ABI
- Complete simulations using AIRS atmospheric profiles
- Routine Validation: Generate and visualize comparison statistics using the new NTB coefficients generated with updated SRFs for ABI. Emphasis will be on stratification for the following categories: clear-sky, cloudy-sky, all-sky, land, water, high elevation, low elevation
- "Deep Dive" validation tool for detailed product analysis

- Extract all of the information that is pertinent for computing the TOA flux at a point, including: NTB coefficients and ADM correction used, solar and satellite geometry, reflectance in each channel used, surface type, snow cover, cloud amount, cloud type, COD
- Correlate errors with individual input sources

• Reprocess fluxes with the ability to change NTB and ADM input values and determine if a better result can be obtained

PUBLICATIONS

Wonsick, M., X. Niu and R. T. Pinker, 2014. Shortwave radiative fluxes from SEVIRI using new algorithms for the Advanced Baseline Imager. In preparation.

DELIVERABLES

Updated NTB coefficients using new spectral response functions provided for ABI

PRESENTATIONS

Pinker, R. T., M. M. Wonsick, Y. Ma, and I. Laszlo, 2013. Support of Shortwave Algorithms Development for ABI on GOES-R. NOAA Satellite Science Week Virtual Meeting, March 18 – 22, 2013

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	N/A
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

This year we have worked on refinements to the shortwave radiation budget algorithm that was delivered in 2010. The updates will be delivered in FY2014. We have made one presentation based on our work and we are in the process of writing a manuscript.

Reference

Loeb, N., *et al.* (2006). Fusion of CERES, MISR, and MODIS measurements for top-of atmosphere radiative flux validation, *J. Geophys. Res., 111*, D18209, doi:10.1029/2006JD007146.

1.4b Scientific Support for the JPSS Mission

CUNY-CREST Support for Development of Neural Network Algorithms for Retrieval of Chlorophyll-a in the Chesapeake Bay and Other Coastal Waters Based on JPSS-VIIRS Bands

Task Leader	Alex Gilerson
Task Code	AGAG_VIIRS_13
NOAA Sponsor	Mitch Goldberg
NOAA Office	NESDIS/JPSSPO
Percent contribution to CICS Themes	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Future Satellites: Scientific Support for the JPSS Mission
Percent contribution to NOAA Goals	Goal 3: 20%; Goal4: 80%

Highlight: Several NN approaches are explored together with other available algorithms to retrieve chlorophyll and mineral concentrations, CDOM absorption in Chesapeake Bay and potentially other coastal waters for the JPSS/VIIRS sensor, results are tested on field data as well as on satellite data

BACKGROUND

Chlorophyll-a concentration [Chl] is one of the main products retrieved from the ocean color satellite imagery which is then used in the estimation of the ocean productivity, modeling of ecosystems, climate studies, evaluation of water quality, and detection of algal blooms. The accuracy of standard blue-green ratio algorithms decreases significantly in the coastal waters because of contamination of the blue and green reflectance signals from CDOM absorption and mineral scattering especially in such complex waters as Chesapeake Bay. CCNY group recently developed a Neural Network (NN) algorithm which showed good performance in coastal waters. In addition, it allows separation of CDOM and mineral absorptions because of the latter's relationship with mineral scattering. This work is aimed at utilizing this NN approach to retrieve chlorophyll and mineral concentrations, CDOM absorption in Chesapeake Bay and potentially other coastal waters for the JPSS/VIIRS sensor. The project started in July 2012, funding – in October 2012.

ACCOMPLISHMENTS

- Chesapeake Bay field campaign was carried out in Aug 2013 in collaboration with NOAA-NESDIS, U. of Maryland, NASA and Columbia University
- Field observations were analyzed to determine range and distributions of in water constituents in the Chesapeake Bay as well as characteristics of water components which can be further used in improvement of the bio-optical model.
- Atmospheric correction limitations were further evaluated based on the comparison of aerosol optical thicknesses and Angstrom coefficients measured by SeaPRISM instrument and Ocean Color (OC) satellites (MODIS and VIIRS) on the Long Island Sound Coastal Observatory (LISCO) site. It was shown that a combination of gain adjustment on the sensor and atmos-

pheric correction in the coastal areas degrade dramatically the quality of remote sensing reflectance data especially in blue part of the spectrum which complicates development of the retrieval algorithms especially for VIIRS with a very limited number of bands in VIS.

- Several sets of satellite and field data were collected and tested. These include: MODIS Aqua reflectance satellite - *in situ* matched database for the Chesapeake Bay region that was previously created using in-situ [Chl] data measured in several different locations throughout Chesapeake Bay and satellite reflectance overpass data coexisting in time and space with these in-situ measurements. NASA Bio-Optical Marine Algorithm Data set (NOMAD) for the Bay which includes above water reflectance data, measured water inherent optical properties (IOPs), [Chl], TSS, etc. Field data collected in the summer of 2013 provided high quality matchups with retrievals.
- New Neural Network (NN) algorithm was developed based on VIIRS bands and global NOMAD data for [Chl] retrieval which include training on NOMAD reflectance data and reflectance data combined with some of retrieved IOPs.
- A multiband inversion algorithm was also developed to derive [Chl] and is based on Rrs 745, Rrs667, Rrs547 and Rrs488 and Rrs443. This algorithm was calibrated on MODIS data.
- The new algorithms were tested on field and satellite data and compared with the standard blue-green OC3 algorithm.

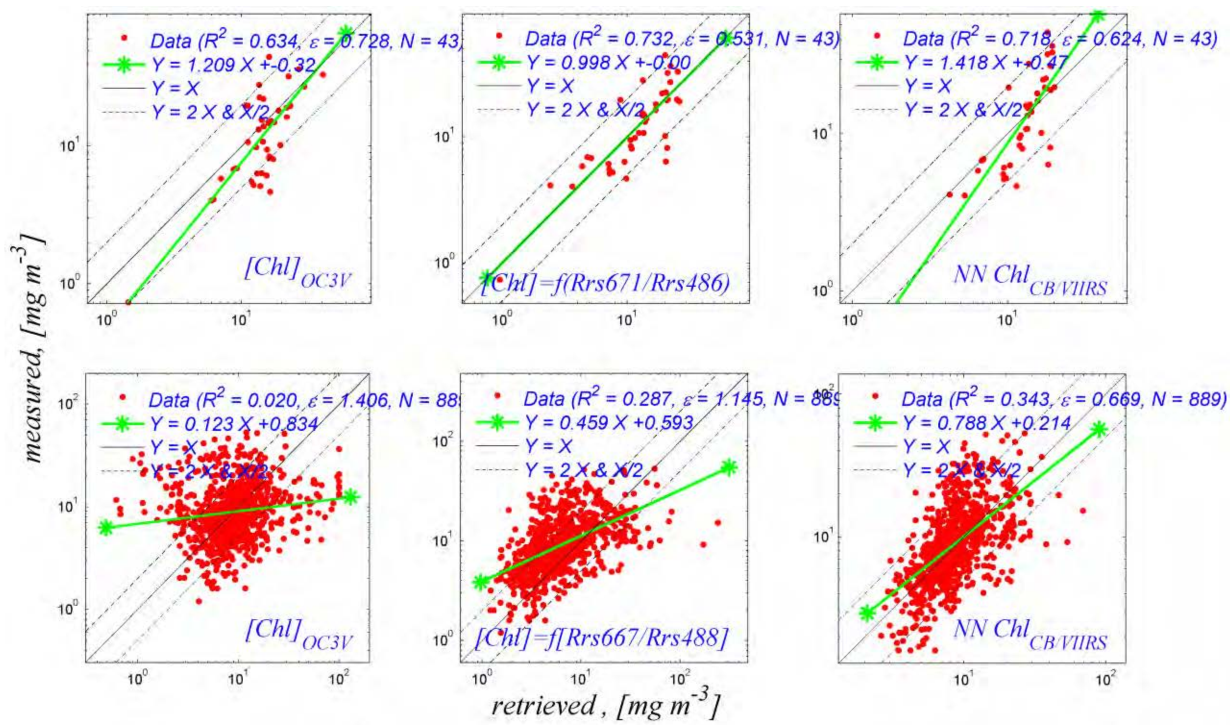


Figure 1: Performance of OC3V, Rrs667/Rrs486 and NN VIIRS on the field (top row) and USF data (bottom row).

PLANNED WORK

- Several new approaches in the algorithm development will be tested in line with the reassessment of all results presented above.

- VIIRS data will be analysed to determine possible matchups with the field data which can be used in the further tests of performance.
- Developed synthetic datasets, bio-optical models will be further optimized for the possible retrieval improvements, tested on reliable field data, NOMAD and satellite data.
- Further approaches of minimizing gain adjustment - atmospheric correction impact on retrieval in the Chesapeake Bay will be further evaluated.

PUBLICATIONS

I. Ioannou, A. Gilerson, B. Gross et al., Deriving ocean color products using neural networks, *Remote Sensing of Environment*, 134(0), 78-91 (2013).

I. Ioannou, R. Foster, A. Gilerson, B. M. Gross, F. Moshary, S. Ahmed, Neural network approach for the derivation of chlorophyll concentration from ocean color, Proc. SPIE 8724, *Ocean Sensing and Monitoring* V, 87240P (June 3, 2013).

I. Ioannou, R. Foster, A. Gilerson, B. M. Gross, F. Moshary, S. Ahmed, Neural network approach to separate the non-algal absorption coefficient into dissolved and particulate, Proc. SPIE 8795, *First International Conference on Remote Sensing and Geo-information of the Environment* (RSCy2013), 87951N (August 5, 2013).

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	2
# of invited presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

PERFORMANCE METRICS EXPLANATION

The undergraduate and graduate students are leveraged.

OSU-CIOSS Support to JPSS Data Products & Algorithms: Validation of VIIRS Ocean Color products for the Coastal and Open Ocean

Task Leader	Curtiss Davis
Task Code	CDCD_VIIRS_13
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	Future Satellites: Scientific Support for the JPSS Mission
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 0%; Goal 3: 60%; Goal 4: 20%; Goal 5: 0%

Highlight: We have developed a new data system for visualizing and managing the VIIRS data for the West Coast. We are analyzing a 6 month time series of VIIRS and MODIS data for the Southern California Bight using Platform Eureka SeaPRISM for validation.

BACKGROUND

This report summarizes the 6 months 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". 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 radiance 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) 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)) and associated *in situ* data. These time series are continuing and overlap with VIIRS on-orbit data collection.

In addition OSU is funded separately to establish and operate a Satellite Receiving Station that receives VIIRS real-time direct broadcast data for the West Coast of North America. The Receiving Station routinely collects Suomi-NPP VIIRS data, MODIS-Aqua and MODIS-Terra data. VIIRS ocean, land and atmosphere products are processed locally in real time using IPOPP (NASA). The processed data are available online at http://omel_test.coas.oregonstate.edu/project/DB/VIIRS/ . Work to date has been to make the station and software operational. During 2014 we will validate the VIIRS direct broadcast ocean products to assure that they are equivalent to the NASA VIIRS products and comparable to the standard NOAA CLASS VIIRS products.

ACCOMPLISHMENTS

We are working with VIIRS data from the IDPS covering the entire Southern California Bight, and validating the VIIRS products using matchups with the Platform Eureka SeaPRISM data. For our website http://meris.coas.oregonstate.edu/viirs/eur_2013_chl/ a system that presents the available data in coverflow so that you can quickly flip through the available imagery and select data for further analysis (Fig. 1). An alternate light box viewer showing 40 scenes at a time is also available.

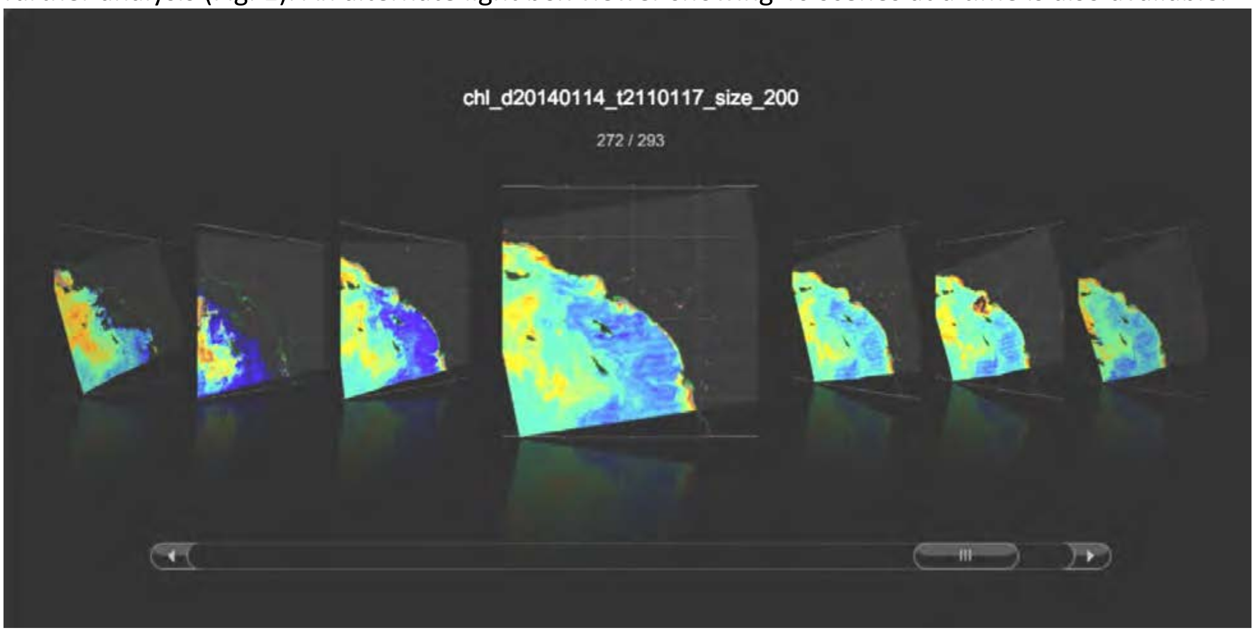


Figure 1. OSU coverflow system for rapid viewing and selection of VIIRS data.

Comparisons of SeaPRISM water leaving radiances and chlorophyll and NOAA IDPS and NASA VIIRS products showed generally good agreement. When compared to the NASA data the NOAA IDPS product was closer to the SeaPRISM in situ data for this coastal water site with an average chlorophyll value of approximately 0.3 mg/m3. A 6 month time series (June through December 2013, Figure 2) shows generally good agreement, but with much more scatter in the VIIRS data compared to

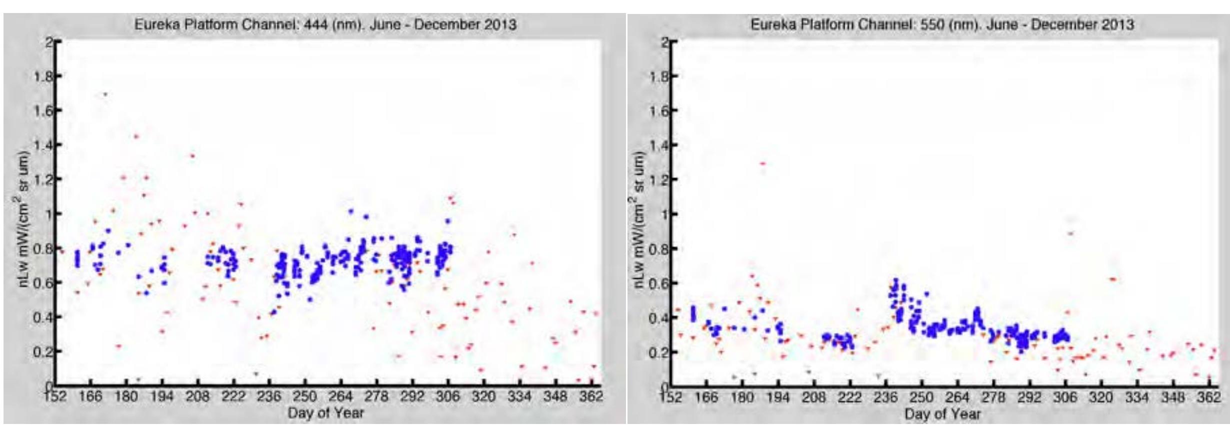


Figure 2. Six month time series of VIIRS IDPS (red) and Platform Eureka (blue) water leaving radiances showing the higher variability of the VIIRS data. left 444 nm, and right 550 nm.

the SeaPRISM data. This is thought to be due to the challenges of atmospheric correction in the coastal waters which is being addressed by the NOAA STAR team.

For the HOT data at station Aloha there are very few matchups due to the infrequency of data collections (monthly), the cloudy conditions and sun glint in this area. However, when we have matched the standard product water leaving radiances from VIIRS with *in situ* HyperPRO measurements, the data show excellent agreement (Figure 3). During the past year we have been working with NOAA (Mike Ondrusek) 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.

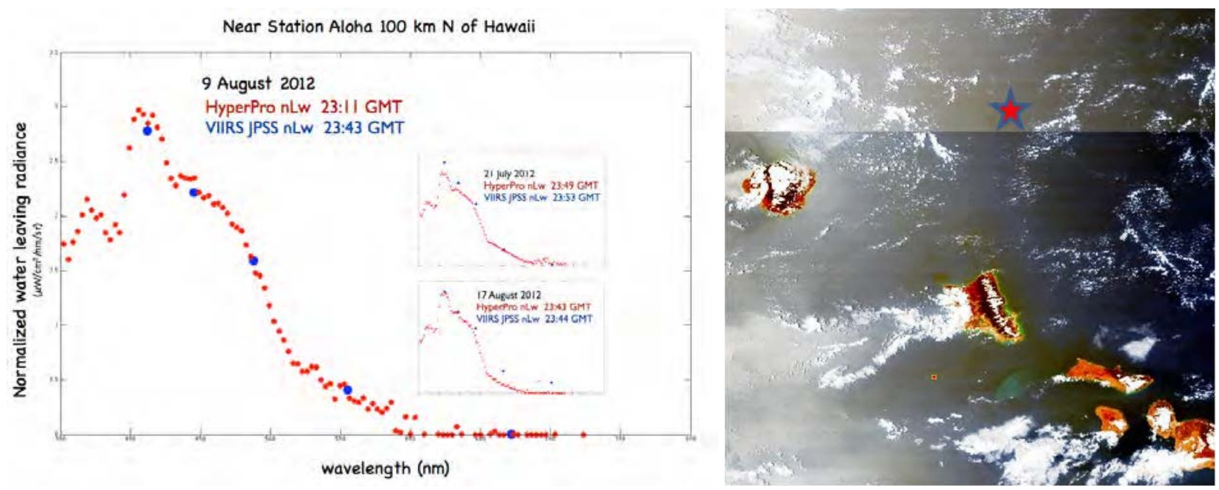


Figure 3. Left, Example spectral matches at Station ALOHA of VIIRS data with HyperPRO cruise data collected within one hour of each other. The VIIRS products shown here are computed with the JPSS processor obtained from the NOAA CLASS archive. Right, VIIRS image over Hawaii from 17 August 2012 (23:43 GMT). The star marks Station ALOHA.

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
- Continue operation of Direct Broadcast station and evaluation of VIIRS data products form direct broadcast compared to products delivered from CLASS
- Evaluate impacts of updates to VIIRS calibration and vicarious calibration on the VIIRS products for the west coast and Hawaii

PUBLICATIONS

Davis, C. O., N. B. Tufillaro, J. Nahorniak, B. Jones and R. Arnone, 2013, “Evaluating VIIRS Ocean Color Products for West Coast and Hawaiian Waters,” Proceedings of the SPIE 8724-24: 1-8. [Published Abstract]

DELIVERABLES

- Monthly time series of Hot HyperPRO data delivered to NOAA/STAR
- Publication on the VIIRS time series analysis for the Southern California Bight
- Evaluation of VIIRS direct broadcast data in comparison to standard NOAA CLASS products for the Southern California Bight

PRESENTATIONS

Davis, C. O., N. B. Tufillaro, J. Nahorniak, B. Jones and R. Arnone, 2013, "Evaluating VIIRS Ocean Color Products for West Coast and Hawaiian Waters," Invited presentation. Proceedings of the SPIE 8724-24.

OTHER (e.g., awards; outreach…)

PERFORMANCE METRICS

	FY13
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	0
# of non-peered reviewed papers	1
# 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	0

PERFORMANCE METRICS EXPLANATION

This project was previously supported through CIOSS at Oregon State University and has been supported through CICS for the last 6 months. Focus during that period has been on 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.

Enhancing Agricultural Drought Monitoring Using NPP/JPSS Land EDRs for NIDIS

Task Leader	Dr. Christopher Hain
Task Code	CHCH_JPSS_13
NOAA Sponsor	Dr. Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Future Satellites: Scientific Support for the JPSS Mission
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%

Highlight: We have implemented data assimilation algorithms in NLDAS and GLDAS. We also generated long term data base of NLDAS/GLDAS climatology from 2002 to present, using the best available forcing data and best initialization.

BACKGROUND

Monitoring land surface soil moisture (SM) and the extent and severity of agricultural drought is an important component of food and water security and world crop market assessment. Because agricultural systems are climate-sensitive, and conventional ground instrument networks are sparse and report with delays, satellite remote sensing and modeling play a vital role in monitoring regional water use and providing early warning of impending moisture deficits, and can be used to supplement coarser resolution data from weather and precipitation networks to assess drought conditions. Because land-surface temperature (LST) is strongly modulated by evaporation and vegetation transpiration that are highly dependent on soil moisture conditions, LST remote sensing data carry valuable information regarding surface moisture availability and therefore have been widely used to map ET, drought, and vegetation stress (Mu et al, 2011; Anderson et al 1997, 2007a,b,c; 2011a,b). Land surface albedo (Al), surface type (ST) and green vegetation fraction (GVF) also directly impact the energy balance of land surface, and thus, accurate information of Al, ST and GVF are all critical to the soil moisture estimates and drought monitoring.

Near real time satellite data products of LST, Al, GVF or NDVI, and newer global land cover or surface type maps have been or are becoming available from NOAA AVHRR, NASA MODIS, or NPP/JPSS routinely or operationally. However, none of these valuable data products has been utilized in the routine runs of NLDAS or GLDAS. Therefore, we propose to develop new or examine existing algorithms for assimilating NPP/JPSS LST, Al, GVF/VI and ST data products into NLDAS and GLDAS to enhance the simulations of root-zone soil moisture and in turn to improve the drought monitoring products. As part of the NOAA JPSS program, a soil moisture (SM) EDR will be generated from the second Advanced Microwave Scanning Radiometer (AMSR2) of JAXA's GCOM-W mission that will be launched in early 2012. An ensemble Kalman filter data assimilation algorithm has been tested to assimilate satellite soil moisture data product from AMSR-E and SMOS (Bolten et al, 2010; Zhan et al, 2008; Crow & Zhan, 2007; Zhan et al, 2011). Once AMSR2 SM EDR becomes available, it will be assimilated into NLDAS/GLDAS simultaneously as the above NPP/JPSS Land EDRs.

ACCOMPLISHMENTS
For the past FY13 funding, the following tasks have been accomplished:

Milestone 1: Initial demonstration of NLDAS/GLDAS capabilities at STAR
Two Linux systems with 10TB data storage were built for the JPSS PGRR project. We installed the Land Information System (LIS) on NESDIS-STAR computers, tested the system with test data sets, developed and tested tools to collect and process NPP/VIIRS Land EDRs (i.e. Surface Type - ST, Land Surface Temperature - LST, Albedo - Al, and Green Vegetation Fraction - GVF), tested data assimilation algorithms using NLDAS.

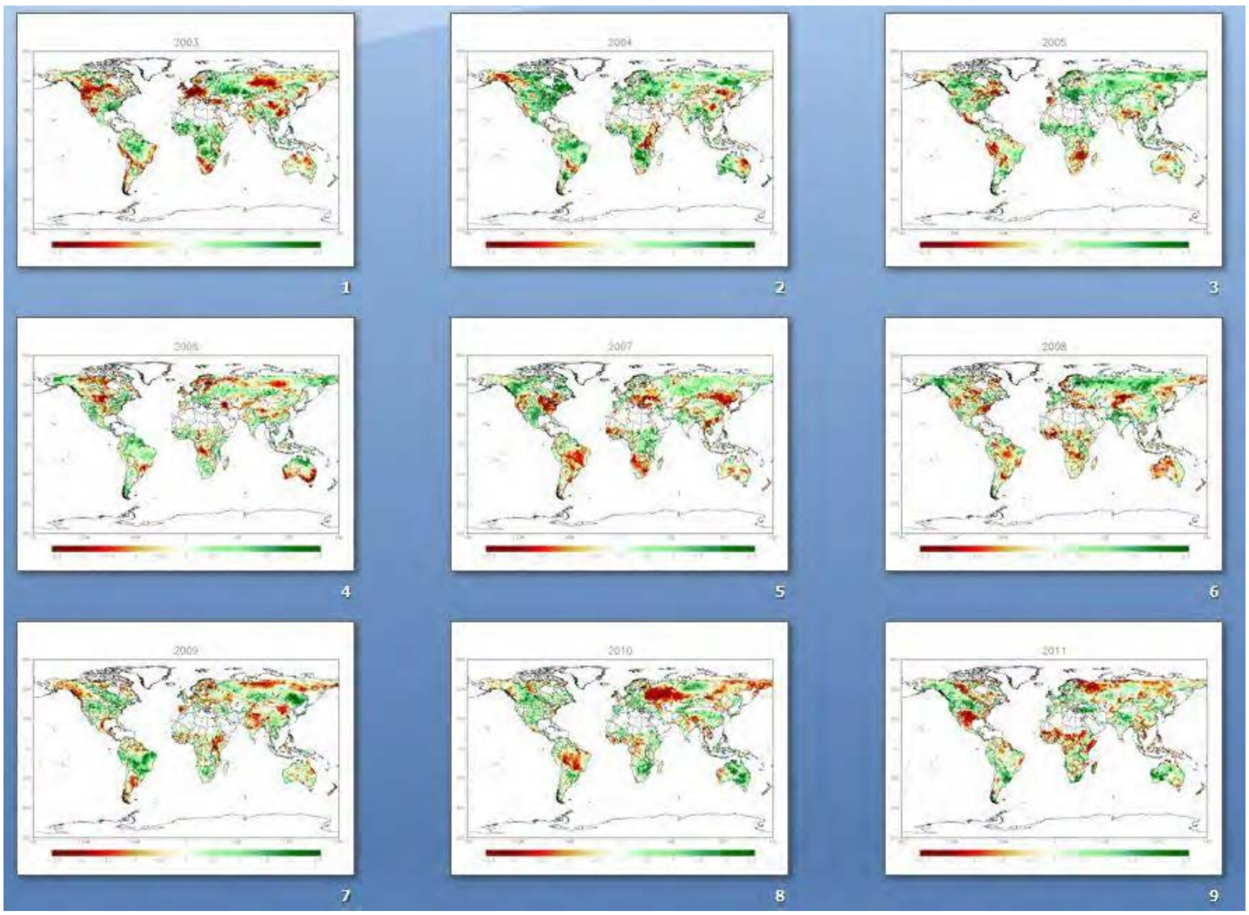


Figure 1. Evaporative Stress Index (ESI) derived from ALEXI model using MODIS land surface temperature data products for the past years.

Milestone 2: Build climatological NLDAS/GLDAS data base for drought monitoring
Based on the best available forcing data sets and initialization strategy for the NLDAS/GLDAS runs, we have built a reliable climatological database of NLDAS/GLDAS simulations for surface layer and root-zone from 2002 to 2012. Before we could fully test S-NPP/JPSS VIIRS observations for drought monitoring, we have tested MODIS data using the ALEXI model approach. Figure 1 demonstrates

how the Evaporative Stress Index (ESI) derived from ALEXI model using MODIS land surface temperature retrievals could be used for drought monitoring. Further development and evaluations of the ESI derived from VIIRS type sensors are currently going on.

Milestone 3: Collection of user feedbacks obtained
We had two meeting with NWS-NCEP EMC and CPC groups on how to improve their NLDAS runs with assimilation of more satellite observations. Leveraging their monthly drought monitoring operations, we'll periodically pass our data assimilation results for their evaluation with a goal toward future implementation of our data assimilation systems for their drought monitoring operations.

PLANNED WORK
For the upcoming FY14 funding, the following tasks will be carried out:

6/30/2014: Milestone 4: NLDAS/GLDAS tested with NPP/JPSS land EDRs
- Outcome/Deliverable: Soil moisture simulation comparison between NLDAS/GLDAS with and without near real time albedo, GVF and SI data assimilation

7/30/2014: Milestone 5: NLDAS/GLDAS tested with JPSS/GCOM-W data files
- Outcome/Deliverable: Soil moisture simulation comparison between NLDAS/GLDAS with and without near real time GCOM-W/AMSR2 soil moisture data assimilation

8/31/2014: Milestone 6: Demonstration of North America and global drought monitoring products
- Outcome/Deliverable: SM simulations and drought maps from NLDAS/GLDAS with optimal assimilation of NPP/JPSS land EDRs and GCOM-W product

9/30/2014: Milestone 7: Initial drought monitoring products using JPSS/GCOM-W data delivered to users
- Outcome/Deliverable: Drought monitoring products from NLDAS/GLDAS using NPP/JPSS/GCOM-W data

12/31/2014: Milestone 8: More collections of user feedbacks
- Outcome/Deliverable: Users information on NLDAS/GLDAS drought monitoring products using NPP/JPSS/GCOM-W data

PUBLICATIONS
Yin, J., X. Zhan, **C. R. Hain**, and **L. Fang**, 2013: Optimal Ensemble Size of Ensemble Kalman Filter in Sequential Soil Moisture Data Assimilation of Land Surface Model, *Submitted to Geophysical Research Letters*.

Zheng, W., X. Zhan, J. Liu and M. Ek. (2014), A Preliminary Assessment of the Impact of Assimilating Satellite Soil Moisture Data Products on NCEP Global Forecast System. *J. Hydromet.*, ***In review***.

PRESENTATIONS
- Co-PI Hain presented a talk to a NASA Applied Sciences: Water Resources workshop in Omaha, NE, 2013

- Our team member L. Fang presented a talk to AMS annual meeting: Impact of Near-real-time Satellite Observations on Soil Moisture Simulations of Noah LSM in NLDAS, in Atlanta, GA, 2014

PERFORMANCE METRICS	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	2
# 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	0

PERFORMANCE METRICS EXPLANATION

This year, we generated U.S. and global root-zone soil moisture and drought products (1) for 2002 to present using the best available forcing data sets and best initialization strategy for the NLDAS/GLDAS. Two journal papers on the microwave retrieval of snow depth related to the project has been submitted. Two presentations summarizing the data assimilation work have been made at different scientific conferences.

NPP/VIIRS Land Product Validation Research and Algorithm Refinement: GEOG Task 3 Land Surface Type EDR

Task Leader	Chengquan Huang
Task Code	CHCH_SMSN_13
NOAA Sponsor	Xiwu Zhan
NOAA Office	NESDIS/STAR/SMCD
Percent contribution to CICS Themes	Theme 1: 30%; Theme 2: 40%; Theme 3: 30%.
Main CICS Research Topic	Future Satellites: Scientific Support for the JPSS Mission
Percent contribution to NOAA Goals	Goal 1: 20%; Goal 2: 20%; Goal 3: 20%; Goal 4: 0%; Goal 5: 40%

Highlight: A whole year's VIIRS data (February 2012 to January 2013) were gridded to create 32-day composites and annual metrics, which was used to produce the first VIIRS QST IP.

BACKGROUND

The surface type Environmental Data Records (EDR) is an important data product from the Suomi NPP satellite. Using the IGBP land cover classification scheme, it labels the land cover types around the world on a daily basis. It is created from the Quarterly Surface Type (QST) Intermediate Product (IP) and other VIIRS EDR products such as ice/snow EDR and fire EDR.

The QST IP will be created every three months after a full year of VIIRS data has been gathered and calibrated. Before that, the MODIS land cover classification product derived by the Boston University (BU) in 2001 is used as a seed QST IP for the surface type EDR and other NPP EDR algorithms that require QST IP as an input. Development of the MODIS land cover classification has been detailed by Friedl et al. (2002).

This task focuses on development of the QST IP and evaluation of the Surface Type EDR.

ACCOMPLISHMENTS

1. Continuous Support of Surface Type EDR

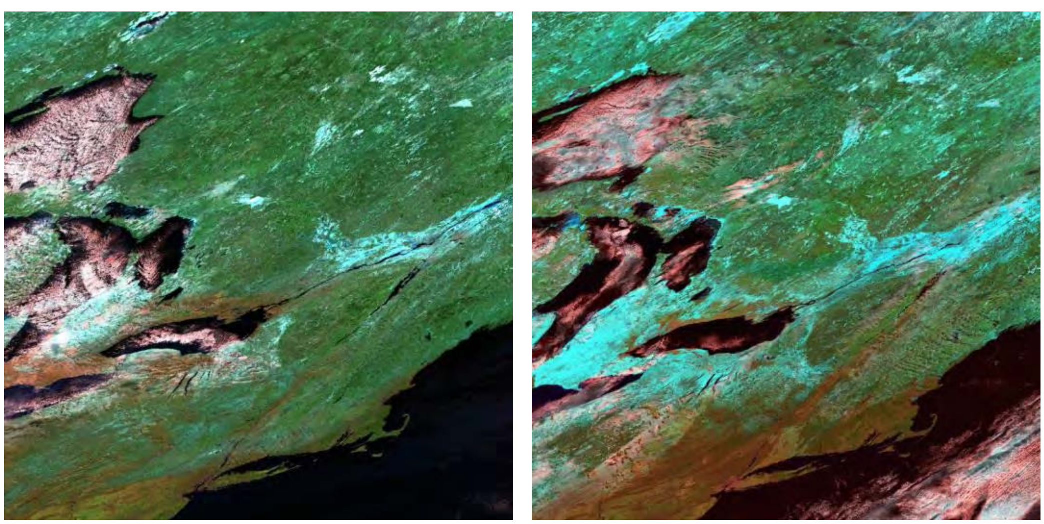
Although the Surface Type EDR algorithm has reach beta maturity and performed as designed in general, two issues were identified with the snow/ice component of this algorithm. The first was related to the different spatial resolutions of the Surface Type (750-m) and Snow EDR (375-m) products. Four (2 x 2) Snow EDR pixels need to be aggregated to create a Surface Type EDR pixel. A 750-m Surface Type EDR pixel should be identified as a snow pixel if at least 2 of the 4 375-m pixels matching that 750-m pixel are mapped as snow in the Snow EDR. However, the existing Surface Type EDR code had a bug and required at least 3 of the 4 375-m pixels to be mapped as snow pixels. This bug has been fixed.

Also, Snow EDR is not produced during night time, but the Surface Albedo EDR is produced for both day and night time, and therefore requires the Surface Type EDR to provide snow information for both day and night time. A decision was made to update the snow flag in the Surface Type EDR using a rolling snow product generated based on other NOAA datasets when snow information is not available from the VIIRS Snow EDR, and the Surface Type EDR code has been modified to reflect this change in the algorithm.

2. Development of Quarterly Surface Type Intermediate Product (QST IP)
The current QST IP algorithm requires one full year's VIIRS data. By January 2013, VIIRS accumulated one full year's of calibrated observations. This allowed development of the first VIIRS QST IP product, which consisted of three major steps:

2.1 Gridding
The VIIRS QST IP algorithm requires annual metrics derived from gridded VIIRS data. Generating gridded VIIRS data is not part of the QST IP algorithm. The IDPS system should provide gridded VIIRS data. Unfortunately, the gridding modules in the IDPS were not turned on until 2013. To avoid further delay in the production of a VIIRS-based QST IP, we downloaded all VIIRS swath data acquired from February 2012 to January 2013 and gridded each of them in house. This extra work accounted for the majority of the effort in developing the first VIIRS QST IP – over 800,000 files (~80,000 VIIRS granules) totaling ~150 TB were gridded using ~30,000 CPU hours.

2.2 Compositing and annual metrics generation
The MODIS compositing algorithm requires quality flags to identify cloud, haze, and other data quality problems. The reliability of the VIIRS quality flags was still being evaluated during the production of the VIIRS QST IP. Therefore, we developed a modified compositing algorithm that did not rely on any quality flags. Fig. 1 shows that our compositing algorithm produced composited products similar to those generated using the MODIS compositing algorithm.



VIIRS, M11-7-5 MODIS, B7-2-1

Figure 1: VIIRS 8-day composites provide better observations over water and snow.

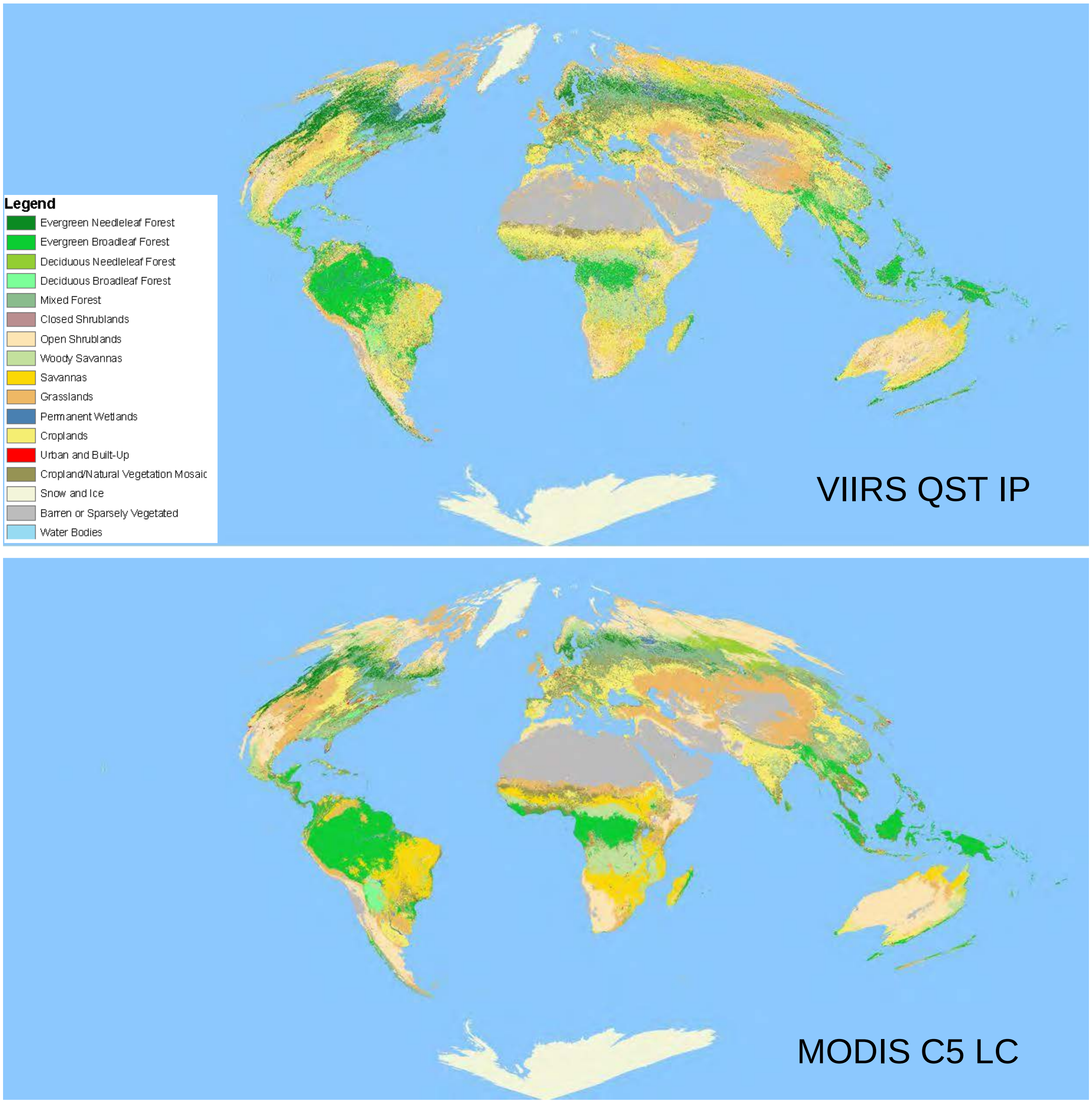


Figure 2: First QST IP produced using VIIRS data acquired from February 2012 to January 2013 (top) as compared with the MODIS Collect 5 (C5) land cover product (bottom).

The modified compositing algorithm was used to create 32-day composites, which were then used to generate the following annual metrics using the method described in the VIIRS Surface Type ATBD and by Hansen et al. (2000; 2002; 2003):

- NDVI Metrics:
    - Second maximum monthly NDVI in a year

  - Minimum NDVI value in the highest 7 monthly NDVIs
  - Median NDVI in the highest 7 monthly NDVIs
  - Range of NDVI in the highest 7 monthly NDVIs
  - Median NDVI in the 5 warmest months
  - NDVI of the warmest month
- Reflectance Metrics (VIIRS M bands 3-8, 10, 11, 15):
  - Second maximum reflectance, during the 7 greenest in the year
  - Minimum reflectance, during the 7 greenest months
  - Median reflectance of the 7 greenest months
  - Range of reflectance, among the 7 greenest months
  - Median reflectance of the 5 warmest months
  - Reflectance of the month with the second highest NDVI in the year
  - Reflectance of the warmest month

2.3 Classification
We used the C5.0 classification tree algorithm to produce the first VIIRS QST IP product. Training data included data provided by Boston University as well as data collected based on a comparison of four existing global land cover products. The derived VIIRS QST IP product appeared to be comparable with the Collection 5 MODIS land cover product (Fig. 2), which is used as the current QST IP seed in IDPS. Further analyses are being conducted to compare these two products and to derive quantitative accuracy estimates for the VIIRS QST IP.

PLANNED WORK
Algorithm and Product Development:
- Continue to develop and improve QST IP using VIIRS data
  - Download 2013 and 2014 VIIRS data
  - Develop high quality monthly composites and annual metrics
  - Increase training data representativeness globally
  - Test different classification algorithms
  - Deliver provisional and validated QST IP products.

PUBLICATIONS
None.

DELIVERABLES
None.

PRESENTATIONS
None.

OTHERS
None.

Performance Metrics	FY13
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guid-ance	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	0

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NPP/VIIRS Land Product Validation Research and Algorithm Refinement: GEOG Task 4 Active Fire Application Related Product

Task Leader	Louis Giglio
Task Code	CJWS_VVLLW_13
NOAA Sponsor	Ivan Csiszar
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Future Satellites: Scientific Support for the JPSS Mission
Contribution to NOAA Goals (%)	Goal 1: 75%; Goal 2: 25%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: We completed a MODIS-Collection 6 equivalent version of the VIIRS fire code.

BACKGROUND

The Active Fire Application-Related Product (AF-ARP) is generated as part of the Suomi-NPP/VIIRS land product suite, but also serves as input for other key mission products (e.g., cloud mask, land surface type). The AF algorithm implemented in the Integrated Data Processing Segment (IDPS) builds on an earlier version (Collection 4) of the EOS/MODIS Fire and Thermal Anomalies algorithm designed to detect and characterize active fires [Giglio et al., 2003], allowing for improved data continuity although fire characterization would not be included in the original baseline VIIRS fire product. The MODIS algorithm has since evolved, incorporating additional tests to minimize potential false alarms, implementing a dynamic background characterization, and expanding processing to offshore pixels to allow detection of gas flares. Meanwhile, a new set of revised requirements was implemented for the VIIRS fire product, which included fire characterization retrievals (fire radiative power), and a 2D image classification product flagging fire and non-fire pixels (e.g., fire-free land surface, clouds, water), both mimicking the MODIS fire product.

This task is focused on the development and refinement of the operational IDPS AF product providing the required algorithm support and data analyses, quality assessment and validation.

ACCOMPLISHMENTS

In December 2013 we completed version 1.2.9 of the replacement VIIRS active fire code. This version implements the last of the improvements that were incorporated into the MODIS Collection 6 fire code that was completed in mid-2013. The VIIRS port is now running in the NASA Land PEATE for testing an evaluation. Delivery of the software to the AIT will follow based on the results of an ongoing NOAA NDE vs. IDPS cost-benefit analysis.

Much work during the past year focussed on identifying problems remaining in those VIIRS SDRs used to produce the VIIRS Active Fire (formerly Active Fires) EDR. In March 2013 we met with NGAS SDR representatives for a detailed discussion about inconcistencies in the SDR quality flags (e.g., QF1), and the periodic occurrence of anomalous M13 scans that produce spurious lines of fire pixels in the Active Fire EDR (Figure 1).