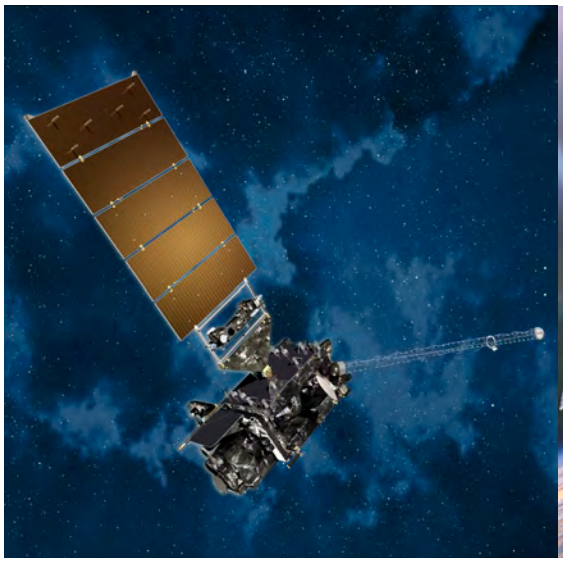

GOES-R

JPSS

COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

Annual Scientific Report

VOLUME II: CICS-MD TASK REPORTS

For the period:
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Dr. Fernando Miralles-Wilhelm, Director
April 30, 2015

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1 CICS-MD PROJECTS

1.1 Data Fusion and Algorithm Development

Validation of Operational AMSR2 SSTs

Task Leader	Andy Harris
Task Code	AHAH_AMSRE_14
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: GAASP AMSR-2 SST product has been evaluated and significant algorithm and calibration artifacts were identified. Validation has been redone for a revised product and similar algorithm-related features were noted. Advice was passed back to the GAASP development team to inform their enhancements to the Day-1 SST algorithm.

Background

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

Accomplishments

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

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

Figure 1 shows the behavior of SST error with respect to wind speed for daytime data. In our previous report, we indicated that daytime data are expected to demonstrate a positive bias as wind tends to zero. This effect is illustrated in the right-hand plot for Figure 1, which shows the result for the Remote Sensing Systems (RSS) AMSR-2 SST retrievals. However, this anticipated behavior is not observed in the GAASP SST product. We have established that the reason is because of the way the GAASP data are processed. The

data are normalized with respect to NCEP temperatures by a histogram equalization approach to remove the effect of potential calibration biases. The histograms are constructed for various data bins, partitioned by temperature and wind speed. However, since the NCEP temperatures do not model diurnal warming, the process removes these genuine geophysical effects.

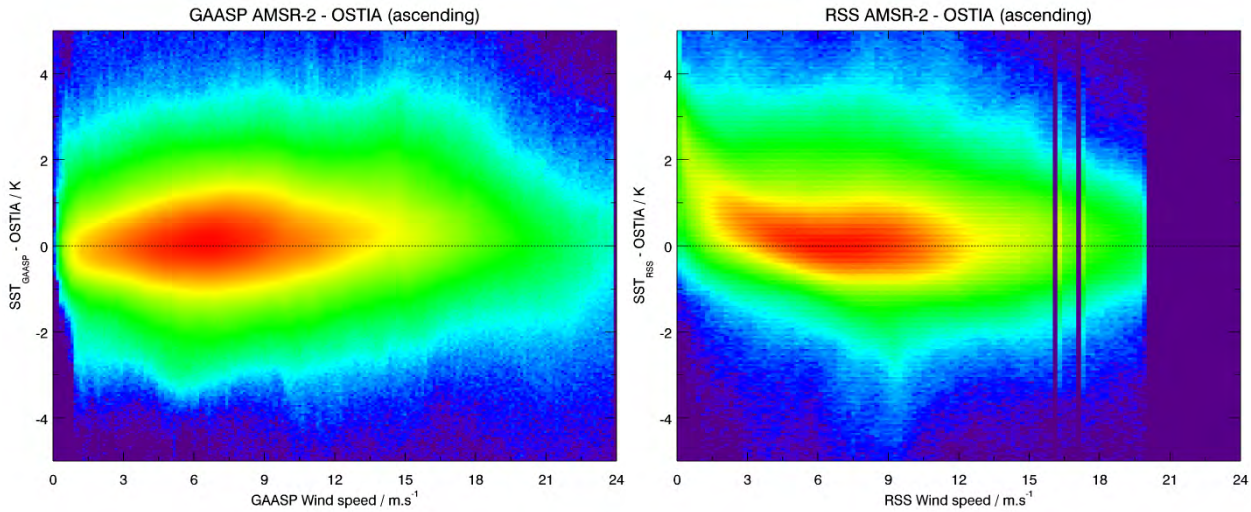


Figure 1. Bias in SST retrieved from AMSR-2 with respect to OSTIA SST Analysis. Left panel shows bias for daytime GAASP data while right panel shows the same plot for RSS data. The lines in the R.H. plot are due to digitization of the wind values in the GHRSST L2P format.

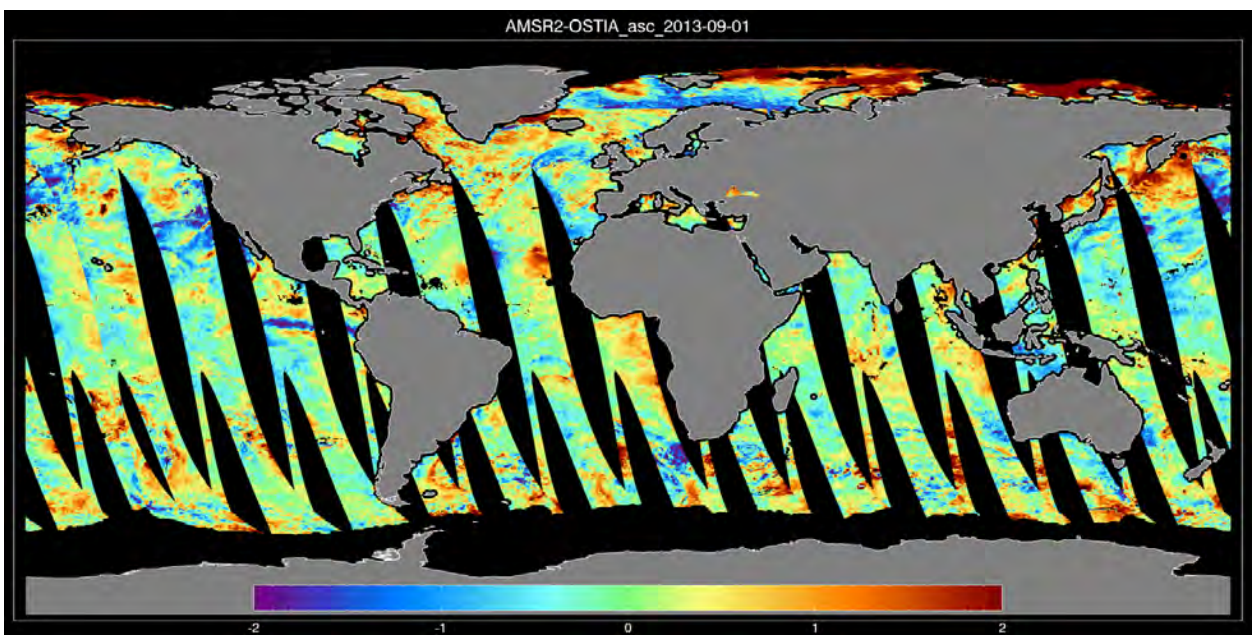


Figure 2. Bias in GAASP SST retrieved from AMSR-2 with respect to OSTIA SST Analysis for ascending passes, 2013-09-01. The color scale runs from -2 K to +2 K.

Figure 2 shows the difference between GAASP AMSR-2 SSTs and the UK Met Office OSTIA SST analysis for a single day. The image shows a number of artifacts, most obvious of which are the glitches in calibration, that are evident from their semi-circular scan pattern. The other key feature is the existence of abrupt

step changes in SST difference (linear across a line of latitude), particularly at high latitude. This turns out to be due to a latitude dependence in the algorithm. Some of the step changes are in excess of 2 kelvin.

As mentioned above, we have performed similar analyses on AMSR-2 SST data obtained from NASA JPL that were originally processed by RSS. Results for these data are significantly improved with respect to the GAASP product (r.m.s. of 0.55 K *cf.* ~0.8 K). At least some of that gain may be due to the calibration methodology that RSS have developed.

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 2015)

- Repeat the validation exercise again, this time on the GAASP Day-1 enhanced AMSR-2 SST product that was produced in response to the feedback from our previous validation work
- Continue to 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
- Continued 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)

Products

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

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

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.

Microwave and Diurnally Corrected Blended Sea Surface Temperatures

Task Leader	Andy Harris
Task Code	AHAH_MDCB_14
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: A global model of near-surface ocean warming has been developed and is being transitioned into operations. The model employs state-of-the-art turbulence closure and includes parameterizations for Stokes' Drift mixing to account for non-local effects. The model is forced by NCEP fluxes of heat and momentum, and wave parameters from the NCEP Wavewatch III model. Code has been developed and tested for the ingestion stage to apply the diurnal adjustment to each SST observation prior to QC and gridding.

Background

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

The product accuracy verified against globally distributed buoys is ~0.02 K, with a robust standard deviation of ~0.25 K. The new analysis has proven a significant success, even when compared to other products that purport to be of similar resolution, and is being used as the basis for other operational environmental products such as coral reef bleaching risk and ocean heat content for tropical cyclone prediction. Forthcoming enhancements include the incorporation of Microwave SST products from the GCOM-W1 AMSR-2 instrument to improve resolution of SST features in areas of persistent cloud, and explicit correction for diurnal effects via a turbulence model of upper ocean heating. It is these enhancements that are the subject of this project.

Accomplishments

Code has been written and tested for the diurnal model. The diurnal modelling is accomplished by using a modified version of the Kantha & Clayson (1994) turbulence closure scheme, with additional mixing to account for non-local wave action (Stokes' Drift). The wave information is obtained from NCEP Wavewatch III output. Scripts, utilities (NCEP's `wgrib2`) and programs have been written to consolidate the various GriB files into a single netCDF file for input into the diurnal warming model, which runs at 0.5°×0.5° resolution and requires nine 6-hour epochs in order to simulate two full days of warming. The first 24-hours are essentially a "spin-up" period, using data for the day prior to the day of interest, and the results from the 2nd 24-hour period are used to adjust the satellite-observed SSTs. An example of the output from the diurnal warming model can be seen in Figure 1.

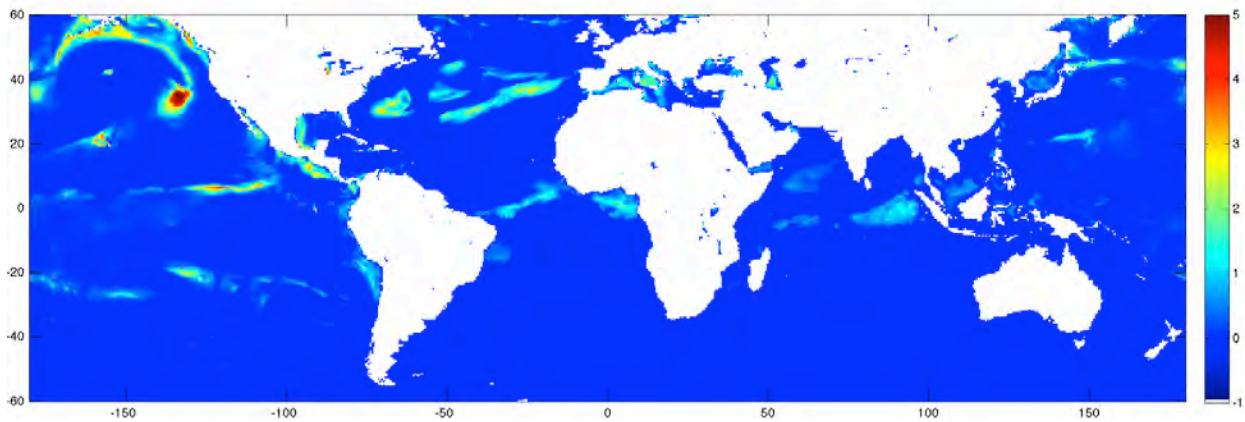


Figure 1: Diurnal warming relative to 5 m depth as predicted for 2014-05-10 01Z. The model has the option to estimate a skin-to-subskin adjustment as well, but this is the difference between the top layer of the model and the 5 m depth. The reference depth is also user-selectable.

While the development of a reliable operational diurnal warming scheme based on a full turbulence model that includes Stokes' Drift is a significant achievement, it is also necessary to apply the adjustment to the satellite data. This must be done for every pixel at the ingest stage prior to quality control and residual bias correction, after which the data can be aggregated onto the analysis input grid. This necessitates an efficient method of interpolating the diurnal model output in space and time. Figure 2 shows the difference between where the difference between input grids using unadjusted and adjusted data.

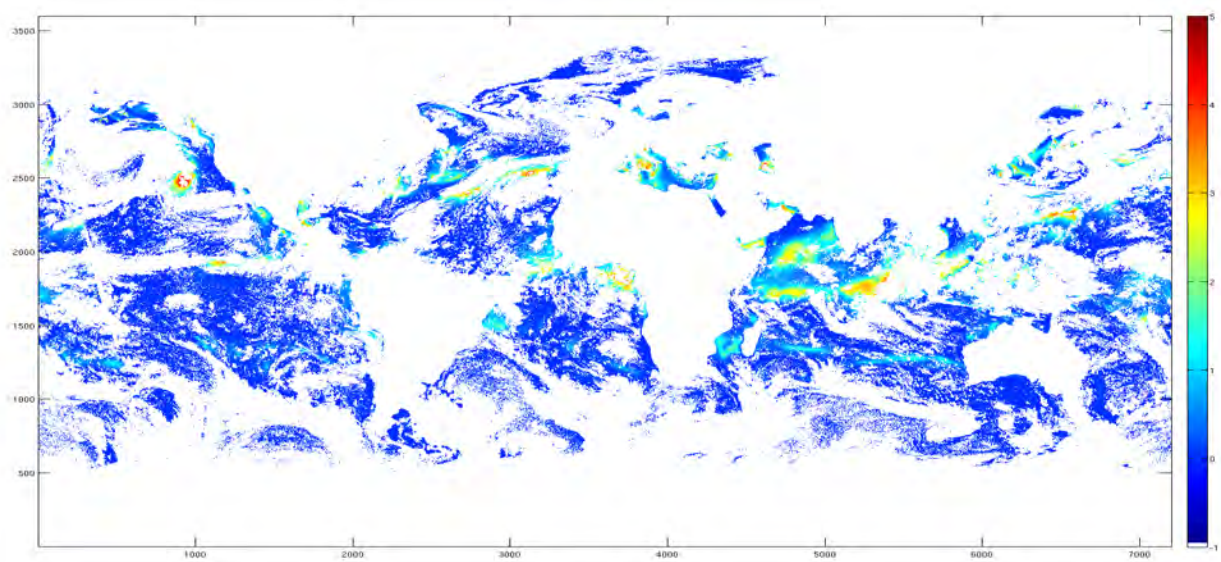


Figure 2: Diurnal warming adjustment applied to daytime VIIRS SST data during the ingestion phase of the Geo-Polar Blended SST analysis. In this example, the correction is relative to a depth of 5 m, but can be configured to correct to any depth between 1 cm and 50 m.

Planned Work

- Completing transition of code to operations
- Incorporation of AMSR-2 MW SSTs into analysis
- Validation of operational output
- Refinement of various diurnal model parameterizations

Products

- Tested diurnal model code transitioned to NOAA Operations;
- Validation of model output

Performance Metrics	
# of new or improved products developed	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# 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**

The MDBC is currently undergoing transition to operations (UTRR complete, code review imminent).

Assimilation of VIIRS SSTs and Radiances into Level 4 Analyses

Task Leader	Andy Harris
Task Code	AHAH_VIIRS_14
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: Assimilation of VIIRS SST data into our high-resolution Geo-Polar Blended SST Analysis has now been transitioned into operations. Research has been conducted into producing more accurate SST retrievals from VIIRS radiances, with encouraging results.

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.

Accomplishments

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. ACSPO VIIRS have recently become available in L2P format, and we are beginning the process of testing the extra capability of our ingestion software to take account of the sensor specific error statistics (SSES) provided for each pixel. The ACSPO team have invested a significant amount of effort in revising their scheme for calculation of pixel-specific SSES. The code has been transitioned to operations, which is currently using a revised netCDF format generated by the NDE system. The revisions to the netCDF format, including some rather unique interpretations on the specification of tagged variables, necessitated support for further code changes.

Since operational transitioning the assimilation of ACSPO VIIRS SST into our high-resolution SST analysis, work has focused on the application of our new MTLS (Modified Total Least Squares) physical retrieval methodology to VIIRS radiances. The algorithm adopts a deterministic paradigm for error minimization,

and is not reliant on accurate knowledge of *a priori* error covariances. Figure 1 shows results for a variety of algorithms applied to VIIRS data, including Optimal Estimation (OEM) and ACSPO regression. The latter is based on the OSI-SAF formulation that was also previously used in our operational GOES-SST retrievals before being replaced by the superior MTLS algorithm in August 2013. Data are sorted according to the MTLS total error calculation (akin to the chi-squared metric of OEM, but accounting for more error sources) and are, unless otherwise noted, filtered using our experimental cloud mask. The following characteristics can be discerned:

1. MTLS produces the best results, with virtually no bias (separation of RMSE & SD)
2. The MTLS total error calculation is a good predictor of retrieval error, except for OEM
3. There is a strong correlation between initial guess error and MTLS total error
4. The OSI-SAF algorithm formulation and ACSPO are very similar (not surprising since the algorithm formulation is the same)
5. Operational ACSPO produces nearly 19% coverage (*cf*. 6% for NAVO) but the error is worse than SSTs from the same [OSI-SAF] algorithm for the best 19% of data using our new cloud detection

The reason for (3) is that MTLS regularization strength is determined by the magnitude of the residual, and when the initial guess is close to truth, the solution is more strongly regularized to reduce the error propagating through from the observations to the solution. The most likely reason for the inability of the MTLS error calculation to predict error in OEM (2) is that the latter uses fixed *a priori* error covariances and is therefore relatively more affected by observation noise when the initial guess SST is more accurate than the value in the covariance matrix.

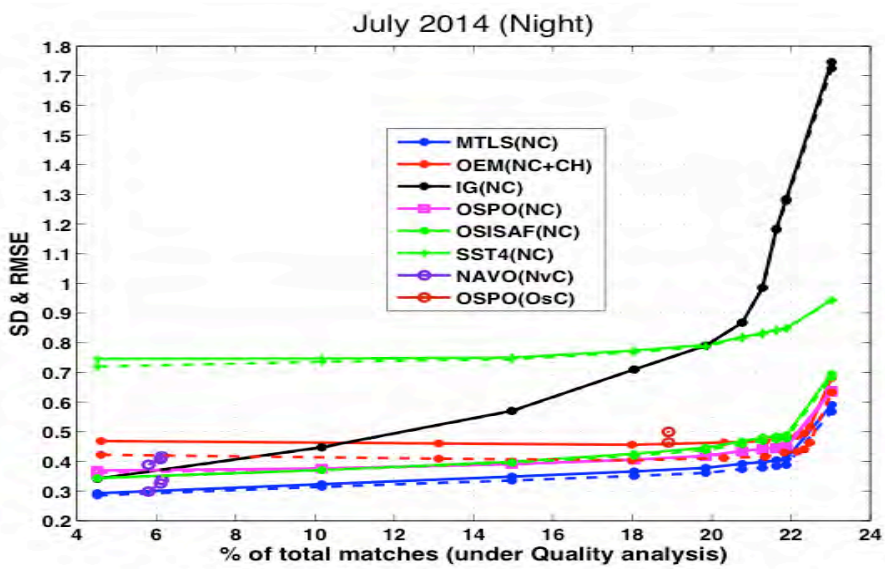


Figure 1: RMSE (solid lines) and SD (dashed lines) for MTLS (blue), Optimal Estimation (red), ACSPO (magenta), SST4 (green diamond), OSI-SAF (solid green circle). All of these results use our experimental cloud mask (NC). Results for some other discrete cloud masking schemes are shown (NAVO – purple; Operational ACSPO – dark red). Accuracy of the initial guess is also shown (black). The data are ordered with respect to the MTLS total error calculation. Matches are initially derived irrespective of cloud, and %age of matches is relative to that total.

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)

- Continued development of physical retrieval of SST from VIIRS radiances
- Assess impact of improved Geo-Polar SST analysis on Coral Reef Watch products

Products

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

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# 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**

The budget for Year 2 was split over Years 2 & 3, so a number of results extend into a third year, as described above.

Development of Global Soil Moisture Product System(SMOPS)

Task Leader	Christopher Hain
Task Code	CHCH_SMOPS_14
NOAA Sponsor	Xiwu Zhan
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development

Contribution to NOAA goals (%) Goal 1: 40%; Goal 2: 25%; Goal 3: 10%; Goal 4: 25%

Highlight : We have finished ingesting ASCAT soil moisture data from MetOp-B into SMOPS. Code has been delivered to Office of Satellite and Product Operations (OSPO) at NOAA/NESDIS. In addition, the cumulative distribution function (CDF) data base used for merging MetOp-B ASCAT soil moisture has also been generated mostly based on MetOp-B ASCAT soil moisture data. The new SMOPS version is expected to go operational in April, 2015.

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

Background

SMOPS went operational in later 2012 with external soil moisture product inputs from SMOS, ASCAT-A, and WindSat. It grids all the orbital soil moisture orbits from these sensors and output a global gridded soil moisture map for each sensor at a quarter degree resolution every 6 hours. In addition to the grid- ded soil moisture layers, SMOPS also generates a blended soil moisture layer that merges all the availa- ble soil moisture values using a cumulative distribution function (CDF) approach. As soil moisture data became available from MetOp-B ASCA, MetOp-B ASCAT soil moisture needs to added in SMOPS and will eventually replace the MetOp-A ASCAT soil moisture layer in SMOPS. After the successful launch of JAXA's GCOM-W1 satellite May 18, 2012, a soil moisture environmental data record (EDR) from Ad- vanced Microwave Scanning Radiometer (AMSR2) onboard GCOM-W1 will be generated at NOAA. This product will also be ingested in SMOPS. To improve the data latency of SMOS soil moisture generation, we are also developing an algorithm to generate SMOS soil moisture inside SMOPS such that more SMOS data will be used in SMOPS.

Accomplishments

SMOPS code has been updated to include soil moisture data from MetOp-A ASCAT. The previous re- search work showed a significant difference between soil moisture values from ASCAT-A and ASCAT-B, a separated CDF data base for merging ASCAT-B soil moisture into SMOPS blended layer is desirable. This data base has been generated using all available data and the SMOPS code has been modified to take this data base accordingly. Both the SMOPS code and the CDF data base has been deliver to OSPO. It is now under testing on the operational system and will go operational in coming months. Table 1 show s the data layers for the new SMOPS version (V1.2). The future version of SMOPS (V2.0) will have soil moisture products from AMSR2 and NOAA SMOS included.

Table 1. Soill Moisture data layers of SMOPS version 1.2.

Layer	Name (V1.2, delivered)	Name (V2.0, working on)
1	Blended	Blended
2	AMSR-E	AMSR2
3	SMOS	ESA SMOS
4	ASCAT-A	NOAA SMOS
5	ASCAT-B	ASCAT-A
6	WindSat	ASCAT-B
7	Reserved	WindSat

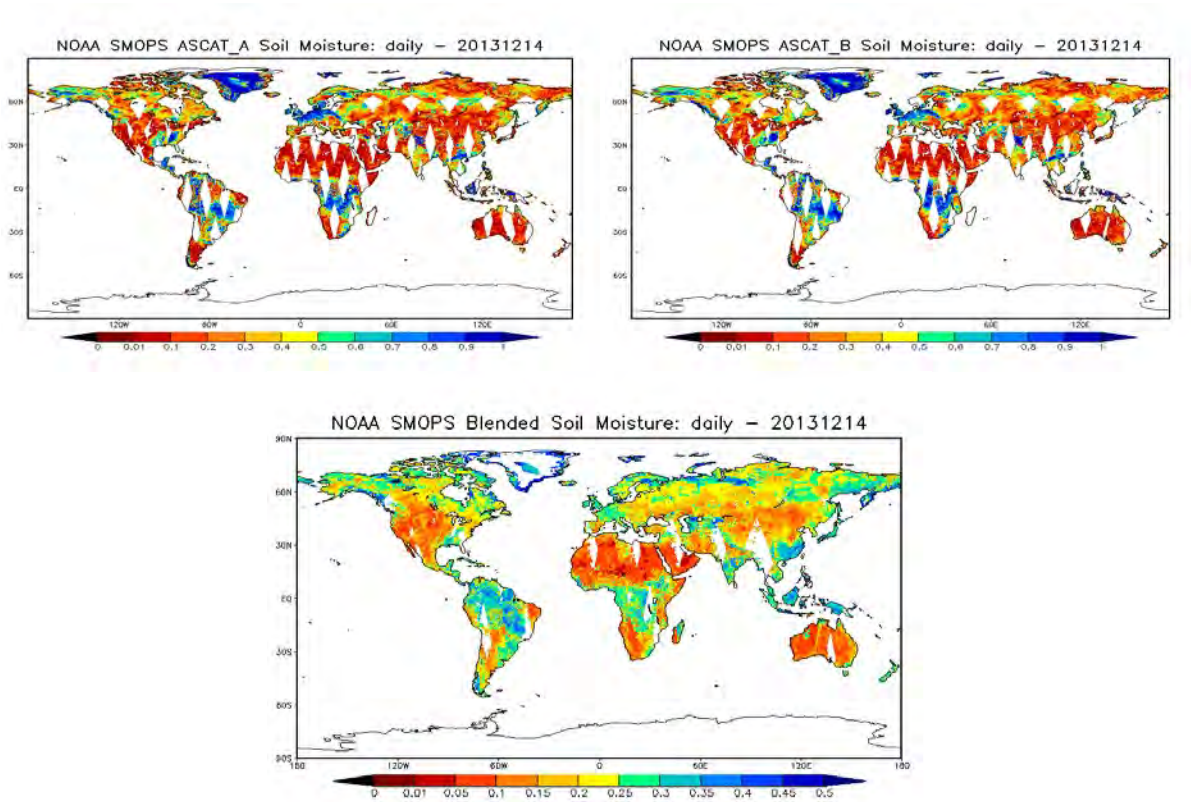


Figure 1 shows an example of gridded soil moisture maps from MetOp-A ASCAT (top –left) and Metop-B ASCAT (top-right) and the SMOPS blended soil moisture layer (bottom).

Planned work

- Work with OSPO to test the updated SMOPS code and make it operational.
- Continue working on generating SMOS soil moisture with SMOPS algorithm.
- Work on adding AMSR-2 soil moisture data in SMOPS once it becomes operationally available.

Publications

Two manuscripts in drafts: one on inter-comparison between ASCAT-A soil moisture and ASCAT-B soil moisture and one on the algorithm generating SMOS near real time brightness temperature at NOAA.

Products

- SMOPS V1.2 code.
- CDF data base for merging ASCAT-B into SMOPS Blended layer.
- Updated SMOPS System Test documents.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# 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**

The new version of SMOPS delivered to OSPO will have both ASCAT-A and ASCAT-B soil moisture products included, therefore, an even better spatial coverage of the 6-hour product.

Blended Sea Ice Concentration Code for the IMS

Task Leader	Kongoli
Task Code	CKCK_BICA_14
NOAA Sponsor	National Ice Center
NOAA Office	NESDIS/STAR
Main CICS Research Topic	Data fusion and algorithm development

Percent contribution to CICS Themes Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.

Percent contribution to NOAA Goals Goal 1: 20%; Goal 2: 80%

Highlight: A new blended ice concentration analysis is being developed for operational application at NOAA's National Ice Center (NIC). As part of this project, several improvements have also been made to the operational IMS snow depth analysis product.

Background

A new 1-km blended ice concentration analysis product is being developed at the National Ice Center. The analysis blends a variety of data sources including VIIRS, AMSR-2 and analyst-derived ice concentration estimates and up-scales them to 1-km resolution. Current data sources all lack the spatial, temporal, or accuracy requirements needed to provide NOAA and the National Weather Service (NWS) to meet their modeling needs for navigation in or around the ice. Improvement of ice concentration monitoring in NOAA National Ice Center's (NIC) snow and ice analysis system will allow NIC to provide timely, superior and objective ice monitoring while not adding to current analysis production time. As part of this project, several improvements are also being made to the IMS 1-km operational blended snow depth analysis product. The snow depth analysis blends in-situ, climatology, microwave and analyst data using optimal interpolation methodology. Improvements to the product include more realistic adjustment of data errors, improved snow depth-elevation climatology relationships. Ingest of AMSR2 snow depth and adjustment of analysis scheme over transitional snow areas.

Accomplishments

For the blended Ice concentration analysis product, accomplishments include the following:

- Preliminary 1-km blended ice concentration analysis scheme and code in Fortran 90/95.
- Ingest of VIIRS and AMSR2 ice concentration data

For the blended snow depth analysis product, accomplishments include the following:

- Adjustment of data errors and an improved blending of background with current analysis scheme
- Ingest of AMSR2 snow depth data

Publications

Peer-reviewed papers

Kongoli, C., R. J. Kuligowski, S. Helfrich and P. Romanov, 2014. "Monitoring precipitation and snow cover using multi-sensor satellite and in-situ data", *International Journal of Ecosystems and Ecology Science (IJEES),* 4(2), 293-300.

Non-peer reviewed papers

Kongoli, C., R. J. Kuligowski, S. Helfrich and P. Romanov, 2014. "Monitoring precipitation and snow cover using multi-sensor satellite and in-situ data", *4th International Conference on Ecosystems,* Proceedings Book ISBN: 978-9928-4068-8-0, pp.14-20, ICE 2014, Tirana, Albania (Conference Proceeding).

Planned Work

- Develop the pre-operational blended ice analysis scheme and code
- Improve snow depth climatology representation in blended snow depth analysis
- Improve blending algorithm in transitional snow areas
- Test improvements and transition to operations

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**1**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**0**

This year, we developed a new ice concentration product and improved an operational sow depth product (2). One journal paper (1) and one non-peer reviewed conference proceedings paper (1) on the IMS snow products related to the project have been published (1).

Monitoring and Day-2 Algorithms for AMSR2 EDRs

Task Leader Patrick Meyers and Jun-Dong Park
Task Code EBPM_AMSR2_14
NOAA Sponsor Paul Chang and Ralph Ferraro
NOAA Office NESDIS/STAR/CRPD/SCSB
Contribution to CICS Research Themes (%) Theme 1: 50%; Theme 2: 50%
Main CICS Research Topic Data Fusion and Algorithm Development
Contribution to NOAA goals (%) Goal 1: 0%; Goal 2: 100%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%
Highlight: Research algorithms precipitation, total precipitable water, wind speed, cloud liquid water, and sea surface temperatures were implemented for routine geophysical retrievals by NOAA.
Link to a research web page
http://manati.star.nesdis.noaa.gov/gcom/datasets/GCOM2Data.php/GCOM2Data.php

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 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 long-term 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 scientists for Environmental Data Records (EDRs) from GCOM-W1/AMSR2 began to be routinely produced in Spring 2014. 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. These preliminary algorithms must be reevaluated and corrected to account for detected systematic retrieval errors. Updated EDR algorithms were delivered to NOAA's Office of Satellite and Product Operations (OSPO) to be incorporated into the GCOM-W1 AMSR2 Algorithm Software Processor (GAASP). Additionally, routine monitoring was established to ensure reliable dataflow and accuracy of the EDRs.

Accomplishments

JAXA's Level 1 AMSR2 brightness temperature data showed significant bias relative to other satellite sensors. This required extensive calibration in order to ensure consistent brightness temperatures across multiple observational platforms. The Community Radiative Transfer Model (CRTM) used data from the Global Data Assimilation System (GDAS) to estimate corresponding AMSR2 brightness temperatures. Regression equations were then calculated to minimize the difference between CRTM and brightness temperature estimates. A double-difference technique comparing CRTM brightness temperatures to collocated measurements from TRMM/TMI and GCOM-W/AMSR2 demonstrated that the calibration procedure eliminated the systematic bias (Fig. 1).

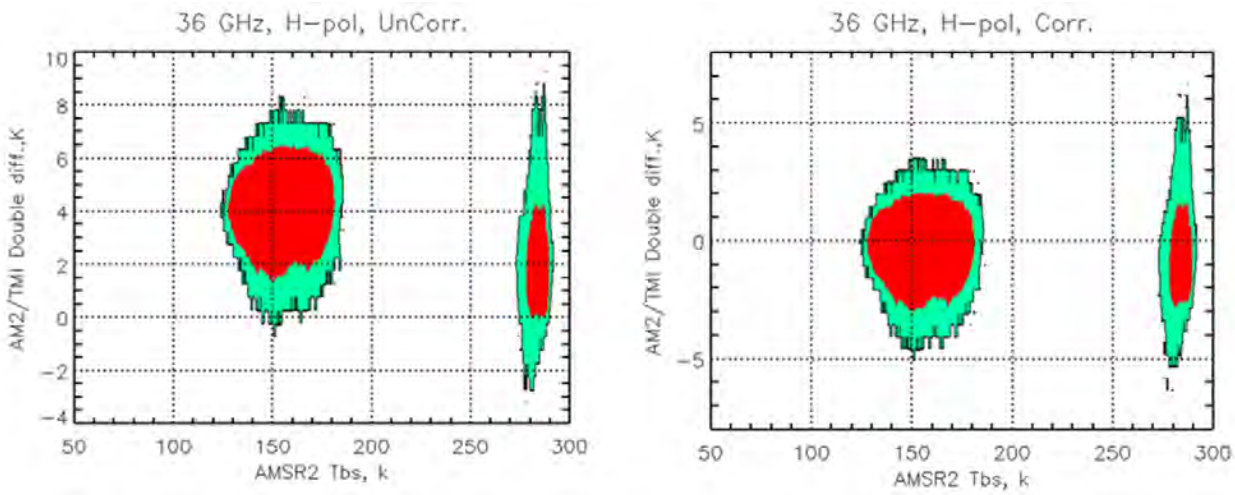


Fig. 1 – Density plot of double-difference calculations comparing AMSR2 and TMI observations to CRTM radiances for the horizontally polarized 36 GHz channels before (left) and after (right) calibration.

The GCOM-W/AMSR2 Algorithm Readiness Review demonstrated that the precipitation and ocean retrieval algorithms were ready for operational implementation. All of the derived products met accuracy and latency requirements determined by the JPSS program. Details of the algorithms were documented in Algorithm Theoretical Basis Document for the Satellite Product and Services Review Board. Routine monitoring and validation of the EDRs began following the delivery of the AMSR2 algorithms. These efforts revealed regional and temporal inaccuracies which will be addressed in future algorithm updates.

A monitoring website using a Google Earth interface was developed for display of AMSR2 EDR data (http://cics.umd.edu/~angelenabohman/mapexample.html). Users are able to overlay all of the derived EDRs from the previous 24 hours. Additionally, 2-dimensional maps of TPW, CLW, and rain rate are also available online (http://cics.umd.edu/~angelenabohman/twodimensionalmap.html; Fig. 2).

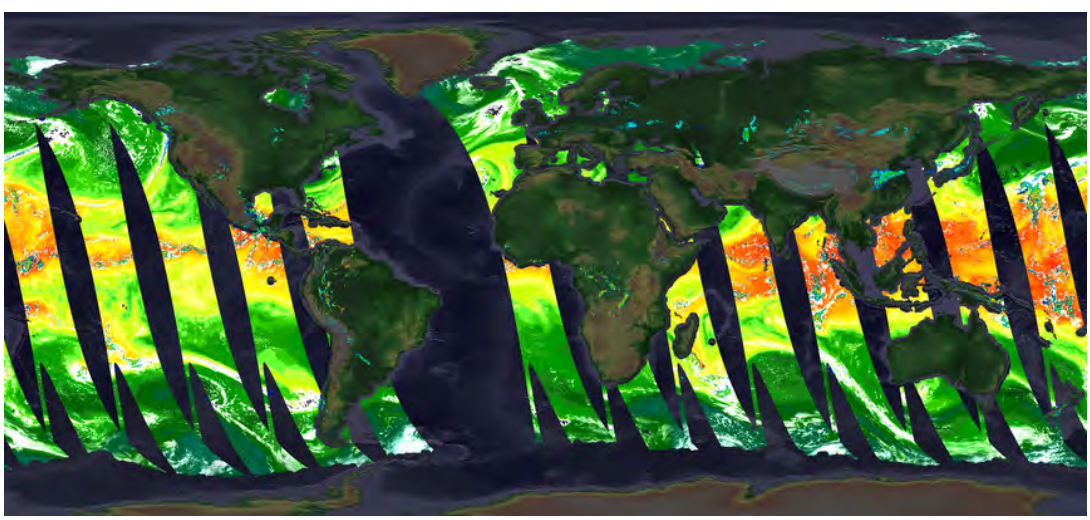


Fig. 2 – Example of daily map produced with AMSR2 TPW, CLW, and rain rate data.

In November 2014, JAXA hosted the JAXA-NOAA AMSR2 Scientific Exchange Meeting in Tokyo. Project scientists from both institutions came together to discuss their approaches for calibration, calculation, and

validation of AMSR2 SDRs and EDRs. The fruitful two-day meeting resulted in several new collaborations, and future meetings are anticipated to result in continued progress.

Planned work

- Calibration of JAXA's Version 2 brightness temperatures
- Update the Bayesian search parameters for AMSR2 Ocean EDRs
- Calibrate surface screening procedures for precipitation algorithm
- Continue monitoring AMSR2 products using ground-based observation network
- Compare GPROF2010V2 and GPROF2014 precipitation retrievals
- Reduce coastal contamination in EDRs
- Explore ingesting AMSR2 EDRs into AWIPS-II

Publications

Meyers, P., N.-Y. Wang, and R. Ferraro, 2015: Updated screening procedures for GPROF2010 over land: Utilization for AMSR-E, *J. Atmos. Oceanic Technol.*, in press.

Alsweiss, S., Z. Jelenak, P. Chang, J. Park, and P. Meyers, 2014: Inter-calibration results of the Advanced Microwave Scanning Radiometer-2 over ocean. *J. of Sel. Top. Earth Obs. Remote Sens.*, **99**.

Meyers, P., S. Alsweiss, L. Soulliard, 2014: Algorithm Theoretcial Basis Document: GCOM-W1/AMSR2 Precipitation Product. NOAA/OSP/SPSRB, 26pp.

Products

EDRs for TPW, CLW, WSPD, SST, and precipitation are routinely produced at STAR. These are in the process of being transitioned to operations by OSPO.

Presentations

Meyers, P. et al.: Validation for NOAA's GCOM-W1 AMSR2 Precipitation Product*, Precipitation Measurement Missions Science Team Meeting,* August 2014, Baltimore, MD, 104.

Meyers, P., Advances in AMSR2 Precipitation Retrievals, *CICS-MD Science Meeting*, November 2014, College Park, MD.

Meyers, P. et al.: Validation and Monitoring of NOAA's AMSR2 Precipitation Product, *7th Workshop of the International Precipitation Work Group*, November 2014, Tsukuba, Japan, P2.13.

Other

Travel grants were awarded to CICS-MD to fund travel in support of the Proving Ground and Training Center initiative. A CICS scientist will be able to travel to the AWIPS-II Experimental Products Development Team training at NASA/SPORT in Huntsville, Alabama.

Patrick Meyers attended the American Meteorological Society's Weather, Water, and Climate Day on Capitol Hill. Teams of scientists met with congressional staff to establish AMS members as a source for weather and climate information that can be used for policy decision-making.

The UMD Campus Visualization Partnership has awarded CICS/ESSIC a grant for the projected "Implementing an AWIPS-II Display at the University of Maryland". Funds from the grant were used to purchase two quad-head workstations, which will be equipped with AWIPS-II, the software package used by the National Weather Service.

Two undergraduate summer interns were employed to contribute to the project. Alex Ortiz ran the experimental lightning-propagation algorithm, and Angelena Bohman developed visualization tools for the AMSR2 EDR product suite.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**5**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**2**
# 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**

This task supported the development and monitoring of AMSR2 algorithms for precipitation, TPW, CLW, WSPD, and SST. The EDRs were calculated using two algorithm frameworks delivered to NOAA. Two peer-reviewed papers were published, as well as an Algorithm Theoretical Basis Document (see publications).

GCOM-W1 Soil Moisture Product Development and Validation

Task Leader	Dr. Jicheng Liu
Task Code	JLJL_GCOM_14
NOAA Sponsor	Dr. Xiwu Zhan
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 40%; Goal 2: 25%; Goal 3: 10%; Goal 4: 25%

Highlight : We have finished the development of GCOM-W1 AMSR2 soil moisture EDR product algorithm. The science code of the algorithm has been completed and delivered to GCOM-W1 team at NOAA/NESDIS/STAR. The code is now under integration into the production system and will be tested and go operational in the near future.

Background

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

The GCOM-W1 AMSR2 Algorithm System Package (GAASP) is designed to produce all Level 2 AMSR2 products at NOAA, and went operational in later 2014 for Day 1 products. Soil Moisture EDR algorithm will take some of the Day 1 product as inputs and will be tested, delivered and go operational in 2015.

Accomplishments

The Single Channel Retrieval algorithm (SCR) for soil moisture is selected as the primary algorithm to retrieve soil moisture values using microwave observations from AMSR2. This algorithm has been heavily tested and some of the major parameters have been tuned for better retrieval results. The science code of this algorithm has been completed and delivered to GCOM-W1 team. The output of the final soil moisture EDR code will be swath soil moisture values in both binary and HDF5 format. The integration of the science code into the GAASP is almost done but more tests will be needed before making this product operational. Figure 1 shows an example of gridded AMSR2 soil moisture product from 2013. The map shows reasonable dynamic range and spatial distribution. More validation will be need for a better evaluation of this product.

In-situ soil moisture observation data has been collected from all available Soil Climate Analysis Network (SCAN) stations. Station data from part of Climate Reference Network (CRN) are collected too. These in-situ data sets will be further processed and used to evaluate the AMSR2 EDR.

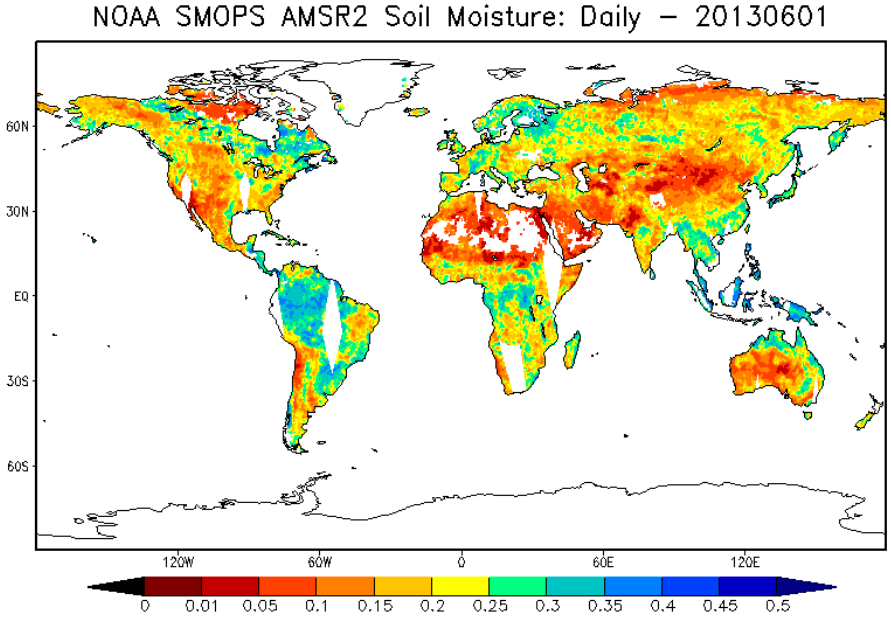


Figure 1. Daily gridded AMSR2 soil moisture product

Planned work

- Work with NOAA/NESDIS/STAR for soil moisture EDR code integration into GAASP.
- Continue working on testing and evaluating the science code.
- Continue working on collecting and processing in-situ soil moisture data.
- Validation of soil moisture EDR.

Products

- GAASP soil moisture EDR science code.
- Documents related GAASP SM EDR code.
- Collection of processors for in-situ soil moisture observations.

Presentations

- X. Zhan, J. Liu, L. Zhao, F. Weng, Global soil moisture data products from AMSR2 and other Satellite sensors. EUMETSAT 2013 Conference. Vienna, Austria, Sept 2013.
- Jicheng Liu et al., NOAA Soil Moisture Operational Product System (SMOPS): Version 2, *2014 CICS-MD Science Meeting*, November, 2014.
- X. Zhan, J. Liu, L. Fang, C. Hain, W. Zheng, M. Ek, L. Zhao, Validation and Applications of Opeational Satellite Soil Moisture Data Products of NOAA-NESDIS. EUMETSAT 2014 Conference. Geneva, Switzerland. Sept. 2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# 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**

The new GAASP SM EDR code has been delivered to NOAA/NESDIS/STAR. The improved single channel retrieval (SCR) algorithm will be used in this system to retrieve soil moisture values using AMSR2 observations.

Observing System Simulation Experiments (OSSEs) in Support of JCSDA's Contribution to NOAA's Quantitative Observing System Assessment Program (QOSAP)

Task Leader Kayo Ide
Task Code KIKI_OSSE_14
NOAA Sponsor Dr. Sid Boukabara
NOAA Office JCSDA
Contribution to CICS Research Themes (%) Theme 1: 30%; Theme 2: 40%; Theme 1: 30%
Main CICS Research Topic Data Fusion and Algorithm Development
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%; Goal 3-5: 0%;
Highlight We have just hired a postdoctoral fellow in January '15 and initiated the project. Preliminary results on OSSEs and Observation System Experiments (OSEs) were obtained using the operational 3D hybrid data assimilation system.
Link to a research web page http://www.jcsda.noaa.gov/projects.php

Background

The Joint Center for Satellite Data Assimilation (JCSDA) improves and accelerates the use of research and operational satellite data in numerical weather and climate prediction models. JCSDA provides a focal point for the development of common models and infrastructure among NASA, NOAA and DoD.

Observing System Simulation Experiments (OSSEs) provide a rigorous, cost-effective approach to evaluate the impact of the new (envisioned) observing systems and alternate deployment strategy for the existing systems, by the assimilation of synthetic observations drawn from a realistic model simulation, called a nature run (NR), into a data assimilation system (DAS). OSSEs can be also used to evaluate DAS. A clear advantage of OSSEs over any real observing system experiments (OSEs) is the availability of the NR as the truth.

Under a separate project, the JCSDA has recently proposed to develop a comprehensive OSSE framework with a focus on the assessment of geo hyperspectral and radio occultation missions. As a part of this project, the NOAA GFS hybrid DAS will be ported into the O2R environment on JCSDA/NASA Linux cluster JIBB. Once validated and tested carefully, this OSSE framework will serve as a platform to conduct various types of OSSEs.

Geo microwave sensor is an envisioned observing system that can potentially improve NOAA's forecast skill for severe weather events, especially over the oceans where observations are sparse. *Advanced Microwave Sounding Unit (*AMSU) observations from polar orbiting satellites have contributed to the improvement of weather and severe storm prediction even with the limited refresh rate. The geo microwave sensor with high refresh rate may contribute to the improvement further by providing better time-evolving information that can be useful in the 4D hybrid DAS. OSSEs will be a perfect platform to assess the potential impact of the geo microwave sensor.

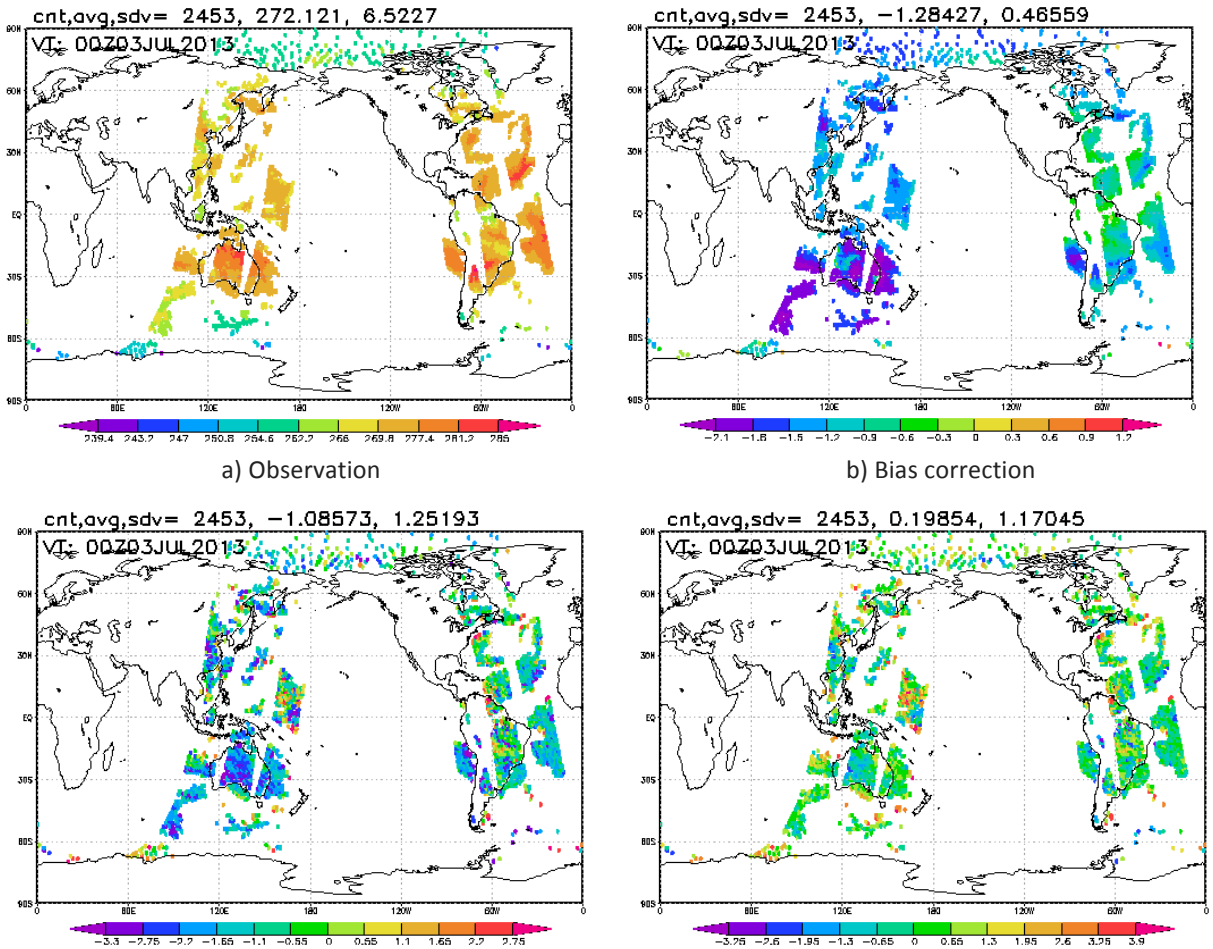
Accomplishments

With hiring of a new postdoctoral fellow in January 2015, two initial directions are currently been pursued using the operational 3D-hybrid data assimilation system:

i) Observing System Experiments (OSEs) using real observations, to investigate the impact of hyperspectral IR sensors (IAS, CR, CrIS, and AIRS); and

ii) Observing System Simulation Experiments (OSSEs) using simulated observations, to investigate the impact of the geostationary microwave observations.

Current 3D-hybrid setting is T670 deterministic and 80-member T254 ensemble Kalman filter.



a) Observation b) Bias correction

c) Background without bias correction d) Background with bias correction

Figure 1: SSMIS F18 observations, bias, and bakcgorund with/without the bias correction for July 3, 2013

All the results are preliminary and shown as example of the progress because the project is just starting and the postdoctoral fellow with her background in satellite observations and but not data assimilation is learning the operational system.

The current OSE is set up for one week, 20130701-20130708. Figure 1 the SSMIS F18 observations and the assimilated results with and without bias correction for July 3, 2013 and for the 183.31 GHz

channel. Figure 2 presents the comparison scorecard for TEST_670 with all observation assimilated while TEST2_T670 with hyperspectral IR observation being with held.

With the new postdoctoral fellow learning quickly all aspects of operational data assimilation, OSEs, and OSSEs, we expect a productive year of ’15 April through ’16 March.

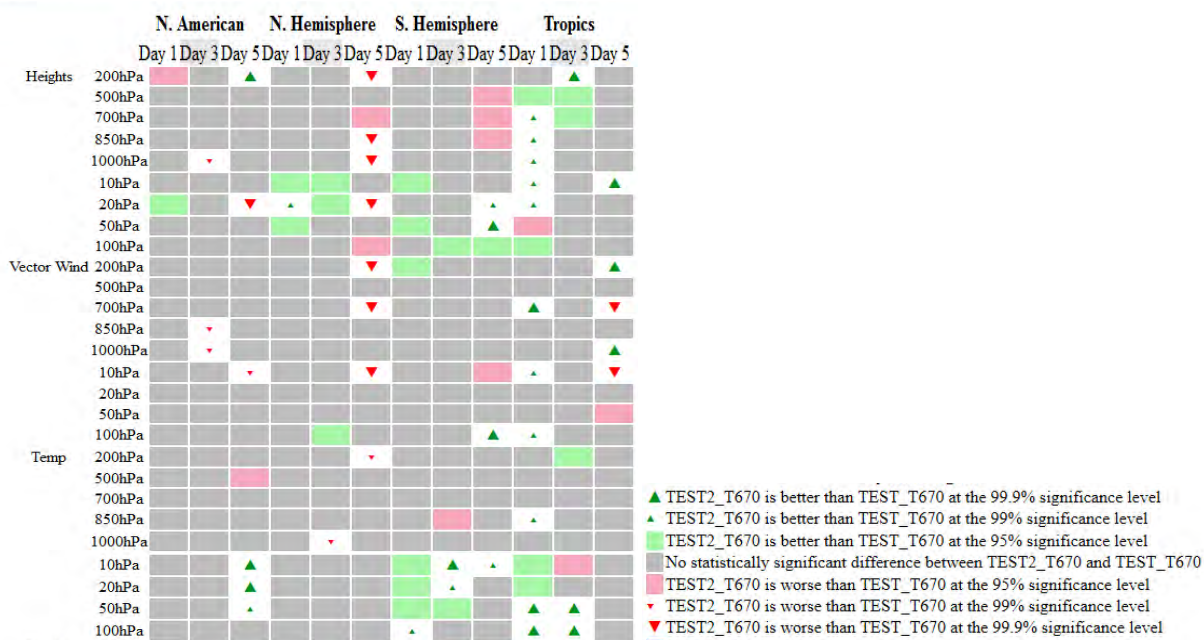


Figure 2: Scorecard comparison with all real observations (TEST_T670) and without nohyperspectral observations (TEST2_T670).

Planned work

- Coordinate with the other JCSDA project, while providing additional support on the building of the OSSE framework.
- Simulate and validate the observations for a geo microwave sensors.
- Conduct baseline OSSEs of the observations for a geo microwave sensors and assess the potential impact.
- Lay out the guideline for the prioritization of the observing systems based on the assessment of their potential impacts.
- Document and publish the results
- Coordinate with the other JCSDA project, while providing additional support on the building of the OSSE framework.
- Summarize the OSSE impact assessment.
- Document and publish the results

Other

A new postdoctoral fellow, Dr. Narges Shahroudi, show just graduated from City College of New York was hired and has been mentored by the task leader.

Performance Metrics	
# of new or improved products developed (please identify below the table)	N/A
# of products or techniques submitted to NOAA for consideration in operations use	N/A
# of peer reviewed papers	N/A
# of non-peered reviewed papers	N/A
# of invited presentations	N/A
# 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

We hired a new postdoctoral fellow in January 2015, who is being trained to perform the Observation System Simulation Experiments (OSSEs). We expect next year's performance metrics will reflect the new hire.

1.2 Calibration and Validation

Support for Diagnostic, Monitoring and Forecast Activities at the Climate Prediction Center

Task Leader Augustin Vintzileos
Task Code AVAV_CPC_2014
NOAA Sponsor Mike Halpert
NOAA Office NWS/CPC
Contribution to CICS Research Theme-3 100(%)
Main CICS Research Topic: Calibration and validation (model) 50% - Climate research and modelling (50%)
Contribution to NOAA goals Weather-Ready Nation (100%)
Highlight We are developing a subseasonal excessive heat outlook system for forecast Week-2 to Week-4. The feasibility of such a system was demonstrated and a prototype excessive heat monitoring system has been developed.

Background

Extreme heat events have had substantial toll on human lives over the contiguous United States (e.g., Sheridan et al., 2009). Longer, more intense and more frequent excessive heat events are expected in the future (IPCC report). One way towards resilience is probabilistic forecasting of heatwaves with lead times from Week-2 to Week-4. Such information would assist decision makers in distributing resources on time. In this work we first address the feasibility of such a system by exploring links between mortality spikes and subseasonal atmospheric variations. We then develop an excessive heat impact index flexible enough to accommodate the challenges of subseasonal forecasting (model biases and drifts, probabilistic information). Based on this index we develop an excessive heat monitoring system which we will use for verifying excessive heat forecasts which initially will be based on a single ensemble forecasting system (GEFS).

Accomplishments

We first addressed the feasibility of a subseasonal excessive heat outlook system by connecting abnormal mortality spikes over the CONUS to subseasonal atmospheric oscillations e.g., the Madden-Julian Oscillation (MJO). We established statistically significant modulations in the distribution of the phase of the MJO two to four weeks prior of heat related mortality spikes in several metropolitan areas. These findings suggest that it is possible to forecast (in a probabilistic sense) heatwaves at subseasonal lead times.

We then combined factors affecting health (apparent temperature, duration of heatwaves, geographic latitude and time of the year) and the challenges in subseasonal forecasting (probabilistic nature, biases and drifts of the forecast mean state) to define an Excessive Heat Impact index (EHII) as follows:

$$\mathrm{EHII}_{\alpha}(t) = -\log\left(\prod_{i=t}^{t-N} p_i\right)$$

With p_i the probability of occurrence of the apparent temperature of the day exceeding the α percentile for $N \geq 2$ consecutive days. Calculations take place on each grid point and probabilities are empirically computed using past observations within a window of one month from the considered day.

We then used the EHII to develop a prototype excessive heat monitoring system based on the NCAR/NCEP Reanalysis which runs from 1948 to present. An example of this monitoring system is shown in Figure 1a for the 1955 heatwave that affected Los Angeles and in Figure 2 for the 1995 heatwave which affected Chicago.

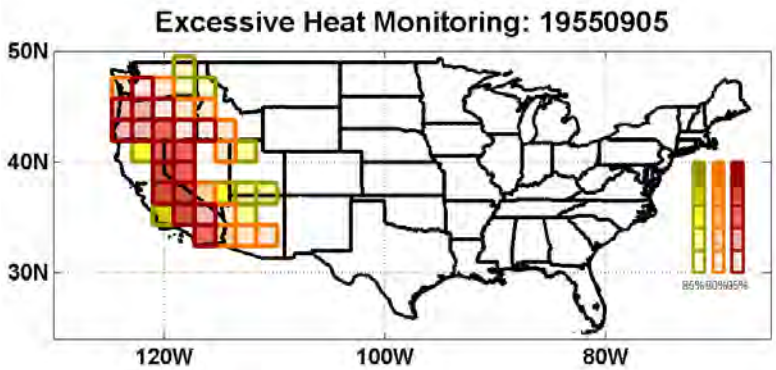


Figure 1: The Los Angeles 1955 heat event.

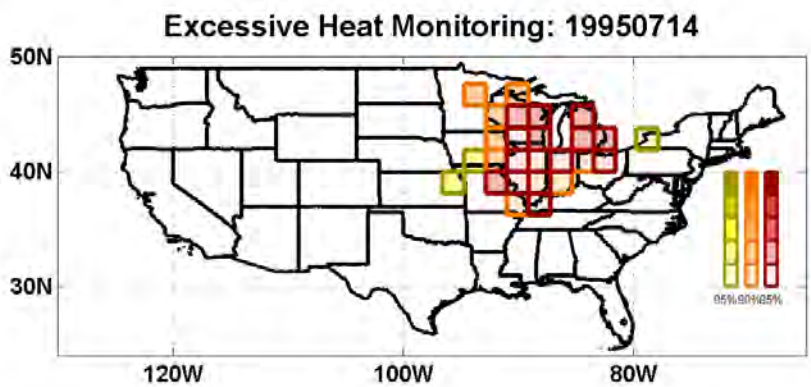


Figure 2: The Chicago 1995 heat event.

We are currently using the GEFS reforecast database from 1985 to 2014 in order to assess its forecast skill of the EHII.

Planned work

- Fine tune the monitoring/verification system based on heat related mortality data.
- Develop and test a quasi-operational realtime monitoring system for use during the 2015 summer season.
- Compute model biases and forecast performance for apparent temperature, temperature, humidity and the EHII starting with the GEFS model.
- Test the system under realtime conditions in summer 2015. We expect to have a prototype forecasting system by September 2015
- Develop the forecasting system to be operational on realtime during summer of 2016.
- Based on lessons learned design and develop the next generation of the system.

- Investigate the value added by the subseasonal NMME and international operational subseasonal forecasting systems to the operational subseasonal excessive heat forecasting system.
- Extend the system to Week-3 and Week-4.

Products

- Excessive Heat Monitoring System

Presentations

Vintzileos, A. et al., 2015: Towards a subseasonal excessive heat outlook system. *13th Climate Prediction and Applications Science Workshop*, 23-26 March 2015, Las Cruces, New Mexico.

Vintzileos and co-authors, 2015: Towards a subseasonal Excessive Heat Outlook system, *Climate Services Program Managers Face-to-face Meeting*, College Park, MD.

Vintzileos and co-authors, 2015: Investigating co-variability between mortality and slow atmospheric oscillations, 10th Symposium on Societal Applications: Policy, Research and Practice, *95th AMS Annual meeting*, Phoenix, AZ

Vintzileos and co-authors, 2015: Heat waves and MJO: prospects for subseasonal excessive heat outlooks. Third Symposium on Prediction of the Madden-Julian Oscillation: Processes, Prediction and Impact, 95th *AMS Annual meeting*, Phoenix, AZ

Vintzileos, A. and co-authors, 2014: Investigating links between mortality and slow atmospheric variations. *International Congress on Biometeorology* (ICB): 28 Sept - 1 Oct, Cleveland, OH

Vintzileos, A., 2014: Climate/Weather and Health. *US-THORPEX Legacy Planning Meeting*, Silver Spring, MD, June, 2014.

Vintzileos, A. and J. Gottschalck, 2014: Realtime Monitoring and Forecast Support for DYNAMO. *DYNAMO Webinar Series*, 28 May 2014.

Vintzileos, A. *et al.*, 2014: Investigating links between mortality and climate. *12th Climate Prediction Applications Science Workshop*, 6-8 May 2014, Fairfax, Virginia.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Improving the real-time monitoring and attribution of subseasonal tropical variability at NOAA Climate Prediction Center

Task Leader:	Augustin Vintzileos
Task Code:	AVAV_OLR_14
NOAA Sponsor:	Pingping Xie
NOAA Office	NWS/CPC and NESDIS
Contribution to CICS Research Themes	Theme 2 (100%)
Main CICS Research Topic:	Calibration and Validation
Contribution to NOAA goals	Weather-Ready Nation (100%)

Highlight: We have developed an algorithm to calibrate IASI OLR data based on AVHRR observations.

Background

In the tropics convective activity can be monitored by satellites measuring the outgoing longwave radiation (OLR). Therefore, observations of OLR can provide not only monitoring of subseasonal climate variations but also a better understanding of the underlying physical processes. NOAA has been a pioneer in the climate applications of satellite observed data. Observations of the infrared window channel brightness temperatures by the Advanced Very High Resolution Radiometer (AVHRR) are converted to OLR by sophisticated conversion techniques, an effort that started in the late 1970s (Gruber and Winston, 1978; Gruber et al. 1985). CPC established an objective analysis system to construct gridded analyses from the level-2 AVHRR OLR orbital data (Janowiak et al. 1985). These data are used operationally by the GTH to monitor subseasonal variability and for verifying the Week-1 and Week-2 outlooks. The current generation OLR dataset has a number of shortcomings (e.g. coarse time and space resolution, artificial trends and discontinuities caused by orbit shifts *etc*). Meanwhile, there was substantial progress in satellite observations from sensors including the Atmospheric Infrared Sounder (AIRS), the Infrared Atmospheric Sounding Interfermeter (IASI) and the Cross-track Infrared Sounder (CrIS) (Goldberg et al. 2003; Sun et al. 2010; Sun and Goldberg 2011). Recently, NESDIS Operations has started the routine production of the level-2 OLR orbit data from the IASI hyperspectral measurements onboard the MetOp-A satellite that is used by CPC to generate a gridded experimental OLR product on a much finer spatial and temporal scale (0.25° x 0.25° versus 2.5° x 2.5° and daily versus pentad). Improved quantitative accuracy, together with refined resolution of the new IASI provide rare opportunity to improve the monitoring and documentation of the tropical convective activities associated with MJO and other major intra-seasonal variability. In the proposed work we will validate this new experimental IASI-OLR product by comparing it to the operational AVHRR-OLR dataset.

Accomplishments

We developed and tested a mapping algorithm for calibrating IASI OLR data based on AVHRR OLR data. This calibration technique is based on computing cumulative distribution functions for both AVHRR and IASI using data within a common space-time window. We conducted sensitivity analysis to the geographical extend of the window; a sufficient window was defined as a 5°x5° window around the grid point under consideration. We identified that calibration is seasonally depended and experimented with time windows of different length; a 3 month window around the time of calibration was judged satisfactory. A demonstration of the algorithm is shown in Figure 1 for the case of random data from two normal distributions with different means and standard deviations. The mapping consists of computing the percentile of value 1 from distribution 1, then mapping this percentile to distribution 2 from where the corresponding value 2 is obtained (Figure 1a).

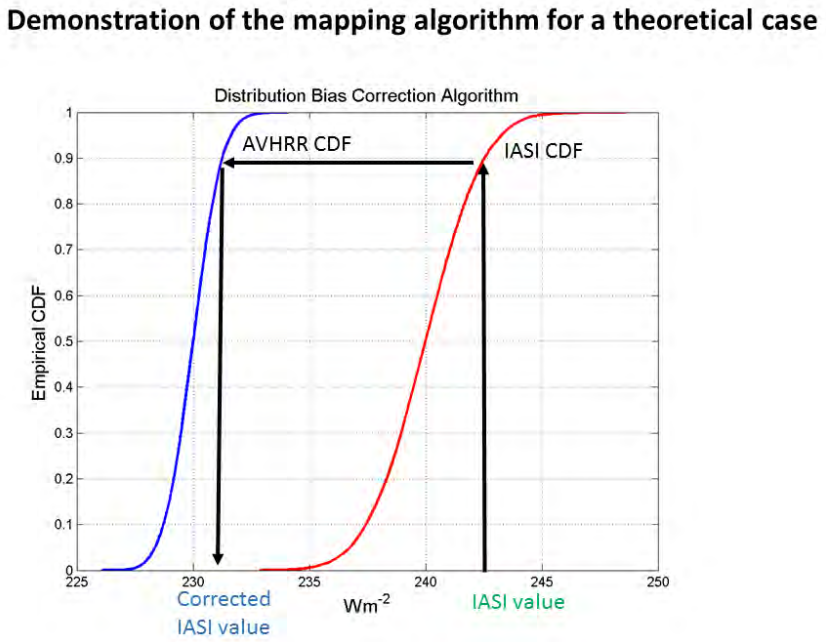


Figure 1a: Graphical demonstration of the mapping algorithm.

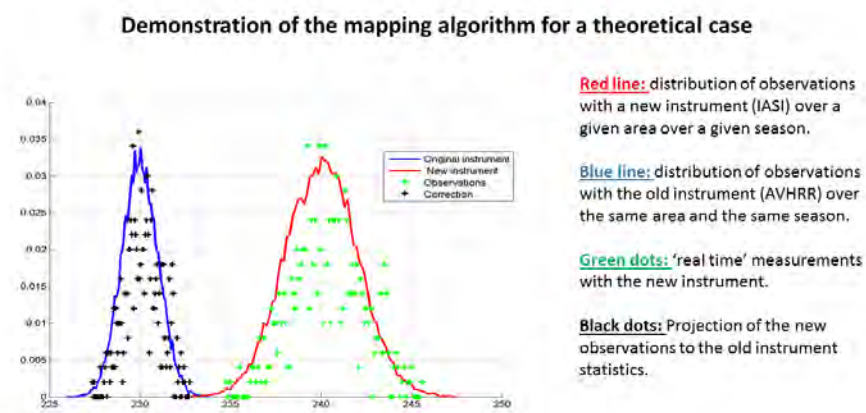


Figure 1b: Example of mapping based on two Gaussian distributions with different mean and standard deviation.

Figure 2 shows an example of the calibration technique applied to observed OLR data. The upper panel shows the systematic difference between IASI and AVHRR. As expected, the highest amplitude differences are located in areas of subsidence (clear sky) where values of humidity are large. The impact of the calibration technique is shown in the lower panels of Figure 2. The technique reduces significantly the systematic differences.

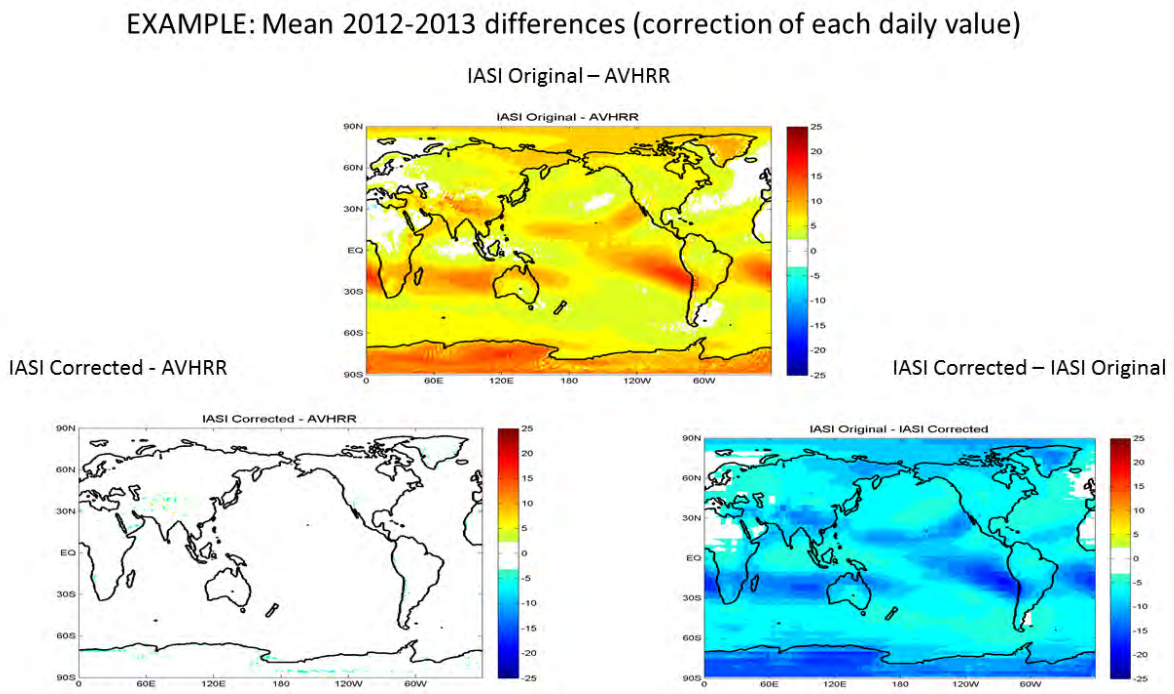


Figure 2: Mean values of IASI minus AVHRR data for the period 2012-2013 (upper panel). Mean values of the calibrated IASI OLR data minus the AVHRR OLR data (lower left panel). Mean impact of calibration of the IASI data (lower right panel).

Planned work

The work has successfully reached its conclusion.

Presentations

Vintzileos, A. et al., 2015: Towards a subseasonal excessive heat outlook system. 13th Climate Prediction and Applications Science Workshop, 23-26 March 2015, Las Cruces, New Mexico.

Vintzileos and co-authors, 2015: Towards a subseasonal Excessive Heat Outlook system, Climate Services Program Managers Face-to-face Meeting, College Park, MD.

Vintzileos and co-authors, 2015: Investigating co-variability between mortality and slow atmospheric oscillations, 10th Symposium on Societal Applications: Policy, Research and Practice, 95th AMS Annual meeting, Phoenix, AZ

Vintzileos and co-authors, 2015: Heat waves and MJO: prospects for subseasonal excessive heat outlooks. Third Symposium on Prediction of the Madden-Julian Oscillation: Processes, Prediction and Impact, 95th AMS Annual meeting, Phoenix, AZ

Vintzileos, A. and co-authors, 2014: Investigating links between mortality and slow atmospheric variations. International Congress on Biometeorology (ICB): 28 Sept - 1 Oct, Cleveland, OH

Vintzileos, A., 2014: Climate/Weather and Health. US-THORPEX Legacy Planning Meeting, Silver Spring, MD, June, 2014.

Vintzileos, A. and J. Gottschalck, 2014: Realtime Monitoring and Forecast Support for DYNAMO. DYNAMO Webinar Series, 28 May 2014.

Vintzileos, A. *et al.*, 2014: Investigating links between mortality and climate. 12th Climate Prediction Applications Science Workshop, 6-8 May 2014, Fairfax, Virginia.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

GEOG Task 1: AVHRR Surface Reflectance FCDR, the Normalized Difference Vegetation Index TCDR, the Leaf Area Index TCDR and the Fraction of Photosynthetically Active Radiation TCDR

Task Leader Chris Justice
Subtask Leader Dr. Eric Vermote
Task Code CJCJ_AVHRR_14
Main CICS Research Topic Calibration and Validation
Percent contribution to CICS Themes Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
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 been promoted to provisional status on March 17,2014 and Validated Stage 1 on September 4, 2014 and VCM is now at validation stage 2. The methods and metrics for evaluation are well in place and a paper in RSE summarized our evaluation. We presented our results in several national and international meetings.

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. 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 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 numerous set of VIIRS surface reflectance product performance (accuracy, precision and uncertainty, APU) for both IDPS version (Figure 2) and improved reprocessed Land PEATE version (Figure 3a-b). This analysis has focused primarily on the validation subset and also applied to the MODIS data.
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)

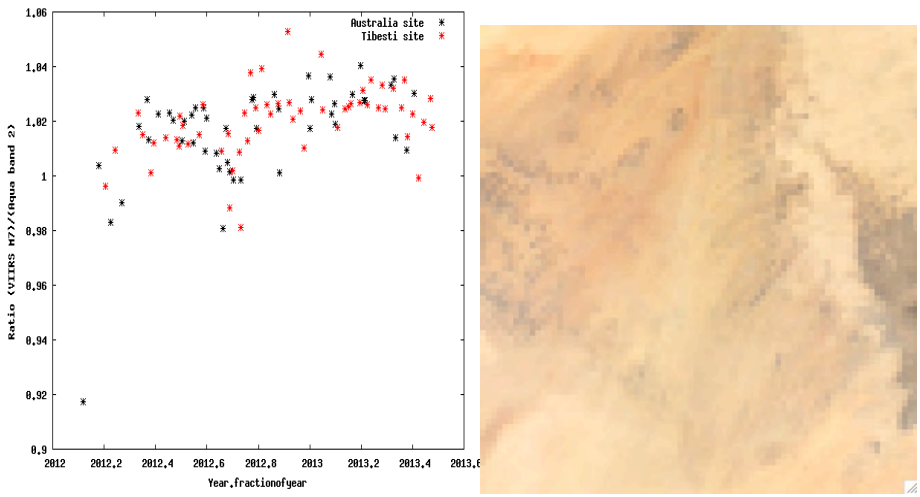


Figure 1: Example of VIIRS continuous calibration monitoring in band M7 (Near-Infrared) over two sites, one over Australia (black symbol) and one over Tibesti (~40km x 40km) (red symbol) (left side). The true color image of the Tibesti calibration site is shown on the right side.

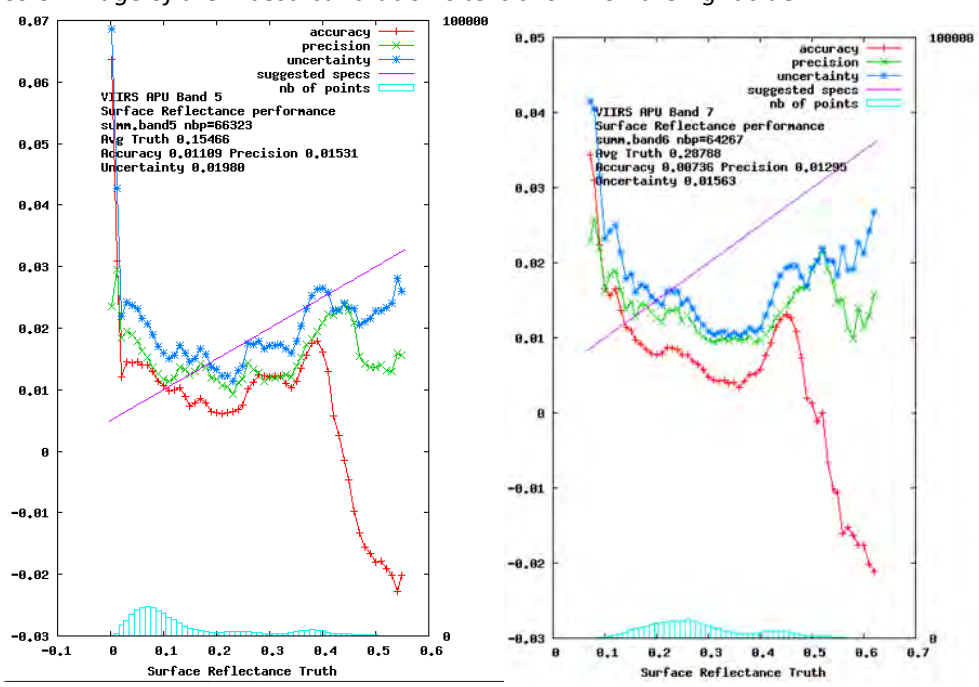


Figure 2: Estimates of VIIRS surface reflectance Accuracy Precision and Uncertainty performances for VIIRS for band M5 (red), Left panel and M7 (Near-Infrared), Right Panel. The surface reflectance 'truth' is computed using the 6S radiative transfer code and the AERONET data for 2012.

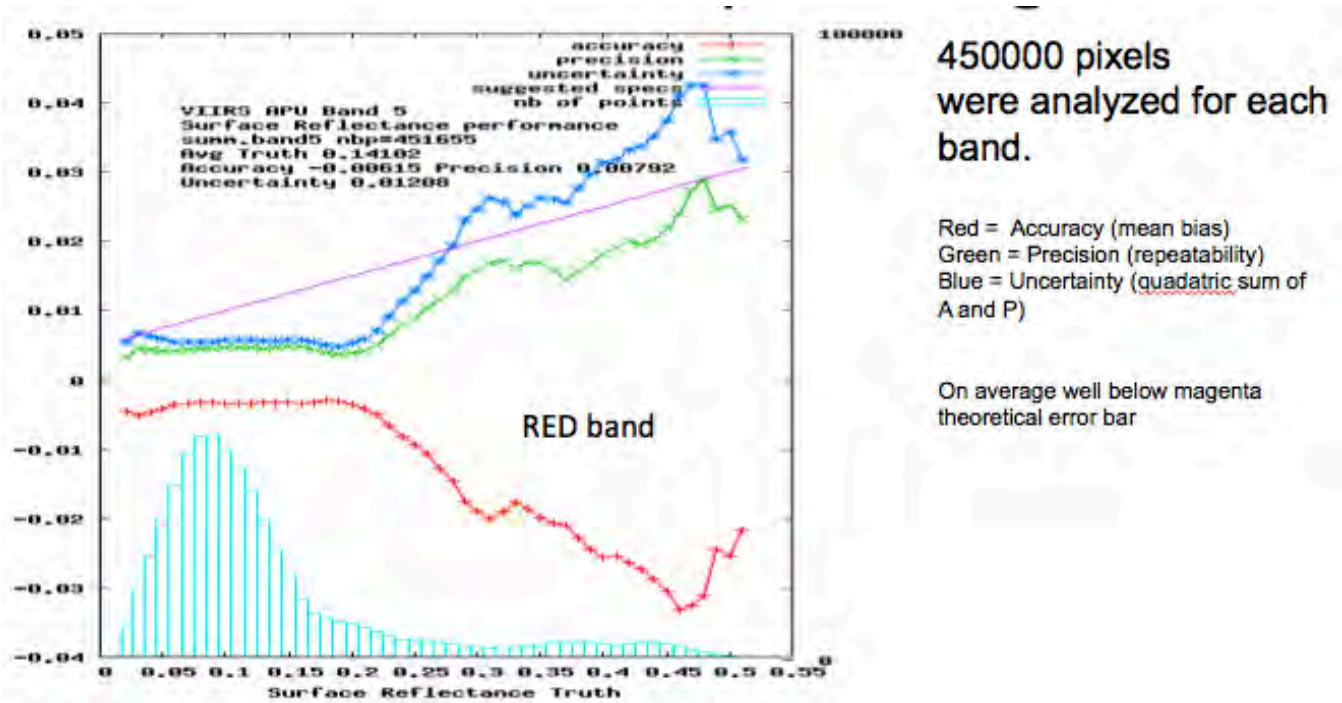


Figure 3a: Performance of the C1.1 reprocessing (APU) for the VIIRS red spectral band over AERONET sites.

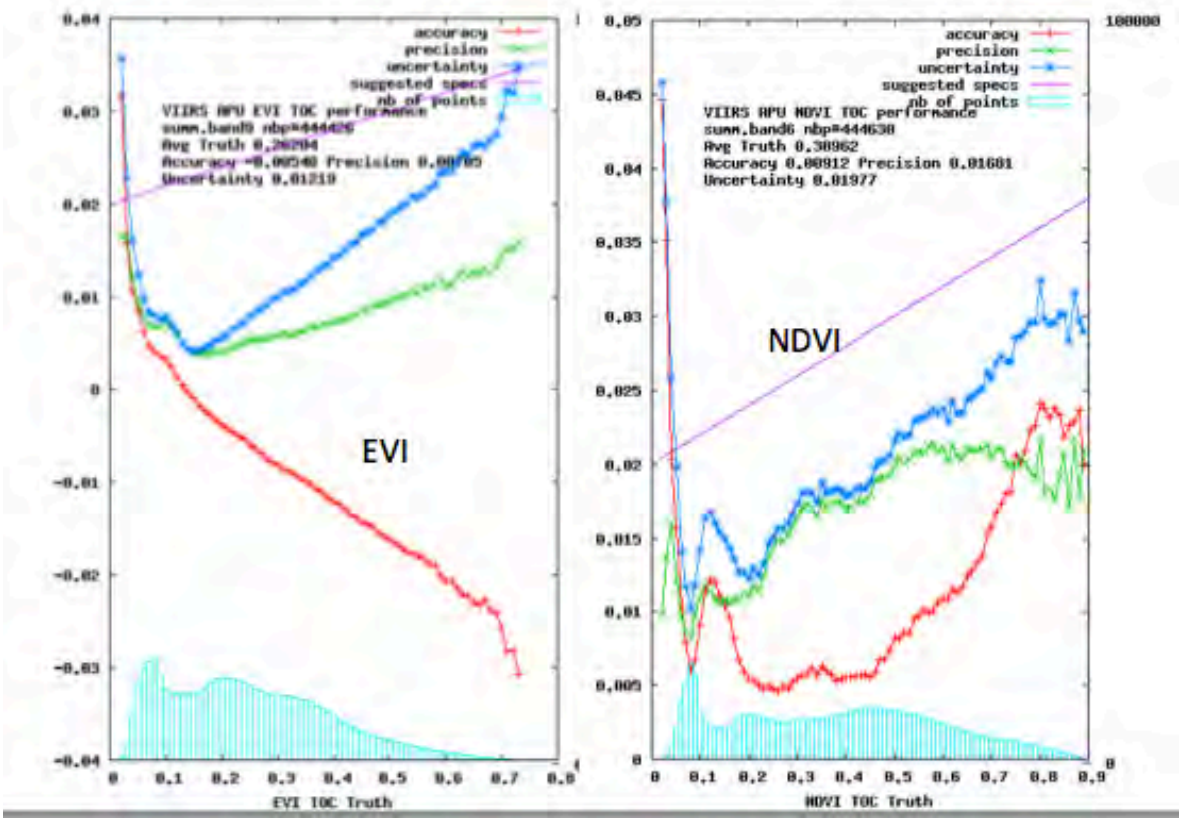


Figure 3b: Same as Figure 1a but the EVI (left) and NDVI (right).

Planned Work

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

Publications

Eric Vermote , Chris Justice, Ivan Csiszar, Early evaluation of the VIIRS calibration, cloud mask and surface reflectance Earth data records, **Remote Sensing of Environment**, Volume 148, 25 May 2014, Pages 134-145, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2014.03.028

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

Vermote E., "MODIS/VIIRS Surface Reflectance", NASA Terrestrial Ecology Site Visit, NASA/GSFC, Mar 30-31, 2015.

Vermote et al., "Challenge with atmospheric correction over Land", CEOS Working Group on Calibration and Validation, Dresden, Germany, Feb 24-25, 2015.

Vermote et al., "Land Long Term Climate Data Records from AVHRR, MODIS and VIIRS", 95th AMS Annual meeting, Phoenix Arizona, Jan 4-8 2015.

Vermote et al., "VIIRS surface reflectance overview", 1st Suomi-NPP Land Workshop at GSFC on December 3-4.

Vermote et al., "Transitioning VIIRS Observations into the Global Agriculture Monitoring (GEOGLAM) system: Status and Long-term Prospective", "Landsat surface albedo product based on MODIS data"," Directional signatures of land surface reflectances: Measurements and corrections", 4Th International Symposium on Recent Advances in Quantitative Remote Sensing, Torrent, Spain 22-26 Sept 2014

Vermote et al., "Validated Stage 1 Science Maturity review for VIIRS surface reflectance", NOAA, College Park, Sept 4 2014.

Vermote E., "Vicarious calibration of large field of view sensors, AVHRR, MODIS and VIIRS using invariant sites", IGARSS 2014, Quebec, Canada, July 13-18 2014

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.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**0**
# of invited presentations	**9**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**1**

GEOG Task 2: NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Science and Management Support for NPP/JPSS VIIRS Land Surface Albedo Product-Land Surface Albedo

Task Leader Shunlin Liang/Dongdong Wang
Task Code SLSL_VIIRS_14
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 successfully achieved the status of provisional and V1 in the past year. We assessed the quality of the current surface albedo EDR data and compared them with the existing products. We developed the temporal filter to further improve the quality of albedo retrievals.

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. Assessing LSA algorithms and products

We collected LSA measurements from various ground monitoring networks across the world. However, because VIIRS data are available only after 2012, not many stations currently provide measurements inthe recent years. Data at 35 sites, including AmeriFlux, BSRN, GC-Net and SURFRAD, were obtained (Figure 1). High spatial-resolution satellite imagery was then used to evaluate the spatial representativeness of the ground measurements. Only spatially homogeneous sites were used for data validation.

VIIRS and MODIS both produce high-quality surface albedo over non-snow pixels with root mean square error (RMSE) of 0.024 and 0.032 respectively. The VIIRS retrievals have a small negative bias of 0.006, whereas MODIS underestimates snow-free albedo by 0.026 (Figure 2). Compared to snow-free data, estimation of snow albedo generally faces more challenges. Both VIIRS and MODIS data significantly underestimate snow albedo (Figure 3). RMSEs of snow albedo are also much higher, twice greater than snow-free cases. Because of large solar zenith angles over high latitudes snow pixels, uncertainties in modeling BRDF will likely generate larger variations in albedo retrievals than cases at lower latitude. Besides, cloud detection over snow-covered surfaces becomes more difficult due to the similarity in optical characteristic between snow and clouds. The spurious extremely low values in both VIIRS and MODIS are likely caused by the undetected cloud coverage. The temporal filter can effectively exclude pixels affected by undetected clouds or cloud shadows. After filtering, the bias of VIIRS retrievals is reduced from -0.039 to -0.023 and RMSE is reduced from 0.084 to 0.065.

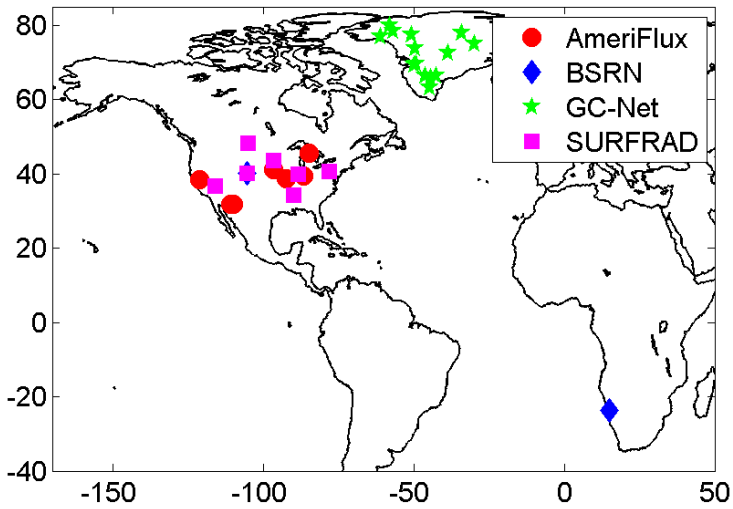


Figure 1. Map of ground stations with albedo measurements in Suomi NPP years.

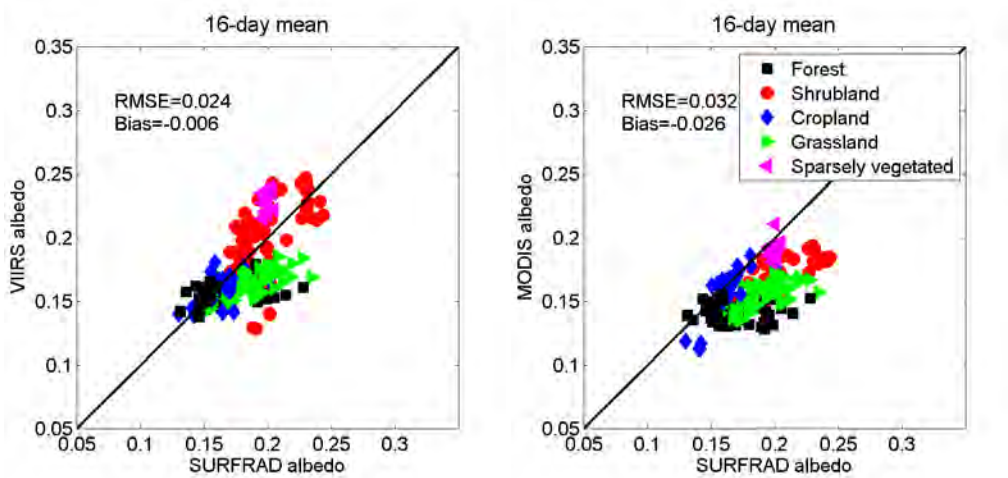


Figure 2. Validation results of 16-day mean snow-free albedo from VIIRS and MODIS.

2. Temporal filtering

The direct estimation approach uses a single clear-sky observation. It has the capability of capturing rapidly-changing surfaces, such as vegetation greening-up, ephemeral snow and snow melting events. However, such methods are also sensitive to uncertainties in individual observations, such as errors in cloud detection. Besides, albedo retrievals are only available for clear-sky pixels. Clouds will lead to data gaps in LSA. To address the two issues, we conducted some post-processing over the LSA retrievals. We applied the LOWESS (locally weighted scatterplot smoothing) filter to exclude spurious values and fill data gaps.

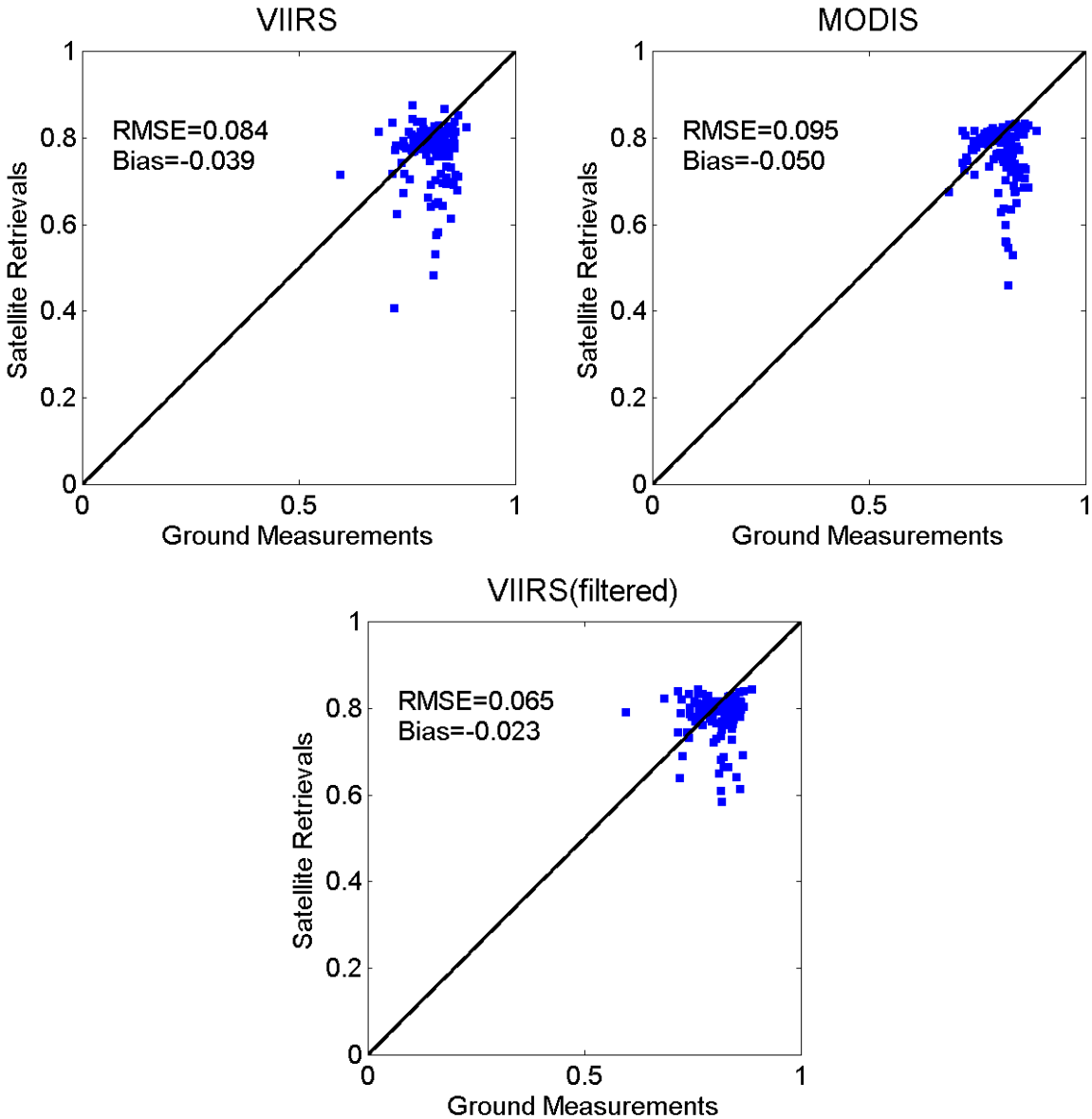


Figure 3. Scatter plots between snow albedo measured over GC-Net sites and those retrieved from various satellite data.

3. Developing long-term monitoring tool

Long-term monitoring (LTM) of land surface albedo is important to 1) help identify issues in the albedo EDR, 2) detect long-term changes of land surface albedo, and 3) attribute the changes to climate and anthropogenic drivers. We are working on developing an independent LTM tool, which can be run separately, suitable for routine monitor of albedo EDR and able to quickly respond to emergency situations.

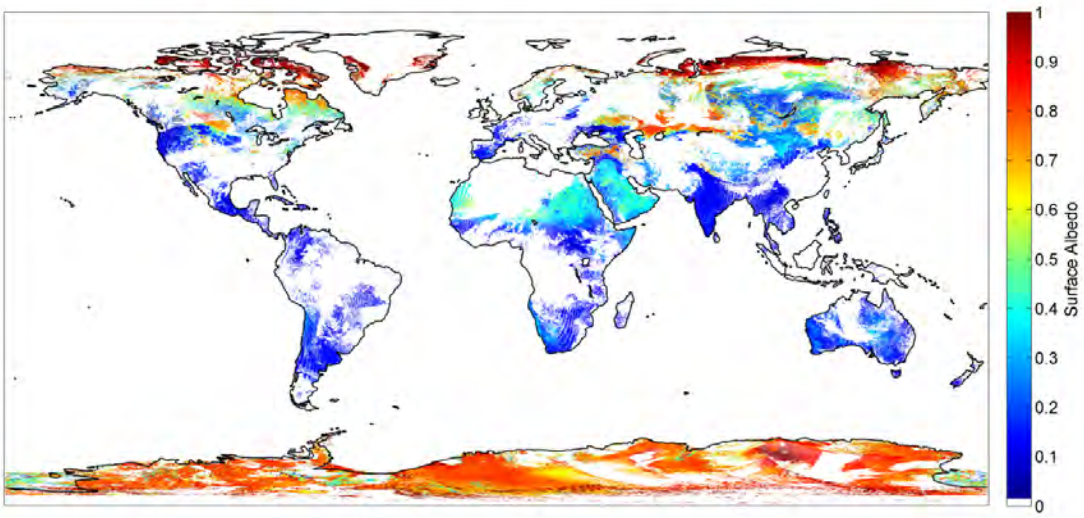


Figure 4. An example of global map of VIIRS land surface albedo acquired on Feb 22 2015.

Planned Work

- Continuing to validate the albedo product;
- Developing snow-specific LUT;
- Developing long-term monitoring tool;
- Updating LUT for sea ice surface albedo.

Publications

Wang, D.; Liang, S.; He, T.; Yu, Y.; Schaaf, C.; Wang, Z. Estimating daily mean land surface albedo from MODIS data. *Journal of Geophysical Research- Atmosphere*, *submitted*.

He, T., S. Liang, and D. Song. (2014). Analysis of global land surface albedo climatology and spatial-temporal variation during 1981-2010 from multiple satellite products. *Journal of Geophysical Research: Atmospheres*, 119, 10281-10298

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**2**
# of graduate students formally advised	**2**
# of undergraduate students mentored during the year	**0**

GEOG Task 3: NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Science and Management Support for NPP VIIRS Surface Type EDR-Land Surface Type

Task Leader	Chengquan Huang
Task Code	CHCH_VIIRS_14
NOAA Sponsor	Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS Themes (%)	Theme 1: 20%; Theme 2: 70%; Theme 3: 10%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 25%; Goal 2: 25%; Goal 3: 0%; Goal 4: 25%; Goal 5: 25%
Highlight	Surface Type EDR Passed Validated 1 maturity review
Link to a research web page	http://vct.geog.umd.edu/viirs-surface-type-development-validation-and-algorithm-refinement/

Background

This report summarizes the work of ongoing NOAA project entitled "NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Science and Management Support for NPP VIIRS Surface Type EDR". The purpose of this project is to develop the surface type environmental data record products using the VIIRS sensor onboard the JPSS/NPP satellite, which represents the continuity of the POES AVHRR and EOS MODIS land cover products. In FY14, a new validation framework for evaluating the quality of surface type products has been proposed and implemented, and the generated global surface type classification map and environmental data record products have been successfully validated using the new framework. The validation results suggested that the developed global surface type map and EDR have exceeded the required classification accuracy threshold. The validated surface type classification data has been delivered to the Interface Data Processing Segment (IDPS) system, and has been activated in the production environment in Nov. 2014. The new validated surface type EDR also passed the validated 1 stage maturity readiness review in Dec. 2014. Meanwhile, researches have been conducted to further improve the surface type products. Post-classification modelling were performed on the original classified data, which would refine the separation of cropland and similar vegetation types. A new classification algorithm support vector machines (SVM) has been implemented to classify the annual metrics data to generate the new global classification map, which is still an ongoing study. The accomplished work leads to several oral and poster presentations in workshops and conferences, and a manuscript introducing the entire development and validation process of surface type products is being prepared for submission to a peer-reviewed journal.

Accomplishments

A new validation framework has been proposed and developed for the surface type EDR products. The main strategy for validating the surface type product is visually comparing the classified surface type pixels against high spatial resolution images as the ground truth or reference data. Here, satellite images provided by Google image services were the primary high resolution data source. An integrated validation tool was developed to facilitate the visual interpretation, which was previously conducted in Google Earth software. The validation tool is able to dynamically retrieve Google Map/Earth satellite images for the requested validation areas, and interactive exploration and zoom features would help to increase the confidence of the visual interpretations. Approximately 5000 validation points have been randomly selected based on the stratified random sampling approach. Each validation points have been manually inspected, and actual ground land types are determined by interpreters. The validation results were measured in a confusion matrix, and the overall accuracy showed 73.92% correct classification rate, which exceeds the

70% accuracy threshold in the level 1 requirement document of the JPSS. Major interface of the validation tool is shown in figure 1.

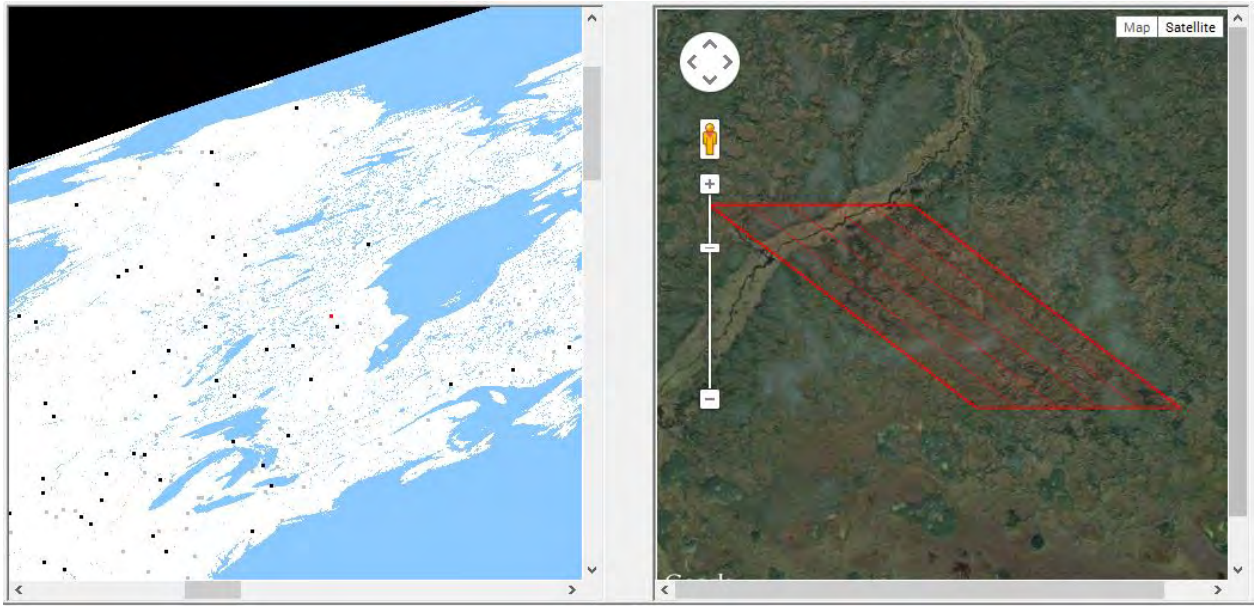


Figure 1. Major interface of the validation tool. Left panel is the plot of geolocations of the validation points. Right panel is the retrieved corresponding high resolution image from the Google Map service.

The new validated global surface type map has been delivered and implemented into the IDPS in the Nov. 2014, and the surface type EDR products have been produced based on the new surface type map (intermediate product). All downstream EDR teams have evaluated the new validated surface type map, and found no negative impacts on their products so far. These validation efforts have been presented in the validated 1 stage maturity readiness review for the surface type EDR in Dec. 2014. The review concluded that the surface type EDR products met the product's specifications. The scientific review board approved that the surface type products proceeded to the validated 1 phase. The algorithm engineering review board also approved the validated 1 review in Mar. 2015.

Besides the major validation and delivery efforts, studies for the algorithm refinement have also been conducted at the same time. A post-classification modelling process has been performed onto the global surface type classification map, especially to the cropland class, in which an external crop probability data has been used to increase the confidence of the croplands. The modelling significantly reduced the errors which were found in previous validations, and confusions among croplands and similar vegetative classes have been lowered. This work has been integrated into the delivered surface type products. Another study is the implementation of the support vector machines classification algorithm in generating the new global surface type map. Software suite has been developed and tested, and global data classification and further improvements are in progress. Preliminary experimental results showed that the SVM classified map presented less speckle noise compared to the map generated by the original C5.0 decision tree classification. Further studies and refinements are needed before any conclusive results can be made. See comparison in figure 2 for example.

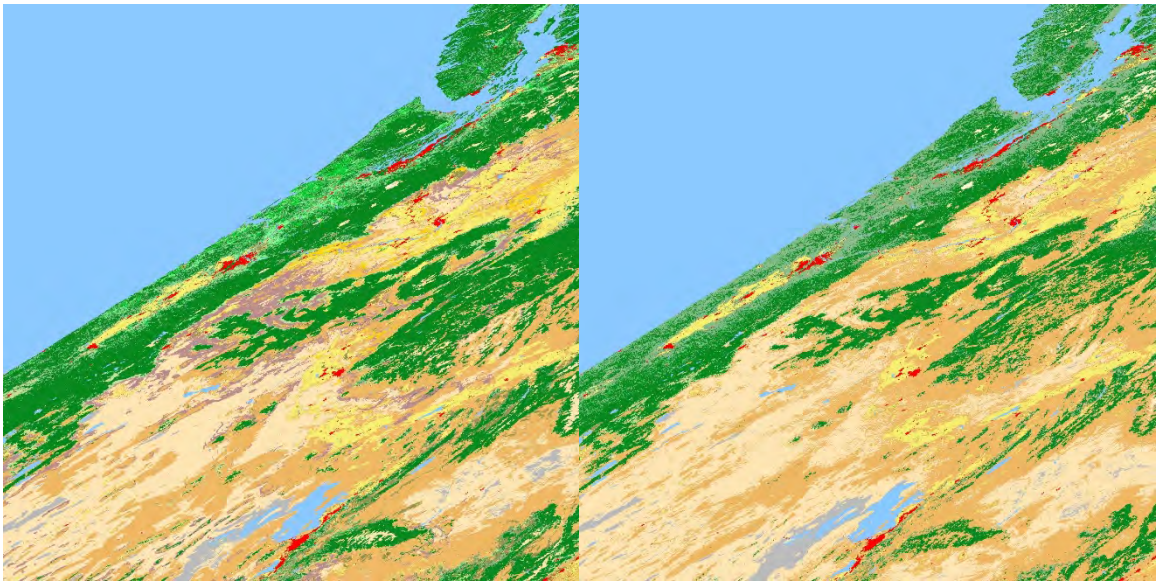


Figure 2. SVM classification result (left) vs. C5.0 decision tree classification result (right) for part of the North America area.

The surface type EDR data has been successfully utilized in mapping a major flood event in city of Asuncion, Paraguay, following the NOAA's request, which has been reported in http://www.star.nesdis.noaa.gov/jpss/ParaguayFlooding.php . The detailed result is also presented in an invited oral presentation in an international symposium.

Planned work

- Continue working on algorithm refinement of the surface type EDR products, including collecting more representative training samples globally, and assessing individual annual metrics.
- Continue working on generating new classification map using the SVM algorithm.
- Refine validation tool and datasets. Prepare the validated 2 stage maturity review.
- Further verify quality flags in the surface type EDR data.

Products

- Global surface type classification map (intermediate product) with the validated 1 maturity.
- Software suite for the surface type products validation.
- Updated algorithm theoretical basis document.

Presentations

Rui Zhang, Chengquan Huang, Xiwu Zhan and John J. Qu. 2014. Impacts of severe storms monitored from VIIRS: flooding, vegetation cover loss, and night light reduction. *International Symposium on Weather and Climate Extremes, Food Security and Biodiversity*. Oct. 20-24. Fairfax, VA, USA

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**1**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

This year, a new validated 1 phase global surface type map and EDR products have been developed and validated (1). The validated 1 surface type map has been delivered to NOAA. After comprehensive testing and evaluation, the new product has been implemented into the production environment IDPS, which is operated by Raytheon (1). An invited talk focusing on severe storm monitoring using VIIRS surface type related data has been made in an international symposium (1). Because the team focused on product development, validation and series of reviews for products delivery, no paper has been published during this period of time. But a manuscript describing the process of surface type data development and validation is under preparation, and will be submitted soon. Two poster presentations have been scheduled in Apr. 2015, and more events in coming months will be scheduled.

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

Task Leader Jingfeng Huang
Task Code EBJH_JPSS_14
NOAA Sponsor Shobha Kongdragunta, Istvan Laszlo
NOAA Office National Environmental Satellite Data and Information Service
Contribution to CICS Research Themes (%) Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic Calibration and Validation; Future Satellite Programs (Scientific Support for the JPSS Mission)
Contribution to NOAA goals (%) Goal 1: 20%; Goal 2: 80%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%
Highlight We have maintained and improved the S-NPP VIIRS Operational Aerosol Algorithm on the NOAA IDPS, conducted intensive Calibration and Validation of the VIIRS Aerosol Products, and provided the validated Products of daily global aerosol observations to user communities to support research and operational activities in weather, climate, and air quality.
Link to a research web page http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/

Background

As part of the NOAA Joint Polar Satellite System (JPSS) mission, the Visible Infrared Imaging Radiometer Suite (VIIRS) launched aboard the Suomi National Polar orbiting Partnership (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 include Aerosol Optical Thickness (AOT) and Aerosol Particle Size Parameter (APSP), and Suspended Matter (SM). The operational S-NPP VIIRS aerosol products are produced by the aerosol algorithm running at NOAA JPSS Interface Data Processing Segment (IDPS), and are publicly accessible from NOAA's Comprehensive Large Array-data Stewardship System (CLASS, http://www.class.ngdc.noaa.gov).

The Calibration and Validation (Cal/Val) of the S-NPP VIIRS Aerosol Products went through Pre-launch, Early Orbit Checkout, Intensive Cal/Val, and is now at the Long-Term Monitoring stage. The Cal/Val experience and the improved algorithms from the S-NPP satellite operation will be applied to future observations from JPSS's J1 satellite and subsequent JPSS satellites (J2/J3).

The S-NPP VIIRS aerosol products are maintained and improved by NOAA's Satellite and Information Service (NESDIS) Center for Satellite Applications and Research (STAR) Aerosol Calibration/Validation (Cal/Val) Team lead by Istvan Laszlo and Shobha Kondragunta. The team of scientists at the University of Maryland Cooperative Institute for Climate studies (CICS-MD) aims for continued research and data management work on the S-NPP VIIRS aerosol algorithm assessment and improvement. CICS-MD scientists will also support future JPSS/J1 VIIRS aerosol Cal/Val activities with the transition of revised VIIRS aerosol algorithm to future JPSS/J1 satellite observations.
This task mainly aims for supporting 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.

Accomplishments

Through the Intensive Calibration and Validation (ICV) phase of the VIIRS aerosol products, the VIIRS AOT product reached ***Validated Stage II*** maturity status on 01/23/2013 over land and on 05/02/2012 over ocean, and the VIIRS Ocean AE products reached ***Validated Stage I*** maturity status on 05/02/2012. The VIIRS Ocean Suspended Matter product reached ***Beta*** maturity status on 05/02/2013 with more in-depth evaluation still needed.

Supported by the task, the CICS Scientists maintain the operation of an automated data archiving and processing system and keep improving its new capabilities. The 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 the 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 at data servers. The archived datasets and any other special requested datasets were used to support other team members for their scientific and operational needs.

CICS scientists also conducted scientific research on new aerosol retrieval and internal testing schemes to further improve the aerosol products. CICS scientists used the Algorithm Development Library (ADL) to develop science version of the operational aerosol code and run it locally at NOAA STAR. The science algorithm was used to make code changes to improve the operational algorithm. 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. For example, 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 developed and code changes were delivered to operation (technique for operational use #1).

In the routine Calibration and Validation activities, CICS Scientists compared the VIIRS aerosol products to the ground or in-situ measures from AERONET, MAN and other operational satellite aerosol products such as MODIS and MISR. Operational procedures were established to conduct the intercomparison systematically. The results from the comparison were used to evaluate the performance of the VIIRS aerosol algorithm and determine their maturity levels (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 scatterplots and statistics respectively.

As part of the Cal/Val activities, CICS scientists participated in the Factory Baseline Tests (FBT) regularly to ensure correct implementation of code changes in the VIIRS algorithms from Mx8.1 to Mx8.8 in the past year. To meet the user needs from global climate modelers, CICS scientists maintain the daily data processing of the gridded VIIRS aerosol 0.25°X0.25° resolution products and provide data support through the NOAA STAR website (research to ops #2). By the support of the CICS scientists, preliminary evaluation results of the VIIRS aerosol products were published in JGR (Liu et al., 2014). Some significant scientific results were presented at AGU Fall Meeting 2014 with a special VIIRS Aerosol Session: Suomi-NPP VIIRS Aerosol Products and Their Applications, and NOAA STAR JPSS Annual Science Team Meeting, CICS-MD Science Meeting etc.

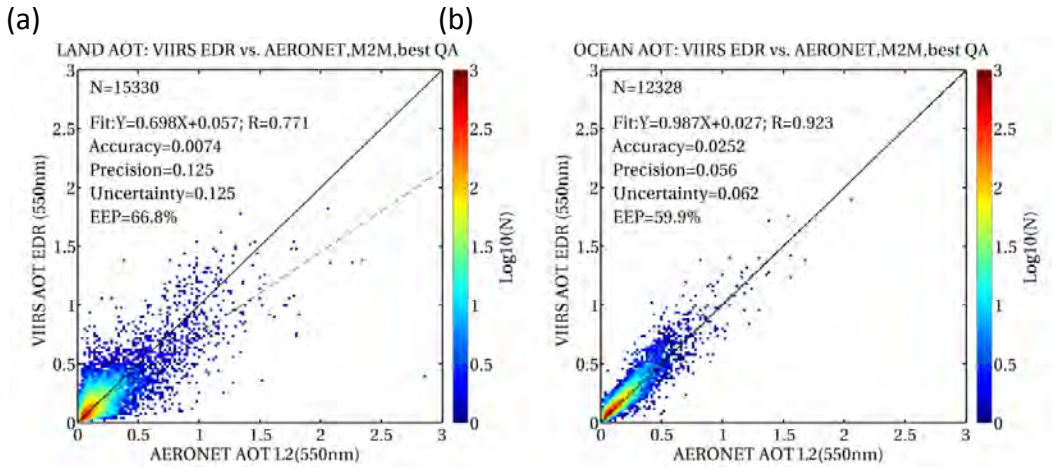


Figure 1. Scatterplots of VIIRS Aerosol AOT against AERONET: (a) land retrievals vs. AERONET AOT over land sites. (b) ocean retrievals vs. AERONET L2.0 over coastal sites.

LAND AOT EDR vs. AERONET L2	Accuracy /Precision	JPSS 1 Specifications	Validated Stage	Achieved?
Land $\tau<0.1$	Accuracy	0.06	**0.0351**	√
	Precision	0.15	**0.0758**	√
Land $0.1\leq\tau\leq0.8$	Accuracy	0.05	**-0.0098**	√
	Precision	0.25	**0.1222**	√
Land $0.8<\tau\leq2.0$	Accuracy	0.20	**-0.1772**	√
	Precision	0.45	**0.3146**	√
Ocean $\tau<0.3$	Accuracy	0.08	**0.0246**	√
	Precision	0.15	**0.0415**	√
Ocean $\tau\geq0.3$	Accuracy	0.15	**0.0298**	√
	Precision	0.35	**0.1280**	√
Ocean AE 865nm/1610nm	Accuracy	0.3	**0.120**	√
	Precision	0.6	**0.588**	√

Table 1. The accuracy and precision of the VIIRS AOT and AE EDR products meet the JPSS1 Specifications and reach the Validated Stage maturity level.

Planned work

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

This includes but not limited to:

1) Conducting Large Array Data Management
2) Participating in FBT and DR, CCR and PCR reporting processes
3) Maintaining the daily data ingesting, visualization, and data analysis
4) Running the operational and science versions of the VIIRS aerosol algorithm in ADL
5) Monitoring long term performance of the VIIRS aerosol algorithm
6) Evaluating the VIIRS aerosol products for higher validated stages.
7) Writing up journal papers to publish and report scientific results in journals and at conferences.

Publications

Peer-Reviewed:

Hongqing Liu, Lorraine A Remer, Jingfeng Huang, Ho-Chun Huang, Shobha Kondragunta, Istvan Laszlo, Min Oo, John M Jackson, 2014: Preliminary Evaluation of Suomi-NPP VIIRS Aerosol Optical Thickness, *J. Geophys. Res. Atmos*., **119**, 3942–3962.

Supported by the task, CICS Scientists contributed to the following Non-Peer-Reviewed Publications that are continuously updated during the algorithm improvement processes:

VIIRS Aerosol Optical Thickness (AOT) and Particle Size Parameter Algorithm Theoretical Basis Document (ATBD): http://npp.gsfc.nasa.gov/sciencedocuments/2014-02/474-00049_ATBD-VIIRS-AOT-APSP_A.pdf

VIIRS Suspended Matter Algorithm Theoretical Basis Document (ATBD): http://npp.gsfc.nasa.gov/sciencedocuments/ATBD_122011/474-00046__VIIRS_Suspended_Matter_ATBD_Rev-_20110422.pdf

VIIRS Aerosol Products (AOT, APSP & SM) Intermediate Product (IP)/Environmental Data Records (EDR) Software – Operational Algorithm Document (OAD): http://npp.gsfc.nasa.gov/sciencedocuments/2014-07/474-00073_OAD-VIIRS-Aerosols-IP-EDR_F.pdf

JPSS Common Data Format Contrl Book (CDFCB) Vol IV-Part 2 - Imagery, Atmospheric, and Cloud EDRs: http://npp.gsfc.nasa.gov/sciencedocuments/2014-07/474-00001-04-02_JPSS-CDFCB-X-Vol-IV-Part-2_0200-.pdf

VIIRS Aerosol Product README File: http://www.class.ncdc.noaa.gov/notification/pdfs/VIIRSAerosolAOT_APSPEDRProvisionalReleaseReadme_Final.docx

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

Products

NPP/VIIRS Operational Aerosol Products: include aerosol optical depth (AOD) at 11 wavelengths, aerosol size parameter (Angstrom Exponent, AE) and type-related information (Suspended Matter).

Presentations

Huang, Jingfeng, Hongqing Liu, Istvan Laszlo, Shobha Kondragunta, Lorraine Ann Remer, Ho-Chun Huang, Hai Zhang, Stephen Superczynski, Maksym Petrenko, Brent N Holben, Robert C Levy, Ralph A Kahn and Charles M Ichoku, Characterization of the Difference between Aerosol Retrievals from Multi-Sensors and AERONET, AGU, 95, Fall Meet. Suppl., Abstract A11I-3108, San Francisco, 15-19 December 2014.

Hai Zhang, Hongqing Liu, Shobha Kondragunta, Istvan Laszlo, Lorraine Ann Remer, Jingfeng Huang and Ho-Chun Huang, Improving Surface Reflectance Estimation for VIIRS AOT Retrieval over Land, AGU, 95, Fall Meet. Suppl., Abstract A11I-3115, San Francisco, 15-19 December 2014.

Lorraine Ann Remer, Leigh A Munchak, Jingfeng Huang, Jose-Vanderlei Martins, Reed Espinosa and Daniel Orozco, VIIRS Aerosol Products During the SEAC4RS Field Experiment, AGU, 95, Fall Meet. Suppl., Abstract A11I-3106, San Francisco, 15-19 December 2014.

Huang, Jingfeng, S. Kondragunta, I. Laszlo, H. Liu, L. Remer, H. Zhang, S. Superczynski, Validation of Aerosol Optical Thickness and Angström Exponent in the Suomi-NPP VIIRS Operational Aerosol Products, *CICS-MD Science Meeting*, College Park, MD (11/12 to 11/13/2014)

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)* International Aerosol Conference 2014, Korea, Aug 31, 2014.

Huang, Jingfeng, Hongqing Liu, Istvan Laszlo, Shobha Kondragunta, Lorraine A. Remer, Ho-Chun Huang, Hai Zhang, Stephen Superczynski, Maksym Petrenko, Brent N. Holben, Robert C. Levy, Ralph A. Kahn, Spatial and Temporal Characterization of the Difference between Multi-Sensor Aerosol Retrievals and AERONET measurements, *NOAA STAR JPSS Annual Science Team Meeting*, NCWCP (5/12 to 5/16/2014)

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**0**
# of presentations (invited)	**6 (1)**
# 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**

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

Task Leader	Evan Ellicott
Task Code	EEEE_VIIRS_14
NOAA Sponsor	Ivan Csiszar
NOAA Office	NESDIS/STAR/SMCD/EMB
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%

Highlight: The 2014 performance period's outcomes successful in progressing the goals of the Proving Ground and Risk Reduction (PGRR) project which includes maximizing the benefits of VIIRS data for downstream end-users. We combined outreach and efforts with VIIRS active fire evaluation through coordinate prescribed fire events while presentations and training included audiences from both the research and operations communities. In addition, we continued to expand and improve our website to offer new data, an archive database, and user-friendly formats based on end-user feedback.

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

Background

Timely and accurate data is needed for both research and operations to develop improved models for wildfire prediction and near-real time situational awareness. The National Oceanic and Atmospheric Administration (NOAA) plays a strategic role in wildfire monitoring and modeling with spaceborne assets developed to provide synoptic and timely data. With the launch of the Suomi NPP (SNPP) in 2011, it was expected that the VIIRS Active Fire (AF) product would be used for wildland fire management to improve situational awareness such as hot-spot detection and characterization, air quality monitoring, and fire weather-related applications. Therefore, the NOAA-supported VIIRS AF Proving Ground and Risk Reduction (PGRR) project was established to maximize the benefits of the data for downstream operational and research users through product evaluation, improvement, outreach and education, and the development of a near-real-time data dissemination to support fire management and NOAA operations. The goal of this project is to leverage the VIIRS AF products for active and post-fire management and NOAA operations to improve research and decision making.

Accomplishments

2014 was a successful year for this CICS task which made great strides get VIIRS AF education, training, and data into downstream end-users hands in user-friendly formats and with reduced latency. Our outreach efforts included teleconferences, user-workshop training, and meeting and conference presentations offering 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.).

Our presentations and training have included both the research and operations community. For example, within the research sphere we have presented over the past several years at the International Geoscience and Remote Sensing Symposium (IGARSS), American Meteorological Society (AMS), European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Satellite conference, GOFC-GOLD Fire Imple-

mentation Team meetings, the NOAA Satellite Science conferences, and the JPSS Proving Ground Seminars.

Operations-oriented meetings at which we have presented have included the Incident Meteorologist (IMET) annual training workshop, the Working Group for Wildland Fire Weather (WG/WFW) meeting at the Office of the Federal Coordinator for Meteorology (OFCM), and the National Interagency Fire Center (NIFC) Annual Predictive Services meeting. In addition, we presented at the Northern California Geographic Area Coordination Center's annual Incident Management Team (IMT) meeting where we also provided an informal breakout session with the Fire Behavior Analysts (FBANs) to discuss with "needs and wants" and offer them guidance on how to get and use VIIRS AF data.

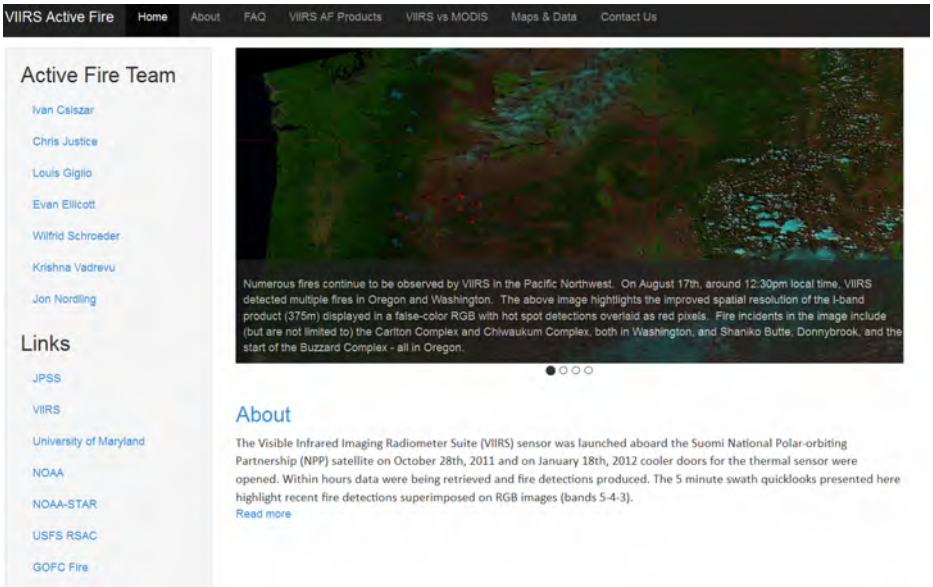
In 2014 we visited the Northwest Coordination Center (NWCC) in Portland, Oregon and the National Interagency Coordination Center (NICC) at the National Interagency Fire Center (NIFC) in Boise, Idaho. These visits provided an opportunity for us to observe how the coordination centers manage regional fire events (e.g. resources, data, weather, etc.) and allow us to educate them on VIIRS AF data (resolution, data type, source and availability). While these visits were not necessarily coordinated to correspond with 2014 fire events, numerous large fires (e.g. 36 Pit Fire) were still persistent, giving us a chance to examine VIIRS AF data from the IDPS and DB stations for ongoing events and discuss the user's needs as well as merits and limitations of satellite fire data.

The incorporation of JPSS data, and specifically the VIIRS AF product, into AWIPS II has been the focus of discussion at meetings with NIFC meteorologists and intelligence staff in 2014. In addition, there was a meeting to discuss this specific topic held at the NOAA Center for Weather and Climate Prediction (NCWCP). In each meeting the emphasis was on understanding the role out schedule for AWIPS II, FX-Net and the transition to the AWIPS 2 CAVE workstation, which will be supported in the NIFC and GACC offices.

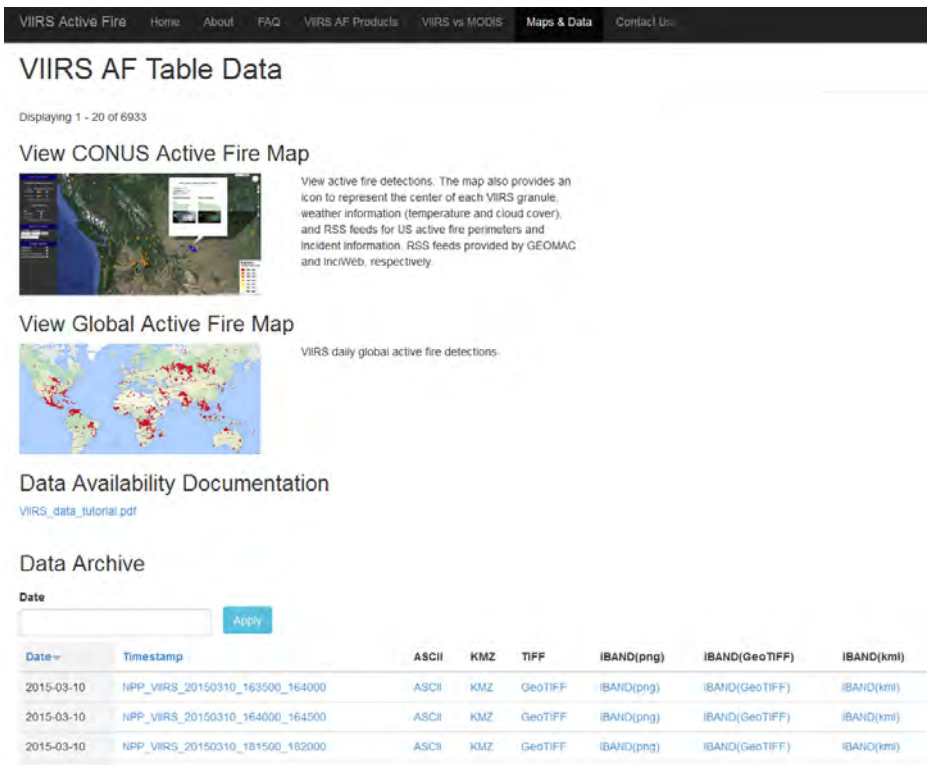
As part of our evaluation of the VIIRS AF products we have participated in prescribed fires working closely with the United States Forest Service. This provided hands on experience with using satellite data for active fires including education about overpass timing, spatial and temporal resolution, detection capabilities, and fire characterization. We conducted satellite validation using *in situ* radiometers to measure radiant flux density and fuel consumption rates. These experiments were performed both in the field and laboratory (Figure 1). Similar prescribed fire research in Kruger National Park, South Africa, provided opportunities to evaluate the detection capabilities and accuracy of the VIIRS AF product while engaging members of the Southern African Fire Network (SAFNet) and provide presentations about the VIIRS AF products (M-band and I-band). In addition, Direct Broadcast (DB) VIIRS AF data continues to be evaluated to ensure consistency with the standard VIIRS AF product (available via CLASS).

We expanded and improved 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 2). The website offers background material and a tutorial document on VIIRS fire detection (including appropriate use and data considerations / limitations). The following is only a brief summary of our accomplishments to date.

Figure 1: Photo examples of VIIRS AF evaluation and validation efforts; a) Prescribed fire (Rx) in George Washing National Forest (GWNF), Virginia, with *in situ,* tower-based radiometers; b) GWNF plots being burned; c) Laboratory experiments being performed at the University of Maryland to validate our radiometers; and d) Rx fire in Kruger National Park, South Africa, using *in situ* measurements to validation VIIRS AF products.



(a).



(b).

Figure 2: (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.

Planned work

Building upon our success over the past several years, the goal of this proposed project is to simultaneously perform VIIRS AF product evaluation, validation, and improvement while collaborating with the wildland fire user community to support product understanding, dissemination, and ultimately to leverage the VIIRS AF products for active and post-fire management and NOAA operations. 2015 will see new fire-related VIIRS products being made available to research and operations. Products such as Fire Radiative Power (FRP) and I-band detections will necessitate a rapid deployment of knowledge sharing and prompt dissemination to end-users. The necessary training to demonstrate VIIRS AF product use and insure optimal utilization continues to be of significant importance and interaction with the Direct Broadcast (DB) community will be critical to develop near real-time data while guaranteeing high quality data and consistency of the fire code within the various DB packages. The outcomes will include improved quantitative estimation of VIIRS AF accuracy through user input, demonstration of fire impact assessment, and expanded end-user availability and understanding of the VIIRS AF products.

Publications

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

Presentations

- E. Ellicott, I. Csiszar, L. Giglio, W. Schroeder, K. Vadrevu, C. Justice; the National Interagency Fire Center (NIFC) Annual Predictive Services Annual Meeting, November 22-24th, 2014, "VIIRS and MODIS Active Fire Products".
- E. Ellicott, I. Csiszar; GOES-R and JPSS OCONUS R2O Interchange Meeting, July 31, 2014, "Fire and Smoke Initiative".
- Several talks were given at the GOFC-GOLD IT meeting at NCWCP in College Park, Maryland (July 29-31, 2014), hosted NOAA sponsor, Ivan Csiszar.
- I. Csiszar, E. Ellicott, C. Schmidt; JPSS Proving Ground Seminar, April 21, 2014, "JPSS and GOES-R activities supporting 2013 fire outbreaks".
- 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".

Other

- While in Kruger National Park for Rx fires and VIIRS validation we had the opportunity to demonstrate the VIIRS AF website to key stakeholders of SAFNet and show how to use the website to monitor fire detections in the region and specifically for our prescribed fire experiments.
- In September, we visited the Northwest Coordination Center (NWCC) in Portland, Oregon and the National Interagency Coordination Center (NICC) at the National Interagency Fire Center (NIFC) in Boise, Idaho. These visits provided an opportunity for us to observe how the coordination centers

manage regional fire events (e.g. resources, data, weather, etc.) and allow us to educate them on VIIRS AF data (resolution, data type, source and availability).

- In October we met with USFS Fire Management Officers (FMO) in Virginia to demonstrate VIIRS capabilities and data website(s) and show the application of the VIIRS AF website for operational purposes.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**0**
# of invited presentations	**5**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

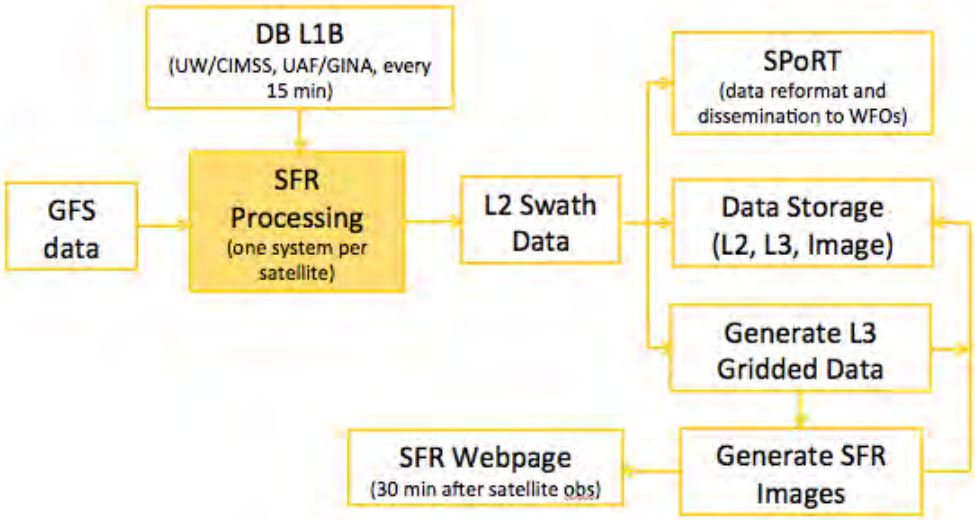
This year our emphasis continued to be outreach and communication, with a strong, collaborative working with the VIIRS AF cal/val team on VIIRS AF evaluation. We provide numerous presentations, many invited, as well as hands on demonstration and training about VIIRS, data access, and applications. Two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

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

Task Leader Jun Dong
Task Code CKCK_ATMS_13
NOAA Sponsor Huan Meng
NOAA Office NESDIS/STAR/
Contribution to CICS Research Themes (%) Theme 1: 30%; Theme 2: 70%; Theme 3: 0%
Main CICS Research Topic Calibration and Validation
Contribution to NOAA goals (%) Goal 1: 25%; Goal 2: 0%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%
Highlight: We built a CONUS ATMS Snowfall Rate retrieval system using the Direct Broadcast data. Using this system, the latency of the SFR product reduced to less than 30 minutes over US CONUS and Alaska. We also built the corresponding system MHS data over CONUS.
Link to a research web page http://www.cics.umd.edu/sfr

Background

It is challenging to forecast and analysis snowfall rate (SFR) for National Weather Service (NWS), especially in data sparse regions where only exist limited radar and gauge coverage. Satellite retrieved SFR is an excellent alternative to provide SFR information for board spatial coverage. Building on the AMSU/MHS SFR algorithm, the ATMS SFR algorithm were developed and expected to perform better with more moisture channels. This project is to build an ATMS SFR retrieval system to provide SFR observation to forecaster more accurately and effectively over CONUS and Alaska. By using satellite Direct Broadcast (DB) data, the new system can retrieve SFR over CONUS/Alaska in 30 minutes for each satellite passes. The diagram of ATMS SFR DB system and data flow is shown below.



Accomplishments

Building on the operational AMSU/MHS SFR product, an ATMS SFR algorithm has been developed in a JPSS Proving Ground (PG) and STAR End of Year (EOY) co-sponsored project. During the past one year, this ATMS SFR algorithm was implemented in a new satellite SFR retrieval system. In this new system, we uses satellite DB data to further reduce the latency. First, the system obtains the updated satellite DB data from UW/CIMSS and UAF/GINA, which typically have about 15 minutes latency. Then, our system uses about 15 minutes to retrieve SFR and generate SFR images, which are transferred to our website immediately (Figure 1). The SFR product is also delivered to NASA/SPoRT for further evaluation.

A corresponding MHS DB system was also built and is running under the same framework. The retrieved SFR for each passes are blended into the same website (Figure 1). The MHS data are from fours satellites: NOAA-18, NOAA19, Metop-A and Metop-B. Therefore, the DB SFR system for CONUS includes five satellites, produces more than 20 passes observations each day totally.

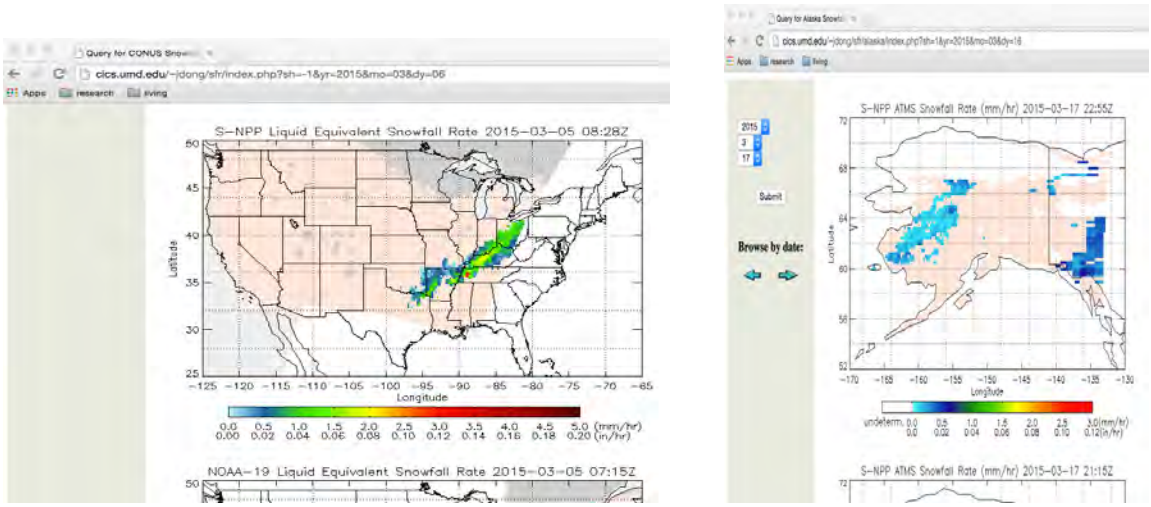


Figure 1: Screenshot of the webpages of ATMS SFR DB system for CONUS (left) and Alaska (right).

The ATMS SFR DB data are accumulating for further investigation and improvement. Based on the data of the last winter season, we can calculate the mean SFR over CONUS (Figure 2). The main features of snowfall pattern are consistent with other research, such as from 30 years gauge dataset (Durre, 2013). Compared with NMQ radar data (not show here), it is clearly shown that satellite data have much better coverage in the mountain region, where radar data quality is poor therefore missed big portion of large snow events. With the aid of the NASA/SPORT evaluation, we also identify some issues of our algorithm for SFR retrieval, such as for sleet events, for which we will improve our algorithm in the future.

Planned Work

- Improve the ATMS SFR algorithm
- Make the DB system more robust to do fast SFR retrieval
- Develop Time Delay Index (DTI) to help forecaster to use satellite SFR product more effectively

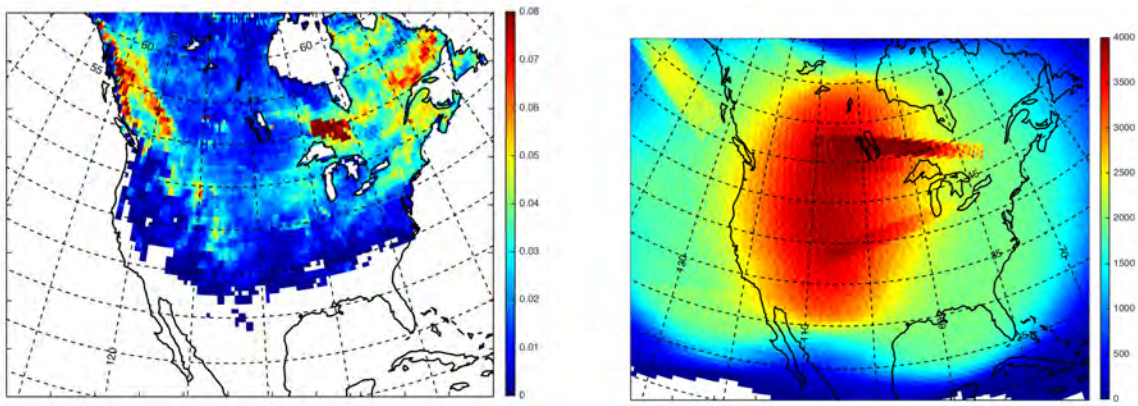


Figure 2: Mean SFR during 2013/2014 winter season from ATMS DB data (left) and number of satellite observations in each 0.5x0.5 degree bin.

Products

ATMS SFR system using DB data over CONUS
ATMS SFR system using DB data over Alaska
DB SFR product during last winter season (2014/10 – present) for both CONUS and Alaska

Presentations

Dong, J., H. Meng, Improvement and Validation of NESDIS Satellite Snowfall Rate Algorithm, *AMS Annual Meeting*, Phoenix, 2015

Meng, H., R. Ferraro, C. Kongoli, N. Wang, J. Dong, B. Zavodskey, B. Yan, L. Zhao, NPP Snowfall Rate Product, Boulder, 2015

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**2**
# 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**

This year, we developed two DB SFR retrieval systems, CONUS and Alaska, to implement ATMS SFR algorithm (2). Two presentations on NPP Snowfall Rate product have been made (2).

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

Task Leader Jian-Jian Wang
Task Code JWJW_SCAV_14
NOAA Sponsor Ralph Ferraro
NOAA Office NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%) Theme 1: 30%; Theme 2: 70%
Main CICS Research Topic Calibration and Validation
Contribution to NOAA goals (%) Goal 1: 25%; Goal 2: 75%
Highlight We have established a validation network for model and satellite derived precipitation estimates. The comparisons between the satellite rainfall products and ground based gauge and radar data are performed for instantaneous swath, daily, and seasonal validations.
Link to a research web page http://cics.umd.edu/ipwg/index.htm

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

Validation of STAR rainfall products is conducted at the end of each meteorological season (Dec-Feb, Mar-May, Jun-Aug, and Sep-Nov), and the results are disseminated via a web page (http://cics.umd.edu/ipwg). Validation is conducted over the contiguous United States. Daily rainfall amounts are validated using rain gauge data as “truth” over both regions, and radar data (Stage IV data) also are used to validate composites of swath rainfall products over the U.S. The purpose of this activity is to provide STAR rainfall algorithm developers with feedback on the performance of their algorithms, which will help to guide decisions on whether to divert resources toward algorithm improvement or perhaps to investigate the reasons for recent algorithm behavior (good or poor).

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, Dec-Feb 2014-2015 seasons. Results were disseminated within a month after the end of each season. The results are discussed with NOAA scientists, and modifications and additions of new statistics in which they are portrayed are conducted as requested.

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.

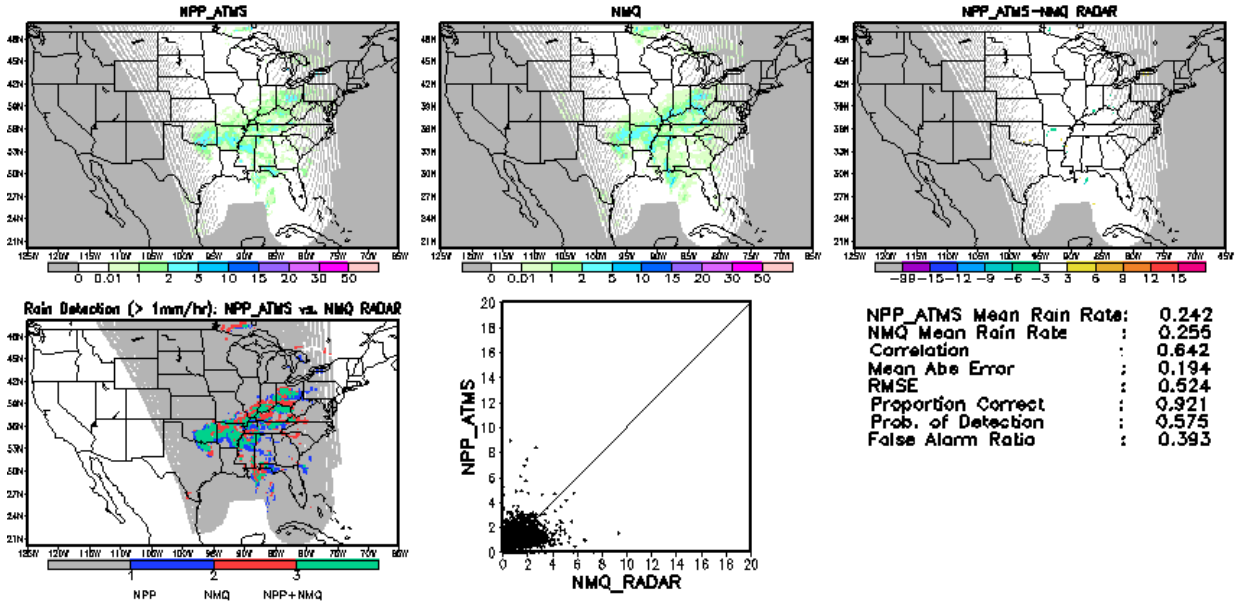


Figure 1: Comparison of satellite rainfall from NPP ATMS/MiRS to ground-based observations integrated by multi-radar multi-sensor system on March 13, 2015

We have expanded our Cal/Val efforts to several exciting new rainfall estimates including JPSS GCOM AMSR-2, ATMS MiRS, and AMSU-B 183-WSL. We have worked with algorithm developers to add these new estimates into the validation system and to develop new metrics that are useful for algorithm assessment. The "truth" used in the validation effort is the Multi-Radar Multi-Sensor system (MRMS), which is an automated system that rapidly and intelligently integrates data from multiple radars and radar networks, surface and upper air observations, and numerical weather prediction (NWP) models.

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 has been prepared.

Planned work

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. As the first step, we will use MRMS data to validate the snowfall rate product developed by Dr. Huan Meng's group. This assessment will involve both the task leader and an hourly student research assistant.

In addition, 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. Our analyses of annual and seasonal composites will continue, along with modifications to the web site, with both projects supported by undergraduate researchers. Upon request by

STAR researchers or the PREPOP, we will provide additional validation analyses that complement the routine analyses described above.

Presentations

Wang, J.-J., 2014: Satellite Calibration and Validation (Cal/Val) efforts for NOAA/STAR Precipitation Products. The 3rd Annual CICS-MD Science Meeting, College Park, UMD.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**1**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**2**

This year, we have expanded our Cal/Val efforts to JPSS GCOM AMSR-2, ATMS MiRS, and AMSU-B 183-WSL. The swath validation of JPSS GCOM AMSR-2 and ATMS MiRS are added to our validation website at http://cics.umd.edu/ipwg/NPPATMS.html?page=0 .

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/ORS
Contribution to CICS Research Themes (%)	Theme 1: 30%; Theme 2: 70%; Theme 3: 0%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 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.

Link to a research web page www.star.nesdis.noaa.gov/socd/sss/4sqm

Background

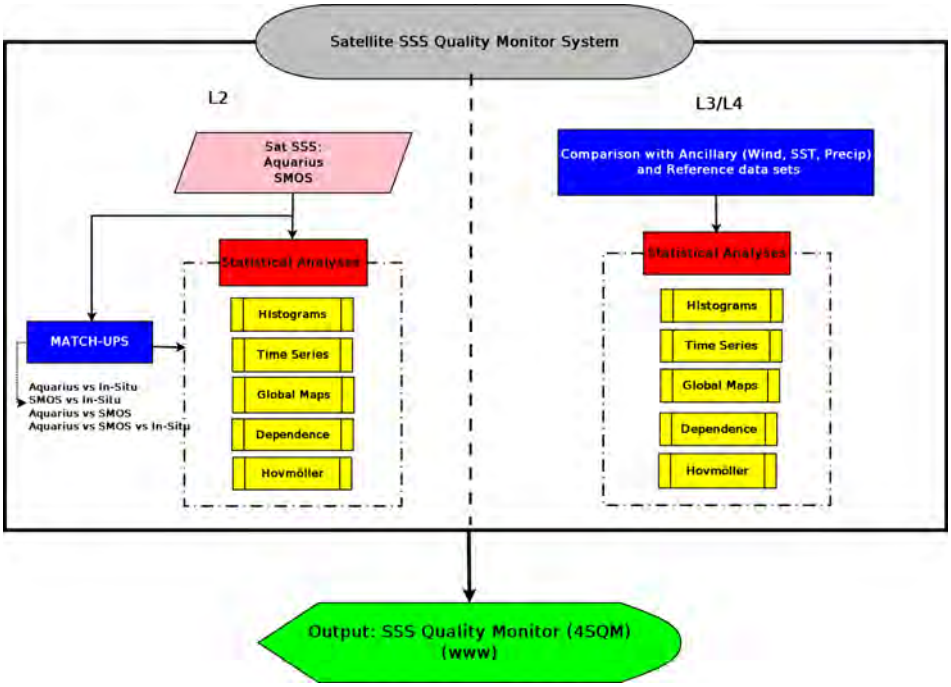
This report summarizes the year-2 work of the ongoing NOAA project entitled "Development of the Satellite Sea-Surface Salinity Quality Monitor System". Satellite data including SMOS and Aquarius are monitored for self- and cross-platform consistency, as well as consistency with *in situ* data. Analyses of satellite SSS data and product quality examine the errors, biases, and trends to identify sensor and algorithm inadequacies and malfunctions, assess cross-platform consistency of products, diagnose artificial dependencies, and generate global difference maps. This effort will build and implement the Satellite Sea-Surface Salinity Quality Monitoring (4SQM) System (Figure 1).

Accomplishments

The ascending and descending differences in both SMOS and Aquarius were analyzed for their self-consistency. For the Aquarius, the most interesting feature was the spatial pattern of alternating positive/negative node being regularly spaced and centered between the multiples of 45° of longitude In the Southern Hemisphere (Figure 2a). The most notable feature in SMOS is the distinct negative trend for from 30°S to 50°N (Figure 2b).

The Level 2 Aquarius and SMOS data were compared with the *in-situ* Argo float data at global, zonal and regional scales. The zonal mean annual means of ADPS and CAP products of Aquarius appear to align with each other with lower biases between 20°S and 20°N in CAP (Figure 2). SMOS data bias in the Northern Hemisphere is notably different from Aquarius data bias. Both ADPS of Aquarius and SMOS show negative bias in the tropics.

Aquarius and SMOS differences from *in situ* near-surface Argo observations were examined with respect to the temporal variability of environmental influences including sea-surface temperature (SST), precipitation, and wind speed, for indications and attribution of bias. For equatorial regimes (ITCZ and SPCZ boxes), the ADPS increasingly negative bias at higher temperatures is evident in the consistently negative satellite – *in situ* SSS difference. In the SPURS region, the Aquarius-Argo differences exhibit little mean bias and variability is small. For colder and windier regimes, the satellite and Argo differences have mixed correlation significance with SST, implying that SST variability does not drive the satellite-*in situ* differences in these regions and counter to expectations, only the ADPS-Argo differences are correlated with wind speed, and only minimally so.



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

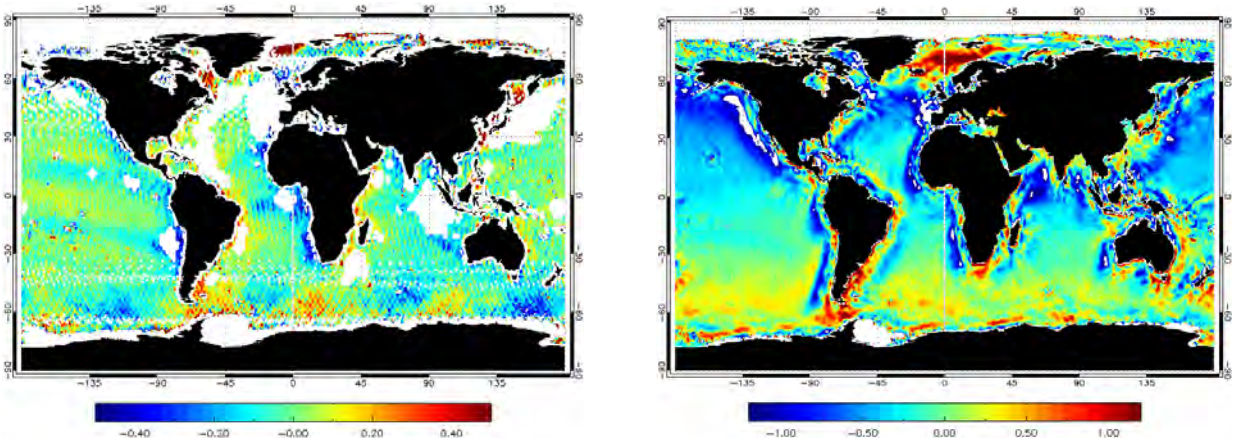


Figure 2: Annual Mean Ascending and descending differences: a) Aquarius and b) SMOS

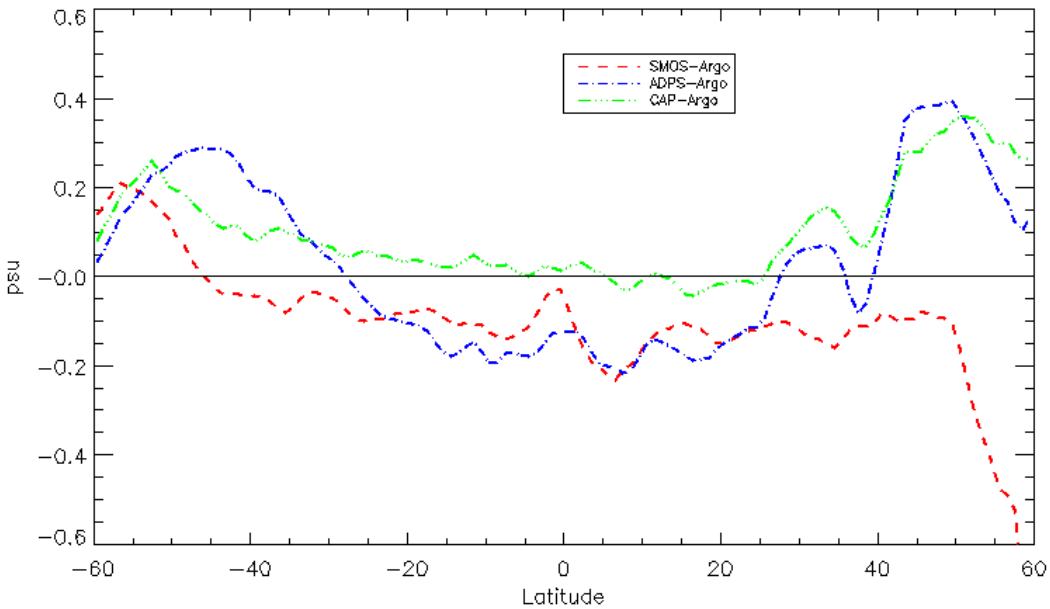


Figure 3: zonal mean annual-mean of SSS differences, ADPS minus Argo (blue), CAP minus Argo (green), and the SMOS minus Argo (red).

The webpage www.star.nesdis.noaa.gov/socd/sss/4sqm is under development and is targeted to be published in year 2015.

Planned work

- Establish data flows for SSS references HYCOM and MOM4, and dependency parameters: sea-surface temperature (SST), wind speed, and precipitation;
- Document one paper for the Remote Sensing of Environment
- Continue developing the web pages and operationalize it

Publications

- **Ren, L.** and E. Bayler, Satellite Sea-surface Salinity Consistency, in preparation to be submitted to Remote Sensing of Environment

Products

- Webpage www.start.nesdis.noaa.gov/socd/sss/4sqm

Presentations

- **Ren, L.** and E. Bayler, Salinity Variation in the Eastern Tropical Pacific, AGU Fall Meeting 2014, San Francisco, 12/2014.
- Bayler, E. and **L. Ren,** Satellite Sea-surface Salinity: Data and Product Biases and Differences, Ocean Salinity Science and Salinity Remote Sensing Workshop, Exeter, UK, 11/2014.
- **Ren, L.** and E. Bayler, Comparison of Level 2 Aquarius SSS with Argo Near Surface Salinity, Aquarius Science Meeting, Seattle, 11/2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**0**
# of invited presentations	**3**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

We developed the webpages for output the satellite sea-surface salinity quality monitor system and it will be operationalized (1). We were invited by the Remote Sensing of Environment to submit a paper for our work on the quality monitor of the satellite sea-surface salinity and it is in preparation (1). Three presentations on the Aquarius and SMOS satellite sea surface quality monitor have been made (3).

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

Task Leader Wilfrid Schroeder
Task Code WSWS_ABI_14
NOAA Sponsor Jaime Daniels
NOAA Office NESDIS Center for Satellite Applications and Research (STAR)
Contribution to CICS Research Themes (%) Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic Calibration and Validation
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%; Goal 3: 0%
Highlight: The GOES-R/ABI active fire deep-dive validation tool was developed. The tool uses high spatial resolution airborne and spaceborne reference fire data in order to quantify commission (false alarm) and omission error rates, and sub-pixel fire characterization retrievals.

Background

The future GOES-R/ABI fire detection and characterization (FDC) algorithm builds on the Wildfire Automated Biomass Burning Algorithm (WF-ABBA), which originated from GOES VAS data applications [Prins and Menzel, 1992]. The WF-ABBA product provides routine detection and characterization of sub-pixel active fires, serving the fire management community as well as the scientific community. Consequently, WF-ABBA must deliver quality data with well-characterized sources of errors.

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

By adapting the validation methods developed for GOES and MODIS fire products to GOES-R/ABI data, this project utilized higher spatial resolution fire reference data to assess and validate the ABI FDC algorithm.

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

Accomplishments

During this funding cycle the GOES-R/ABI deep-dive active validation tool was further developed, including: (i) customization of Graphical User Interfaces (GUIs) to allow simplified operation of tool box, (ii) summary graphic output describing commission and omission error rates as a function of pixel area and land cover conditions, (iii) and development of robust reference fire data derived from Landsat-8/OLI imagery. Proper arrangements with the U.S. Geological Survey are being made in order to allow processing of large volumes of Landsat-8 fire reference data in support of GOES-R/ABI pre- and post-launch validation activities.

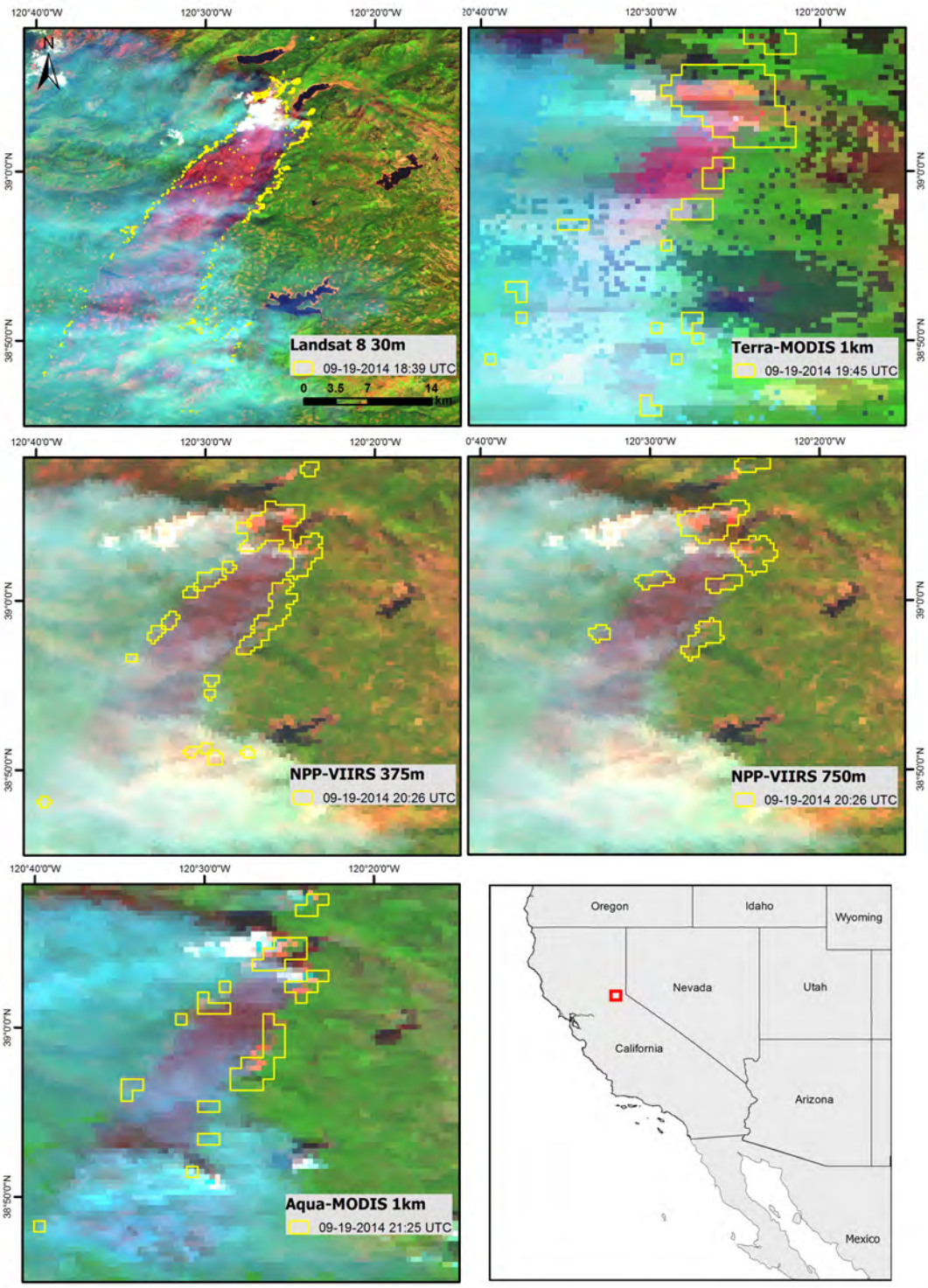


Figure 1: Landsat-8/OLI active fire detections generated on 19 September 2014 for the King fire in California. For comparison purposes, we show same-day fire detections derived from 375 m, and 750 m S-NPP/VIIRS data, and 1 km Terra and Aqua MODIS data.

Planned work

- Finalize fire deep-dive validation software and initiate pre-launch phase testing
- Validation of pre-launch ABI binary active fire test data samples based on input AHI data: apply deep-dive tool using moderate spatial resolution (e.g., Landsat-class) and airborne imagery, continue development and testing of fire reference data sets
- Deep-dive tool reactive maintenance and updates will be undertaken in response to new reference data sets and/or changes to existing ones
- Publish Landsat-8 algorithm used to generate reference fire data for the deep-dive fire validation tool

Publications

Schroeder, W., Oliva, P. Giglio, L., Quayle, B., Morelli, F., Lorenz, E. (2015). Active fire detection using Landsat-8 data. *Remote Sensing of Environment*, in review.

Products

Active fire detection algorithm developed for Landsat-8/OLI data. Product being generated by the U.S. Department of Agriculture Remote Sensing Applications Center (RSAC) in Salt Lake City/UT.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

New active fire detection algorithm developed for Landsat-8/OLI data. Product being generated by the U.S. Department of Agriculture Remote Sensing Applications Center (RSAC) in Salt Lake City/UT.

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

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

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

Background

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

Instrument calibration, characterization, and validation are essential to GOES-R mission success and the production of high-quality data products. To ensure the mission requirements are met, the ABI sensor radiometric calibration will utilize onboard calibration devices, including a solar diffuser (SD) for solar reflective channels and a blackbody for the infrared bands. Due to the partial aperture used on GOES-R for solar diffuser (SD) calibration and no on-board SD stability monitor, the in-flight calibration process will also make extensive use of views of the Moon and stars. We will perform lunar and stellar calibration and support imagery navigation and registration (INR) for GOES-R ABI. Our work prepares for post-launch testing (PLT), on-orbit verification and long-term monitoring of instrument performance of GOES-R ABI. In particular, we propose to work on

Accomplishments

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

1. **Cross-comparison of lunar irradiance models to support lunar calibration of ABI**

We used two lunar irradiance models, namely, the Community Lunar Irradiance Model (CLIM) developed by L-1 and *Miller-Turner* [2009] (MT2009) model to support lunar calibration of ABI. CLIM is a lunar irradiance model developed by L-1 to support lunar calibration for GOES-R and GOES satellites. It has been benchmarked with ROLO model [*Kieffer and Stone*, 2005] over ~180 predictions for 6 visible and near-infrared channels of GOES-R ABI. These two models are compared to cross-calibrate lunar irradiance as observed by GOES-R ABI bands [Figure 1]. Figure 1 also assesses the effects of lunar libration and lunar

waxing and waning phase on the ABI calibration. It shows that MT 2009 vs. ROLO model difference depends on lunar phases and wavelength. There are large differences for waning lunar phase and near full moon due to opposition effect.

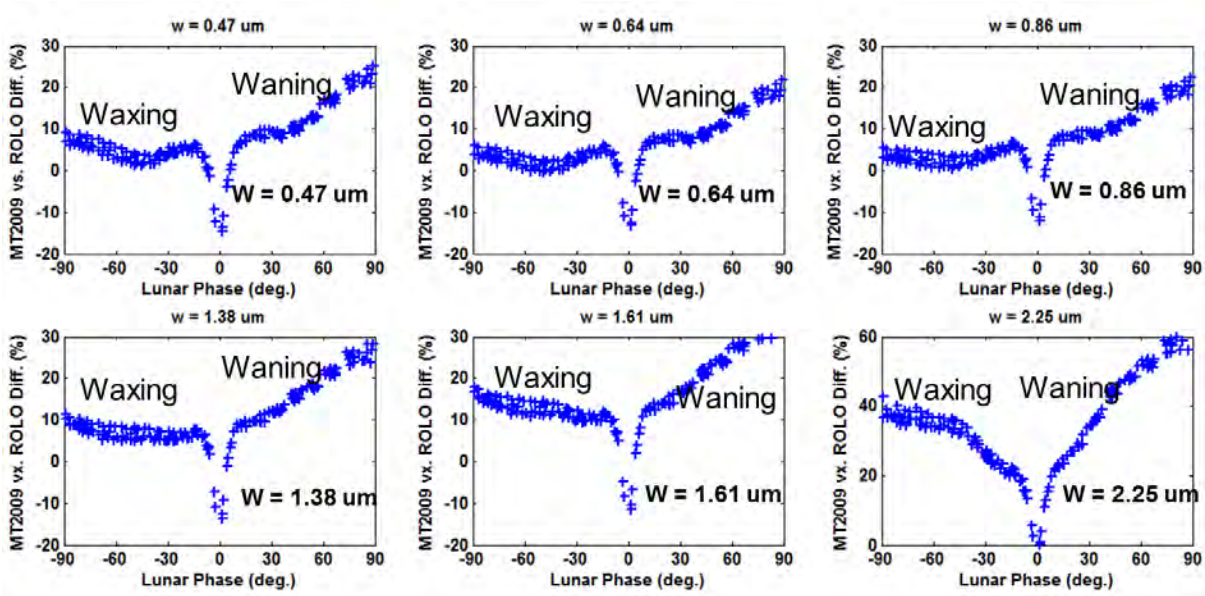


Figure 1: Comparison of two lunar irradiance models for GOES-R ABI Channels.

2. **Using long term lunar observation from VIRS on TRMM to improve lunar irradiance model for ABI lunar calibration**

Since lunar irradiance depends strongly on lunar phase and differs between waxing and waning phases, an accurate modeling of dependence of lunar irradiance on lunar phase angle is needed to improve lunar irradiance model for ABI lunar calibration and requires long term consistent observations of the moon. Since its operation in 1998, the Visible and Infrared Scanner (VIRS) aboard the Tropical Rainfall Measuring Mission (TRMM) satellite makes regular observations of moon through space view for about 15 years with comprehensive coverage of lunar phases varying from waxing to waning. Two of these VIRS bands are reflected solar bands centered at 0.62 and 1.61um. Long term lunar observation by VIRS on TRMM is an invaluable dataset for both verifying and calibrating lunar irradiance models. We performed analysis of long-term lunar observations using VIRS data and phase-angle dependence of lunar irradiance is modeled [Figure 2]. The derived phase angle-dependences of lunar disk effective reflectance for these two channels are compared with model. The use of lunar calibration in VIRS to enable the separation of solar diffuser degradation from that of the sensor can be extremely helpful for the calibration of satellite radiometers such as GOES-R ABI that uses on-board solar diffuser, but does not monitor the degradation of the solar diffuser. Results are published in SPIE conference proceeding.

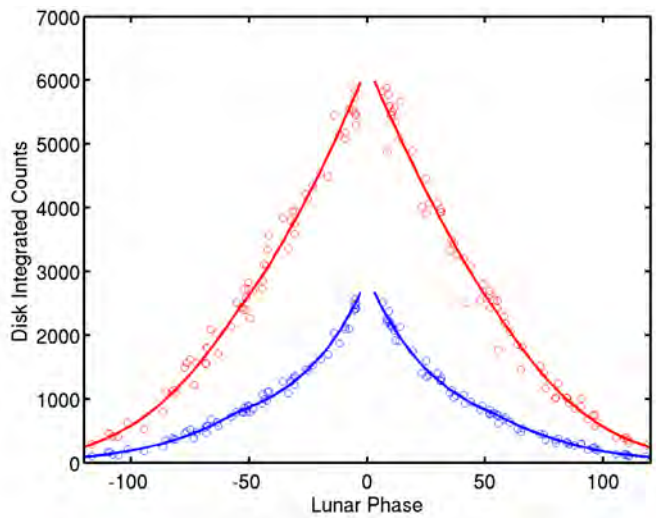


Figure 2: Lunar disk-integrated intensity vs. lunar phase derived from data collected over 15 years together with fitted curves for 0.62 um channel (blue curve and symbol) and 1.61 um channel (red curve and symbol), respectively. Circles represent the actual data and lines represent fitted curve.

3. **Support ground-based lunar observation at UMD Astronomical Observatory to assess polarization effects on lunar irradiance model**

In viewing that the imaging instrument on GOES-R ABI can be prone to polarized light, we will perform lunar polarization measurement. We have worked with L-1 Standards and Technology and modified a reflector telescope and replaced the second mirror with an automated polarization filter. By mounting polarizer filter to telescope, controlling the rotation of the polarizer, and recording spectral radiance of moon with ASD spectrometer, we will be able to record the lunar irradiance at different polarization as observed at ground. This helps us to assess the effect of polarization on the lunar irradiance model and therefore improve the lunar irradiance model to better support post-launch calibration of GOES-R ABI using the moon.

4. **Support the development and maintenance of GOES-R ABI Calibration Working Group (CWG) webpage**

The webpage (http://ncc.nesdis.noaa.gov/GOESR/index.php) has the information and documents for GOES-R ABI such as ABI spectral response function, calibration parameters, SNO predictions, Cal/Val sites, lunar events, stellar radiometric trending, presentation, ABI ATBD and, collaboration activities with JMA.

5. **Developing capability of using lunar observation to perform INR quality check**

We are developing tools to predict expected lunar locations in the image. These tools can be used to predict the appearance of stars and moon in the GOES-R ABI field of regard (FOR). The stellar and lunar imaging opportunities prediction tools are based on the SGP4 satellite orbit tracking software and the JPL's lunar and stellar orbit prediction software. The predicted stellar and lunar position will be transformed to pixel and line position in the image. For moon, comparison of lunar measurements with predicted values will be performed. Particular attention will be paid on oversampling rate along the scan line and determine the stability of oversampling rate. This is also important to the lunar radiometric calibration.

6. **Developing capability of using stellar observation to perform radiometric trending**

We acquired some stellar observation for current GOES Imager and are analyzing the data for radiometric trending and compare that with lunar observations.

Planned Work

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

- Support lunar calibration for GOES-R ABI through
  - *Cross-comparison of lunar irradiance models*
  - *Using long term space-borne lunar observation to improve lunar irradiance model*
  - *Ground-based lunar observation at University of Maryland Astronomical Observatory to assess polarization effects on lunar irradiance model*
- Develop tools to support stellar calibration for GOES-R ABI through
  - *Stellar radiometric trending to monitor ABI degradation*
  - *Cross-comparison of stellar radiometric trending with calibration from other methods such as lunar, solar diffuser and using other satellites*
- Develop tools to support Imagery Navigation and Registration (INR) of GOES-R ABI through
  - *Software adaptation and development to support INR verification and validation*
  - *INR quality check through validation with stellar, lunar and landmark observation*
  - *Assessing effects of dynamic environment on INR*
- Support development and maintenance of GOES-R ABI Calibration Working Group (CWG) webpage

Publications

Non-peer reviewed

1. Xi Shao, Bin Zhang, Changyong Cao, "Modeling phase-angle dependence of lunar irradiance using long-term lunar measurements by VIRS on TRMM", in Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, Xiaoxiong Xiong; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9264 (SPIE, Bellingham, WA 2014), 92641E.

Presentations

1. Xi Shao, Bin Zhang, Changyong Cao, "Modeling phase-angle dependence of lunar irradiance using long-term lunar measurements by VIRS on TRMM", in Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, SPIE Asia-Pacific Remote Sensing Conference, Oct., 2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	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	1

VIIRS Operational Calibration Science Support and JPSS-1 Prelaunch Test Data Analysis

Task Leader Xi Shao
Task Code XSXS_VIIRS_14
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 provides operational science support for S-NPP VIIRS instrument through support on-orbit calibration of VIIRS using the onboard solar diffuser (SD), lunar observations and vicarious methods, as well as inter-comparisons with instruments on other satellite using SNOs, support DNB stray light correction software development, and support the prelaunch test data analysis of VIIRS on JPSS-1.

Background

VIIRS (Visible Infrared Imager Radiometer Suite) is one of five instruments onboard the Suomi-NPP satellite. The VIIRS observations primarily focus on clouds, Earth surface variables, Sea Surface Temperature (SST) and Imagery. VIIRS is designed to provide moderate-resolution, radiometrically accurate images of the globe twice daily. 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 RSBs, the calibration uncertainty in spectral reflectance for a scene at typical radiance is expected to be less than 2%. To meet this requirement, we will support on-orbit calibration of VIIRS using the onboard solar diffuser (SD), lunar observations and vicarious methods, as well as inter-comparisons with instruments on other satellite using SNOs. We will investigate the cause of striping and petulant mode occurred during the operation of VIIRS. In addition, independent calibration of LGS for DNB is critically needed. The moon is a natural light source at night and can be used to perform vicarious calibration of DNB when it illuminates the ground calibration site. The proposed work will support the calibration of DNB using moon light.

When the Suomi-NPP spacecraft moves from day to night in the northern hemisphere and from night to day in the southern hemisphere, stray light occurs and contaminates the DNB imagery. It is critical to correct for stray light and this is done by generating look-up table (LUT) using DNB radiance data that are close to new moon phase and have minimal light contamination from light sources such as aurorae or due to human activities. We support the software development for DNB stray light correction.

We focus on providing support to the VIIRS calibration to ensure that the mission requirements are met. We also support the prelaunch test data analysis for VIIRS on JPSS-1.

Accomplishments

We supported the VIIRS calibration in a broad scope by:

1. Supported quantitative analysis of VIIRS DNB nightlight point source for light power estimation and stability monitoring. Results are published in journal paper.
2. Performed trending of Suomi-NPP VIIRS radiometric performance with lunar band ratio. Results are reported in SPIE conference proceeding. We use Lunar Band Ratio (LBR) to trend satellite radiometer performance so that the usage of lunar irradiance model is not required. The LBR method is applied to

monitor long term radiometric performance of VIIRS. Total lunar digital number are calculated for each VIIRS reflective solar bands (RSBs) from lunar observations and one of the most stable bands of VIIRS such as M4 band is chosen as the reference band for calculating the band ratio. LBRs are compared with the degradation factors derived from VIIRS operational radiometric calibration of RSBs using onboard solar diffuser [Figure 1]. The LBR analysis reveals that M6 and M7 degrade the fastest and agree well with the trending independently determined from onboard solar diffuser. For stable bands such as M3-M4 of VIIRS, the variation range of band ratios of M2/M4 and M3/M4 are all within 0.6%, indicating the LBR can be used to reveal the sub percent band to band stability. For M11 band of VIIRS, there have been large uncertainties in verifying its radiometric performance using vicarious ground targets. LBR of M11 provides an independent and useful radiometric stability monitoring tool for verifying the relative stability of M11 band. The LBR analysis also shows that band-to-band variability in the spectrally similar band pairs such as I2 vs. M7 and I3 vs. M10 of VIIRS are consistent within 0.2%. It is demonstrated that long-term performance monitoring of VIIRS instrument using LBR is an important part of the VIIRS lunar calibration for solar bands and can effectively reveal the degradation of instruments.

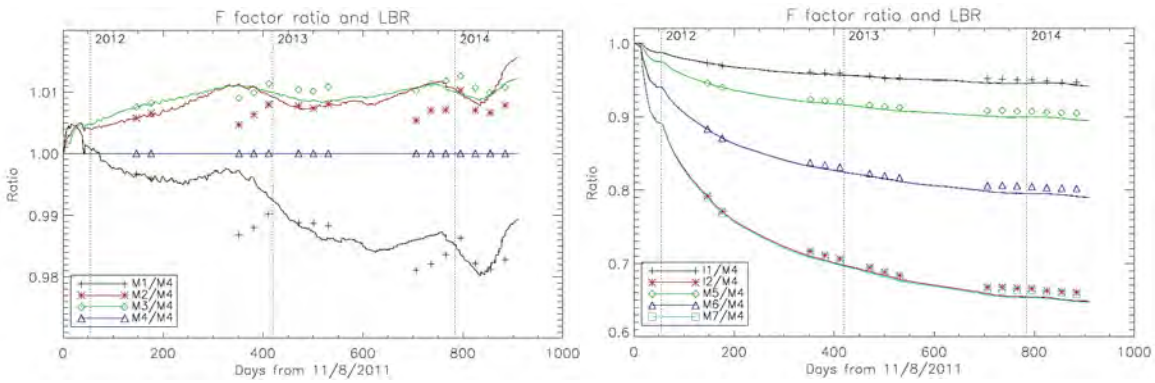


Figure 1: (Left) Operational F-factor ratios vs. LBRs in the VNIR bands M1 to M3 of VIIRS. Solid lines are the normalized operational F-factor ratios and the symbols are the corresponding LBRs. First point of LBRs on April 2nd, 2012 is aligned with the operational F-factors ratios on that day. (Right) Operational F-factor ratios vs. LBRs in the VNIR bands of M5- M7, I1 and I2. Solid lines are the normalized operational F-factor ratios and the symbols are the corresponding LBRs.

3. Performed inter-satellite calibration such as radiometric calibration of DMSP-OLS sensor using VIIRS day/night band**.** Results are reported in SPIE conference proceeding. DMSP-OLS sensor does not have on-board calibration and data is recorded as digital number (DN). Therefore, VIIRS-DNB provides opportunities to perform quantitative radiometric calibration of DMSP-OLS sensor. We perform vicarious radiometric calibration of DMSP-OLS at night under lunar illumination. Events were selected when satellite flies above Dome C in Antarctic at night and the moon illuminates the site with lunar phase being more than quarter moon. The data from DMSP-OLS and VIIRS-DNB were analyzed to derive the characteristic radiance for the region of interest. The scaling coefficient for converting DMSP-OLS DN values into radiance is determined in to optimally merge the observation of DMSP-OLS into VIIRS-DNB radiance data as a function of lunar phases [Figure 2]. Calibrating the nighttime light data collected by the DMSP-OLS sensors into radiance unit can enable applications of using both sensor data and advance the applications of night time imagery data.

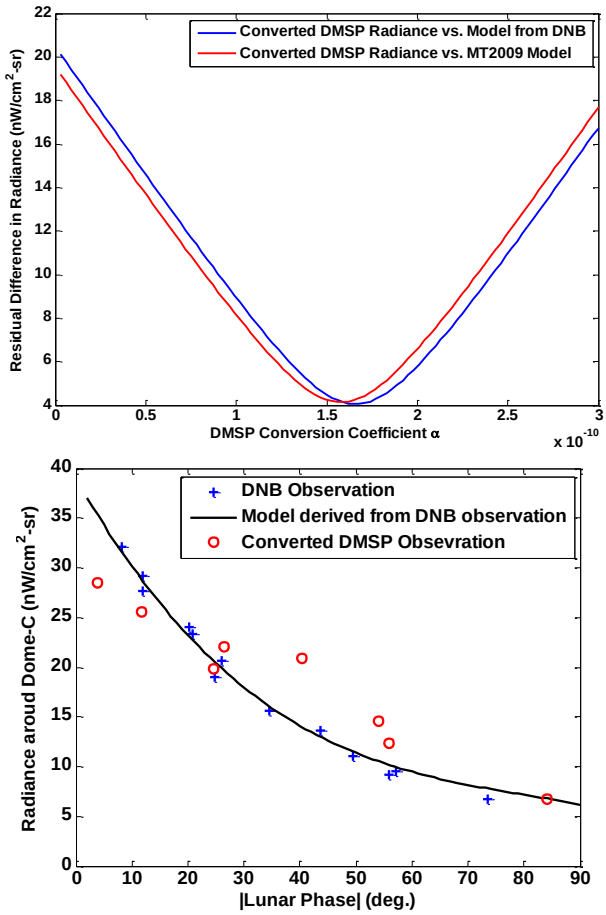


Figure 2: (Left) Residual difference between converted DMSP-OLS radiance and predicted radiance from model derived from DNB observation (blue line) or Miller-Turner [2009] model (red line) as a function of conversion coefficient α; (Right) Radiances from DNB measurement, from prediction of Miller-Turner [2009] lunar model (red line) and from converted DMSP-OLS measurement vs. lunar phase.

4. Supported development of Suomi NPP VIIRS calibration knowledge base for SDR data quality assurance, anomaly investigation, and EDR applications. Results are reported in SPIE conference proceeding.

5. Participated Suomi NPP VIIRS sensor data record verification, validation, and long-term performance monitoring for both RSB and TEB bands and supported an overview assessment of Suomi NPP VIIRS performance in the last 2.5 years. Results are reported in SPIE conference proceeding.

6. Performed Vicarious validation of Suomi-NPP/VIIRS Day/Night Band using DOME-C and Greenland under moon-light: Results are reported in AGU conference.

7. Performed modeling Suomi-NPP VIIRS solar diffuser degradation due to space radiation and results are reported in AGU conference.

8. Supported DNB stray light correction software development through support generation and validation of DNB stray light correction LUT. These LUTs are being delivered to IDPS for operation month by month.

9. Support the prelaunch test data analysis for VIIRS on JPSS-1. Performed data analysis of pre-launch testing for VIIRS on JPSS-1 and develop JPSS-1/VIIRS pre-launch performance baseline. Characterized VIIRS sensor in terms of a series of performance metrics such as dynamic range, stability, nonlinearity, uniformity, detector operability, gain transition, uncertainty, NEdT, and OBC operability.

10. We acquired and maintained a data sever to support calibration working group for processing, archiving and backup of public data for calibration of VIIRS.

Planned Work

- Continue to support radiometric calibration for VIIRS through
  - *Perform lunar calibration for VIIRS using band ratio and investigate alternative calibration schemes when moon is in space view*
  - *Perform calibration of VIIRS RSB and TEB bands*
  - *Assess VIIRS stability through comparing lunar, solar diffuser and vicarious calibration*
  - *Inter-satellite calibration between VIIRS and instrument on other satellites*
- Continue to support DNB stray light correction software development through
  - *Support generation and validation of DNB stray light correction LUT*
  - *Investigate air glow removal in DNB calibration*
  - *Automate and improve stray light correction LUT generation*
- Continue to support the prelaunch test data analysis for VIIRS on(JPSS-1).
- Maintain the data sever to support calibration working group for processing, archiving and backup of public data for calibration of VIIRS.

Publications

Peer-Reviewed

1. Cao C, Bai Y., Quantitative Analysis of VIIRS DNB Nightlight Point Source for Light Power Estimation and Stability Monitoring. **Remote Sensing**. 2014; 6(12):11915-11935.

Non-Peer-Reviewed

2. Xi Shao, Taeyoung Choi, Changyong Cao, Slawomir Blonski, Wenhui Wang, Yan Ban, "Trending of Suomi-NPP VIIRS radiometric performance with lunar band ratio", in Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, Xiaoxiong Xiong; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9264 (SPIE, Bellingham, WA 2014), 92640K.
3. Xi Shao, Changyong Cao, Bin Zhang, Shi Qiu, Chris Elvidge, Michael Von Hendy, "Radiometric calibration of DMSP-OLS sensor using VIIRS day/night band", in Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, Xiaoxiong Xiong; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9264 (SPIE, Bellingham, WA 2014), 92640A.
4. Yan Bai, Changyong Cao, Xi Shao, Wenhui Wang, "Suomi NPP VIIRS calibration knowledge base for SDR data quality assurance, anomaly investigation, and EDR applications", in Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, Xiaoxiong Xiong; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9264 (SPIE, Bellingham, WA 2014), 92641M.
5. Changyong Cao, Slawomir Blonski, Wenhui Wang, Xi Shao, Tayoung Choi, Yan Bai, Xiaoxiong Xiong, "Overview of Suomi NPP VIIRS performance in the last 2.5 years", in Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, Xiaoxiong Xiong; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9264 (SPIE, Bellingham, WA 2014), 926402.

Presentations:

1. Shi Qiu, Xi Shao, Changyong Cao, Vicarious Validation of Suomi-NPP/VIIRS Day /Night Band using DOME-C and Greenland under moon-light,AGU Fall Meeting, San Fransisco, 15 - 19 December 2014, Poster presentation, IN13C-3654.
2. Xi Shao and Changyong Cao, Modeling Suomi-NPP VIIRS Solar Diffuser Degradation due to Space Radiation, AGU Fall Meeting, San Fransisco, 15 - 19 December 2014, Poster presentation, A23E-3296.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**4**
# 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**

Scientific Support for Joint Polar Satellite System (JPSS) CrIS, VIIRS and OMPS Calibration

Task Leader	Yong Chen
Task Code	YCYC_JPSS_14
NOAA Sponsor	Fuzhong Weng
NOAA Office	NOAA/STAR/SMCD
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Calibration/Validation
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 100%

Highlight: CICI Scientist Yong Chen developed the CrIS full spectral resolution (FSR) SDR processing system and delivered on 01/15/2015 to NOAA/STAR Algorithm Integration Team and Raytheon IDPS to test. This SDR software has been validated and will be JPSS CrIS baseline code. CICS Scientist Likun Wang developed novel methods to evaluate and improve radiometric, spectral, and geolocation accuracy of Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR) on current operational Suomi NPP and future JPSS satellites. CICS Scientist Chunhui Pan has developed new comprehensive data analysis algorithms and models to evaluate and characterize sensor orbital stray light contamination, wavelength calibration and optical system stability. CICS Scientist Slawomir Blonski provided continued support for the on-orbit calibration of the VIIRS instrument onboard the S-NPP satellite and began analysis of the pre-launch test data from the VIIRS instrument built for the future JPSS-1 satellite.

Yong Chen

Background

This report summarizes the first year work of the ongoing NOAA project entitled "Scientific Support for Joint Polar Satellite System (JPSS) CrIS, VIIRS and OMPS Calibration". In this report, we only focus on the Cross-track infrared Sounder (CrIS) related calibration and validate activities. On December 4, 2014, CrIS on board the Suomi National Polar-Orbiting Partnership (S-NPP) satellite was commanded to the Full Spectral Resolution (FSR) mode from the Normal Spectral Resolution (NSR) mode which had been in operation since the beginning of CrIS measurements in February 2012. On the FSR mode, the interferograms of the three spectral bands are recorded with the same Maximum Path Difference (MPD), while on the NSR mode, the interferograms in the Mid-wave (MW) and shortwave (SW) bands are recorded with MPDs at a half of and a quarter of the long-wave (LW) band MPD, respectively.

The interferogram measurements together with the calibration data are sent to the ground in the form of Raw Data Records (RDRs). The ground processing software converts the interferogram measurements into calibrated and geolocated radiance spectra in the form of Sensor Data Records (SDR). The SDR software has two packages, which share the same processing code. One package is for operational use, running on the Interface Data Processing Segment (IDPS). The other is the Algorithm Development Library (ADL). ADL uses file based inputs and outputs, while IDPS uses a Data Management Subsystem (DMS) to manage the inputs and outputs.

After the transition of the CrIS instrument from the NSR to FSR mode operation, the IDPS system continued to process the RDRs into NSR SDRs by truncating the MW and SW band data into the NSR interferograms and will remain doing so for the foreseeable future. Therefore, the spectral resolution of the SDR data archived on NOAA's Comprehensive Large Array-data Stewardship System (CLASS) remains unchanged. In order to provide FSR SDR data to the user community, an ADL based processing system was

developed to transform the RDRs into FSR SDRs. The FSR processing system is based on the NSR IDPS CrIS SDR software of the version Mx8.5/Block2.0.

Accomplishments

We developed the FSR processing system to convert the FSR interferogram measurements to well calibrated FSR Sensor Data Records (SDRs). STAR CrIS SDR group has been using this system to provide SDR products to the user community with a data latency of 12 hours via GRAVITE and the STAR FTP site: ftp://ftp2.star.nesdis.noaa.gov/smcd/xxiong (Note, the NOAA operational system (IDPS) will continue to process the raw data into normal resolution SDRs). This accomplishment is very significant: S-NPP CrIS full spectral resolution data processing provides a higher spectral resolution radiance data in MWIR and SWIR bands for better NWP data assimilations and trace gas retrievals. Generation of CO, CH_4 and CO_2 products are listed as the level-1 requirement in J-1. The absorption line structures for CO, CH_4 and CO_2 are dramatically improved in CrIS FSR mode than NSR mode (see Figure 1).

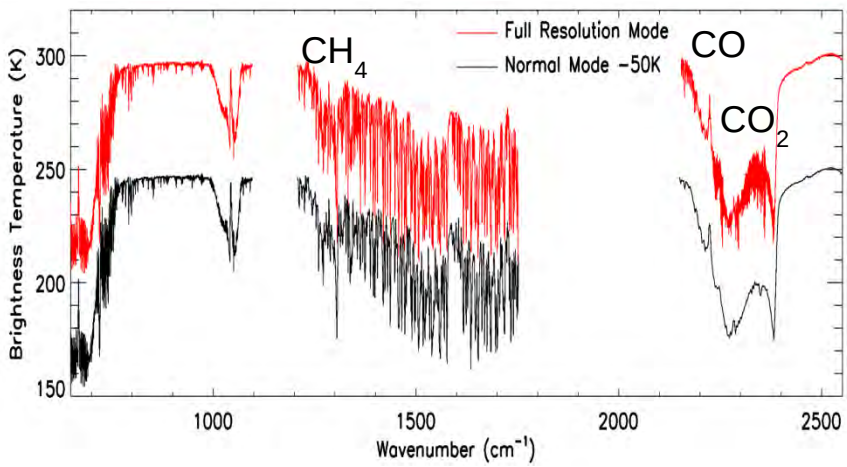


Figure 1. CrIS full spectrum with 2223 channels (unapodized, red) vs current normal mode with 1317 channels (black)

We have been working to improve the SDR calibration algorithms. For FSR SDR processing, it has been found that some of the calibration algorithms, while workings well for NSR SDR processing, do not produce acceptable results for the FSR SDR processing, and therefore must be changed or updated. In addition, changes to calibration algorithms were also made because they improve the calibrations results. The main changes made in converting the NSR-IDPS code to FSR-ADL code are in spectral calibration and radiance noise estimation algorithms, which are summarized below:

1. Resampling Algorithm

The resampling matrices are re-computed for each Neon calibration. The FSR-ADL software re-computes the resampling matrix for each neon calibration, which reduces spectral calibration uncertainty up to 2 ppm which is the threshold used in NSR-ADL software. We also use un-decimated bin size in resampling matrix calculation instead of decimated bin size. The results are consistent with the Sinc channel spectral response function defined for the SDR radiance product.

2. Self-Apodization Matrix Algorithm

In both FSR-ADL and NSR-IDPS systems, the SA matrix is computed in the un-decimated spectral domains (JPSS Configuration Management Office, 2011). The dimension size of the SA matrix is optimized to bal-

ance the computational efficiency and energy conservation that requires the summation of the column of the SA matrix equal to one. The dimension size is given by N_b*r, where r is the expansion factor. For NSR-IDPS, r takes the value of 1.1 for all spectral bands. The three expansion factors were determined as 1.4, 1.6 and 2.0 for the LW, MW and SW bands, respectively for FSR-ADL based on numerical experiments. With this change, the ringing artifacts that appear in the spectrum with the original expansion factor are effectively eliminated.

3. CMO Handling

The Correction Matrix Operator (CMO) is a matrix that combines the three spectral calibration components $\boldsymbol{SA^{-1}}$(inverse of self-apodization), ***F*** (resmpling) and *f* (post filter). In NSR-IDPS processing, the CMO matrices are loaded from a CMO file. If the variation of the metrology laser wavelength exceeds 2 ppm, they need to be recomputed and then saved. In FSR SDR processing, the CMO file only contains the $\boldsymbol{SA^{-1}}$ matrices, which do not need to be updated because they are constant. The CMO matrix is dynamically generated by combining the SA-1 matrix with the resampling matrix F and post-filter f.

4. NEdN Algorithm

The radiance noise level is measured with the Noise Equivalent Differential Radiance (NEdN), computed as the standard deviation of calibrated ICT spectra within the sliding window. In NSR-IDPS processing, the ICT spectra used for computing NEdN are not spectrally calibrated since the NEdN difference between with and without the CMO correction is small. However, for FSR SDRs, it was found that the noise levels and noise correlations between adjacent channels were significantly increased on the MW and SW bands by the self-apodization correction. Therefore, the CMO correction must be included in the NEdN calculations to take the noise effect into account.

Planned work

- Continue work to improve the calibration algorithms, including optimization of the calibration equation
- Implement ringing artifact reduction algorithm updates into FSR-ADL software once they are finalized
- Further assess the spectral and radiometric accuracies of the SDR product from the FSR processing system
- Transition algorithm to operations
- Analyze JPSS-1 pre-launch test data and derive parameters for CrIS spectral and radiometric calibration

Publications

Peer Reviewed

Wang L., Y. Han, X. Jin, Y. Chen, and D. Tremblay: Inter-comparison of Suomi NPP CrIS radiances with AIRS and IASI toward infrared hyperspectral benchmark radiance measurements, *Journal of Atmospheric and Oceanic Technology*, 2015, submitted

Non-Peer Reviewed

Chen, Y., Y. Han, D. Tremblay, L. Wang, X. Jin, and F. Weng: CrIS full resolution processing and validation system for JPSS, the 19th International TOVS Study Conference (ITSC-19), March 26 to April 1, 2014, Jeju Island, South Korea, 1p.06, 2014 (conference proceedings)

Han, Y. Y. Chen, X. Xiong, and X. Jin: S-NPP CrIS full resolution SDR processing and data quality assessment, the 95th AMS Annual Meeting, January 4-8, 2015, Phoenix, Arizona, J18.5, 2015 (conference proceedings)

Products

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

Presentations

Chen, Y., Y. Han, D. Tremblay, L. Wang, X. Jin, and F. Weng: CrIS full resolution processing and validation system for JPSS, the 19th International TOVS Study Conference (ITSC-19), March 26 to April 1, 2014, Jeju Island, South Korea, 1p.06, 2014

Xin, J., Y. Han, N. Sun, F. Weng, L. Wang, Y. Chen, and D. Tremblay: Monitoring Suomi-NPP CrIS instrument status and data quality at NOAA, the 19th International TOVS Study Conference (ITSC-19), March 26 to April 1, 2014, Jeju Island, South Korea, 1p.01, 2014

Xin, J., Y. Han, Y. Chen, L. Wang, D. Tremblay: The investigation of the S-NPP CrIS scene homogeneity, 2014 IGARSS and 35th Canadian Symposium on Remote Sensing, July 13-18, 2014, Quebec, Canada, WEP.M.89, 2014

Chen, Y., Y. Han, L. Wang, D. Tremblay, X. Jin, and F. Weng: S-NPP CrIS full resolution Sensor Data Record processing and evaluations, 2014 AGU Fall Meeting, December 15-19, 2014, San Francisco, California, IN13C-3650, 2014

Xin, J., Y. Han, N. Sun, F. Weng, L. Wang, Y. Chen, and D. Tremblay: S-NPP CrIS instrument status and raw data quality since the mission, 2014 AGU Fall Meeting, December 15-19, 2014, San Francisco, California, A511-3146, 2014

Liu, Q., N. Nalli, A. Ignatov, K. Garrett, Y. Chen, X. Liang, F. Weng, S. Boukabara, P. vanDelst, D. Groff, A. Collard, E. Joseph, V. Morris, P. Minnett: Community Radiative Transfer Model for Inter-satellites Calibration and Verification, 2014 AGU Fall Meeting, December 15-19, 2014, San Francisco, California, A511-3148, 2014

Chen, Y., Y. Han, X. Jin, L. Wang, D. Tremblay, and F. Weng: Assessments of CrIS spectral calibration accuracy and stability, 2014 STAR JPSS Annual Science Team Meeting, May 12-16, 2014, College Park, Maryland, 2014

Tremblay, D., Y. Han, Y. Chen, X. Jin, and L. Wang: JPSS-1 CrIS bench data and preliminary assessment of the instrument stability, 2014 STAR JPSS Annual Science Team Meeting, May 12-16, 2014, College Park, Maryland, 2014

Chen, Y., Y. Han, D. Tremblay, L. Wang, X. Jin, and F. Weng: Preparation of CrIS full resolution processing, 2014 STAR JPSS Annual Science Team Meeting, May 12-16, 2014, College Park, Maryland, 2014

Wang, L., Y. Han, Y. Chen, D. Tremblay, and X. Jin: Inter-comparison of hyperspectral sounders towards establishing hyperspectral benchmark radiance measurements, 2014 STAR JPSS Annual Science Team Meeting, May 12-16, 2014, College Park, Maryland, 2014

Xin, J., M. Esplin, L. Wang, D. Tremblay, N. Sun, Y. Han, Y. Chen, L. Wang, and F. Weng: Proxy dataset for testing and evaluating J1 CrIS SDR products, 2014 STAR JPSS Annual Science Team Meeting, May 12-16, 2014, College Park, Maryland, 2014

Chen, Y., Y. Han, D. Tremblay, L. Wang, X. Jin, and F. Weng: Preparation of CrIS full resolution processing, JPSS Mission Partner's and User's Conclave Forum, June 10-12, 2014, Riverdale, Maryland, 2014

Chen, Y., Y. Han, L. Wang, D. Tremblay, X. Jin, and F. Weng: S-NPP CrIS full resolution Sensor Data Record processing and evaluations, 2014 CICS Science Meeting, November 12-13, 2014, College Park, Maryland, 2014

Wang, L., Y. Han, Y. Chen, D. Tremblay, and X. Jin: Inter-comparison of Suomi NPP CrIS radiances with AIRS and IASI toward infrared hyperspectral benchmark radiance measurements, 2014 CICS Science Meeting, November 12-13, 2014, College Park, Maryland, 2014

Chen, Y., Y. Han, F. Weng, L. Wang, D. Tremblay, and X. Jin: Assessment of hyperspectral infrared sensors CrIS and IASI spectral accuracy using Community Radiative Transfer Model, the 95th AMS Annual Meeting, January 4-8, 2015, Phoenix, Arizona, 212, 2015

Chen, Y., Y. Han, L. Wang, D. Tremblay, X. Jin and F. Weng: Comparison of different calibration approached in S-NPP CrIS full spectral resolution processing, the 95th AMS Annual Meeting, January 4-8, 2015, Phoenix, Arizona, 213, 2015

Han, Y. Y. Chen, X. Xiong, and X. Jin: S-NPP CrIS full resolution SDR processing and data quality assessment, the 95th AMS Annual Meeting, January 4-8, 2015, Phoenix, Arizona, J18.5, 2015

Wang, L., Y. Han, Y. Chen, X. Jin and D. Tremblay: Inter-comparison of CrIS radiances with AIRS and IASI toward infrared hyperspectral benchmark measurements, the 95th AMS Annual Meeting, January 4-8, 2015, Phoenix, Arizona, 156, 2015

Other

Innovation award to CrIS SDR team from NOAA/NESDIS/STAR for developing a state-of-art system for processing, calibrating, and monitoring Suomi NPP CrIS SDR data to support weather and climate application

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**2**
# of invited presentations	**18**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

This year, we developed CrIS FSR-ADL SDR processing system and delivered on 01/15/2015 to NOAA/STAR Algorithm Integration Team and Raytheon IDPS to test for consideration in operation use (1). Based on this system, STAR CrIS SDR group has been using this system to provide SDR products to the user community since 12/04/2014 (1). One journal paper on the Inter-comparison of Suomi NPP CrIS radiances with AIRS and IASI toward infrared hyperspectral benchmark radiance measurements which is related to the project has been submitted (1). Two non-peered reviewed papers documented the FSR-ADL processing system, and users can refer them as guidance. Eighteen presentations summarizing the calibration and validation activities have been made (18).

Likun Wang

Background

This work is part of the project "Scientific Support for Joint Polar Satellite System (JPSS) CrIS, VIIRS and OMPS Calibration" but emphasizes more on Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR). The goal of this project is to focus on NOAA operational calibration support for CrIS and development of innovative techniques to improve the calibration of JPSS instruments for advanced applications. The CrIS SDR calibration and validation (Cal/Val) process includes both prelaunch and

postlaunch activities. Radiometrically, spectrally, and geolocated calibrated radiances with annotated quality indicators from CrIS SDR are used not only to provide improved atmospheric temperature and humidity profiles information, but are also used extensively by the scientific community for global measurements of trace gases, land surface properties, cloud properties, and medium-term climate trending. 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; and 3) data processing quality assurance involving in discovering SDR data processing anomalies, investigating root causes, and providing solutions to CrIS SDR team.

Accomplishments

The radiometric and spectral consistency among the Atmospheric Infrared Sounder (AIRS), the Infrared Atmospheric Sounding Interferometer (IASI), and the Cross-track Infrared Sounder (CrIS) is fundamental for the creation of long-term infrared (IR) hyperspectral radiance benchmark datasets for both inter-calibration and climate-related studies. These measurements are used not only to retrieve atmospheric temperature and humidity profiles, but more importantly, to be directly assimilated into numerical weather prediction (NWP) models as inputs. Moreover, owing to their hyperspectral nature and accurate radiometric and spectral calibration, hyperspectral IR radiances have been used as references to independently assess spectral and radiometric calibration accuracy of broad- or narrow-band IR instruments, as well as for long-term climate change monitoring, strict testing of climate model outputs, and validation of numerical weather model analyses and re-analyses.

CrIS is a step-scan Fourier transform spectrometer onboard Suomi NPP spacecraft. It can be operated in two modes: normal and full spectral resolution (FSR) mode. CrIS radiance spectrum (without apodization) covers three IR bands from 650 to 1095 cm^{-1}, 1210 to 1750 cm^{-1}, and 2155 to 2550 cm^{-1} with spectral resolutions of 0.625 cm^{-1}, 1.25 cm^{-1}, and 2.5 cm^{-1} at the normal operational mode (a total of 1305 spectral channels); it has an identical spectral resolution of 0.625 cm^{-1} in all three bands at the FSR mode (a total of 2211 channels). CrIS was operated at the normal mode since launch (except for several tests on 23 February 2012, 12 March 2013, and 27 August 2013). CrIS has been switched into the FSR mode since 4 December 2014. On one hand, the official CrIS sensor data records (SDR) are still processed and released as the normal resolution by Interface Data Processing Segment (IDPS). On the other hand, the NOAA/STAR CrIS SDR team off-line processed and released CrIS FSR SDR products (Han et al. 2015), which can be obtained at **ftp://ftp2.star.nesdis.noaa.gov/smcd/xxiong**.

In 2014, the CrIS radiance measurements on Suomi National Polar-orbiting Partnership (*SNPP*) satellite are directly compared with IASI on *MetOp-A* and *-B* at the finest spectral scale and with AIRS on *Aqua* in 25 selected spectral regions through one year of simultaneous nadir overpass (SNO) observations to evaluate radiometric consistency of these four hyperspectral IR sounders. The spectra from different sounders are paired together through strict spatial and temporal collocation. The uniform scenes are selected by examining the collocated Visible Infrared Imaging Radiometer Suite (VIIRS) pixels. Their brightness temperature (BT) differences are then calculated by converting the spectra onto common spectral grids. The results indicate that CrIS agrees well with IASI on *MetOp-A* and IASI on *MetOp-B* at the longwave IR (LWIR) and middle-wave IR (MWIR) bands with 0.1-0.2 K differences. There are no apparent scene-dependent patterns for BT differences between CrIS and IASI for individual spectral channels. CrIS and AIRS are compared at the

25 spectral regions for both Polar and Tropical SNOs. The CrIS-AIRS BT differences are less than or around 0.1 K among 21 of 25 comparison spectral regions and they range from 0.15 K to 0.22 K in the remaining 4 spectral regions. CrIS-AIRS BT differences in some comparison spectral regions show weak scene-dependent features.

In addition, efforts are also made to inter-compare FSR CrIS SDR with IASI spectra, as shown in examples in Figure 1. During 26-28 December 2014, CrIS met IASI on MetOp-B almost every orbit for three days, the so-called simultaneous nadir overpass (SNO) events. The spectra from two sensors are paired together through strict spatial and temporal collocation. The uniform scenes are selected by examining the collocated Visible Infrared Imaging Radiometer Suite (VIIRS) pixels. Their brightness temperature (BT) differences are then calculated by converting the IASI spectra onto CrIS spectral grids. A total of 144 pairs of spectra collocated in the North Polar Region and 187 spectra in South Polar Region during this SNO event. Figure 2 shows the CrIS spectral distribution as well as the mean and standard deviation of CrIS-IASI BT differences. The preliminary results indicate that CrIS full spectral resolution SDR products agree well with IASI in the longwave and middle-wave bands, where CrIS is slightly warmer than IASI by around 0.1-0.2 K, which is similar to the inter-comparison results between CrIS normal resolution SDR with IASI on MetOp-A and MetOp-B. Finally, a ringing pattern can be seen in the shortwave band, which is probably due to the large noise found for cold scenes for both sensors. The root cause of this bias pattern is still under investigation. Inter-comparison of both FRS and normal resolution CrIS SDR will be continued to monitor the calibration stability of CrIS sensor by the NOAA/NESDIS/STAR CrIS SDR team.

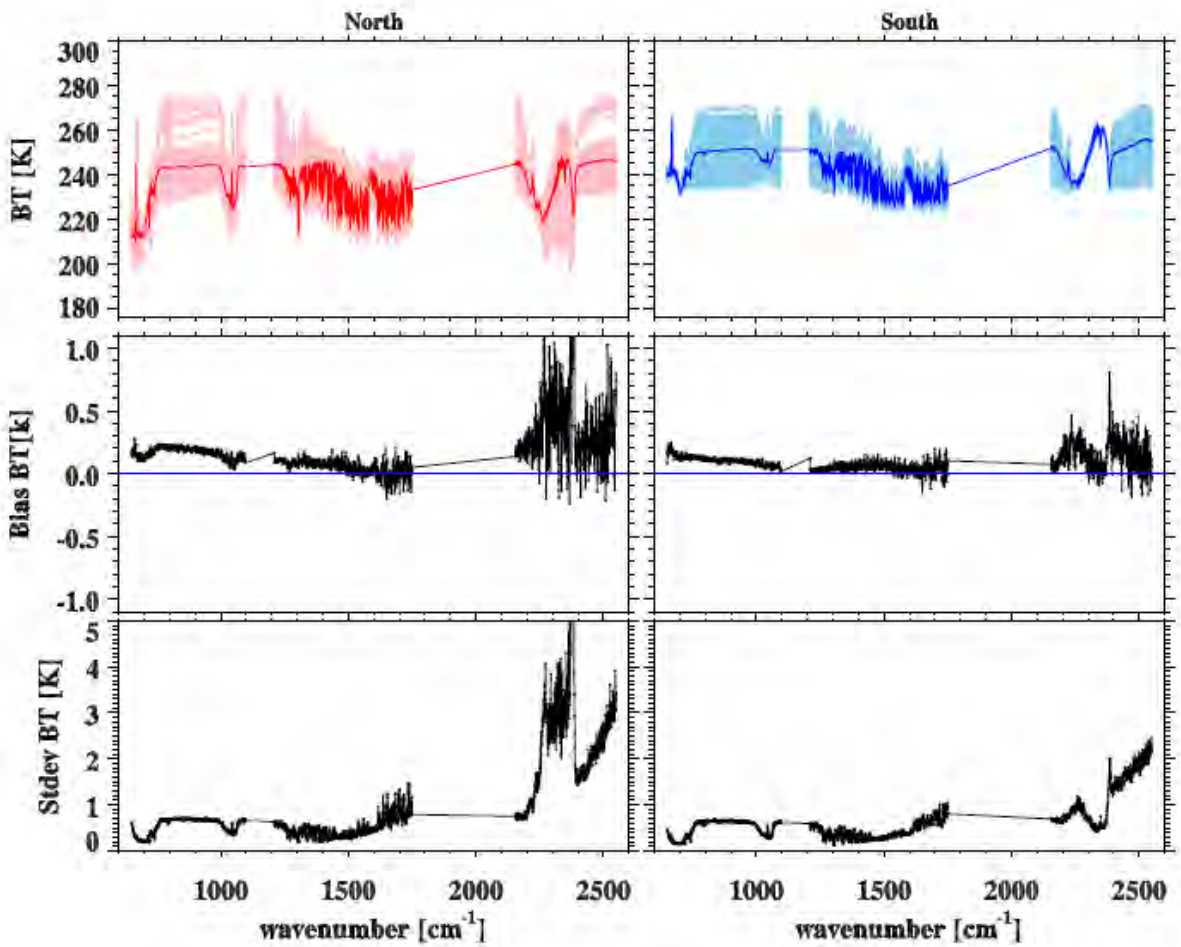


Figure 1: CrIS spectral distribution (top) for CrIS-IASI on MetOp-B for North Polar SNOs (left) and South Polar SNOs (right) and the mean (middle) and standard deviation (bottom) of CrIS-IASI BT differences.

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.
- Process pre-launch calibration data for JPSS-1 satellite.
- Improve the CrIS calibration algorithm including reordering of equation, full resolution, ringing reduction, and more.
- Draft a paper on CrIS/ATMOS-VIIRS accurate collocation.

Publications

Zou, C.-Z., H. Qian, W. **Wang, L.** Wang, and C. Long, 2014: Recalibration and Remerging of SSU Observations for Stratospheric Temperature Trend Studies. *Journal of Geophysical Research*, **119**, 13,180–13,205, doi:10.1002/2014JD021603.

Wang, L., Y. Han, X. Jin, Y. Chen, and D. A. Tremblay, 2014: Inter-Comparison of Suomi NPP CrIS Radiances with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements. *Journal of Atmospheric and Oceanic Technology (Submitted).*

Wang, L., Y. Han, X. Jin, Y. Chen, X. Xiong, and D. A. Tremblay, 2015: Inter-comparison of CrIS full resolution radiances with IASI. GSICS Quarterly Newsletters, Vol. 8 No. 4, DOI:10.7289/V5KW5CZB.

Products

- JPSS-1 CrIS Calibration Algorithms;
- Software system for Inter-comparing CrIS, AIRS, and IASI ; and
- Trending system for CrIS geolocation assessment using VIIRS.

Presentations

Wang L., Yong Han; Yong Chen; Xin Jin; Denis A. Tremblay, 2015: Inter-Comparison of Suomi NPP CrIS Radiances with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements. *The 95th AMS Annual Meeting*, January 4-9 2015. Phoenix, AZ.

Wang L., Yong Han; Yong Chen; Xin Jin; Denis A. Tremblay, 2014: Inter-Comparison of Suomi NPP CrIS Radiances with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements. *The Fifth Asia-Oceania Meteorological Satellite Users Conference*, November 19-21 2014, Shanghai, China.

Wang L., Yong Han; Yong Chen; Xin Jin; Denis A. Tremblay, 2014: Inter-Comparison of Suomi NPP CrIS Radiances with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements. *2014 EUMETSAT Metrological Satellite Conference*. Geneva, Switzerland.

Wang L., Yong Han; Yong Chen; Xin Jin; Denis A. Tremblay, 2014: Inter-Comparison of Suomi NPP CrIS Radiances with AIRS and IASI toward Infrared Hyperspectral Benchmark Radiance Measurements. 2014 NOAA STAR JPSS Annual Science Team Meeting. May 12-16, 2014, College Park, MD.

Other

- An Award by NOAA/NESDIS/STAR for outstanding performance and lasting contributions to the satellite Instrument Calibration and Product Development Research
- The 2014 Innovation Award by NOAA/NESDIS/STAR for developing a state-of-the-art system for processing, calibrating and monitoring Suomi NPP CrIS SDR data to support weather and climate applications.
- The 2014 Best Paper Award by NOAA/NESDIS/STAR for the widely acclaimed research article published in the Journal of Climate on “Construction of Stratospheric Temperature Data Records from the Stratospheric Sounding Unit Instruments.”
- Employee Spotlight: Likun Wang in NESDIS newsletter in July 2014

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**1**
# of invited presentations	**4**
# 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**

This year, the task leader received three (3) rewards and one (1) highlight from NOAA/NESDIS. Three papers has been published (2) or submitted (1). Four presentations have been presented in the domestic and international conferences. We improved the JPSS-1 CrIS calibration algorithms through the simulation work and completed the software development for CrIS-AIRS-IASI inter-comparison.

Chunhui Pan

Background

The Ozone Mapping Profiler Suite (OMPS) is one in a series of ozone monitoring sensors flown by NOAA and NASA. It continues more than 30 years of global ozone monitoring by providing data products of ozone in the Earth's atmosphere. The OMPS Nadir system comprises two instruments: a Nadir Mapper (NM) and a Nadir Profiler (NP). My primary responsibility is to perform sensors' calval. using ground test and orbital data. This report summarizes the year-3 work of the ongoing NOAA project entitled "The Ozone Mapping and Profiler Suite (OMPS) Sensor Data Record (SDR) Calibration". New comprehensive sensor performance analysis tools have been developed and used for sensor performance evaluation and calibration, including electronic, spectral, wavelength and radiometric calibration and validation. Much of the efforts also made to support sensor operation, such as transition of calibration SDR tools and delivery of calibration tables. Below are the accomplishments during the third year of the project, followed by future plans for fourth year.

Accomplishments

A. Three OMPS Articles Published

I have a new article on performance evaluation of the S-NPP Ozone Mapping and Profiler's Suite (OMPS) published in the IEEE Journal of Selected Topics in Earth Observations and Remote Sensing. It discusses the implementation of modified calibration sequences for determining the sensors' orbital characteristics. Pan, Chunhui, L. Flynn, Rich Buss, Xiangqian Wu, W. Yu, and Michael Grotenhuis, 2014: Performance monitoring of the S-NPP Ozone Mapping and Profiler Suite's Sensor Data Records. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., 7, 1763–1770, doi 10.1109/JSTARS.2014.2319738.

In addition, I had two articles in the special issue in *Journal of Geophysical Research: Atmospheres* on Suomi NPP Calibration and Validation Scientific Results:

- Flynn, L. , 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, and C. Seftor, 2014: Performance of the Ozone Mapping and Profiler Suite (OMPS) products, *J. Geophys. Res.: Atmos.*, **119**, 6181–6195, doi:10.1002/2013JD020467; and
- Xiangqian Wu, Quanhua Liu, Jian Zeng, Michael Grotenhuis, Haifeng Qian, Maria Caponi, Larry Flynn, Glen Jaross, Bhaswar Sen, Richard H. Buss Jr., William Johnsen, Scott Janz, Chunhui Pan, Jianguo Niu, Trevor Beck, Eric Beach, Wei Yu, M. K. Rama Varma Raja, Derek Stuhmer, Daniel Cumpton, Cristina Owen, and Wen-Hao Li, 2014: Evaluation of the Sensor Data Record from the nadir instruments of the Ozone Mapping Profiler Suite (OMPS), *J. Geophys. Res.: Atmos.*, **119**, 6170–6180, doi:10.1002/2013JD020484.

B. Progress on OMPS Calval activates

I have developed new comprehensive data analysis algorithms to evaluate SNPP OMPS sensor orbital wavelength calibration and optical system stability. I have also established a preliminary stray light calibration models for Nadir Profiler sensor to analyze both prelaunch and orbital data. Additionally, I have made numbers of deliveries to STAR, including SNPP sensor performance assessment, software tools, and weekly delivery of dark calibration tables after I have performed an anomalous screen and a functional validation tests. I also verified JPSS1 OMPS prelaunch calibration tables and delivered JPSS1 radiance calibration coefficients for both NP and NM. The following are some examples of my major accomplishments that are critical performance parameters and issues in the current OMPS operation.

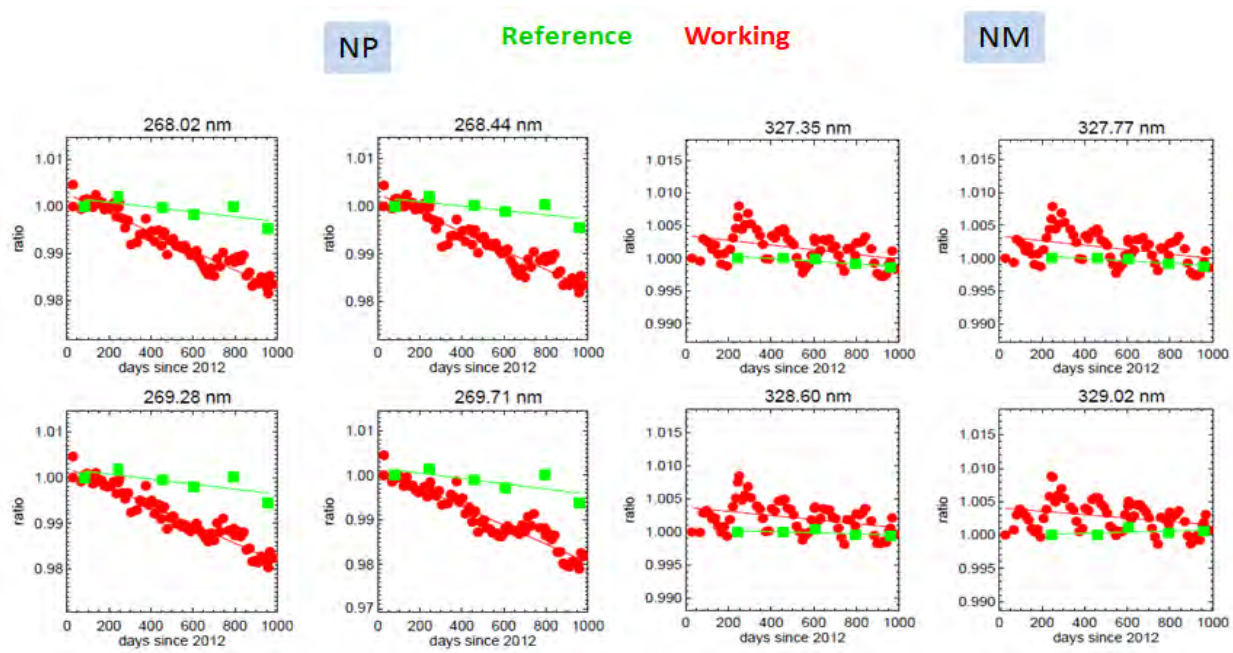


Figure 1 Time dependent changes in NP and NM optics throughput from the working and reference diffusers for different channels.

1. *Optical system 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 spec-

tral 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.

2. Cross-Track Position

The OMPS NM sensor exhibits wavelength-dependent differences in the radiometric calibration as a function of the cross-track position. Such a feature presents in both the observed solar flux and the Earth radiance, so goniometric errors are not the cause. Fig. 2 compares measured solar flux to the predicted synthetic data at two different cross-track positions (11 and 26) relative to the nadir view position 17 before (left) and after (right) wavelength adjustment. The adjustment removes the difference up to 2.5% at the two edge positions on the NM CCD.

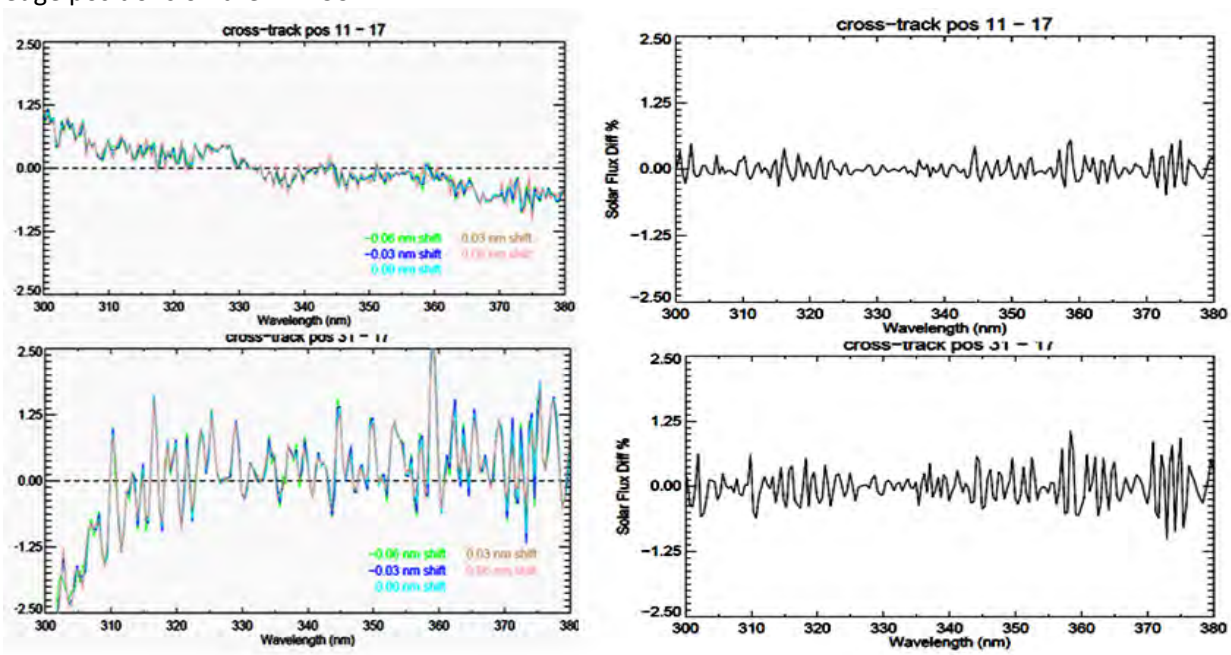


Figure 2 Wavelength varies in scan direction (left two subfigures) cause up to 2.5 % radiance error. The error was delimited after wavelength adjustment (right two subfigures).

3. Wavelength shift from ground to orbit

The in-flight wavelength calibration is performed by periodically comparing the OMPS observed solar spectrum with a standard solar spectrum. OMPS in-flight wavelength calibration is conducted through the calculation of the band center at each illuminated pixel by using the position of Fraunhofer absorption lines in the observed solar spectrum. Wavelength shifts from ground to orbit were computed by differencing the ground and orbital solar wavelength scales. OMPS wavelength changes are largely due to spectral filter shape changes that are produced by thermal loading changes and angular changes in various optical elements. It is unlikely caused by a single optical element, but one could be the dominant.

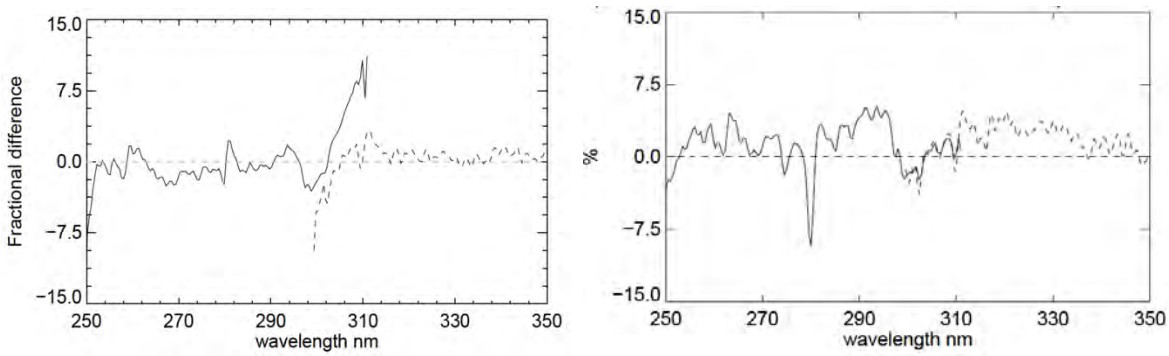


Figure 3 Left: 12% percent difference between observed solar flux and the predicted solar flux based on the orbital wavelengths occurred in spectral range 300-310 nm. Right: After adding 0.15 nm shift to the orbital wavelength, the difference in the NP and NM overlap region drops to 5%.

4. Orbital wavelength calibration

Wavelength shifts in flight, specifically those of the OMPS NM sensor, do not change monotonically with time. In particular, temperature cycles in the sensor result in shifts in spectral registration on the focal plane. The dominant cycles are orbital and annual illuminations by the sun. The estimated maximum annual cycle in spectral registration shown in Fig. 10 is about 0.012 nm for NM and 0.02 nm for NP, as obtained from a baseline regression of 59 (NM) and 65 (NP) solar working diffuser measurements. By comparing the predicted shift with the actual (nominal) shift on every measurement date, we find the relative wavelength change pattern by taking the slopes of local quadratic fits of spatially averaged points along wavelength channels. From the fitted curves, I create a set of normalized fractional difference spectra, normalizing by each time-averaged value along a wavelength channel. To derive the time series, we linearly fit the relative wavelength changes at each time to find the wavelength shift over all wavelength channels for that time. The solar data collected from the reference diffuser were also processed in the same way, and co-plotted with the working diffuser data as triangles. So far, there were five measurements made with the reference diffuser since the sensor launch, and the wavelength variation results derived from these five measurements are highly consistent with the shifts derived from working diffuser measurements.

The in-flight spectral shifts are consistent with prelaunch predictions, and the resulting errors range from 0.2% at high ozone values to 0.65% at low ozone values. These errors have been applied to the sensor precision allocations.

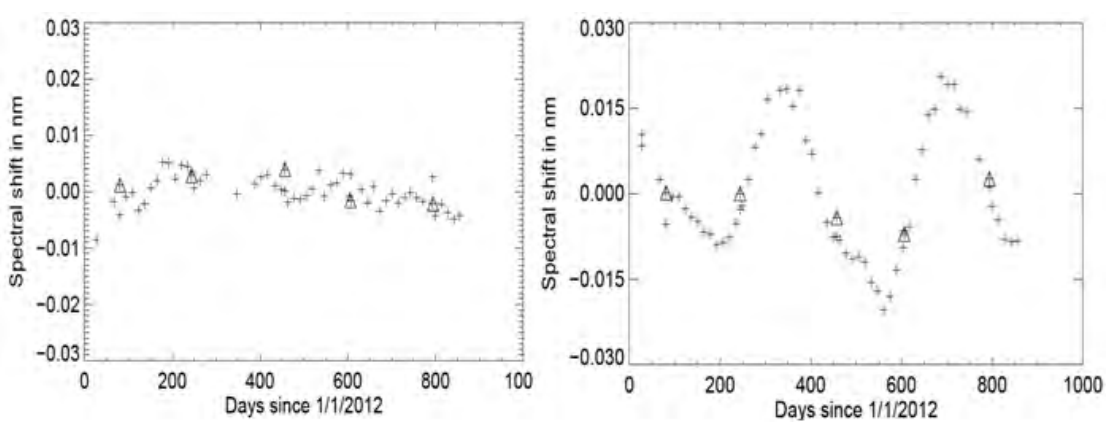


Figure 4 Observed annual cycle in sensor spectral registration for sensor NM (left) and NP (right). The data was collected from both reference diffuser measurements (+) as well as working diffuser measurements (Δ).

5. Stray light model

Two preliminary stray light models were recently developed with 4-dimension matrix coefficients. The models includes all in band stray light, out of band scattering and out of band ghosts. Figure 5 shows an example of the NP model results and the stray light contamination.

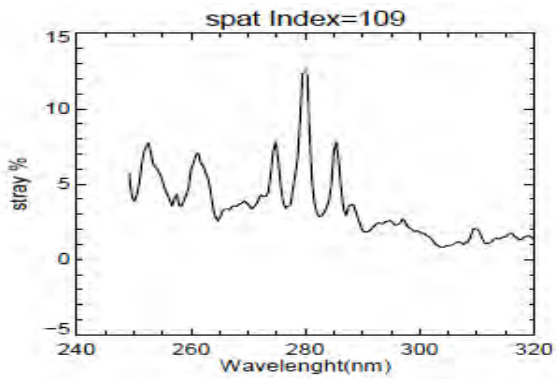


Figure 5 an example of the NP model results that show the stray light contamination is up to 13% around 280 nm.

C. OMPS NP and NM Dark Current Calibration Tables Delivered Successfully

I have successfully completed my work on the Dark Current Calibration Tables for the Nadir Profiler (NP) and Nadir Mapper (NP) of the Ozone Mapping and Profiler Suite (OMPS). The NASA Dark Current Tables were verified with in-house developed anomalous screen algorithms. The dark tables were validated with Algorithm Development Library (ADL) functional tests and validated test results for two independent sensors. 12 packages of different DRs were derived and delivered. Each package includes newly-derived dark tables, ADL-derived validate results, functional test files and outputs, expected Sensor Data Records (SDR), letters for the delivery and letters for the Joint Polar Satellite System (JPSS) Data Products Engineering (DPE) look-up table processing coefficient files (PCT); Delivery Checklist and Ingest Directive and letters for JPSS DPE Processing Request. The Dark Current Calibration Tables are significant because they mitigate and correct the OMPS NP and NM radiance calibration errors and improve the accuracy of NP and NM Earth view radiance up to 0.7 – 1.5 % (on short wavelengths), thereby improving the downstream products derived from NP and NM radiance.

Planned work

- Continue work on stray light models for different data resolution and Field of Views (FOVs) for both NP and NM.
- Continue work on stray light models for different spectral dynamic ranges for both NP and NM. Derive and deliver stray light calibration tables.
- Continue work to monitoring SNPP-OMPS sensor orbital performance
- Support Calibration SDR transition from NASA to GRAVITE.
- Continue work on J1 OMPS prelaunch calibration tables.

Publications

Peer reviewed papers in 2014

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 Journal of Selected Topic in Applied Earth Observation and Remote Sensing*. Volume 7, Issue 5. May 20, 2014 10.1109/JSTARS.2014.2319738

C. Pan, Larry Flynn, Xiangqian Wu and Rich Buss, "Suomi National Polar-orbiting Partnership Ozone Mapping Profiler Suite Nadir instruments in-flight performance", J. Appl. Remote Sens. 8(1), 083499 (Dec 30, 2014). doi:10.1117/1.JRS.8.083499

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*, MAY 20, 2014 DOI: 10.1002/2013JD020467

X. Wu, Q. Liu, J. Zeng, M. Grotenhuis, H. Qian, M. Caponi, L. Flynn, G. Jaross, B. Sen, R. Buss, W. Johnsen, S. Janz, C. Pan, J. Niu, T. Beck, E. Beach, W. Yu, M. Varma Raja, 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*, MAY 20, 2014. DOI: 10.1002/2013JD020484

Products

1. Computation of sensor dichroic filter wavelength shift algorithm development
2. NP stray light contamination numerical model development
3. Computation of orbital wavelength variation algorithm development
4. Software readers of SNPP/JPSS1 operation tables
5. Weekly dark table packages generation

Presentations

1. C. Pan, L. Flynn, J. Niu, M. Grotenhuis, T. Beck, E. Beach, Z. Zhang and A. Tolea, S-NPP OMPS Nadir In-Flight Performance. Dec. 15-19, 2014, San Francisco. USA
2. C. Pan, L. Flynn, X. Wu, J. Niu, Z. Zhang, M. Grotenhuis, T. Beck and E. Beach S-NPP Ozone Mapping Profiler Suite (OMPS) Nadir System Calibration, The 2014 EUMETSAT Meteorological Satellite Conference, 22 - 26 September 2014, Geneva, Switzerland
3. C. Pan and Fred Wu, S-NPP OMPS Nadir Performance and Calibration, European Geosciences Union General Assembly 2014. 27 April – 02 May 2014, Vienna, Austria
4. C. Pan and L. Flynn Evaluation of S-NPP Ozone Mapping Profiler Suite Nadir Instrument In-flight Performance. The Second Annual CICS-MD Science Meeting, 12 - 13 November 2014. College Park, MD20740
5. C. Pan, X. Wu, L. Flynn, M. Grotenhuis, T. Beck, S-NPP Ozone Mapping Profiler Suite Nadir Sensor Performance Monitoring. STAR JPSS Annual Meeting. May 12-16 2014. College Park, MD20740

Performance Metrics	
# of new or improved products developed (please identify below the table)	**6**
# of products or techniques submitted to NOAA for consideration in operations use	**6**
# of peer reviewed papers	**4**
# of non-peered reviewed papers	**0**
# of invited presentations	**5**
# of graduate students supported by a CICS task	**NA**
# of graduate students formally advised	**NA**
# of undergraduate students mentored during the year	**NA**

Explanation of Table

6 New or improved products developed

1. NP stray light contamination table
2. SNPP NP dark table package
3. SNPP NM dark table package
4. Software readers of SNPP/JPSS1 operation tables
5. JPSS1 NP radiance calibration constant table
6. JPSS1 NM radiance calibration constant table

6 of products or techniques submitted to NOAA for consideration in operations use

1. NP stray light contamination table
2. SNPP NP dark table package
3. SNPP NM dark table package
4. Software readers of SNPP/JPSS1 operation tables
5. JPSS1 NP radiance calibration constant table
6. JPSS1 NM radiance calibration constant table

Slawomir Blonski

Background

The Joint Polar Satellite System (JPSS) is the next generation of the U.S. polar-orbiting satellites that will continue observations from the NOAA Polar-orbiting Operational Environmental Satellites (POES) and the Suomi National Polar-orbiting Partnership (S-NPP) mission. The first JPSS spacecraft, JPSS-1, scheduled for launch in 2017, takes advantage of the technologies developed for the S-NPP satellite and its scientific instruments. The Visible Infrared Imaging Radiometer Suite (VIIRS) is one of the instruments onboard the current S-NPP satellite and the future JPSS-1 and JPSS-2 spacecraft. VIIRS continues and enhances Earth observation capabilities of the AVHRR instruments from the NOAA POES satellites and the MODIS instruments from the NASA Aqua and Terra satellites. Calibration methods developed for the S-NPP VIIRS have improved the current operational data products and will also apply to the future JPSS measurements. Accurate calibration ensures continuity of the satellite measurements for operational weather forecasting and climate change studies.

VIIRS is a 22-band multispectral imaging radiometer with a spectral range from 400 nm to 12 µm that includes both reflective solar bands and thermal emissive bands. VIIRS uses a unique spatial sampling aggregation scheme that reduces changes in the pixel ground footprint size along the Earth surface scan. Several of the spectral channels also use a dual-gain setup that dynamically adjusts to the imaged scene brightness. Novel observational capabilities are also offered by the day-night band with unprecedented dynamic range that enables Earth imaging under both solar and lunar illumination. These characteristics necessitate development of new techniques for on-orbit calibration and validation of the VIIRS instruments.

Accomplishments

Project activities undertaken during the current reporting period included both continued support for the on-orbit calibration of the VIIRS instrument on-board the S-NPP satellite and analysis of the pre-launch test data from the VIIRS instrument built for the JPSS-1 satellite. Revised operational versions of the VIIRS sensor data record processing codes were analyzed to ensure correct implementation of scientific algorithms and calibration procedures. Ongoing automation of the VIIRS radiometric calibration was supported by providing validation of the code constants and look-up table updates required for algorithm implementation and deployment. Simultaneous nadir overpass observations were used to compare radiometric calibration of VIIRS and MODIS in further support of the automated calibration. Stability of VIIRS radiometric calibration and accuracy of product geolocation were monitored using multiple pseudo-invariant calibration sites in Sahara. Analysis of the JPSS-1 pre-launch test data has begun, and preliminary sensor constants and look-up tables were derived in preparation for incoming testing of the updated VIIRS data processing software.

One of the main accomplishments was the reprocessing of the VIIRS onboard solar calibration data acquired since the launch of the S-NPP satellite. The latest operational automated calibration software was used to calculate radiometric calibration coefficients for all VIIRS reflective solar bands. While the operational calibration coefficients are generated weekly, the automated procedure has provided the coefficients for every orbit during more than three years of the S-NPP mission. After converting the onboard calibrator data files to the latest format required by the processing software, the automated calibration code from the operational software was used to generate radiometric calibration coefficients for the VIIRS reflective solar bands. The calculated estimates of the solar diffuser reflectance changes over time have shown unexpected variability of the reflectance in 2014 and indicated that the diffuser stability monitoring during unfavorable observational conditions each October and November could still be improved (Fig. 1).

The diffuser reflectance time series have also revealed that one of the trend change coincided with the decrease in frequency of the solar diffuser stability monitor measurements in mid-May 2014, although it is still unclear how frequency of the measurements can affect the measured values.

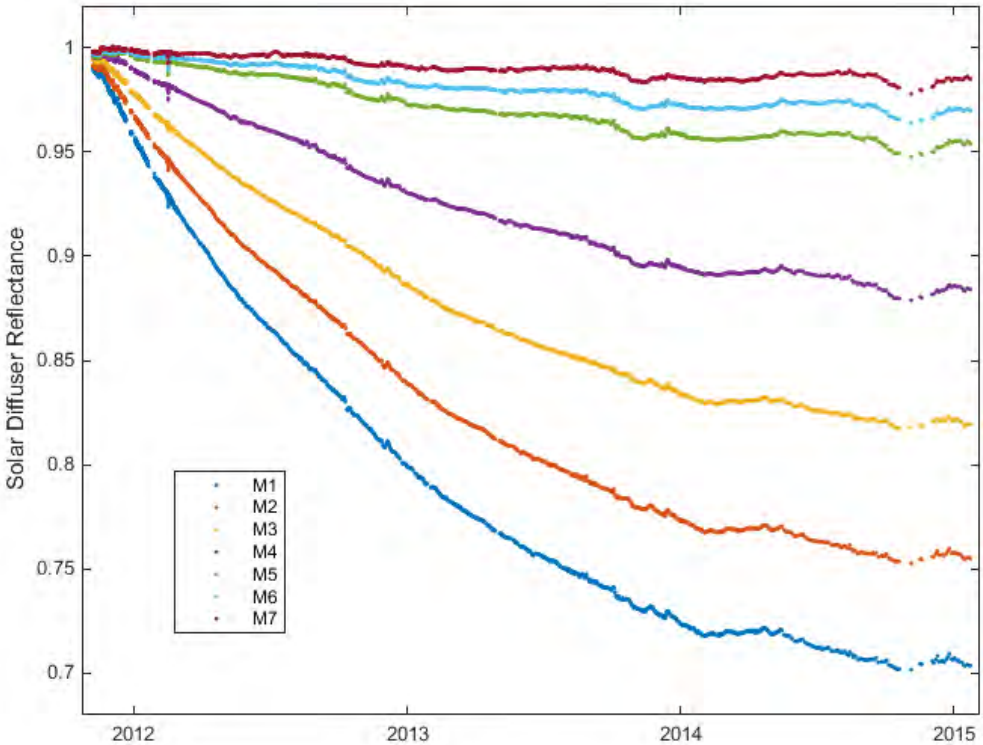


Figure 1. Time series of the S-NPP VIIRS solar diffuser reflectance derived by the operational automated calibration code (without interpolation or filtering) from the measurements collected by the onboard solar diffuser stability monitor.

In preparation for the JPSS-1 launch and on-orbit operations, an initial version of the relative spectral response (RSR) lookup table (LUT) for the JPSS-1 VIIRS was created. The table is based on prelaunch testing data provided by the instrument vendor with a performance verification report. The RSR values are detector averaged as required by the current VIIRS data processing software. Some additional filtering was used to remove duplicate wavelengths. Fig. 2 shows the JPSS-1 VIIRS spectral responses from the new LUT. While only the reflective solar bands and the day/night band are included in the RSR LUT, spectral response data for the thermal emissive bands were gathered as well and will be used in derivation of other lookup tables and processing coefficients for these bands.

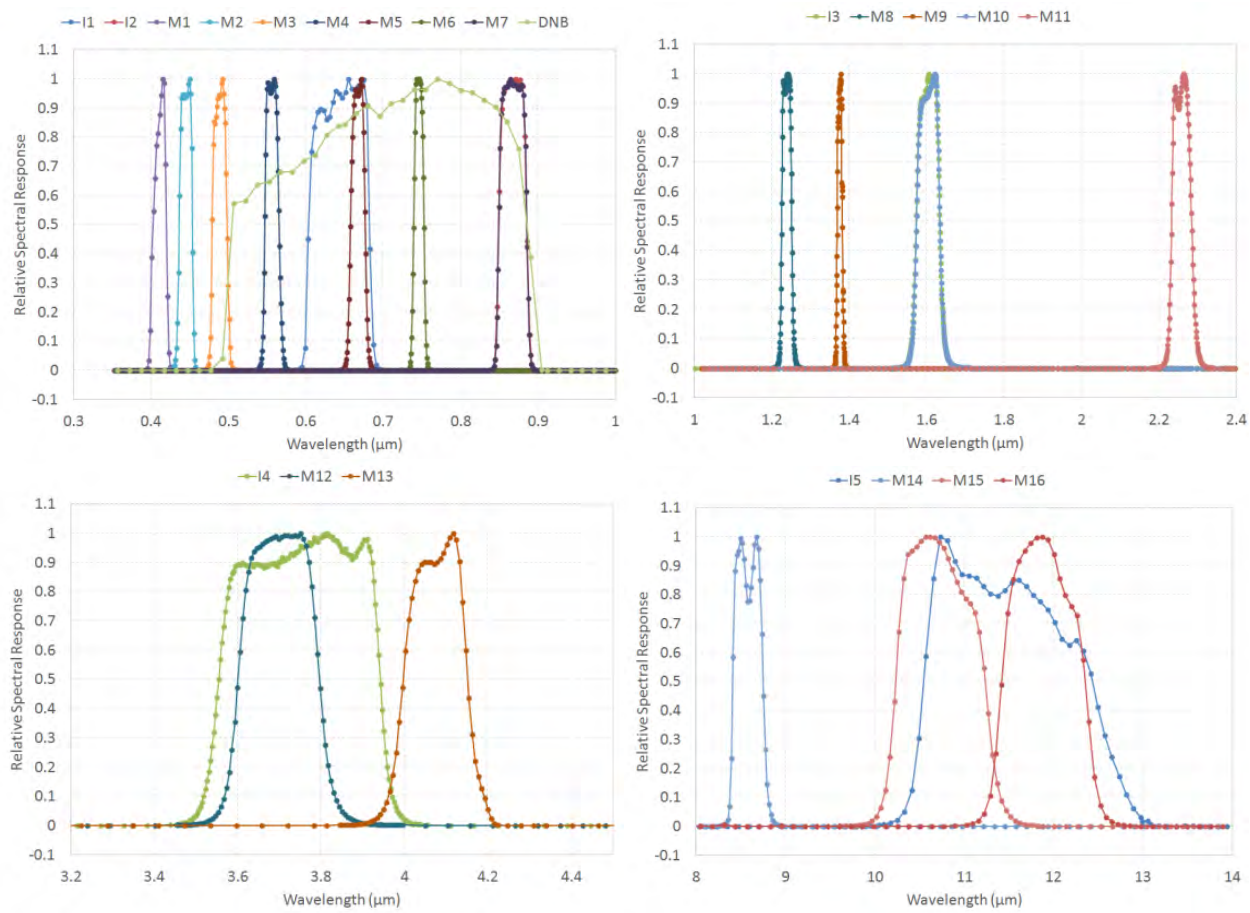


Figure 2. JPSS-1 VIIRS spectral response functions derived from the prelaunch testing data.

Planned work

- Analyze JPSS-1 pre-launch test data and derive appropriate sensor constants and look-up tables for testing of the VIIRS SDR processing software updated for the JPSS-1 mission and for maintaining VIIRS SDR products within required performance metrics during the post-launch period
- Provide analysis of the VIIRS SDR processing codes to ensure correct implementation of scientific algorithms and calibration procedures
- Provide validation of updates to the on-orbit look-up tables with processing parameters needed by the JPSS program for the VIIRS SDR algorithms
- Support automation of the VIIRS radiometric calibration by providing validation of the code constants and look-up table updates required for algorithm implementation and deployment

Publications

Non-peer reviewed

Blonski, S., C. Cao. X. Shao, and S. Uprety, 2014: VIIRS reflective solar bands calibration changes and potential impacts on ocean color applications, *Proc. SPIE*, **9111**, 911106, doi:10.1117/12.2053315.

Presentations

Blonski, S., C. Cao. X. Shao, and S. Uprety: VIIRS reflective solar bands calibration changes and potential impacts on ocean color applications, *SPIE Ocean Sensing and Monitoring VI Conference*, Baltimore, Maryland (6-7 May 2014)

Blonski, S., Resolving RSB Performance Issues, 2014 JPSS STAR Annual Science Team Meeting, College Park, Maryland (12-16 May 2014), http://www.star.nesdis.noaa.gov/star/documents/meetings/2014JPSSAnnual/dayThree/01_Session4a_Blonski_annual-review.pdf

Blonski, S., C. Cao. X. Shao, and S. Uprety: VIIRS Reflective Solar Bands Calibration Changes and Potential Impacts on Applications, *Conference on Characterization and Radiometric Calibration for Remote Sensing (CALCON)*, Logan, Utah (11-14 August 2014), http://digitalcommons.usu.edu/calcon/CALCON2014/All2014Content/12/

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of non-peered reviewed papers	**1**
# of invited presentations	**1**
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

1.3 Surface Observation Networks

Long-Term Changes in Cloudiness from Surface Observations

Task Leader	Hyelim Yoo
Task Code	HLHL_LTCC_14
NOAA Sponsor	Melissa Free
NOAA Office	OAR/ARL
Contribution to CICS Research Themes (%)	Theme 1: 30%; Theme 2: 70%; Theme 3: 0%.
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 10%; Goal 3: 0%; Goal 4: 0%; Goal 5: 40%

Highlight : Variability and trends in total cloud cover for 1982-2009 across the contiguous U.S. from International Satellite Cloud Climatology Project (ISCCP), AVHRR Pathfinder Atmospheres Extended (PATMOS-x) and EUMETSAT Climate Monitoring Satellite Application Facility CLoud Albedo and RAdia- tion (CLARA-A1) satellite datasets are inter-compared with homogeneity-adjusted weather station data.

Background

This annual report summarizes the ongoing NOAA project entitled "Long-term changes in cloudiness from surface observations". Although past intercomparisons of satellite cloud datasets have focused mainly on climatological mean cloud amount, temperature and height, and other physical properties, interannual variations and long-term trends for the contiguous U.S. from both independent surface weather station observations and three of the current leading satellite datasets are evaluated.

Accomplishments

Climatologically, relative to weather station data, ISCCP trends to have more cloud cover, particularly in the afternoon, while PATMOS-x trends to have less cloud cover in both 1:30pm and daily average products. CLARA-A1 has lower cloud amounts, particularly for night data, in most areas of the country, but anomalously higher cloud cover values over the West and Southwest during daytime. Figure 1 shows the time series of annual U.S. mean cloud cover for military, NWS and combined locations from station and collocated satellite data. All satellite datasets show negative trends for 1984-2009. For 1984-2007, the trend in PATMOS-x 1:30pm (-0.55%/decade) is the closest of the satellite trends to that in the NWS station data, and PATMOS-x diurnally corrected data is next closest. For the military data, PATMOS-x 1:30pm and PATMOS-x diurnally corrected data trends (-0.65 and -0.79) are very close to those in the station data. For both station subsets, ISCCP trends are somewhat more negative than the PATMOS-x results and the CLARA-A1 results are almost an order of magnitude larger (e.g., -4.7%/decade) than those in the station data.

Planned work

- Examination of reanalysis data to determine how well they capture the time evolution of total cloud cover in the U.S. in terms of inter-annual variations and long-term trends;
- Calculation of correlation coefficients between station time series and collocated data from four different reanalysis data; and
- A plan for archiving the homogeneity-adjusted dataset at a national data center.

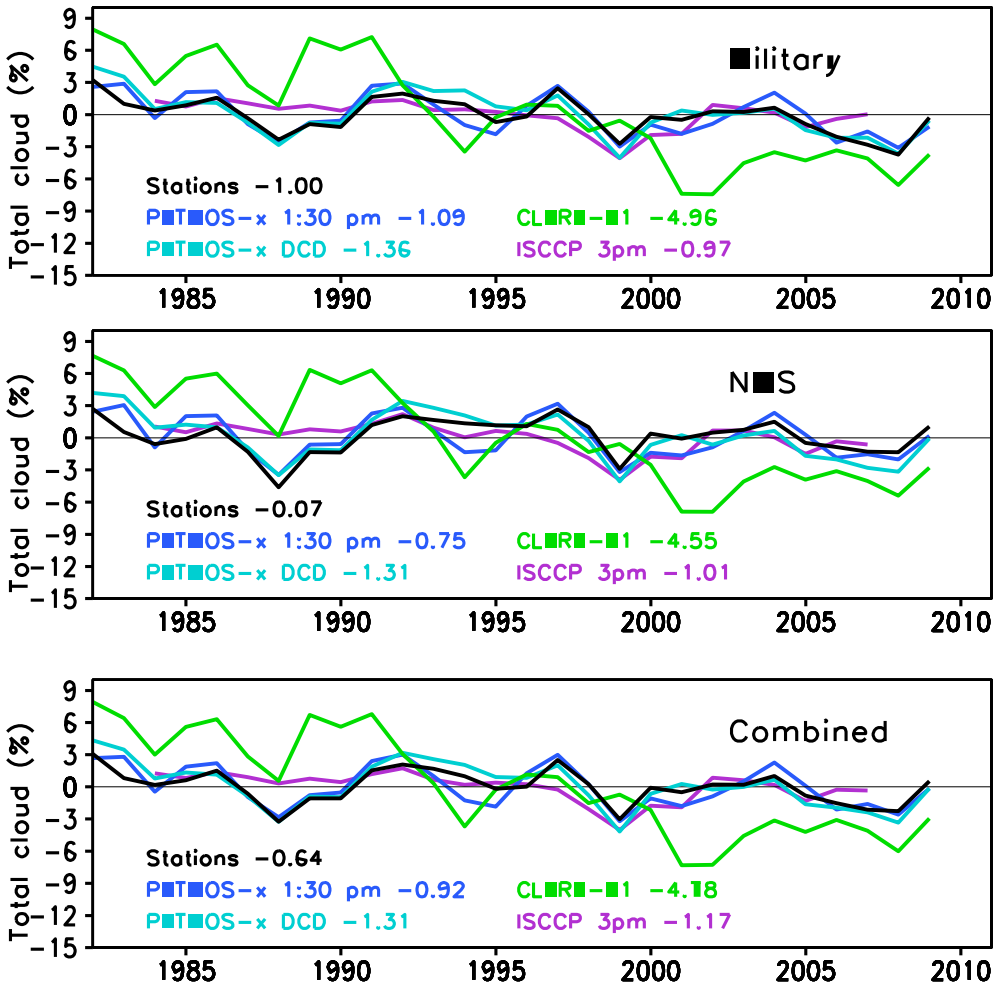


Figure 1. Annual mean US mean cloud fraction anomalies from satellite data collocated with US weath- er stations for (top) military, (middle) NWS, and (bottom) all stations combined, with trends (%/decade). Trends are for 1982-2009, except for ISCCP which is for 1984-2007.

Publications

Sun, B., M. Free, H. Yoo, M. Foster, A. Heidinger, KG. Karlsson, 2015: Variability and trends in U.S. cloud cover: ISCCP, PATMOS-x, and CLARA-A1 compared to homogeneity-adjusted weather observations, J. Climate, doi: http://dx.doi.org/10.1175/JCLI-D-14-00805.1.

Presentations

Free, M., B. Sun, H. Yoo 2014: Trends in U.S. Cloud Cover (invited talk), Stony Brook University, New York (1-3 Oct.)

Yoo, H., M. Free, B. Sun 2015: Long-term cloud cover trends over the U.S. from ground-based data and satellite products, 2015 AMS annual meeting, Phoenix, Arizona (4-8 Jan.)

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**0**
# of invited presentations	**2**
# 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**

This year, one journal paper on the trends of total cloud cover over the U.S. from satellite products and weather station data has been published. Two presentations have been made.

Participation in Climate Research Activities at the Air Resources Laboratory

Task Leader	Russ Dickerson
Task Code	RDRD_AQS_14; RDXR_AOD_14
NOAA Sponsor	Rick Artz
NOAA Office	NWS/ARL
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Surface Observing Networks & Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 25%; Goal 2: 50%; Goal 3: 25%; Goal 4: 0%; Goal 5: 0%

Highlight: In 2014, the seven CICS research scientists working with NOAA's ARL made air quality measurements and forecasts to complement ongoing atmospheric chemistry studies at UMD..

Link to a research web page: http://www.arl.noaa.gov/

Li Pan

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Background

The NWS (National Weather Service) continuously conducts the NAQFC (National Air Quality Forecasting Capability) project. This project has been upgraded to include dry deposition velocity calculation modifications, PBL height thresholds, improved treatment for chemical boundary conditions (BC), new chemical mechanisms for gas and aerosol phase species, new emission for dust and fire and emission adjustment for snow cover. The newly upgraded system was implemented on January 21, 2015. This system to enable PM forecasting will become publically available in the near future. In that light, CMAQ is being configured and tested with additional vertical levels and modules to ingest hourly aerosol concentrations at its lateral boundaries given by a NCEP global dust/smoke model. The DISCOVER-AQ Front Range, CO, field experiment was conducted in July and August 2014. As usual, ARL provided both 12km and 4km resolution forecasting to support the campaign. We made good progress in the chemical data assimilation project and a demonstration case for July 2011 has been successfully completed. We have also made important initial steps in achieving a chemical observation simulation experiment by doing simulations for meteorology using two global simulations, one being the control GFS and the other being enhanced by a futuristic AIRS-like retrieval assimilation. The two results are processed down-stream the same way with WRF-ARW and CMAQ. The resulted chemical fields showed considerable difference – analyses are on-going.

Accomplishments

1. The system upgrading for NAQFC

CMAQ version in NAQFC operation run was upgraded from 4.5 to 4.6. It includes switching the ozone chemical mechanism from CB04 to CB05 and enhancing NTR removal processing to reduce nitrogen lifetime in the atmosphere. The newer CMAQ version has an aerosol mechanism included that enables PM forecasting, publically available in the near future.

2. CMAQ in-line dust and smoke emissions

Wind-blown dust emissions are calculated in CMAQ according to wind velocity, soil moisture and land use. Besides dust emissions, smoke emissions are also calculated in CMAQ through HMS-Bluesky-Smoke algorithm. In this algorithm, Hazard Mapping System (HMS) detects smoke and fire, the fire information (location) then is entered into Bluesky to calculate the intensity of fire emission and the duration of the fire. Subsequently, this information is converted to a CMAQ ready emission through SMOKE. Dust and smoke

emissions are critical to PM forecasting. By including those emissions, PM forecasting accounts not only for anthropogenic emissions, but also those with an intermittent and episodic nature.

3. Winter time PM emission adjustment
PM emission in CMAQ was adjusted in winter based on ice and snow cover. The PM positive bias is reduced in winter time.

4. DISCOVER-AQ in Colorado
The DISCOVER-AQ campaign in Colorado was conducted in July and August, 2014. We provided CMAQ forecasting to support this field experiment. Both 12km and 4km resolution results were used by the field measurement crews. Primary evaluation shows that CMAQ results are reasonably consistent with the observations.

5. Chemical data assimilation
Chemical data assimilation targets PM. By using the best available input data, such as meteorology and emission, and the best available CMAQ model, version 5.0.2, PM was simulated by assimilating with AQS PM2.5 and MODIS AOD observations. The assimilated results can be used as the best available chemical concentration fields to initiate a new implementation and provide reliable initial and boundary conditions for retrospective and SIP modeling. Assimilation in July, 2011 was chosen as a demo case to verify model input and model setting. The evaluation results demonstrated that CTM simulation was improved by using assimilated results.

Planned Work

- Using a global model to provide boundary conditions for CMAQ;
- Increasing CMAQ vertical levels from 22 layers to 35 layers;
- Using EPA 2011 NEI to replace EPA 2005 NEI in current NAQFC operation;
- PM evaluations;

Publications

1. **L. Pan**, D.Q. Tong, P. Lee, H. Kim and T. Chai, Assessment of NOx and O_3 forecasting performances in the U.S. National Air Quality Forecasting Capability before and after the 2012 major emissions updates, *Atmospheric Environment*, 95(2014), Pages 610-619. doi:10.1016/j.atmosenv.2014.06.020
2. D.Q, Tong, L. Lamsal, **L. Pan**, C. Ding, H. Kim, P. Lee, T. Chai, K. E. Pickering and I. Stajner, Long-term NOx trend over large cities in the United States during the great recession: Comparison of satellite retrievals, ground observations, and emission inventories, *Atmospheric Environment*, Volume 107, April 2015, Pages 70-84. doi:10.1016/j.atmosenv.2015.01.035

Presentations

1. **Li Pan**, Pius Lee, Hyun Cheol Kim, , YouHua Tang, Daniel Tong ,Rick Saylor, Ivanka Stajner, Weiwei Chen, Tianfeng Chai and Barry Baker, Evaluating wildfire emissions and assessing their influences in National Air Quality Forecasting Capability (NAQFC) system by comparison with ground, satellite and flight measurements during Southeast Nexus (SENEX) field experiment, 13th Annual CMAS Conference, OCT 27-29, Chapel Hill, NC, 2014
2. Weiwei Chen, Daniel Tong, Hang Lei, **Li Pan**, Global emissions of PM10 and PM2.5 from agricultural tillage and harvesting, 13th Annual CMAS Conference, OCT 27-29, Chapel Hill, NC, 2014
3. Ivanka Stajner, Jeff McQueen, Pius Lee, Roland Draxler, Jinaping Huang, Perry Shafran, Daniel Tong, **Li Pan**, Phil Dickerson, and Sikchya Upadhayay, National Air Quality Forecast Capability: recent progress and plans, 13th Annual CMAS Conference, OCT 27-29, Chapel Hill, NC, 2014

4. Jianping, Huang, Jeff McQueen, Perry Shafran, Pius Lee, Daniel Tong, **Li Pan**, Youhua Tang, Sikchya Upadhayay, Geoff DiMego, and Ivanka Stajner, Impact of meteorological inputs on NOAA PM2.5 predictions**,** 13th Annual CMAS Conference, OCT 27-29, Chapel Hill, NC, 2014

Performance Metrics	
# of new or improved products developed (please identify below the table)	**3**
# of products or techniques submitted to NOAA for consideration in operations use	**5**
# of peer reviewed papers	**2**
# 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	**N/A**
# of undergraduate students mentored during the year	**N/A**

Alice Crawford
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Background
This report summarizes the year-1 work accomplished by Dr. Alice Crawford on the volcanic ash product development team (VAPDT) at the air resources laboratory (ARL). One goal of the current research is to improve the NOAA HYSPLIT transport and dispersion model's ability to quantify airborne ash concentration levels. Although no international requirement for ash concentration forecasts currently exists, some parts of the aviation community are interested in more detailed guidance on ash concentrations. In addition, satellite analyses which provide quantitative information on ash cloud heights and mass loading are increasingly available. Incorporating these data into the model has the potential to improve model output. Another goal is to promote communication between volcanic ash advisory centers (VAACs) by developing a common display of model products and inputs. There are 9 VAACs and most VAACs run their own model. During a large eruption VAACs need to coordinate their response and be able to easily compare their model inputs and outputs. Although large eruptions happen infrequently, the eruption of Eyjafjallajökull in 2010 highlighted the importance of a coordinated response. The development of a model evaluation database contributes to both goals by providing a platform for model verification and comparison.

Accomplishments

- *Development of quantitative model output*

The 2008 eruption of Kasatochi in the Aleutian Islands was used as an initial test case because satellite analyses from NESDIS were available for this eruption. Reliable estimates of the source term (initial position, size and mass of ash) are essential to producing an accurate forecast of airborne ash concentration levels. A method of producing quantitative output using an empirical equation which relates an estimated plume height to mass eruption rate was developed. The quantitative output produced by this method has a large uncertainty. To reduce the uncertainty, model output was compared to satellite analyses which measured the column mass loading of the ash cloud at some time after the eruption. The source terms were then adjusted to produce model output mass loading which more closely agreed with the satellite observations.

Quantitative model output was also produced by using an estimate of the cloud thickness and satellite measurements of the ash cloud position, top height and mass loading as input into the model. The two methods are compared in figure 1.

Another person in the group is using the satellite analyses in an inverse modeling scheme to estimate a source term. Dr. Crawford provided support for the inverse modeling work by formatting the satellite data so that it is suitable for input into the inverse modeling programs.

Finally, I performed preliminary work to discover if a one-dimensional plume model could be used to leverage our knowledge of meteorological conditions at the eruption site into a better estimate of the plume geometry and mass eruption rate. The code for two one-dimensional plume models (Plumeria and BENT) was obtained from Larry Mastin and Marcus Bursik. I wrote a python script capable of running Plumeria multiple times with different inputs and summarizing the outputs.

- *Dispersion model standardization among VAACs*

A proto-type web page for exchanging model information among VAACs was developed and access to the password protected page was given to the IAVWOPSG (International Airways Volcano Watch Operations Group) ad-hoc group for evaluation. Product guidance for the format of netCDF output was written in consultation with other modeling groups.

Preliminary python scripts for creating standard graphics files, kml files and tables from the netCDF output were written.

- *Model evaluation database*

To support both the development of quantitative output and dispersion model standardization a model evaluation database/website was developed. Currently the database contains information about the Kasatochi 2008 eruption and the Eyjafjallajökull 2010 eruption. Suggested source parameters as well as input meteorology are available. Mass loading information from the satellite analyses was also output into a text file formatted in the same way as data from ARLs Data Archive of Tracer Experiments and Meteorology (DATEM). This will allow users of the database to use code from ARL to generate verification statistics.

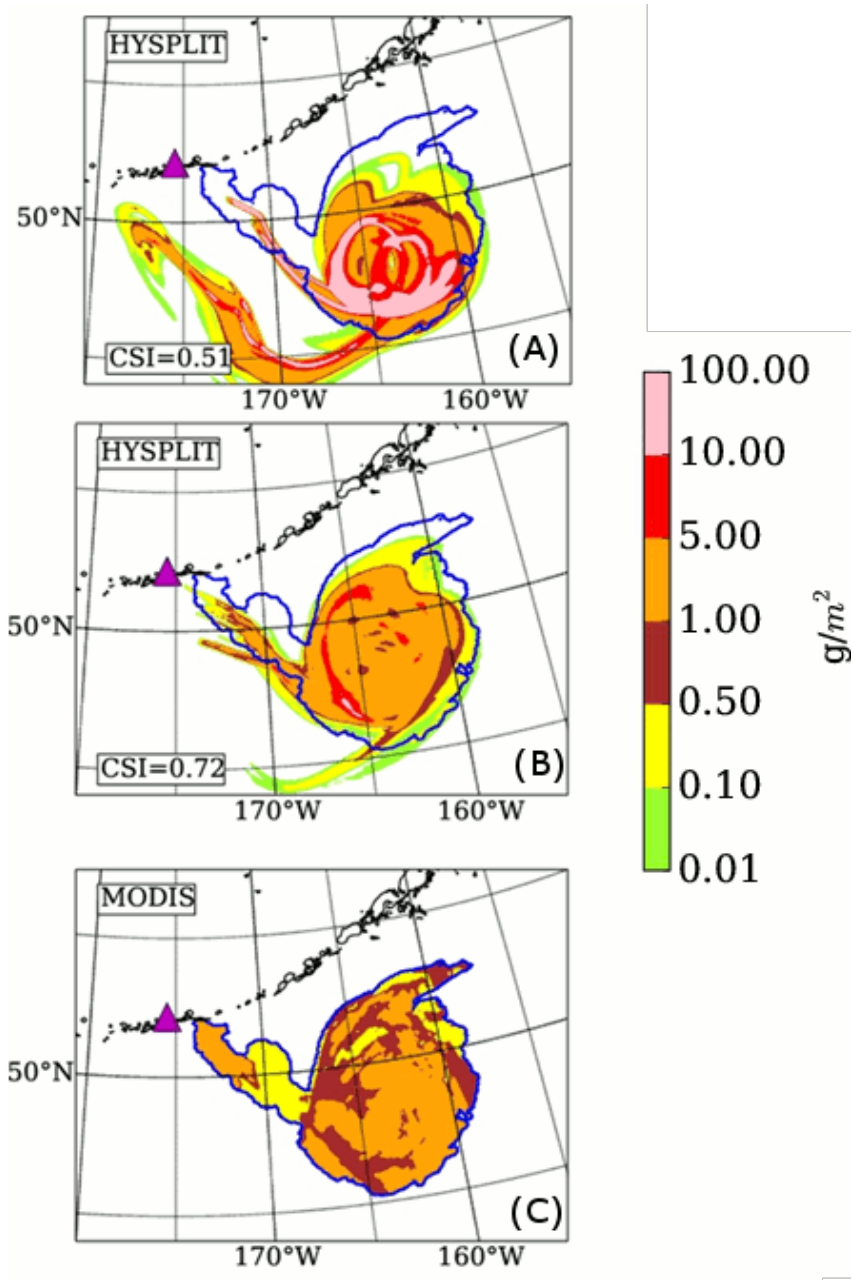

Figure 1: Ash mass loading about 24 hours after the end of the eruption of Kasatochi in 2008. (A) HYSPLIT forecast for 12:00-1300 UTC 09 August 2008, 32 hours after the eruption began, using a uniform line source above the vent as a source term. The mass eruption rate is first determined from an empirical equation using observations of plume height and then adjusted downwards by three orders of magnitude after comparing with satellite retrievals at an earlier time. (B) HYSPLIT forecast for 12:00-13:00 UTC 09 August 2008 using a satellite retrieval at 13:40 UTC 08 August 2008 to create the source term. (C) Satellite retrieval at 12:50 UTC 09 August 2008. The blue outline shown in each panel is the footprint of the satellite retrieval shown in (C). The critical success index (CSI) is a measure of the spatial overlap of the model output and satellite observation. A value of 0 indicates no overlap, while a value of 1 indicates perfect overlap.

Planned work

Satellite analyses for part of the 2010 eruption of Eyjafjallajökull were obtained in March of 2015 and in year 2 we expect to obtain analyses for at least one more eruption. These eruptions will be analyzed in a similar manner and added to the model evaluation database. We will be looking at which methods or combinations of methods produces the most reliable output.

The proto-type web page for exchanging model information among VAACs will be modified in response to anticipated feedback from the IAVWOPSG group and the VAACs.

We will continue investigating the use of one-dimensional plume models to improve the source term estimation and write an internal report summarizing our findings.

Publications

Non-peer reviewed

Alice Crawford and Barbara Stunder, "Report on preliminary quantitative dispersion output." *Report of the volcanic ash product development team (VAPDT) to the Federal Aviation Weather Division*. Sept 26, 2014.

Products

Proto-type web page for exchanging information between Volcanic Ash Advisory Centers (VAACs).

Presentations

Alice Crawford, Barbara Stunder, Steven Albersheim, Michael Pavolonis. "R&D to support volcanic ash forecasting for aviation", oral presentation at the meeting of the American Meteorological Society. Jan. 5 2015.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	
# of non-peered reviewed papers	**1**
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Paul Kelley
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Background:
Mr. Kelley is working in support of two atmospheric chemists at ARL (Drs. Luke and Ren) and to provide data for model validation for a global mercury model written by Dr. Cohen, also at ARL. One of the major long-term goals is to understand how gaseous elemental mercury (GEM) in the atmosphere is transformed into more highly bio-available reactive gaseous mercury (RGM) and fine particulate mercury (FPM). This involves a complicated cycle of convection of anthropogenic GEM into the free troposphere and lower stratosphere, subsequent oxidation into RGM and FPM, and then wet deposition by deep convective thunderstorms or dry deposition following strong post-frontal subsidence.

Accomplishments:
NOAA / ARL has installed and maintains three ground stations devoted to long term monitoring of speciated atmospheric mercury and operates them according to National Atmospheric Deposition Program sampling protocols (AMNET). The site in Beltsville, MD has a complete, speciated mercury instrument with an inlet at 10 meters. Another site in the Grand Bay National Research Reserve in Grand Bay, MS has a speciated atmospheric mercury instrument, as well as a range of other trace gas instruments (NO, NO_y, SO_2, CO, O_3, black carbon) and standard meteorology instruments. The third site is at the Mauna Loa Observatory (MLO) on the island of Hawaii. ARL currently operates a single speciated atmospheric mercury system there, an additional analyzer that measures GEM only, an SO_2 and O_3 instruments.

Mr. Kelley performs weekly maintenance and repair at the Beltsville, MD site to keep it operating according to AMNET protocols. One trip in 2014 was made to the Grand Bay, MS site to repair instruments and perform calibrations.

A new speciation system has been developed in order to measure Hg(II) using a single elemental Hg detector with an inlet alternating between two flow paths. On one side is a quartz wool pyrolyzer held at 650°C that reduces particulate and reactive mercury to elemental mercury. On the other side is a series of filters to trap particulate and reactive mercury. The difference between these two signals is a measure of Hg(II) in the atmosphere. While a normal speciation system also measures particulate and reactive mercury, there are questions as to its collection efficiency under changing ozone and water vapor concentrations. Currently we plan to test this new system at MLO in late March 2015 using an AMNET protocol speciation system for comparison.

Planned Work
- Continue support for long-term Hg monitoring at the three AMNET sites.
- Install difference Hg(II) system at Mauna Loa and compare to AMNET-protocol run system currently there.

Publications:
1. Ren, X.; Luke, W.T.; Kelley, P.; Cohen, M.; Ngan, F.; Artz, R.; Walker, J.; Brooks, S.; Moore, C.; Swartzendruber, P.; Bauer, D.; Remeika, J.; Hynes, A.; Dibb, J.; Rolison, J.; Krishnamurthy, N.; Landing, W.M.; Hecobian, A.; Shook, J.; Huey, L.G. Mercury Speciation at a Coastal Site in the Northern Gulf of Mexico: Results from the Grand Bay Intensive Studies in Summer 2010 and Spring 2011. *Atmosphere* **2014**, *5*, 230-251.

2. Brooks, S.; Ren, X.; Cohen, M.; Luke, W.T.; Kelley, P.; Artz, R.; Hynes, A.; Landing, W.; Martos, B. Airborne Vertical Profiling of Mercury Speciation near Tullahoma, TN, USA. *Atmosphere* **2014**, *5*, 557-574..

3. Song, S., Selin, N. E., Soerensen, A. L., Angot, H., Artz, R., Brooks, S., Brunke, E.-G., Conley, G., Dommergue, A., Ebinghaus, R., Holsen, T. M., Jaffe, D. A., Kang, S., Kelley, P., Luke, W. T., Magand, O., Marumoto, K., Pfaffhuber, K. A., Ren, X., Sheu, G.-R., Slemr, F., Warneke, T., Weigelt, A., Weiss-Penzias, P., Wip, D. C., and Zhang, Q.: Top-down constraints on atmospheric mercury emissions and implications for global biogeochemical cycling, *Atmos. Chem. Phys. Discuss*., 15, 5269-5325, doi:10.5194/acpd-15-5269-2015, **2015**.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**3**
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

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Background

(1) *Development and evaluation of WRF-HYSPLIT inline coupling* – Like other atmospheric transport and dispersion models using an offline approach, NOAA's dispersion model, HYSPLIT, extracts relevant meteorological variables from archived files at regular time intervals and diagnoses other parameters for the dispersion calculation. Interpolation of archived meteorological data to higher temporal frequencies required by the dispersion calculation may introduce aliasing errors because such interpolation does not provide an accurate representation of the state of the atmosphere at these time-scales. For this study, the HYSPLIT model is directly (inline) coupled with the WRF-ARW meteorological forecast model so that the meteorological fields are available at the WRF integration time step (minutes or even seconds) for the dispersion computation. The inline WRF-HYSPLIT system provides for meteorological data at a finer temporal resolution and on the WRF vertical coordinate system without the high cost of data storage and with an improved fidelity of the representation of the atmosphere. Furthermore, near-source dispersion is not affected by artificial diffusion associated with Eulerian solutions.

(2) *Support of HYSPLIT modeling by providing WRF-ARW meteorological data* – Atmospheric transport and dispersion are sensitive to the wind and temperature near the surface, as well as the planetary boundary layer condition. The quality of meteorological data used influences the accuracy of the dispersion modeling. Meteorological simulations using WRF-ARW model were conducted for various dispersion applications. And the results were evaluated with observations to identify inaccuracies in meteorological data possibly affecting the simulation of pollutant transport.

Accomplishments

(1) WRF-HYSPLIT inline coupling

The HYSPLIT model is inline coupled into the WRF-ARW by modifying the process of getting the meteorological input (available in time intervals of minutes or even seconds) for the dispersion computation and its vertical coordinate system. No temporal and vertical interpolations are required in the inline framework. Both inline and offline HYSPLIT simulations were run for two tracer experiments in different model spatial resolutions: the CAPTEX in regional scale (at 9-km grid spacing) and the ASCOT in fine scale (at 333.3-m grid spacing). Comparing the model to the measured values, the results of two approaches were similar for all six releases in CAPTEX. However, for the ASCOT cases, the cumulative score of the inline simulations were better than offline runs in four out of five releases. The improvement shown in the inline results is attributed to the elimination of temporal and vertical interpolation of the meteorological data compared to the offline version. The inline coupling system is especially beneficial for ASCOT type of application because the drainage flow occurred over an area of complex terrain, over a short time period and in fine spatial resolution, which required very detailed and rapid changes in the wind vectors and mixing parameters to accurately model the movement of tracer particles. A manuscript presenting the WRF-HYSPLIT inline coupling was accepted by *Journal of Applied of Meteorology and Climate* for publication.

(2a) Meteorological simulations for Grand Bay intensive studies of atmospheric mercury

To support mercury modeling for two intensive studies (summer 2010 and spring 2011) conducted at the Grand Bay NERR site, WRF-ARW was used to develop fine resolution meteorological fields. Two sets of sensitivity tests were performed, to examine the influences on model performance and regional flow predictions: 1) the use of different reanalysis data for WRF initialization; 2) the use of different nudging configurations. Grid nudging reduced errors in the wind predictions, but nudging of mass fields produced unrealistic

precipitation that would have large impacts on mercury wet deposition. The most inner domain inherited differing features of reanalysis that resulted in generating different regional wind patterns. Higher uncertainties in the numerical model prediction were observed during the summer intensive period than the spring period. A manuscript summarizing this study was accepted for publication in *Atmosphere*.

(2b) Meteorology inputs for the use in dispersion ensemble

Using ensembles has been an attractive method to improve dispersion modeling. A dispersion ensemble of 24 members for CAPTEX was created by WRF meteorological data using two different PBL schemes, with or within the TKE prognostic field, and time-averaged or instantaneous wind fields. Two reduction techniques were applied to the ensembles: 1) with no use of observation and based on the exclusion of redundant members by using lack of correlation as a measure of distance among the members; and 2) based on measured data to find the minimum mean squared error of the average of all possible model combinations. The first reduction technique down selecting members provides results comparable to the full ensemble for 4 out 6 CAPTEX releases while the second method shows the selective members a similar or superior performance for all cases. For a forecast application, reduction technique with available observational data provides a potentially promising tool for improving the dispersion simulation. The study was included in manuscript accepted for publication by Weather and Forecasting.

Planned work

- Continue work on the WRF-HYSPLIT inline coupling to evaluate the system with other tracer experiments, test other parameters from WRF most relevant to plume mixing, stability, and convection; improve computational efficiency.
- Create a long-term meteorological data archive using the WRF-ARW model for the Data Archive of Tracer Experiments and Meteorology (DATEM) which provides meteorological reanalysis archives for HYSPLIT dispersion modeling.

Publications

Ngan, F., M. Cohen, W. Luke, X. Ren and R. R. Draxler, 2015: Meteorological modeling using WRF-ARW model for Grand Bay Intensive studies of atmospheric mercury. *Atmosphere,* Vol. 6, 209-233.

Ngan, F., A. Stein and R. R. Draxler: Inline coupling of WRF-HYSPLIT, 2015: model development and evaluation using tracer experiments. *J. Appl. Meteor. Climatol.*, accepted.

Lee, D. G., S. T. Kim, H. C. Kim and **F. Ngan**, 2014: Retrospective Air Quality Simulations of the TexAQS-II: Focused on Emissions Uncertainty. *Asian Journal of Atmospheric Environment.* 8, 212-224.

Rolph, G., **F. Ngan** and R. R. Draxler, 2014: Modeling the Fallout from Stabilized Nuclear Clouds using the HYSPLIT Atmospheric Dispersion Model. *Journal of Environmental Radioactivity*. 136, 41-55.

Ren, X., W. T. Luke, P. Kelly, M. Cohen, **F. Ngan**, and co-author, 2014: Mercury Speciation at a Coastal Site in the Northern Gulf of Mexico: Results from the Grand Bay Intensive Studies in Summer 2010 and Spring 2011. *Atmosphere*. Vol. 5, 230-251.

Stein, A., **F. Ngan** R. R. Draxler and T. Chai, 2015: Potential Use of Transport and Dispersion Model Ensembles for Forecasting Applications. *Weather and Forecasting*, accepted.

Presentations

Ngan, F., A. Stein and R. Draxler, 2014: Dispersion Simulations Using Inline WRF-HYSPLIT for Atmospheric Studies in Complex Terrain (ASCOT) Experiment. 2014 AGU Fall Meeting, San Francisco, CA.

Kim, H. C., P. Lee, S. T. Kim, **F. Ngan**, C. Bae, B. Kim and E. Kim, 2014: Synoptic perspectives of pollutant transport patterns observed from satellites over East Asia, 2014 AGU Fall Meeting, San Francisco, CA.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**5**
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

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Comparisons of NAQFC surface and column NO_2 with satellites, surface, and field campaign measurements during 2009-2014

National Oceanic and Atmospheric Administration (NOAA) National Air Quality Forecast Capability (NAQFC) NO_2 surface concentration and tropospheric vertical column density (VCD) during 2009-2014 were compared with multiple observations including satellites, surface observations and field campaign *in-situ* measurements, to investigate the performance of model and current emission inventory, and multi-year trends of NO_2 fields over Contiguous United States. We conducted comparisons for:

(1) NO_2 VCDs between NAQFC and satellites,
(2) Surface NO_2 concentrations between NAQFC and US Environmental Protection Agency (EPA) Air Quality System (AQS),
(3) surface NO_2 concentrations between AQS and satellite-NAQFC hybrid approach,
(4) Continuous Emissions Monitoring System (CEMS) measurements at plant stacks and corresponding NAQFC NO_2 concentrations, and
(5) NO_2 concentration and VCDs from field campaigns and NAQFC and/or satellites.

Satellite-based NO_2 VCD measurements from the Scanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY), the Ozone Monitoring Instrument (OMI) and the Global Ozone Monitoring Experiment-2 (GOME-2), surface measurements from US EPA AQS sites, and California Nexus (CalNex, California, 2010) and Deriving Information on Surface Conditions from Column and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ, Baltimore-Washington D.C., 2011; California, 2013; Houston, 2013) campaigns are utilized. For satellite data comparisons, the vertical and horizontal information is greatly improved using the Averaging Kernel and conservative downscaling method, respectively.

We demonstrated satellite NO_2 measurements near urban cities always show serious underestimation due to coarse satellite footprint pixel sizes compared to typical urban NO_2 spatial gradients, and these biases can be resolved by using the conservative downscaling technique. Preliminary results showed that NAQFC NO_2 VCD is considerably overestimated at several locations (e.g., Los Angeles, Houston and New Orleans) while good agreements are seen in other mega cities, especially in New York. OMI and P3 aircraft NO_2 VCD comparison during 2010 CalNex also shows an excellent agreement when the resolution effect is considered, with the correlation improved from R=0.45 to R=0.88.

Recent changes of satellite-observed NO_2 column densities in East Asia

In this study, we reported recent changes of tropospheric NO_2 vertical column density (VCD) in East Asia observed from multiple satellites, highlighting on the declining trend over China since 2012. Tropospheric NO_2 VCD data from GOME, SCIAMACHY, OMI, and GOME-2, retrieved from the Royal Netherlands Meteorological Institute (KNMI) and available from the Tropospheric Emission Monitoring Internet Service (TEMIS), are utilized to investigate annual trends of NO_2 VCD since 2001. Until 2011, changes of NO_2 VCD over East Asia countries agree well with previous researches including the impact of economic downturn during 2008-2009 and following quick recovery in China. After peaking at 2011, NO_2 VCD observations from active instruments (OMI and GOME-2) over China started to show a slow decreasing trend, mostly led by the rapid changes in Jing-Jin-Ji (JJJ, Beijing-Tianjin-Hebei) region in northern China. The decreasing trend continues as of spring in 2014. Trends over Korea are weaker, but similar to those in China, with a slight peak in 2011, and Japan shows continuous declining trend since early 2000. Possible explanations for the trend, including policy-driven emission change and inter-annual variance of meteorology and satellite retrieval uncertainties, are discussed. We suggest further investigations on anthropogenic NO_x emission changes using bottom-up approach and the climatological impact from inter-annual variance of natural condition.

Synoptic perspectives of pollutant transport patterns observed from satellites over East Asia

In this study, we showed that wintertime pollutant transport patterns in East Asia are visible from multiple satellite observations when inspected with corresponding synoptic weather analysis charts. Transport pathways of pollutants and anthropogenic emissions in East Asia are investigated using satellite images, surface weather chart, and chemical transport model simulations in the context of conceptual categorization of synoptic weather patterns. We combined daily distributions of Moderate Resolution Imaging Spectroradiometer (MODIS) Aerosol Optical Depth (AOD) and Community Multi-scale Air Quality (CMAQ) simulated particulate matter (PM) to represent aerosol distribution, GOME-2 and OMI NO_2 column density as a proxy for fresh anthropogenic emission flux, Korean Meteorological Administration surface weather analysis chart to understand synoptic weather pattern using GIS geo-referencing technique.

We identified a periodic extension of the Siberian high to south China; its associated migratory systems are important to understanding transport patterns in this region. We investigatied a two-year data set between June 2012 and May 2014 of synoptic weather chart and clustering information. Based on the relative location and strength of high pressure system over south China and low pressure system over Manchuria, we classified three types of synoptic patterns that might affect surface PM pollution events in China and Korea. Classified patterns include (1) Expansion of the Siberian high as a result of cold surge, (2) Cold front passage associated with migratory northern low pressure system, and (3) Stagnant high pressure systems near the Yellow Sea.

In all cases, the development of a high pressure system in south China is essential for the development of pollution events associated with conducive meteorological conditions. We demonstrated that observed and simulated surface PM show good agreement, not only with MODIS AOD but also with NO_2 column density, implying the possible contributions of transported anthropogenic emissions to regional surface high PM events. Particularly, in the type 2 pattern, we demonstrate unique narrow-band-shaped high PM plumes are well reproduced in CMAQ, MODIS AOD; NO_2 column density observations, show excellent performance in the current modeling system. We also demonstrate that these PM plumes originate from northeastern China, and are push southward by cold front passage.

All three types of transport patterns are important in regional air quality and global meteorology, in terms of intensity (e.g., type 3), frequency (e.g., type 1 & 2), and vertical lifting (e.g., type 2). We conclude the general placement of synoptic patterns in East Asia is strongly favorable for the transport of emissions and

pollutants from China to Korea and Japan. Synoptic flow patterns work as an efficient pumping machine (associated with periodic Rossby wave propagation and baroclinic instability) to shift East Asian anthropogenic emission into Pacific, resulting in direct and indirect impact on global scale meteorology and climate.

Publications

Journals

Tong, D. Q., L. Lamsal, L. Pan, C. Ding, **H. Kim**, P. Lee, T. Chai, K. E. Pickering, I. Stajner, 2015: Long-term NOx trends over large cities in the United States during the Great Recession: Comparison of satellite retrievals, ground observations, and emission inventories, *Atmos. Env.*,doi:10.1016/j.atmosenv.2015.01.035, *Accepted*.

Lee, D., S. Kim, **H. Kim** and F. Ngan, 2014: Retrospective Air Quality Simulations of the TexAQS-II: Focused on Emissions Uncertainty, *Asian J. of Atmos. Env.*, 8(4), 212-224, doi: http://dx.doi.org/10.5572/ajae.2014.8.4.212.

Pan, L., D. Tong, P. Lee, **H. Kim**, and T. Chai, 2014: Assessment of NOx and O3 forecasting performances in the U.S. National Air Quality Forecasting Capability before and after the 2012 major emissions updates, *Atmos. Environ*, 95, 610-619, doi:10.1016/j.atmosenv.2014.06.020.

Book chapters

Kim, H. C., H. Choi, F. Ngan, and P. Lee, 2014: Surface ozone variability in synoptic pattern perspectives, *Air Pollution Modeling and its Application XXIII*, Springer International Publishing, 551-556, DOI 10.1007/978-3-319-04379-1__91

Chai, T., P. Lee, L. Pan, **H. Kim**, and D. Tong, 2014: Building and testing atmospheric chemistry reanalysis modeling system, *Air Pollution Modeling and its Application XXIII*, Springer International Publishing, 581-585, DOI 10.1007/978-3-319-04379-1__96

Tong D., P. Lee, L. Pan, T. Chai, **H. Kim**, M. Wang, and S. Kondragunta, 2014: Assimilation of satellite oceanic and atmospheric products to improve emission forecasting, *Air Pollution Modeling and its Application XXIII*, Springer International Publishing, 563-569, DOI 10.1007/978-3-319-04379-1__93

Lee P., L. Pan, **H. Kim**, and D. Tong, 2014: Intensive campaigns supported by air quality forecasting capability to identify chemical and atmospheric regimes susceptible to air quality standard violations, *Air Pollution Modeling and its Application XXIII*, Springer International Publishing, 587-592, DOI 10.1007/978-3-319-04379-1__97

Pan Li, D. Tong, P. Lee, **H. Kim**, and T. Chai, 2014: Diagnostic Evaluation of NOx Upgrades on Air Quality Forecast, *Air Pollution Modeling and its Application XXIII*, Springer International Publishing, 511-517, DOI 10.1007/978-3-319-04379-1__84

Presentations

Kim, H., P. Lee, S. Kim, F. Ngan, C. Bae, B.-U. Kim, and E. Kim, 2014: Impact of synoptic patterns on East Asia pollutant transport pathways observed from satellites, 2014 AGU Fall Meeting, San Francisco, CA

Tang, Y., L. Pan, P. Lee, D. Tong, **H. Kim** and R. Artz, 2014: Comparison of CMAQ Modeling Study with Discover-AQ 2014 Aircraft Measurements over Colorado, 2014 AGU Fall Meeting, San Francisco, CA

Judd, L., B. Lefer, J. Herman, N. Abuhassan, A. Cede, S. Janz, J. H. Crawford, A. Weinheimer, R. Cohen, X. Ren, W. Luke, **H. C. Kim**, and R. Long, 2014: Comparison of Pandora spectrometer NO2 measurements to aircraft, satellite, and ground measurements during the DISCOVER-AQ Texas campaign, 2014 AGU Fall Meeting, San Francisco, CA (Poster)

Pan., L., P. Lee, I. Stajner, S. Kondragunta, J. McQueen, C.-H. Lu, M. Ruminski, D. Tong, **H. Kim**, Y. Tang, J.-P. Huang, H.-C. Huang, S. Upadhayay, 2014: Real-time testing of satellite-based wildfire detection and their associated pollution impact of surface concentration of particulate matter, 2014 AGU Fall Meeting, San Francisco, CA (Poster)

Kim, H., P. Lee, L. Pan, L. Judd, D. Tong, Y. Tang, T. Chai, B. Lefer, and I. Stajner, 2014: Comprehensive comparisons of NAQFC surface and column NO2 with satellites, surface, and field campaign measurements during 2009-2014, 2014 CMAS conference, Chapel Hill, NC

Kim, H., P. Lee, S. Kim, C. Bae, B.-U. Kim, and E. Kim, 2014: Synoptic perspectives of pollutant transport patterns observed from satellite over East Asia, 2014 CMAS conference, Chapel Hill, NC

Kim, H., P. Lee, Y.-K. Lim, S. Kim, J.-H. Woo, B.-U. Kim, C. Bae, and E. Kim, 2014: Recent changes (2010-2013) of satellite-observed NO2 column densities in East Asia, 2014 CMAS conference, Chapel Hill, NC (Poster)

Kim, E., S. Kim, and **H. Kim**, 2014: Use of high-resolution spatial and temporal sea surface temperature for air quality modeling in Korea, 2014 CMAS conference, Chapel Hill, NC (Poster)

Pan, L., P. Lee, **H. Kim**, Y. Tang, D. Tong, R. Saylor, I. Stajner, W. Chen, T. Chai, and B. Baker, 2014: Evaluating wildfire emissions and assessing their influences in National Air Quality Forecasting Capability (NAQFC) system by comparison with ground, satellite and flight measurements during Southeast Nexus (SENEX) field experiment, 2014 CMAS conference, Chapel Hill, NC (Poster)

Tang, Y., T. Chai, L. Pan, P. Lee, D. Tong, and **H. Kim**, 2014: Assimilation of Surface PM2.5 and Satellite AOD in CMAQ, 2014 CMAS conference, Chapel Hill, NC (Poster)

Tong, D.Q., L. Lamsal, L. Pan, C. Ding, **H. Kim**, P. Lee, T. Chai, K. E. Pickering and I. Stajner, 2014: Assessing the impact of the 2008 economic recession on NOx emissions in US megacities: intercomparison of satellite remote sensing, ground monitoring, and emission inventories, 2014 CMAS conference, Chapel Hill, NC

Bae. C., S. Kim, **H. Kim**, and B.-U. Kim, 2014: Impact of emission inventory update on ozone forecast over Northeast Asia, 2014 CMAS conference, Chapel Hill, NC (Poster)

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**8**
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

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Project 1: NOAA Backtracking Support to CTBTO (Comprehensive Nuclear-Test-Ban Treaty) using the HYSPLIT (HYbrid Single Particle Lagrangian Integrated Trajectory) Model (NOAA Lead: Roland Draxler)

Background

The National Oceanic and Atmospheric Administration, through the National Weather Service (NWS) with support from the Office of Atmospheric Research (OAR), is one of the WMO designated Regional Specialized Meteorological Centers (RSMC) for transport model products. NOAA backtracking support to the

Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) started on October 1, 2012 for the implementation of the CTBTO-WMO (World Meteorological Organization) Backtracking Response System required by the CTBTO Verification regime

Accomplishments
After the web-based interface for the CTBTO backtracking Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) was delivered to NOAA NWS Central Operations (NCO), we have continuously provided the technical support and assistance to the NWS and NCO. The CTBTO backtracking capability was implemented into NCEP (National Centers for Environmental Prediction) on September 30, 2014.

Software has been developed to determine the time-variation of emissions using a network of radionuclide measurement sites and model predicted unit-source. The software and documentation were provided to CTBTO on 29 September 2014. A paper (Chai, et al. 2015, *Atmospheric Environment,* **106**, pp. 241-251, 2015) has been published, presenting the method using Fukushima incident as a test case.

Planned Work
Continue to support NWS in CTBTO backtracking capability test and future operations. A source attribution analysis system will be developed to determine the most likely source location based on monitor data. This system will be transitioned to CTBTO in the future.

Project 2: Volcanic Ash Model Development & Enhancement for the Federal Aviation Administration (FAA) (NOAA Lead: Barbara Stunder)

Background
Although volcanic ash forecasts are provided at NWS using HYSPIT, they are not quantitative. At present, no international requirement for ash concentrations exist. However, it is prudent for the U.S. to develop this capability. Efforts will be placed on developing quantitative volcanic ash concentration forecast capability.

Accomplishments
I completed FORTRAN code that generates a Transfer Coefficient Matrix (TCM), "sat2array.f". It reads in multiple HYSPLIT unit-source dispersion runs where volcanic ash is released from different heights and at different times. The TCM records the sensitivities of the MODIS-observed ash mass loading with respect to all independent HYSPLIT dispersion runs. It has been tested using the 2008 Kasatochi eruption as an example.
Planned Work We will use the satellite retrieval of ash cloud top height and mass loading to create an emissions file for HYSPLIT that will generate improved forecasts

Publications:

1. "Source term estimation using air concentration measurements and a Lagrangian dispersion model – Experiments with pseudo and real cesium-137 observations from the Fukushima nuclear accident," by **Chai, T.**, R. R. Draxler, and A. Stein**,** Atmospheric Environment, **106**, pp. 241-251, doi:10.1016/j.atmosenv.2015.01.070, 2015
2. "Long-term NO_x trends over large cities in the United States during the Great Recession: Comparison of satellite retrievals, ground observations, and emission inventories," by Tong, D. Q., L. Lamsal, L. Pan, C. Ding, H. Kim, P. Lee, **T. Chai**, K. E. Pickering, and I. Stajner**,** Atmospheric Environment, **107**, pp. 70-84, doi:10.1016/j.atmosenv.2015.01.035, 2015

3. "Changes in nitrogen oxides emissions in California during 2005–2010 indicated from top-down and bottom-up emission estimates," by M. Huang, K.W. Bowman, G. R. Carmichael, **T**. **Chai**, R. B. Pierce, J. R. Worden, M. Luo, I. B. Pollack, T. B. Ryerson, J. B. Nowak, J. Andrew Neuman, J. M. Roberts, E. L. Atlas, and D. R. Blake**,** J. Geophys. Res., **119** (22), pp. 12928-12952, DOI: 10.1002/2014JD022268, 2014
4. "Root mean square error (RMSE) or mean absolute error (MAE)? – Arguments against avoiding RMSE in the literature," by **Chai, T.** and Draxler, R. R., Geosci. Model Dev., 7, 1247-1250, doi:10.5194/gmd-7-1247-2014, 2014
5. "Assessment of NO_x and O_3 forecasting performances in the US National Air Quality Forecasting Capability before and after the 2012 major emissions updates," by L. Pan, D. Tong, P. Lee, H. Kim, and T. **Chai,** Atmospheric Environment, **95** (2014), pp. 610-619, doi: 10.1016/j.atmosenv.2014.06.020, 2014
6. "Building and testing atmospheric chemistry reanalysis modeling system," by **Chai**, **T.**, P. Lee, L. Pan, H. Kim, and D. Tong, Air Pollution Modeling and its Application XXIII, ed. Steyn, D. and R. Mathur, Springer Proceedings in Complexity, pp. 581-585, doi:10.1007/978-3-319-04379-1_96, Springer International Publishing, Switzerland, 2014.
7. "Assimilation of satellite oceanic and atmospheric products to improve emission forecasting," by Tong D., P. Lee, L. Pan, **T. Chai**, H. Kim, M. Wang, and S. Kondragunta, Air Pollution Modeling and its Application XXIII, ed. Steyn, D. and R. Mathur, Springer Proceedings in Complexity, pp. 563-569, doi:10.1007/978-3-319-04379-1_93, Springer International Publishing, Switzerland, 2014.
8. "Diagnostic Evaluation of NOx Upgrades on Air Quality Forecast," by Pan L., D. Tong, P. Lee, H. Kim, **T. Chai**, and C. Ding, Air Pollution Modeling and its Application XXIII, ed. Steyn, D. and R. Mathur, Springer Proceedings in Complexity, pp. 511-517, doi:10.1007/978-3-319-04379-1_84, Springer International Publishing, Switzerland, 2014.

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

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Background

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

Accomplishments

In past year, I have completed the following tasks on a 75% part-time schedule:

1. NAQFC-related emission tasks:

a) *Emission Inventory Updates*: Led ARL efforts to update the emission inventories for NWS National Air Quality Forecast Capability (NAQFC). Eight sectors of the previous 2005-based emission inventories have been updated into the 2011 level, including replacing agricultural NH_3, railroad and inland water navigation, nonroad engines and sources in Mexico and Canada. The update also incorporated two new sources into NAQFC, including residential wood burning and oil/gas emissions.

b) *Operational CONUS Emissions:* Generated emission files for the CONUS domain, including 365-D area source files, 365-D mobile files, ~30 point source files and other ancillary emission files;

c) *Experimental CONUS Emissions:* Generated the similar emission datasets for the Experimental run with CB05 chemical mechanism (total of ~760 files);

d) *Operational Hawaii Emissions:* Generated emission files for the Hawaii domain, including 365-D area source files, 365-D mobile files, ~30 point source files and other ancillary emission files;

e) *Operational Alaska Emissions:* Generated emission files for the Hawaii domain, including 365-D area source files, 365-D mobile files, ~30 point source files and other ancillary emission files;

2. Support AQF group research activities:

f) *DISCOVER-AQ emissions*: Generated high-resolution emission data to support DISCOVER-AQ Colorado simulations.

g) *Windblown dust for $PM_{2.5}$* forecast: As part of the team efforts to upgrade the NAQFC system into CB05 and implement $PM_{2.5}$ forecast, the windblown dust emission module developed by Daniel Tong has been successfully tested and integrated with the NAQFC CMAQ system. Initial evaluation showed high biases during some dust storm events. A second version of the dust code was prepared and the new

module displayed much better performance to capture dust storms.

h) Led the ARL study to examine urban emission changes during the Great Recession: The study examines the impact of the great recession on nitrogen oxide (NOx) emissions in eight major U.S. cities. The study compares changes in NOx emissions trends from the National Weather Service led National Air Quality Forecasting Capability (NAQFC), the U.S. EPA ground-based network (Air Quality System or AQS), and the NASA satellite (Ozone Mapping Instrument or OMI) over the time period before, during, and after the recession (2005-2012). Both the OMI and AQS detect substantial downward trends, -35 percent and -38 percent, respectively. The NAQFC, which relies on national emissions inventories (NEIs), shows a slower reduction rate (-25 percent). This is likely because the NEI data years are several years behind the forecasting year and do not fully account for the effects of the economic recession. All of the datasets show that the NOx emissions reductions have slowed down after 2009 or during the economic recovery. There are two important conclusions in this paper. 1) The study demonstrates the feasibility of using satellite and ground-based observations to detect changes in air pollution during an economic event, such as the recession, and 2) The satellite and ground- based observations can be used to evaluate major updates of emission inventories objectively. For more details see ARL news release at http://www.arl.noaa.gov/NOxTrends_GreatRecession.php

Planned Work

*Continue working on the FY2015 emission data to support the National Air Quality Forecasting operation;
*Continue developing the NOAA dust storm forecasting system based on CMAQ dust module.

Publications

1. **Tong, D.Q.,** L. Lamsal, L. Pan, C. Ding, H. Kim, P. Lee, T. Chai, and K.E. Pickering, and I. Stajner, 2014. Long-term NO_x trends over large cities in the United States during the 2008 Recession: Intercomparison of satellite retrievals, ground observations, and emission inventories, *Atmospheric Environment*, doi:10.1016/j.atmosenv.2015.01.035.
2. Zhao, H., **Tong, D. Q**., Gao, C., & Wang, G. (2015). Effect of dramatic land use change on gaseous pollutant emissions from biomass burning in Northeastern China. *Atmospheric Research*, *153*, 429-436.
3. Pan, Li, **Daniel Tong,** Pius Lee, Hyuncheol Kim and Tianfeng Chai, 2014: Assessment of NOx and O_3 forecasting performances in the U.S. National Air Quality Forecasting Capability before and after the 2012 major emissions updates, *Atmos. Environ.* **95**, 610–619, doi:10.1016/j.atmosenv.2014.06.020.
4. Chai, T., Kim, H.-C., Lee, P., **Tong, D.,** Pan, L., Tang, Y., Huang, J., McQueen, J., Tsidulko, M., and Stajner, I.: Evaluation of the United States National Air Quality Forecast Capability experimental real-time predictions in 2010 using Air Quality System ozone and NO_2 measurements, Geosci. Model Dev., 6, 1831-1850, doi:10.5194/gmd-6-1831-2013, 2013.

PRESENTATIONS

1. Daniel Q. Tong, 2014. NAQFC Emission Forecasting. US Weather Research Program Air Quality Workshop, November 6-7, 2014, College Park, MD.
2. **Weiwei Chen and Daniel Tong, 2014.** Global emissions of PM10 and PM2.5 from agricultural tillage and harvesting. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.
3. Li Pan, Pius Lee, Hyun Cheol Kim, , YouHua Tang, Daniel Tong, Rick Saylor, Ivanka Stajner, Weiwei Chen, Tianfeng Chai and Barry Baker, 2014. Evaluating wildfire emissions and assessing their influences in National Air Quality Forecasting Capability (NAQFC) system by comparison with ground, satellite and flight measurements during Southeast Nexus (SENEX) field experiment. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.

4. Youhua Tang, Tianfeng Chai, Li Pan, Pius Lee, Daniel Tong, and Hyun-Cheol Kim, 2014. Assimilation of Surface PM2.5 and Satellite AOD in CMAQ. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.
5. Daniel Q. Tong, Lok Lamsal, Li Pan, Charles Ding, Hyuncheol Kim, Pius Lee, Tianfeng Chai, Kenneth E. Pickering, and Ivanka Stajner, 2014. Assessing the impact of the 2008 economic recession on NOx emissions in US megacities: intercomparison of satellite remote sensing, ground monitoring, and emission inventories. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.
6. Hyun Cheol Kim, Pius Lee, Li Pan, Laura Judd, Daniel Tong, Youhua Tang, Tianfeong Chai, Barry Lefer, and Ivanka Stajner, 2014. Comprehensive comparisons of NAQFC surface and column NO2 with satellites, surface, and field campaign measurements during 2009-2014. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.
7. Ivanka Stajner, Jeff McQueen, Pius Lee, Roland Draxler, Jinaping Huang, Perry Shafran, Daniel Tong, Li Pan, Phil Dickerson, and Sikchya Upadhayay, 2014. National Air Quality Forecast Capability: recent progress and plans. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.
8. Jianping, Huang[1,2*], Jeff McQueen[2], Perry Shafran[1,2], Pius Lee[3], Daniel Tong[3,4], Li Pan[3,4], Youhua Tang[3,4] Sikchya Upadhayay[5,6], Geoff DiMego[2], and Ivanka Stajner, 2014. Impact of meteorological inputs on NOAA PM2.5 predictions. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.
9. Nina Randazzo, Daniel Tong, Pius Lee, Xiaozhen Xiong, Feng Ding, Juying Warner, Monika Kopacz, 2014. Comparisons of CO emission trends over US large cities observed by satellite remote sensing and ground observations during the 2008 Great Recession. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.
10. Daniel Q. Tong, 2014. NAQFC Emission Forecasting. USWRP Air Quality Workshop, November 6-7, 2014, College Park, MD.
11. Pius Lee, Greg Carmichael, Tianfeng Chai, Rick Saylor, Li Pan, Hyuncheol Kim, Daniel Tong, and Ariel Stein, 2014. A regional chemical reanalysis prototype. The **12th Annual CMAS Conference**, October 28-30, 2014, Chapel Hill, NC.
12. Li Pan, Pius Lee, Hyun Cheol Kim, Daniel Tong, Rick Saylor and Tianfeng Chai, 2014. Preliminary analyses of flight measurements and CMAQ simulation during Southeast Nexus (SENEX) field experiment. The **12th Annual CMAS Conference**, October 28-30, 2014, Chapel Hill, NC.
13. Hongmei Zhao, Daniel Q. Tong, Pius Lee, Hyuncheol Kim, Hang Lei, 2014. Reconstructing fire records from ground-based routine aerosol. The **12th Annual CMAS Conference**, October 28-30, 2014, Chapel Hill, NC.
14. Hang Lei, Daniel Tong, Li Pan, Pius Lee, Menghua Wang, Brett Gantt, 2014. Validation of Suomi-NPP VIIRS marine isoprene emission products with in-situ measurements. The **12th Annual CMAS Conference**, October 28-30, 2014, Chapel Hill, NC.
15. Hongmei Zhao, Daniel Q. Tong Xianguo Lu, Guoping Wang[1], Pius Lee, 2014. Impact of dramatic land use change on gaseous pollutants emission from biomass burning. The **12th Annual CMAS Conference**, October 28-30, 2014, Chapel Hill, NC.
16. Hyun Cheol Kim [1,2], Li Pan, Pius Lee, Rick Saylor, and Daniel Tong, 2014. HCHO and NO2 column comparisons between OMI, GOME-2 and CMAQ during 2013 SENEX campaign. The **12th Annual CMAS Conference**, October 28-30, 2014, Chapel Hill, NC.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
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# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

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Background
My current role in the NOAA Air Resources Laboratory is supporting NOAA/NCEP's operational air quality forecasting, to perform an air quality re-analysis and to test/develop/evaluate the algorithm or methods for improving the performance in air quality prediction. I started my current position in May 2014. During July and August 2014, I provided real-time air quality forecast support for NASA DISCOVER-AQ and NSF FRAPPÉ in Colorado. Based on that work, I made model evaluations and comparisons, presented at the AGU falling meeting (Dec, 2014). I also tested the optimal interpolation method with MODIS and AIRNow data, and the preliminary results were shown in the Annual CMAS meeting in Chapel Hill, NC.

Accomplishments
I finished testing the impact of optimal interpolation (OI) method on adjusting the ozone and aerosol initial conditions of air quality model using AIRNow in-situ data and MODIS AOD. Provided the real-time forecast for DISCOVER-AQ and FRAPPÉ in the 12km CONUS domain and nested 4km domain using the latest CMAQ (version 5.0.2). Provided support for NCEP's operational air quality forecasting and other related projects. Worked with EPA to test the parallel netcdf I/O on NCEP WCOSS's GPFS file system for speeding up CMAQ, but its performance is still unstable.

Planned work
In 2015, I will start testing the GSI assimilation tool and apply it to air quality prediction if it works well. I also plan to test several other methods for improving the performance of current AQ forecasting. There are several proposals in preparation. One manuscript has been submitted to CMAQ special issue.

Presentations

Youhua Tang, Tianfeng Chai, Li Pan, Pius Lee, Daniel Tong, Hyun-Cheol Kim, and Weiwei Chen, 2014: Using Optimal Interpolation to Assimilate AirNOW Surface Measurement and MODIS AOD into CMAQ for July 2011, 13th Annual CMAS Conference, OCT 27-29, Chapel Hill, NC, 2014

Youhua Tang, Li Pan, Pius Lee, Daniel Tong, Hyun-Cheol Kim , Qiang Zhao, Chuanyu Xu, Shobha Kondragunta4, Richard Artz, 2014: Comparison of CMAQ Modeling Study with Discover-AQ/FRAPPÉ 2014 Aircraft Measurements over Colorado, 2014 AGU Fall meeting, San Francisco, CA.

Li Pan, Pius Lee, Hyun Cheol Kim, **Youhua Tang**, Daniel Tong ,Rick Saylor, Ivanka Stajner, Weiwei Chen, Tianfeng Chai and Barry Baker, Evaluating wildfire emissions and assessing their influences in National Air Quality Forecasting Capability (NAQFC) system by comparison with ground, satellite and flight measurements during Southeast Nexus (SENEX) field experiment, 13th Annual CMAS Conference, OCT 27-29, Chapel Hill, NC, 2014.

Kim, H., P. Lee, L. Pan, L. Judd, D. Tong**, Y. Tang**, T. Chai, B. Lefer, and I. Stajner, 2014: Comprehensive comparisons of NAQFC surface and column NO2 with satellites, surface, and field campaign measurements during 2009-2014, 2014 CMAS conference, Chapel Hill, NC

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

During 2014, I tested the method of adjusting initial condition using optimal interpolation (OI) method. It works but also has some limitations, e.g. its impact could fade away in 12 hours. I also tested CMAQ 5.0.2 and used it in the real-time forecast support for Discover-AQ 2014 field campaign. NOAA is considering data assimilation for air quality prediction, but it must be GSI-based. So I will move to GSI.

Xinrong Ren

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Background: Mercury is a serious environmental toxin. Gaseous elemental mercury (GEM) is observed ubiquitously in the troposphere. The distributions of two other forms of mercury species, gaseous oxidized mercury (GOM) and particulate bound mercury (PBM), are not well documented. It is highly desirable to conduct measurements of a variety of trace gases along with atmospheric mercury to facilitate source identification. Very few studies have been conducted on measurements of atmospheric mercury from aircraft. Aerosol optical depth (AOD) observed from satellites can provide a view broad in space and time, but the accuracy of retrievals for varying surface properties, and varying aerosol optical properties, as well as the relationship between remotely sensed AOD and surface concentration of PM2.5 remain as major unanswered questions in atmospheric science.

Accomplishments: With the support from CICS, Dr. Xinrong Ren has been working primarily on two projects in the past year: (1) the atmospheric mercury monitoring project at NOAA Air Resources Laboratory; (2) the aircraft observations in Support of GOES-R/VIIRS calibration and validation at University of Maryland's Department of Atmospheric and Oceanic Science. Below is a summary of the accomplishments in the past year.

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

(2) Data analyses for atmospheric mercury process studies
Dr. Ren work on the data analysis for the two atmospheric mercury process studies: (1) Intensive study on mercury speciation observations at a coastal site in the northern Gulf of Mexico in summer 2010 and spring 2011, and (2) Airborne vertical profiling of mercury speciation near Tullahoma, TN, USA. Two papers have been published to summarize the results from these two studies.

(3) Aircraft Observations in Support of GOES-R/VIIRS Calibration and Validation (RDXR_AOD_15)
Dr. Xinrong Ren conducted further aircraft observations of aerosol properties and trace air pollutants in summer 2014 over the Eastern Shore to validate GOES EAST Aerosol/Smoke Product (GASP) and the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS). The objective of this study is to link the satellite-observed aerosol optical depth (AOD) to the surface particulate matter (PM). Initial analysis shows that the integrated aerosol extinction within the aerosol layer observed by the aircraft is highly correlated with the PM2.5 concentration observed at the surface. A better correlation was found between the surface PM2.5 concentration and the averaged aerosol scattering in a layer close to the surface.

In collaboration with a group at the NOAA/NESDIS/STAR, Dr. Ren also investigated the aerosol extinction during the DISCOVER-AQ studies in four areas: Baltimore/Washington (2011), California (2013), Houston (2013), and Colorado (2014). Aircraft observations of aerosol extinction were compared to the surface PM2.5 observations and will be compared to the concurrent satellite observations.

Planned work

- To continue the monitoring of mercury compounds (GEM, GOM, and PBM) at the three EPA Atmospheric Mercury Network (AMNet) sites operated by NOAA ARL.
- To conduct data analysis for the atmospheric mercury observations at the Beltsville and Grand Bay AMNet sites made over the past 7 years.
- To conduct further airborne observations and data analysis in support of GOES-R/VIIRS calibration and validation.

Publications

Ren, X., W. T. Luke, P. Kelley, M. Cohen, F. Ngan, R. Artz, J. Walker, S. Brooks, C. Moore, P. Swartzendruber, D. Bauer, J. Remeika, A. Hynes, J. Dibb, J. Rolison, N. Krishnamurthy, W. M. Landing, A. Hecobian, J. Shook, L. G. Huey, Mercury speciation at a coastal site in the northern Gulf of Mexico: Results from the Grand Bay intensive studies in summer 2010 and spring 2011, *Atmosphere*, 5, 230-251, 2014.

Brooks, S., **X. Ren**, M. Cohen, W. T. Luke, P. Kelley, R. Artz, A. Hynes, W. Landing, and B. Martos, Airborne vertical profiling of mercury speciation near Tullahoma, TN, USA. *Atmosphere*, 5, 557-574, 2014.

VandenBoer, T. C., M. Z. Markovic, J. E. Sanders, **X. Ren**, S. E. Pusede, E. C. Browne, R. C. Cohen, L. Zhang, J. Thomas, W. H. Brune and J. G. Murphy, Evidence for a nitrous acid (HONO) reservoir at the ground surface in Bakersfield, CA, during CalNex 2010, J. *Geophys. Res*., 119(14), 9093-9106, 2014.

Pinto, J. P., J. Dibb, B. H. Lee, Rappenglück, E. C. Wood, M. Levy, R.-Y. Zhang, B. Lefer, **X.-R. Ren**, J. Stutz, C. Tsai, L. Ackermann, J. Golovko, S. C. Herndon, M. Oakes, Q.-Y. Meng, J. W. Munger, M. Zahniser, and J. Zheng, Intercomparison of Field Measurements of nitrous acid (HONO) during the SHARP campaign, *J. Geophys. Res*., 119(9), 5583-5601, doi: 10.1002/2013JD0202872014.

Pusede, S. E., D. R. Gentner, P. J. Wooldridge, E. C. Browne, A. W. Rollins, K.-E. Min, A. R. Russell, J. Thomas, L. Zhang, W. H. Brune, S. B. Henry, J. P. DiGangi, F. N. Keutsch, S. A. Harrold, J. A. Thornton, M. R. Beaver, J. M. St. Clair, P. O. Wennberg, J. Sanders, **X. Ren**, T. C. VandenBoer, M. Markovic, J. G. Murphy, A. Guha, R. Weber, A. H. Goldstein, and R. C. Cohen, On the temperature dependence of organic reactivity, nitrogen oxides, ozone production, and the impact of emission controls in San Joaquin Valley California, *Atmos. Chem. Phys*., 14, 3373–3395, 2014, doi:10.5194/acp-14-3373-2014.

Lei, H., D. J. Wuebbles, X.-Z. Liang, Z. Tao, S. Olsen, R. Artz, **X. Ren**, and M Cohen, Projections of atmospheric mercury levels and their effect on air quality in the United States, *Atmos. Chem. Phys*., 14, 783–795, 2014.

Ngan, F., M. Cohen, W. Luke, **X. Ren** and R. Draxler, Meteorological modeling using WRF-ARW model for Grand Bay Intensive studies of atmospheric mercury, *Atmosphere*, 6, 209-233, doi:10.3390/atmos6030209, 2015.

Song, S., Selin, N. E., Soerensen, A. L., Angot, H., Artz, R., Brooks, S., Brunke, E.-G., Conley, G., Dommergue, A., Ebinghaus, R., Holsen, T. M., Jaffe, D. A., Kang, S., Kelley, P., Luke, W. T., Magand, O., Marumoto, K., Pfaffhuber, K. A., **Ren, X**., Sheu, G.-R., Slemr, F., Warneke, T., Weigelt, A., Weiss-Penzias, P., Wip, D. C., and Zhang, Q.: Top-down constraints on atmospheric mercury emissions and implications for global biogeochemical cycling, *Atmos. Chem. Phys. Discuss*., 15, 5269-5325, doi:10.5194/acpd-15-5269-2015, 2015.

Presentations

Ren, X., D. Anderson, J. Stehr, R. Dickerson, C. Xu and S. Kondragunta, Linking AOD from Satellites to Surface PM2.5 over the Eastern US Using Aircraft Observations, Abstract #: A11I-3111, *AGU Fall Meeting*,, San Francisco, CA, December 15-19, 2014.

Dickerson, R. R., X. Ren, A. Thompson, R. Salawitch, P. Shepson, J. Burrows, S. Sahu, D. Kollonige, and O. Schneisingen, Emissions from natural gas operations in the Marcellus Shale formation: In situ and remote sensing, Abstract #, A11L-04, *AGU Fall Meeting*, San Francisco, CA, December 15-19, 2014.

Lefer, B. L., J. H. Flynn III, L. Judd, X. Ren, M. J. Estes, R. J. Griffin, The spatial and temporal variability of ozone in the Houston Metropolitan area during DISCOVER-AQ and its relation to meteorological conditions, Abstract #: A13Q-04, *AGU Fall Meeting*,, San Francisco, CA, December 15-19, 2014.

Judd, L., B. Lefer, J. Herman, N. Abuhassan, A. Cede, S. Janz, J. H. Crawford, A. Weinheimer, R. Cohen, X. Ren, W. Luke, H. C. Kim, R. Long, Comparison of Pandora spectrometer NO2 measurements to aircraft, satellite, and ground measurements during the DISCOVER-AQ Texas campaign, Abstract #: A33I-3318, *AGU Fall Meeting*,, San Francisco, CA, December 15-19, 2014.

Nault, B. A., C. Garland, P. J. Wooldridge, J. D. Crounse, P. O. Wennberg, J. Mao, X. Ren, L. Zhang, W. H. Brune, I. B. Pollack, J. Peischl, T. B. Ryerson, R. C. Cohen, NOx Loss and Lifetime via Its Reaction with HOx in the Upper Troposphere, *AGU Fall Meeting*, San Francisco, CA, December 15-19, 2014.

Martin, C. R., N. Zeng, K. Weber, W. Tribett, T. Kelly, R. Dickerson, and X. Ren, Calibration and initial measurements with a low-cost and moderate-precision CO_2 sensor, *AMS Annual Meeting*, Phoenix, AZ, January 4-8, 2015.

Dickerson, R., N. Zeng, X. Ren, K. Ide, and E. Kalnay, Greenhouse Gas Observations and Assimilation Methods for Emissions Estimates, *AMS Annual Meeting*, Phoenix, AZ, January 4-8, 2015.

van den Bossche, M., N. Rose, D. Chestnut, X. Ren, C. Sloop, and S. F. J. De Wekker, Development of a low-cost gas sensor network for atmospheric methane concentration monitoring, *AMS Annual Meeting*, Phoenix, AZ, January 4-8, 2015.

Ren, Xinrong, Linking AOD from Satellites to Surface $PM_{2.5}$ over the Eastern US Using Aircraft Observations, *CICS-MD Science Meeting*, College Park, MD, November 12-13, 2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**9**
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

1.4 Future Satellite Programs

Year 4 GOES-R/JPSS Visiting Scientist Program

Task Leader: Michael J. Folmer
Task Code: EBMF_GOESR_14/ EBMF_JPSS_14 (GOES-R/JPSS Proving Ground Scientist)
Main CICS Research Topics: Future Satellite Programs (GOES-R and JPSS)
Percent contribution to CICS Themes: Theme 1: 20%; Theme 2: 80%; Theme 3: 0%.
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 since May 2011. These proving grounds allow forecasters and researchers the opportunity to evaluate new satellite technologies in every day operations.

Background

The Geostationary Operational Environmental Satellite R-Series (GOES-R) and Joint Polar-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 College Park, 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 for the last three years. In addition to the GOES-R and JPSS objectives, the VS is currently working with Proving Ground partners to prepare for Himawari-8 data in the summer of 2015.

Accomplishments

The 2014 GOES-R and JPSS Proving Ground activities at WPC, OPC, TAFB, and SAB continued to focus on observing and analyzing convection for heavy rainfall and high wind events from land to sea. The new products that were introduced to forecasters included the GOES-R Convective Initiation product, the Nearcast model (uses GOES Sounder data), Hybrid Geo/Leo imagery, AIRS Total Column Ozone and Ozone Anomaly, and a brief introduction to the Fog/Low Stratus products. Products such as the Air Mass RGB, GLD-360 Lightning Density, and Overshooting Top Detection were included in the demonstrations as a second year evaluation. Additionally, new passive microwave imagery was introduced to TAFB as part of a collaboration between NASA SPoRT and the Naval Research Laboratory. This imagery is courtesy of the

Defense Meteorological Satellite Program (DMSP – F15-F18), Tropical Rainfall Measurement Mission (TRMM), the JAXA Advanced Microwave Scanning Radiometer 2 (AMSR-2), and the Advanced Technology Microwave Sounder (ATMS) on the S-NPP satellite. Approximately 50 of 80 forecasters and analysts were trained on the products between 1 January and 30 November and a survey was conducted to collect their feedback. One forecaster at OPC noted that using the OTD/OTM products in conjunction with the GLD-360 lightning density and infrared imagery provided useful information on the potential severity of individual maritime thunderstorms. Other forecasters found some of the products to be more advantageous than just the legacy products alone as it added a new dimension to analyze the weather event. A big change this year was in the increased number of product mentions in the respective center text products issued to the public.

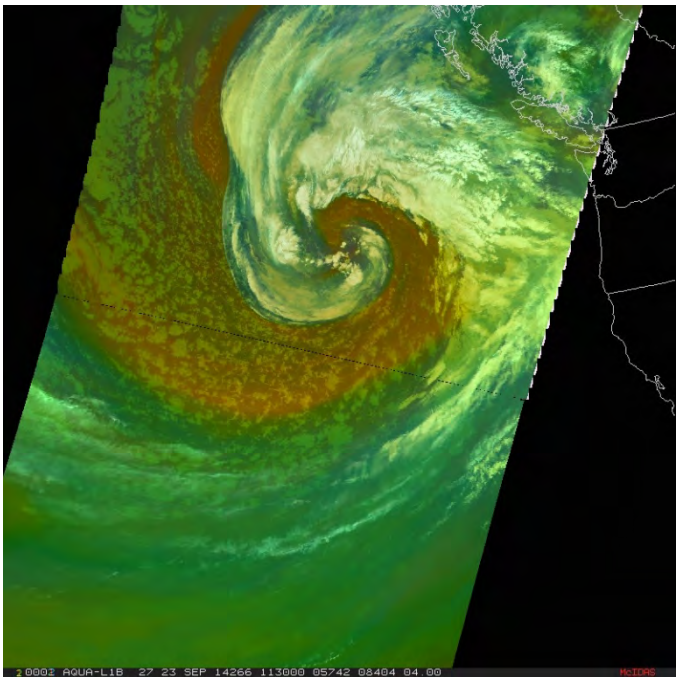

Figure 1: MODIS Air Mass RGB of a hurricane-force low off the Pacific Northwest of the U.S. on 23 September 2014. Forecasters at OPC used this image along with other available data in the absence of reliable ASCAT scatterometer passes to upgrade this low from a storm-force to a hurricane-force system. The red coloring indicates stratospheric drying from an upstream tropopause fold and the hurricane-force winds are located near the southern portion of the comma-head. For more, please see: https://satelliteliaisonblog.wordpress.com/2014/09/30/first-hurricane-force-low-in-the-east-pacific/

Once again, GOES-14 was taken out of storage for science testing two times in 2014 (May and August). 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 at WPC and SAB found the imagery particularly useful in monitoring flash flood potential in Tennessee in mid-August. Finally, the new products that were introduced this year provided some unique perspectives for convective monitoring such as the Nearcast model which allows the forecasters to analyze a theta-e difference between mid-levels and low-levels which helps to identify the most likely regions for convective development.

The fourth year of the Proving Ground included a third 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 10 forecasters were trained on products that included the RGB Dust and Pseudo-Natural Color products to monitor the Saharan Air Layer, Tropical Overshooting Tops, and the GLD-360 lightning density product near developing tropical cyclones. The field campaign has ended, but there was some valuable feedback on how these products can assist forecasters and scientists during real-time scientific field operations.

As part of the PG activities, the CICS VS was able to shed light on some satellite display problems at WPC and OPC back in 2012. 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, MTSAT-2, Meteosat-10, and Meteosat-7.

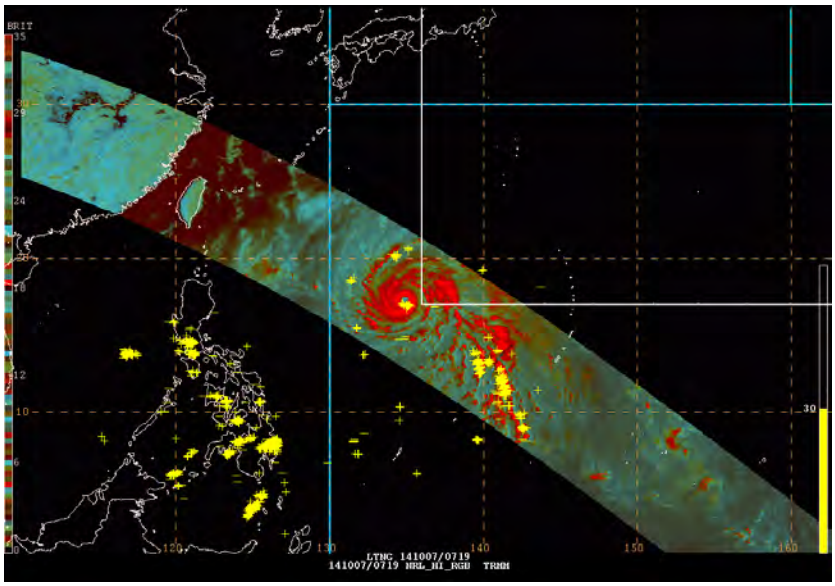

Figure 2: Super typhoon Vongfong was a significant storm in 2014, peaking at 155 kt (175 mph) on 17 October 2014. This TRMM 89GHz RGB image shows the typhoon at maximum intensity with GLD-360 lightning strikes overlaid.

The new satellite sectors (native projections) have been introduced to the forecasters through a powerpoint that was presented by the VS and these will be implemented in April 2015. The VS continues to work with NESDIS and the JPSS program to make more S-NPP products available and this should pick up in summer 2015. Additionally, Himawari-8 data should start flowing into the centers sometime during the summer 2015 and work is underway to make all 16 bands available to the forecasters as both an operational capacity and a training tool for GOES-R (launches in March 2016). 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 that highlights satellite usage during Hurricane Sandy. Work has also begun on getting some of the products into AWIPS II by the end of 2015 to prepare for the field release of the National Center's Perspective (NCP)

beginning with OPC in early 2016 and finishing with the other remote National Centers in 2017. Finally, the VS has been leading a group of representatives from NASA SPoRT, CIRA, and CIMSS on developing an RGB "on the fly" capability in the NCP of AWIPS II. With 16 bands available from the Advanced Himawari Imager (AHI, Himawari-8) and Advanced Baseline Imager (ABI, GOES-R), it is necessary to look for ways to allow band combinations in the AWIPS II environment rather than relying on stand-alone RGB products.

Planned work

- The 2015 Winter Demonstrations runs from 01/15/15-04/15/15 for the following products:
    - RGB Air Mass
    - AIRS Ozone Products
    - Hybrid Imagery
    - Fog and Low Stratus
    - GeoColor
    - Nighttime Microphysics RGB
- The 2014 Summer Demonstration runs from 05/15/15-10/31/15 for the following products:
    - Cloud-Top Cooling (new)
    - Layered Precipitable Water (new)
    - GOES-14 SRSOR
    - OTD/OTM
    - GLD-360 Lightning Density
    - Convective Initiation
    - Nearcast
    - RGB products
- JPSS products that will be introduced through the year
    - Passive Microwave
    - NUCAPS
- Work with AWIPS-II experts to display GOES-R/JPSS products
- Assist in ingesting and displaying Himawari-8 imagery
- Continue research collaborations with CICS scientists and other academic partners

Publications

Folmer, M.J., M. DeMaria, R. Ferraro, J. Beven, M. Brennan, J. Daniels, R. Kuligowski, H. Meng, S. Rudlosky, L. Zhao, J. Knaff, S. Kusselson, S.D. Miller, T. Schmit, C. Velden, B. Zavodsky, 2015: Satellite Tools to Monitor and Predict Hurricane Sandy: Current and Emerging Products. Submitted to Atmospheric Research in February 2015.

Berndt, E.B., B.T. Zavodsky, M.J. Folmer, 2015: Development and Application of Atmospheric Infrared Sounder Ozone Retrieval Products for Operational Meteorology. Submitted to IEEE Transactions on Geoscience and Remote Sensing in February 2015.

Presentations (* indicates invited)

Folmer, M.J., J. Kerkmann, G. Bridge, C. Georgiev, and P. Chadwick, 2015: Applications of Meteosat Second Generation: Air Mass RGB. Training Seminar at the National Hurricane Center, Miami, FL.*

Folmer, M.J., M. Pavolonis, C. Calvert, S. Lindstrom, S. Bachmeier, K. Smith, and C. Schultz, 2015: Forecaster Training for GOES-R Fog/Low Stratus Products. Training Seminar at the National Hurricane Center, Miami, FL.*

Folmer, M.J., J. Cangialosi, J. Halverson, E. Berndt, J. Sienkiewicz, S. Goodman, and M. Goldberg, 2015:

The 'Unusual' Evolution of Hurricane Arthur 2014: GOES-R and JPSS Satellite Proving Ground Perspective. 95th AMS Annual Meeting, Phoenix, AZ.

Folmer, M.J., E. Berndt, J. Dunion, J. Halverson, M. DeMaria, S. Goodman, and M. Goldberg, 2014: Improved Satellite Techniques for Monitoring and Forecasting the Transition of Hurricanes to Extratropical Storms. 47th AGU Fall Meeting, San Francisco, CA.

Folmer, M.J., A. Terborg, E. Berndt, and K. Strabala, 2014: Use of S-NPP in NOAA National Weather Service Operations. 2nd S-NPP Applications Workshop, Huntsville, AL.*

Folmer, M.J. and D. Plummer, 2014: National Centers Current Satellite Data Capabilities and Look Towards the Future (with AWIPS II). JPSS Data to AWIPS II Workshop, College Park, MD.*

Folmer, M.J., A. Stinner, J.M. Sienkiewicz, H. Cobb, C. Schultz, S. Rudlosky, and S. Goodman, 2014: Danger at Sea: Diagnosing and Communicating the Threat for Strong Maritime Thunderstorms. 39th National Weather Association Annual Meeting, Salt Lake City, UT.

Folmer, M.J., A. Orrison, D. Novak, J. Kibler, S. Goodman, and M. Goldberg, 2014: The Forecasting and Monitoring of Convection Associated with Flash Flood Threats. 39th National Weather Association Annual Meeting, Salt Lake City, UT.

Folmer, M.J., D. Novak, A. Orrison, J. Sienkiewicz, H. Cobb, J. Kibler, S. Rudlosky, and S. Goodman, 2014: Preparing for GOES-R at the Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis. 2014 EUMETSAT Meteorological Satellite Conference, Geneva, Switzerland.

Folmer, M.J., A. Stinner, J.M. Sienkiewicz, H. Cobb, C. Schultz, S. Rudlosky, and S. Goodman, 2014: Danger at Sea: Diagnosing and Communicating the Threat for Strong Maritime Thunderstorms. 2014 EUMETSAT Meteorological Satellite Conference, Geneva, Switzerland.

Folmer, M.J., 2014: The Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis. SPoRT Science Advisory Committee Meeting, Virtual Presentation, Huntsville, AL.*

Folmer, M.J., A. Stinner, J.M. Sienkiewicz, H. Cobb, C. Schultz, S. Rudlosky, and S. Goodman, 2014: Danger at Sea: Diagnosing and Communicating the Threat for Strong Maritime Thunderstorms. The World Weather Open Science Conference, Montreal, Canada.

Folmer, M.J., 2014: GOES-R Program and Training Update. Weather Prediction Center International Desk Seminar, College Park, MD.*

Folmer, M.J., 2014: GOES-R Program and HS3 Training Update. Hurricane and Severe Storm Sentinel 3rd Year, Wallops Flight Facility, VA.*

Folmer, M.J., 2014: GOES-R Program and Training Update. National Hurricane Center Seminar, Miami, FL.*

Folmer, M.J., 2014: The Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis: GOES-R and JPSS Products at OPC, SAB, TAFB, and WPC. Mt. Holly National Weather Service Seminar, Mt. Holly, NJ.*

Folmer, M.J., 2014: The Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis. GOES-R/JPSS Proving Ground/User Readiness Meeting, Kansas City, MO.*

Folmer, M.J., 2014: The RGB Air Mass Product: A "New" Multispectral Technique for Analyzing Extratropical Cyclones. 2nd Environment Canada/NOAA Collaboration Workshop, Halifax, Nova Scotia.*

Other

Outreach:

- Mesonet development project with the Marine Academy of Technology and Environmental Sciences
- Co-mentoring a PhD student at Saint Louis University (SLU)
- Co-mentoring a PhD student at the University of Alabama-Huntsville (UAH)

- Co-mentoring a Coast Guard Cadet Intern at OPC
- Co-mentoring two University of Maryland Interns at OPC

Performance Metrics	
# of new or improved products developed (please identify below the table)	**N/A**
# of products or techniques submitted to NOAA for consideration in operations use	**6**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**2**
# of invited presentations	**11**
# 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**

Facilitating Direct CICS Support for Satellite Proving Ground Efforts

Task Leader: E. Hugo Berbery
Task Code: EBSR_GOESR_14/EBSR_JPSS_14
NOAA Sponsor: Steven Goodman, Mitch Goldberg
NOAA Office: NESDIS - GOES-R / JPSS
Contribution to CICS Research Themes (%): Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic: Future Satellite Programs
Contribution to NOAA goals (%): Goal 1: 25%; Goal 2: 75%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%
Highlight: CICS-MD has acquired, installed, and implemented two computers running AWIPS-II, McIDAS, and WDSS-II. These software platforms allow for analysis and display of real-time data. Our IT staff is currently connecting to local data manger (LDM) feeds that mimic what the Satellite Broadcast Network (SBN) will soon provide.
Link to a research web page: http://cicsmd.umd.edu/

Background

The JPSS and GOES-R programs have provided initial support for developing a CICS-MD Proving Ground and Training Center (PGTC). The PGTC is an operational framework that allows CICS-MD to maximize its satellite PG contributions. Infrastructure is being built to promote sustained interaction between JPSS/GOES-R algorithm developers and end users for training, product evaluation, and solicitation of user feedback. Many SCSB/CICS-MD scientists develop algorithms that have a variety of operational applications, but these scientists have limited channels for direct interaction with NWS forecasters. The proposed research will help bridge this gap by supporting an IT expert and several student liaisons. This effort will broaden the influence of CICS-MD within the satellite PGs, and bring operational meteorology into the classroom. The IT expert will optimize our ability to mimic various operational environments as well as our connectivity with external partners. The student liaisons will become experts on individual products, helping with each stage from product visualization through the shadowing of forecasters during evaluations. Target products include ATMS and SSMIS snowfall rates, regional AMSR-2 products for the OCONUS, and lightning enhanced precipitation products. The PGTC will serve additional JPSS product lines being developed by NESDIS/STAR scientists located adjacent to SCSB/CICS-MD at the NCWCP (e.g., aerosol and fire products). The proposed research will develop satellite education and training materials through e-learning modules, seminars, weather event simulations, and special case studies. Implementation of AWIPS-II and McIDAS at CICS-MD coincides with development of similar capabilities just 2.5 miles away at UMD/AOSC. Student interns will cross-populate these efforts, greatly benefit both parties, and providing valuable educational and training opportunities for UMD students. The result will be graduates with remote sensing experience ready to staff future NESDIS activities as support contractors and civil servants.

Accomplishments

The JPSS and GOES-R programs provided initial support during FY14 for developing a CICS-MD Proving Ground and Training Center (PGTC). CICS-MD has acquired, installed, and implemented two computers running AWIPS-II, McIDAS, and WDSS-II. These software platforms allow for analysis and display of real-time data. Our IT staff is currently connecting to local data manger (LDM) feeds that mimic what the Satellite Broadcast Network (SBN) will soon provide. Final planning is underway for the installation of an SBN antenna/server that will provide real-time data feeds comparable to those available at National Weather Service (NWS) Weather Forecast Offices (WFOs). The SBN will lighten the incoming bandwidth load (as well as add a powerful server), providing more bandwidth for serving out experimental products. Implementation of AWIPS-II and McIDAS at CICS-MD coincides with development of similar capabilities at UMD/AOSC. Student interns will cross-populate these efforts, greatly benefiting both parties, and providing valuable

educational and training opportunities for UMD students. Only the most advanced students can be expected to take lead roles, so we anticipate most serving backup roles. Alternatively, graduate students may well be capable of leading the efforts on individual products.

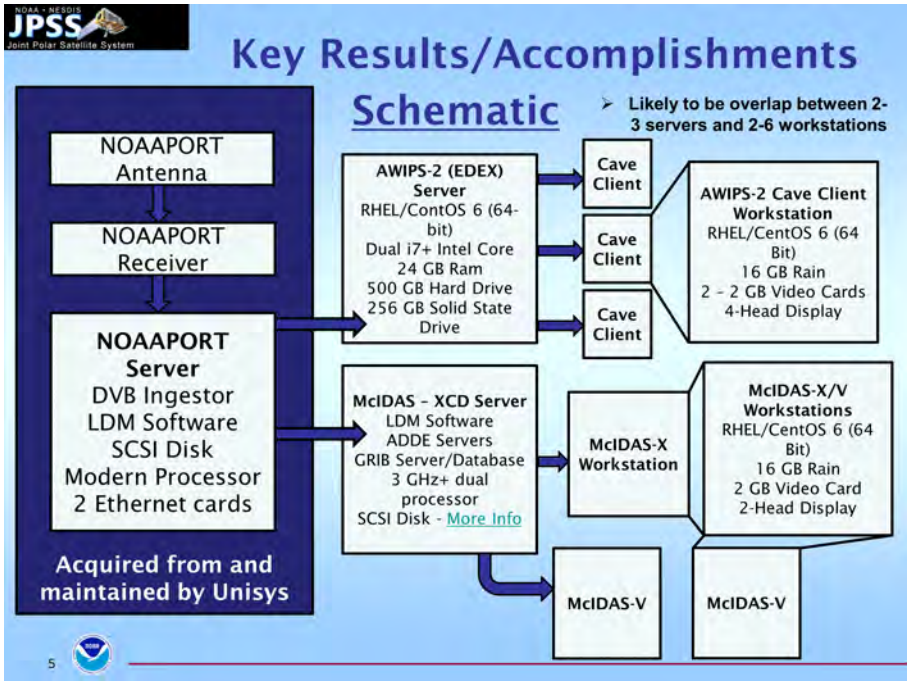

Figure 1: Schematic depicting the hardware and software solutions for the CICS-MD PGTC.

Figure 2: Image above depicts two eager students putting the machines through their paces. These machines were funded by a University of Maryland grant.

During January 2015, GOES-R Visiting Scientist travel grants were awarded to CICS-MD to fund travel in support of the Proving Ground and Training Center initiative. This project will fund Deb Molenar (CIRA/NOAA) to assist in the configuration of the PGTC AWIPS-II workstations after the installation of the NOAAPORT antenna and receiver. Additionally, CICS scientist Pat Meyers will be able to travel to the AWIPS-II Experimental Products Development Team training at NASA/SPORT in Huntsville, Alabama.

Planned work

- Implement AWIPS-II and McIDAS – AWIPS-II will play a key role in the CICS-MD PGTC, but experimental products also will be developed for compatibility with the N-AWIPS environment to encourage NCEP National Center participation in the JPSS/GOES-R PGs.
- Install a NOAAPORT – Deploying a NOAAPORT antenna and server is an integral step for providing real-time data feeds. We are contracting Unisys to install the hardware (antenna/server), software, and server, which they will also maintain. Their server support will ensure the reliability (and uptime) of our SBN feed.
- Implement the Community Software Processing Package (CSPP) – Although the SBN is the main NWS data distribution tool, other (newer) data sets often must be gathered using different means. The CSPP provides a standardized means for interacting with the direct broadcast community, and thus provides an essential tool for product developers.
- Build an LDM Server – Since many NWS WFOs currently receive products and datasets via LDM feeds, the development of LDM capabilities at CICS-MD will expand the influence of our demonstration products, and promote their smooth transition into operations.
- Develop AWIPS-II plug-in Capabilities – AWIPS-II will provide tremendous flexibility for developers in the form of plug-ins. These tools can be developed for implementation at WFOs and National Centers using existing data feeds.
- Define a Local Governance Structure – The CICS-MD PGTC aims to provide a centralized approach to addressing many of the common PG challenges facing CICS-MD/STAR scientists. A project management framework and local governance structure must be developed to ensure project success.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

1.4a Scientific Support for the GOES-R Mission

GOES Evapotranspiration (ET) and Drought Product System (GET-D)

Task Leader Christopher Hain
Task Code CHCH_GETD_14
NOAA Sponsor Xiwu Zhan
NOAA Office NESDIS/STAR/SMCD/EMB
Contribution to CICS Themes (%) Theme 1: 50%; Theme 2: 50%; Theme 3: 0%. **Main CICS Research Topic** Scientific Support for the GOES-R Mission **Contribution to NOAA Goals (%)** Goal 1: 70%; Goal 2: 30%
Highlight: We are developing an operational evapotranspiration and drought monitoring system using GOES Land Surface Temperature product, meteorological data and other ancillary satellite remote sens- ing data.

Background

This report summarizes the year-2 work of the ongoing NOAA project to develop an operational evapotranspiration and drought monitoring system at the NOAA Office of Satellite and Product Op- erations (OSPO) in 2015. Our group has developed a surface energy balance model specifically adapted for geostationary satellite data to calculate the evapotranspiration (ET) and the potential ET (PET). Primary remote sensing inputs to the Atmosphere-Land Exchange Inverse (ALEXI) model are time-changes in land-surface temperature (LST), hourly downwelling short and long-wave radia- tion, and leaf area index. We have spearheaded use of anomalies in the remotely sensed ET/PET fraction (fPET) 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. ALEXI provides a framework for interpreting LST and vegetation index remote sensing drought signals within the context of a physically based energy balance model.

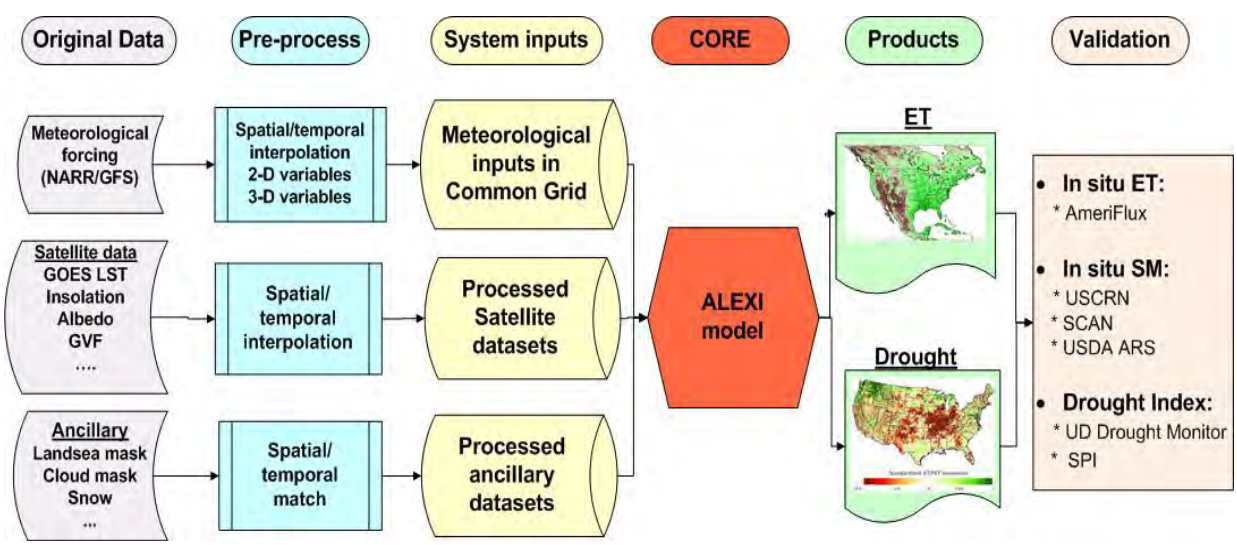

Figure 1. GOES Evapotranspiration and Drought Product (GET-D) system design.

This is the first ET and drought monitoring data product that are operationally supported at NESDIS from GOES. Figure 1 presents high-level design and data flow of the GET-D system. Below are the accomplishments during the first year of the project, followed by future plans for next year.

Accomplishments

The GET-D software system was under development in the second year of the project in 2014. We have finished the detailed design of the GET-D system and successfully implemented the major sub unit layers of the software system. We also finished the GETD Algorithm Theoretical Basis Document (ATBD) and the initial validation of products in 2014. The Critical Design Review (CDR) for GET-D project was success- fully performed in Aug 2014. Figure 2 presents an example of the algorithm generating the daily ET and ESI in 8km resolution over the North American domain.

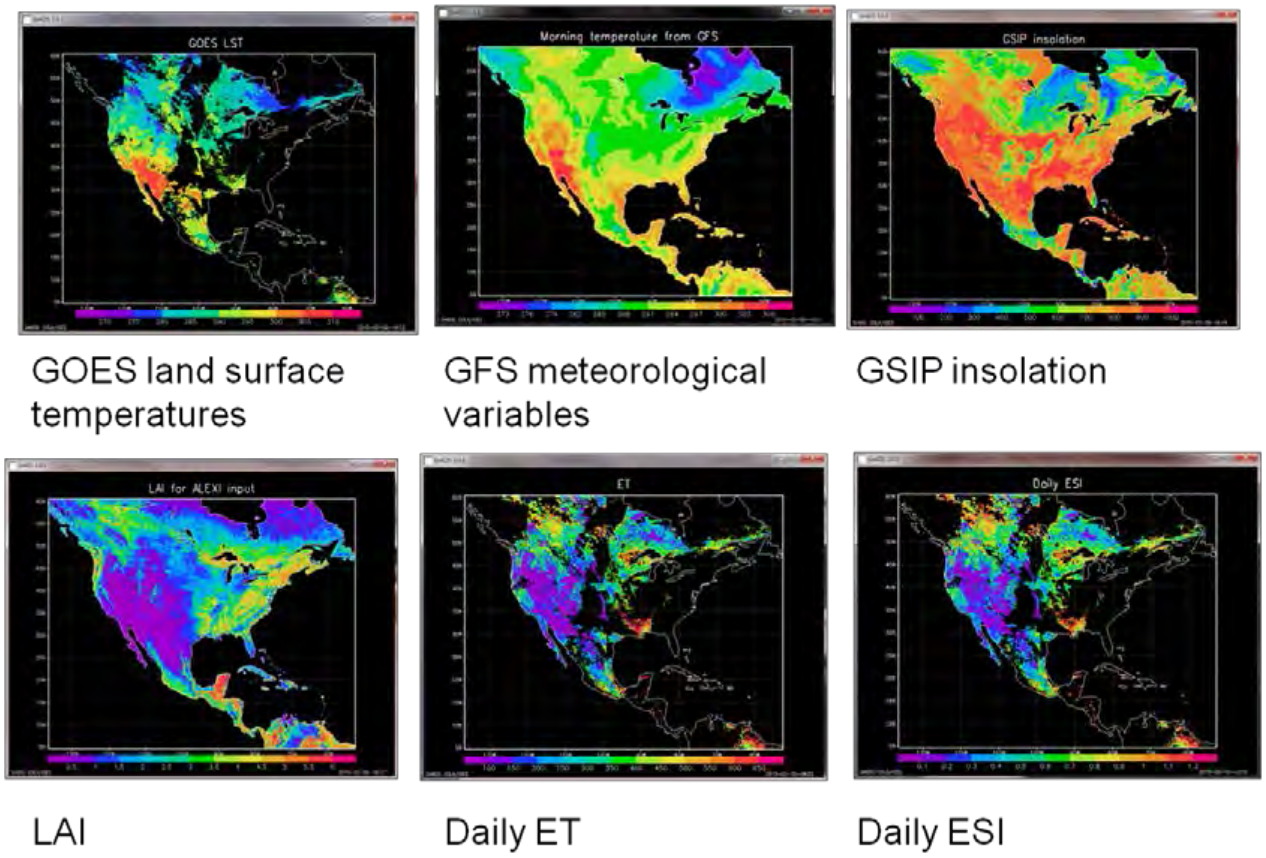

Figure 2. Example inputs and outputs of the GET-D system

We also developed the unit tests plan and test case has been implemented on the STAR development machine. The project deliverables (documentation and software) and milestones have been accom- plished as planned. Currently, the software system is under development/transfer phase.

Planned work

- Software Review
- Algorithm Readiness Review
- Transition of the system to operations

Publications

Zhan, X., Chris Hain, Li Fang and Zhengpeng Li, GETD Algorithm Theoretical Basis Document (ATBD), version 1.0, 2014

Zhan, X., Hanjun Ding, Chris Hain, Li Fang, Zhengpeng Li and Priyanka Roy, GOES Evapotranspiration and Drought Product System (GET-D) , report prepared for the NESDIS SPSRB Critical Design Review (CDR), August 21, 2014.

Products

- Software system for the Atmosphere–Land Exchange Inversion MODEL (ALEXI).
- Software system for GOES Evapotranspiration (ET) and Drought Product System (GET-D).
- Documentation for the drought monitoring algorithm and software system.

Presentations

Li Fang, Christopher R. Hain, Xiwu Zhan, Jicheng Liu, and Martha Anderson, Inter-Comparison and Validation of Soil Moisture Estimates from Microwave and Thermal Infrared Remote Sensing and Land Sur- face Model, Poster, CICS-MD Science Meeting, November 12-13, 2014, College Park, MD

Christopher R. Hain, Martha Anderson, Jason Otkin, Kathryn Semmens, Xiwu Zhan, Li Fang, Zhengpeng Li, Use of Land Surface Temperature Observations in a Two-Source Energy Balance Model Towards Improved Monitoring of Evapotranspiration and Drought, American Geophysical Union 2014 Fall meeting, December 15-19, 2014, San Francisco, CA

Xiwu Zhan, Jicheng Liu, Li Fang, Christopher R. Hain, Development and Validation of Global Soil Moisture Data Products from GCOM-W1/AMSR2 and NESDIS SMOPS, American Geophysical Union 2014 Fall meeting, December 15-19, 2014, San Francisco, CA

Li Fang, Christopher R. Hain, and Xiwu Zhan, Jicheng Liu, and Martha Anderson, Inter-Comparison and Validation of Soil Moisture Estimates from Microwave and Thermal Infrared Remote Sensing and Land Surface Model, Poster, American Geophysical Union 2014 Fall meeting, December 15-19, 2014, San Francisco, CA

Christopher Hain, Use of Land Surface Temperature Observations in a Two-Source Energy Balance Mod- el Towards Improved Monitoring of Evapotranspiration and Drought, CICS-MD Science Meeting November 12-13, 2014, College Park, MD

Zhengpeng Li, Christopher R. Hain, Li Fang and Xiwu Zhan, GOES Evapotranspiration and Drought Prod- uct System (GET-D), Poster, CICS-MD Science Meeting November 12-13, 2014, College Park, MD

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**6**
# 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**

This year, we developed a new 8-km North American domain drought monitoring product (1). Its development involved moving the prior drought research to operations. Two presentations summa rizing the product have been made in the CICS-MD Science Meeting in College Park, MD.

ATMS Derived Snowfall Rates to Support Weather Forecasting

Task Leader Cezar Kongoli
Task Code CKCK_ATMS_14
NOAA Sponsor
Main CICS Research Topic b. Scientific Support for the Future Satellite Missions: (i) Scientific support for the GOES-R Mission
Percent contribution to CICS Themes Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Percent contribution to NOAA Goals Goal 1: 20%; Goal 2: 80%
Highlight: The new ATMS snowfall detection and snowfall rate algorithms are being extensively evaluated using high quality in-situ and radar data. Evaluation of snowfall detection algorithm is complete, whereas the snowfall rate algorithm evaluation is under way.

Background

This report describes the work performed to evaluate the new suite of ATMS snowfall algorithms consisting of a snowfall detection (SD) and snowfall rate (SFR) algorithm. The SD algorithm computes the probability of snowfall based on principal components of the ATMS high frequency brightness temperatures 89 GHz and above and logistic regression. The SD algorithm is used as a snowfall mask to retrieve snowfall rate, the latter based on inversion of a radiative transfer model. SD algorithm was evaluated against high quality in-situ data over US and Alaska. Several snowfall events were sampled during the 2013-2014 and 2014-2015 winter seasons. The performance metrics included the probability of snowfall detection (POD) and the false alarm rate (FAR). In addition, the effects of temperature, satellite view angle and other ancillary data were evaluated. Results showed that algorithm was robust in detecting snowfall events in a wide range of weather conditions including colder weather. In addition, retrievals were also robust over mountaineous terrain although sample size of in-situ data collocated with ATMS measurements was smaller than over flat terrain. An in-depth investigation was also conducted to test the effectiveness of several weather filters on algorithm performance. These filters employ ancillary weather data and are applied to reduce FAR due to snow cover on the ground or cloud effects. It was shown that of all the ancillary data used, cloud thickness was the most efficient parameter in that it removed much more false alarm than legitimate snowfall. Work is on-going to modify application of these filters and improve algorithm performance. Evaluation of the SFR algorithm is also being conducted. As many as ten snowfall events have been selected and are being collocated with radar data.

Accomplishments

Six snowfall events during two winter seasons (2013-2014 and 2014-2015) were used to evaluation the SD algorithm and ten snowfall events were selected to evaluate the SFR product. In addition, an investigation was conducted to assess the effectiveness of several weather filters that employ ancillary data and applied in concert with ATMS data to improve algorithm performance. Figure 1 shows ATMS retrieved SFR (top left) over Pacific Northwest, not captured by Stage IV analysis (top left). NOAA's Snow Data Assimilation system (SNODAS) also shows a similar event. Table 1 shows overall perfomace statistics: probability of snowfall detection (POD) and false alarm rate (FAR) over the two weather regimes. As shown, statistics deteriorates for colder weather. It is important to note, however, that these statistics include "trace snowfall" events. For higher intensity snowfall statistics improve (Figure 20

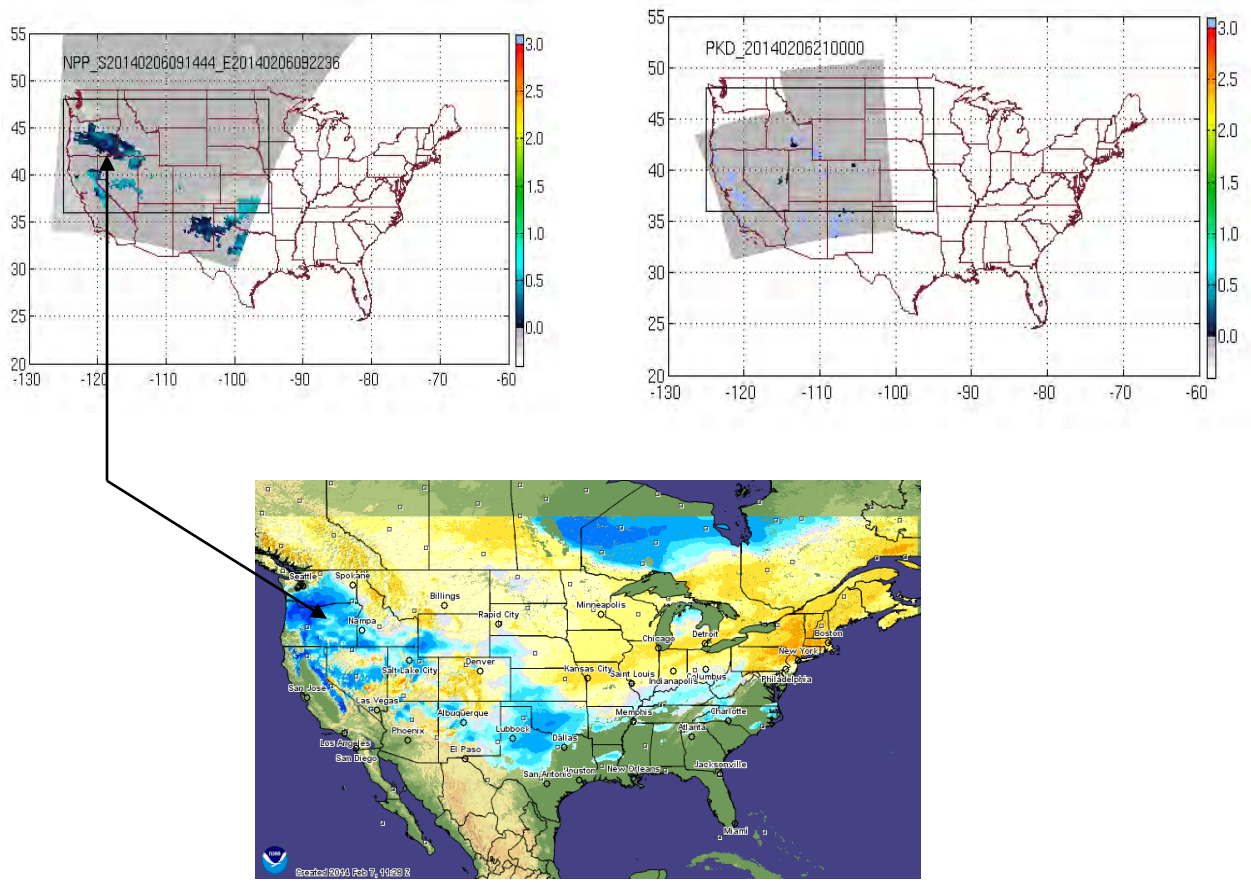

Figure 1. ATMS retrieved snowfall (right) on February 6, 2014 in Pacific Northwest was not captured by Stage IV (left). NOAA's Snow Data Assimmilation System (SNODAS, bottom) shows extensive snowfall over same area.

Table 1. Overall SD algorithm performance statistics

	POD (%)	FAR (%)
Regime 1 (warmer)	**62**	**15**
Regime 2 (colder)	**43**	**16**

Planned work

- Carry out further validation study involving SFR
- Adjust weather filters in the SD algorithm

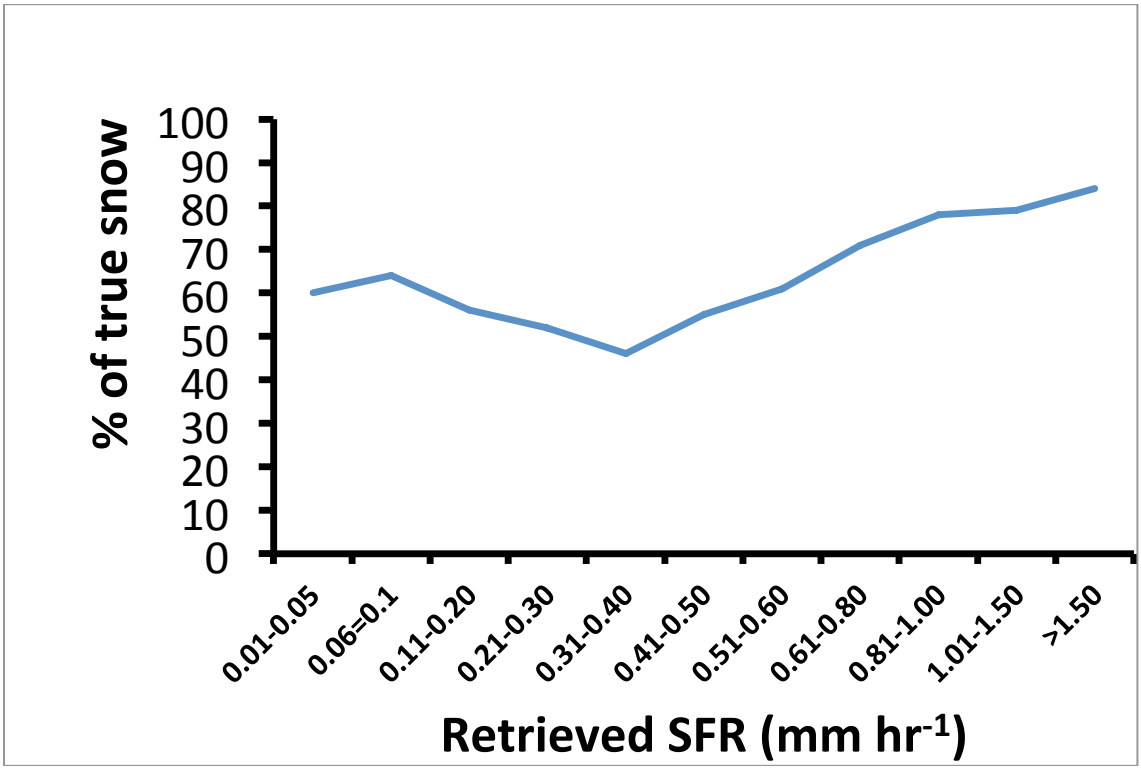

Figure 2. Percent of snowfall captures as a function of retrieved SFR. Moderate to high SFR over 1 mm hr-1 are associated with high fraction of retrieved snowfall of 80% ad higher.

Publications

Kongoli, C., H.Meng, J.Dong and R. Ferraro. 2015. A Snowfall detection algorithm over land utilizing high-frequency passive microwave measurements – Application to ATMS. *J. Geophys. Res. – Atmospheres* (in production). DOI: 10.1002/2014JD022427

Products

- Webpage http://cics.umd.edu/sfr
- Webpage http://cics.umd.edu/~jdong/data

Presentations

Meng, H., R. Ferraro, C. Kongoli, N. Wang, J. Dong, and B. Yan, 2014. "Snowfall rate retrievals using S-NPP ATMS measurements", (poster) 2014 NOAA Satellite Science Week, March 10-13, 2014, Madison, WI.

Meng, H., C. Kongoli, N. Wang, J. Dong, R. Ferraro, B. Yan and L. Zhao, 2014. "Snowfall rate retrieval using NPP ATMS passive microwave measurements", (oral) 13th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment, Pasadena, California, March 24-27, 2014.

Huan Meng, Ralph Ferraro, Cezar Kongoli, Banghua Yan, Jun Dong, Nai-Yu Wang, Limin Zhao, "NESDIS Snowfall Rate Products and New Development", Presentation to NASA Short-term Prediction Research and Transition Center (SPoRT), July 2, 2014, Huntsville, AL

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**0**
# of invited presentations	**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	**0**

This year, we evaluated the SD and SFR algorithms, published one refereed paper (1) and made three presentations (3).

Washington D.C. Lightning Mapping Array Maintenance and Outreach

Task Leader: E. Hugo Berbery
Task Code: EBSR_DCLMA _14
NOAA Sponsor: Steven Goodman
NOAA Office: NESDIS/GOES-R
Contribution to CICS Research Themes (%): Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic: Future Satellite Programs - Scientific support for the GOES-R Mission
Contribution to NOAA goals (%): Goal 1: 0%; Goal 2: 100%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%
Highlight: Several recent projects have helped improve the visibility of the DCLMA and demonstrate its value for severe weather analysis and public outreach.
Link to a research web page: http://cicsmd.umd.edu/

Background

The Washington D.C. Lightning Mapping Array (DCLMA) is a joint demonstration project between the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), New Mexico Institute of Mining and Technology, and 10 local site hosts. The DCLMA has been operational since 2007, providing detailed 3D lightning observations that inform decision makers about the severe weather and lightning threats. The network consists of 10 sensors that monitor very high frequency (VHF; MHz) radio waves (radiation sources) emitted by lightning. These total lightning observations provide detailed insights into the structure and evolution of convective storms, and help protect lives and property. The DCLMA has many uses, including severe storm research, public safety outreach efforts, and preparations for the planned Geostationary Lightning Mapper (GLM).

Accomplishments

1. *Database of Severe and Non-Severe Storms (continuation of published work)*
   - Investigated lightning jump occurrence alongside radar parameters (e.g., MESH – Maximum Expected Size of Hail);
   - Quantified relationships between DCLMA, NLDN, and radar-derived parameters using correlation coefficients and profile histograms; and
   - Examined the persistence of lightning/radar parameters using autocorrelation functions (originally for effective sample sizes).

2. *Research using WDSS-II*
   - Ongoing research uses the DCLMA and Earth Networks Total Lightning Network (ENTLN)
   - WDSS-II allows visualization and clustering of convective storms in an interactive, 3-D graphic display
   - Total lightning observations (see figure) provide detailed insights into the structure and evolution of convective storms and in turn help protect people and property

3. *DCLMA Outreach Efforts*
   - Examined specific lightning cases to match lightning paths, heights, and strike locations with lightning photographs
   - Collaborations resulted in multiple Capital Weather Gang blog posts
   - Coordinated with local media outlets to distribute this information

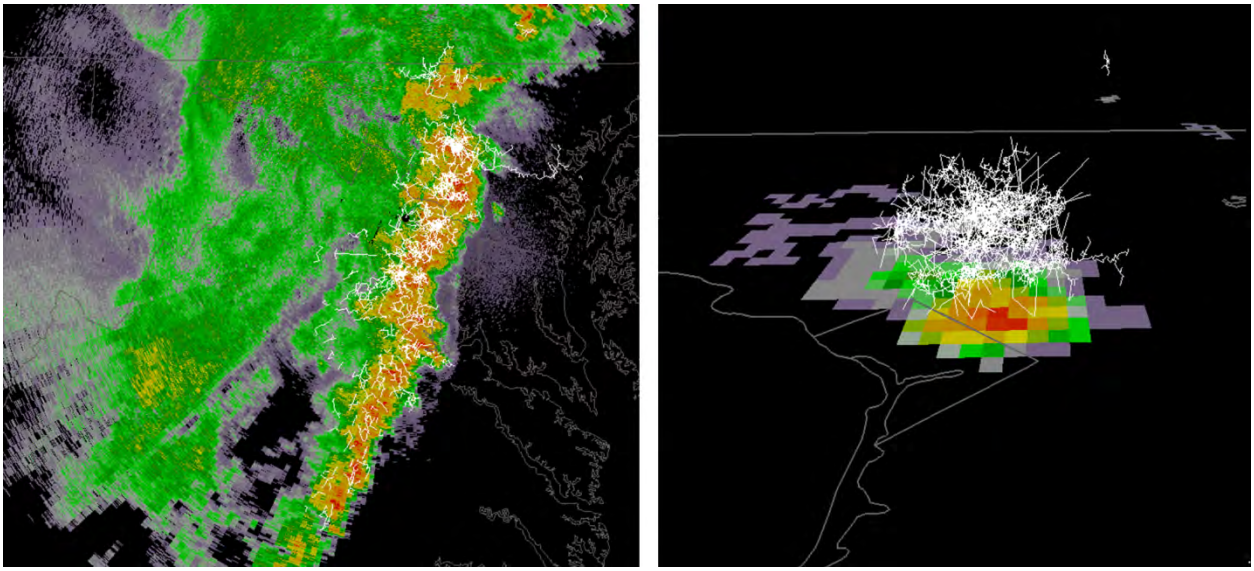

Figure 1: Schematic depicting the hardware and software solutions for the CICS-MD PGTC.

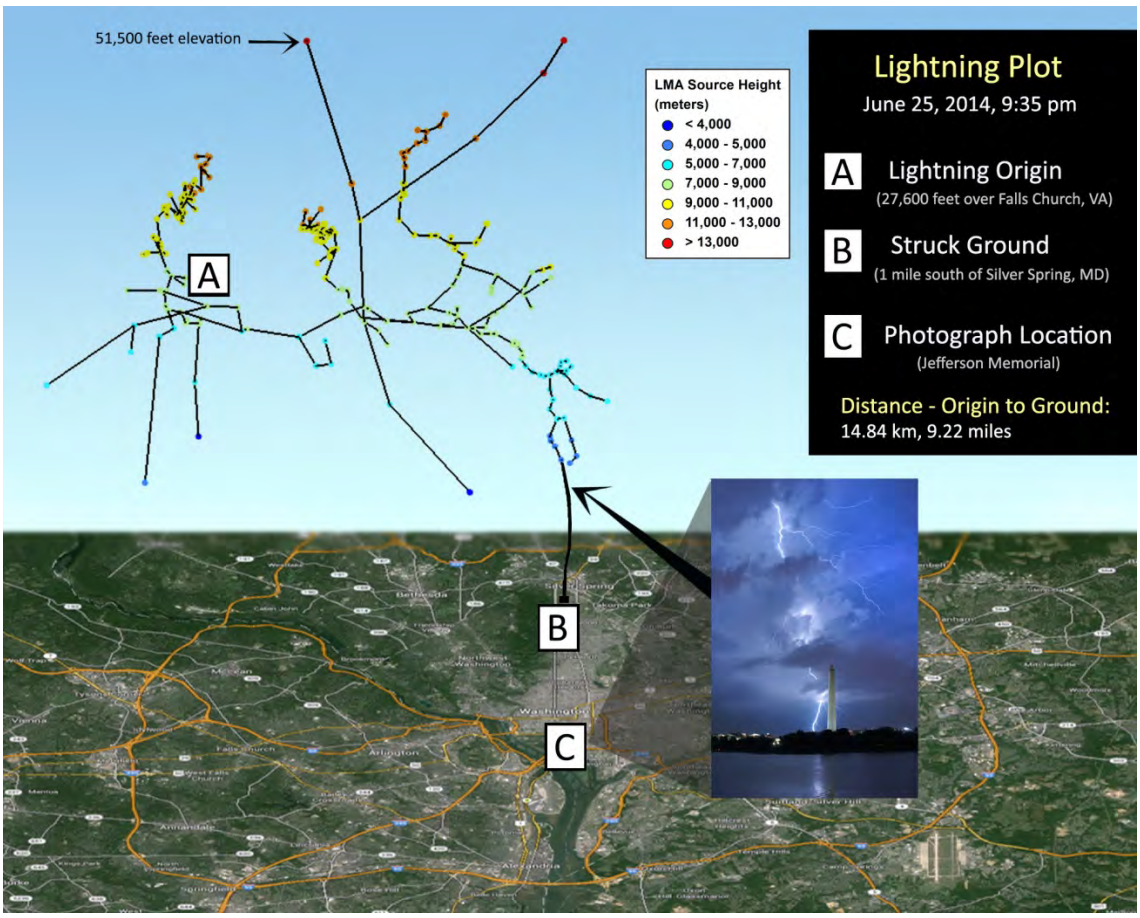

Figure 2: Example from a Capital Weather Gang article that matched a photograph with DCLMA observations. This type of imagery has important science and public outreach applications.

Planned Work

- Continue collaborations with scientists at the University of Alabama Huntsville and NASA Marshall Space Flight Center
- Take advantage of new LMA installment at Wallops Island for collaborations and to gain interesting insights into storms along the Delmarva Peninsula
    - Potential for merging the LMAs to cover a larger region
- Better define lightning and radar datasets and promote their use in NWS operations
    - Expand existing lightning and radar data set to include years since 2009
- Compile DCLMA archive and continue to document significant severe weather, lightning induced structural damage, and any lightning casualty events
- Support hourly undergraduate researchers who visit sensors that fail to bring them back online
- Conduct GOES-R sponsored visiting scientist research to facilitate access to DCLMA data in AWIPS-II at the Sterling, VA Weather Forecast Office

Publications

Rudlosky, S.D. and H.E. Fuelberg, 2013: Documenting storm severity in the mid-Atlantic region using lightning, radar, and sounding information, *Mon. Weather Rev.* **141**, 3186-3202, doi: 10.1175/MWR-D-12-00287.1.

Rudlosky S. D., 2015: Evaluating ENTLN performance relative to TRMM/LIS, *J. Oper. Meteor.*, **3**, 11-20, http://dx.doi.org/10.15191/nwajom.2015.0302 (new publication)

Presentations

Rudlosky, S., 2015: Lightning Observations and Applications. *EUMETSAT Lightning Imager - Geostationary Lightning Mapper (LI/GLM) Meeting*. Rome, Italy, 27-29 May. (Invited)

Rudlosky, S., 2015: Lightning Observations and Applications. *ULPA/LPI Annual Conference*. Nashville, TN, 26-27 March. (Invited)

Kahn, D. and S. Rudlosky, 2015: The Washington D.C. Lightning Mapping Array (DCLMA), *AMS Annual Meeting*, Phoenix, AZ, P337 (1/4 to 1/8/2015)

Other

Matthew Bielec, an ESSIC/CICS-MD High School Research Assistant working with Scott Rudlosky (ESSIC and NOAA) was honored with several science awards: first prize in Earth and Planetary Science at the Greenbelt Eleanor Roosevelt High School Science Fair, second place in the same category at the 67th Annual Prince George's Area Science Fair, NOAA's 2015 “Taking the Pulse of the Planet Award,” the American Meteorological Society Certificate of Outstanding Achievement, and First Place from the Geological Society of Washington.

Performance Metrics	
# of new or improved products developed (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	2

Updating CRTM for Supporting GOESR-R AWG Applications

Task Leader Hu (Tiger) Yang
Task Code HYHY_CRTM_14
Reporting Period April 1, 2014 ~ March 31, 2015
NOAA Sponsor Fuzhong Weng
NOAA Office NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%) Theme 1: 100%
Main CICS Research Topic GOES-R
Contribution to NOAA goals (%) Goal 5: 100%
Highlight: Vertical hydrometeor profiles from the Tropical Rainfall Measuring Mission (TRMM) 2A12 product were collocated with ATMS and being used as inputs in CRTM to simulate the Advanced Technology Microwave Sounder (ATMS) brightness temperature observations at 22 channels over selected West-North Pacific typhoon cases. Study results show that for cloud type with low cloud water content and ice content, the bias between observation and the simulation is similar. To verify the impacts of discrete dipole approximation model for ice particle scattering calculation, the DDA based single particle scattering look up table was adopted and used in CRTM. Simulation results show that, compare with traditional Mie scattering look up table used in CRTM, the DDA based simulation is more closely approach the satellite observation, especially at deep convective region in typhoon case, where the ice content is high.

Background

Cloud water and ice contents are important for cloud radiance simulation of Community Radiative Transfer Model (CRTM). Direct and accurate information of different type of cloud particle is expected to increase the accuracy of radiance simulation over cloud region. In this study, vertical hydrometeor profiles from the Tropical Rainfall Measuring Mission (TRMM) 2A12 product were used as inputs for CRTM to simulate the Advanced Technology Microwave Sounder (ATMS) brightness temperature observations at 22 channels over selected West-North Pacific typhoon cases. Study results show that for cloud type with low cloud water content and ice content, the bias between observation and the simulation is similar. To verify the impacts of discrete dipole approximation model for ice particle scattering calculation, the DDA based single particle scattering look up table developed by Guosheng Liu from FSU was adopted and used in CRTM. Simulation results show that, compare with traditional Mie scattering look up table used in CRTM, the DDA based simulation is more closely approach the satellite observation, especially at deep convective region in typhoon case, where the ice content is high.

Accomplishments

1. Collocation of ATMS and TRMM/GPM

Software for collocation of TRMM/GPM rain profiles with ATMS observations was developed and put into operational run on the daily basis. Collocated GPM 88 layer rain profile at 5km resolution was stored in HDF file together with ATMS brightness temperature. A software being used to display the collocated results was also developed.

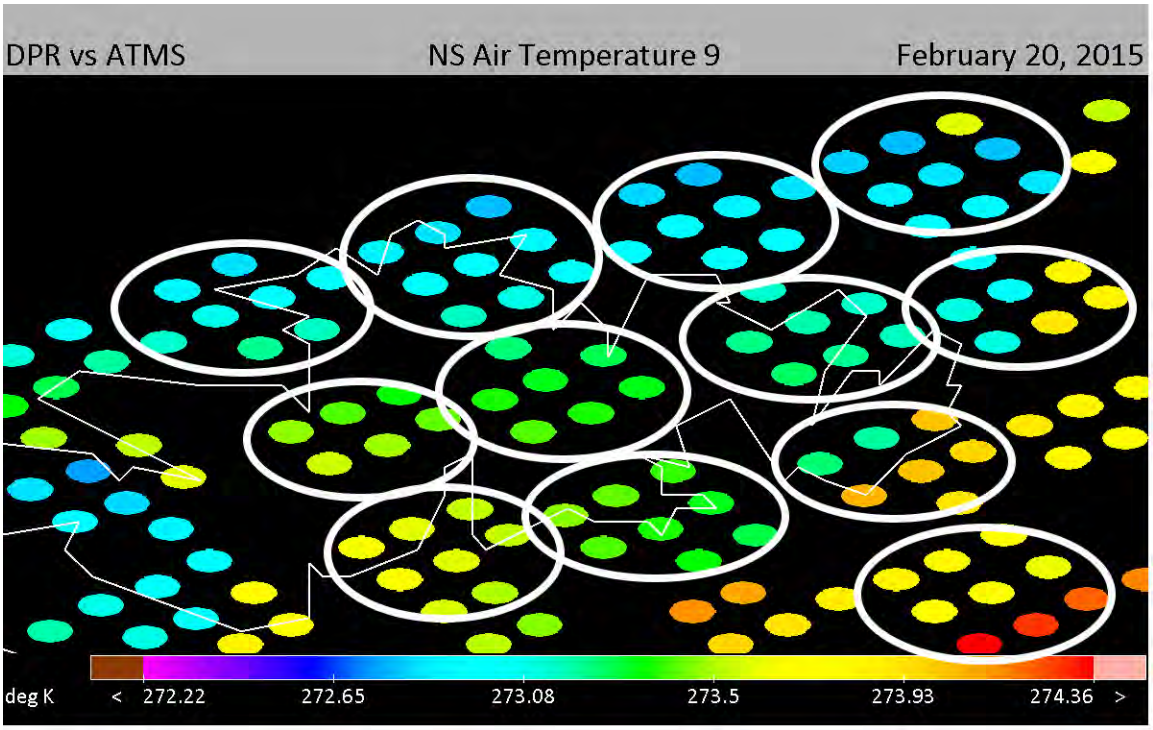

Figure 1: Collocated GPM spots within ATMS FOVs.

2. Cloud Radiance Simulation with New DDA LUT

In microwave, Mie theory and Discrete Diploe Approximation (DDA) have been used to calculate scattering and absorption efficiencies, and phase matrices for a given type of hydrometeor mixing ratio and effective size. An advantage of DDA over Mie is its capability of computing non-spherical particles associated with ice phase hydrometeors formed under various cloud environments through their habit growths. In CRTM, we consider five types of hydrometeors including cloud, ice, rain, graupel and snow. Some of these five types of hydrometeors require DDA in order to accurately compute their optical parameters. We have obtained the DDA database from Florida State University and converted the database into LUT that complies with CRTM interface. Based on new generated DDA LUT, the brightness temperatures simulated from both Mie and DDA were assessed under various atmospheric cloudy.

Planned Work

The planned work includes continued support for improving CRTM capability for cloudy Radiance Assimilation:

1) Characterize the DDA based CRTM cloud radiance simulation error under different cloud type by using GPM profile as inputs
2) Inclusion of the azimuthal variation of surface emission for microwave imager radiance simulation

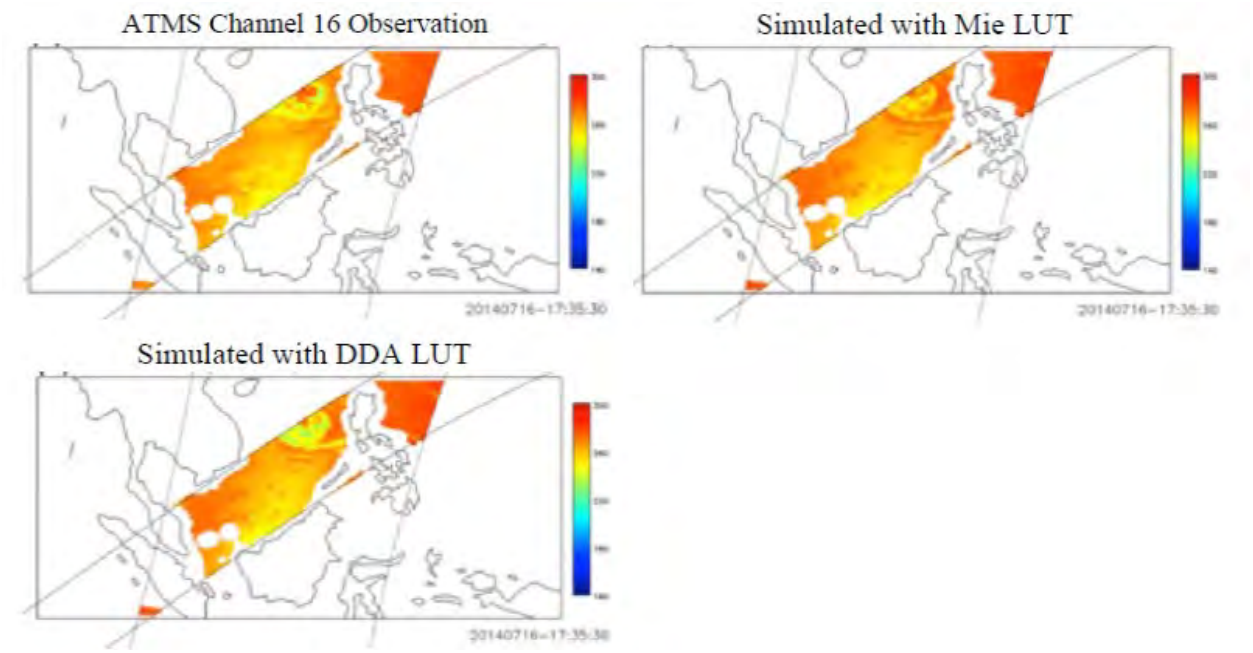

Figure 2: ATMS observation compared with simulations using the Mie Look-Up Table and the DDA Look-Up Table.

Publications

Peer-Reviewed

Yang, Hu, and Xiaolei Zou. "Optimal ATMS Remapping Algorithm for Climate Research." IEEE Transactions on Geoscience and Remote Sensing 52 (2014): 7290-7296

Zou, Xiaolei, Fuzhong Wang, and Hu Yang, 2014: Connecting the Time Series of Microwave Sounding Observations from AMSU to ATMS for Long-Term Monitoring of Climate, *J. Atmos. Oceanic Technol.*, **31**, 2206-2222, doi: 10.1175/JTECH-D-13-00232.1

Non-Peer-Reviewed

Yang, Hu, and Fuzhong Weng, 2014: On-Orbit ATMS Lunar Contamination Corrections, *GSICS Quarterly*, **8**, 7-9, doi: 10.7289/V55H7D64

Products

Collocated 88 layers GPM rain profile products at ATMS FOVs with 5km spatial resolution and 250m vertical resolution.

Presentations

Yang, Hu, and Miao Tian, Nonlinearity Analysis for JPSS-1 ATMS Instrument, *AMS Annual Meeting*, Phoenix, AZ (1/4 to 1/8/2015)

Yang, Hu, Introduction of an Advanced Radiance Transformation System (ARTS) , *CICS-MD Science Meeting*, College Park, MD (11/12 to 11/13/2014)

Other

Outreach to International Scientists: Two meteorology scientist from CWB were invited as visiting scientists to perform part of project study at CICS for 6 months start from June 01, 2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1***
# of products or techniques submitted to NOAA for consideration in operations use	**1***
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**1**
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

*Collocated 88 layers GPM rain profile products at ATMS FOVs with 5km spatial resolution and 250m vertical resolution.

Technical Support of GOES-R Land Surface Temperature Algorithm and Validation

Task Leader: Peng Yu
Task Code: PYPY_GOESR_14
NOAA Sponsor: Yunyue Yu
NOAA Office: NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%): Theme 1: 30%; Theme 2: 70%; 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: A combined regression and validation packages has been finished, a new multi-sensor LST monitoring and evaluation system has been established.

Background

This report summarizes the ongoing NOAA project entitled "Technical support for GOES-R land surface temperature algorithm and validation". The goal of this project is to continue performing the tasks determined at the AWG land team LST schedule and Validation Plan. Following the successful delivery of the 100% readiness Algorithm Package for ABI LST in September 2010, the validation tool delivery in September 2012, the major works for FY13 have been on the algorithm maintenance, improvement and continuity of the validation and validation tool development. The algorithm maintenance includes the required GOES-R Ground Segment Contractor Verification Support.

The GOES-R launch time approaches, the focus of this period of time has been to get the retrieval algorithm and validation tool ready for operational use. The validation tool has been pipelined with the regression package, so that the process from generation of new algorithm coefficients to its evaluation and validation with proxy data becomes much more efficient. It has been used in the study of many different algorithms. In addition to the SNPP VIIRS and MODIS AQUA proxy data which continued to be collected, we closely collaborated with the AIT group for the newly available Himawari-8 AHI data from JMA. As an international collaboration effort, we have discussed with scientists from CMA for sharing their in-situ observations in the AHI coverage area. To facilitate the cross-satellite LST comparison, a new system to generate daily LST composite from both VIIRS and AQUA for both daytime and nighttime has been established.

Accomplishments

The updated regression software package and the LST validation tool have been completed. With the simulated database from MODTRAN, it usually takes two main steps to evaluate and test any new algorithm, the regression to generate the coefficients for the algorithm and the validation process to evaluate the algorithm's performance with data sets from multiple sensors as the proxies for ABI or other sensors, *e.g.*, VIIRS. Both packages are not so pipelined and needs much modification of the current code or addition of new codes. During these processes, mistake can easily be made. In order to make the two more integrated, easy, and quicker, both were modified. The details are summarized as follows: Obsolete sensors such as GOES-8 are deleted. Sensors currently included in the regression package are GOES-R, VIIRS, TERRA, AQUA, SEVIRI, GOES-13, GOES-14, and GOES-15; the regression package was revised so that the definition of water vapor range is more flexible; the process to generate random noises during regression has been revised; the way to define different new retrieval algorithms was modified, which makes inclusion of new algorithm much easier; the format of the output from regression has been changed so that it can be directly used by the validation tool; variables in the validation tool matchup

data output have been changed; the validation tool was modified so that it can automatically recognize the additional algorithm(s) output from the regression software and update the retrieval algorithm list in the GUI interface. The two packages for retrieval and validation can be combined to work together more efficiently (Figure 1).

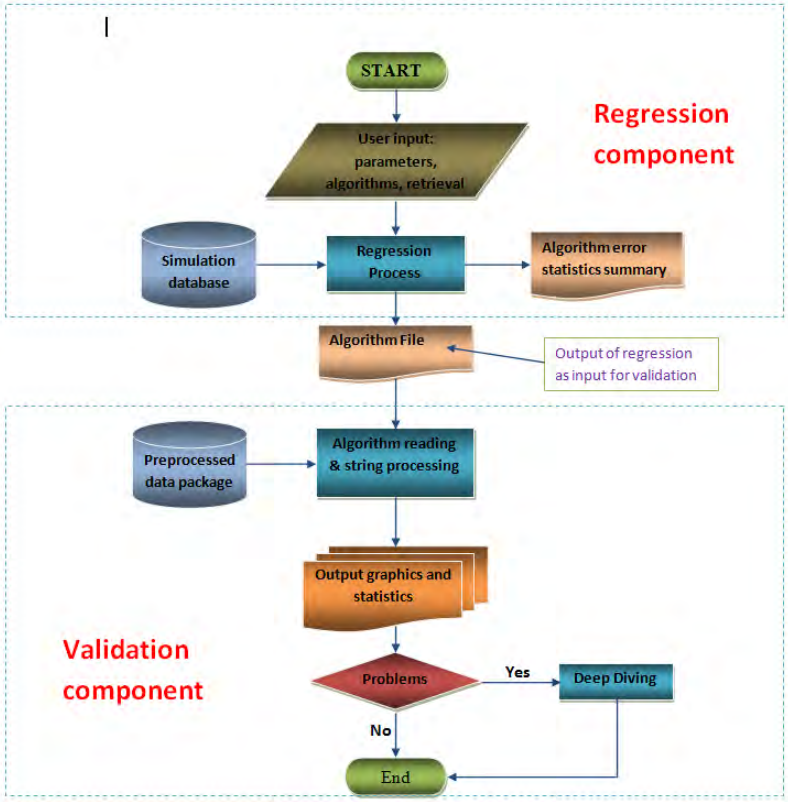

Figure 1. Flow chart of the integrated regression and validation package for LST retrieval algorithm evaluation.

The package has been used to do research on improving the retrieval algorithm, *e.g.*, the effect by different satellite view zenith angle, inclusion of additional term of emissivity difference between two split-window channels, different ways to stratify the retrieval, etc. Performance improvement over the proposed ABI algorithm has been observed and will be finalized.

For LST cross-sensor comparison, a near-operational system has been built for both VIIRS and AQUA sensor data. The system consists of two main components, the satellite-ground matchup and validation component and the global composite data generation component. The former routinely match the satellite to the in-site observation sites and retains the matchup data pairs along with all ancillary data sets for ABI retrieval to evaluate the ABI algorithm. The second component automatically generates daily LST data for both VIIRS and AQUA for both daytime and nighttime. The output data files retain all variables necessary for ABI LST retrieval so that they can be used to evaluate the ABI algorithm and compare the VIIRS retrievals and MODIS retrievals to their ABI counterpart. Results can be found at ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/VIIRS_monitoring/global/. These datasets have been also used to generate monthly LST animations (ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/VIIRS_monitoring/global/animations/) and study of LST diurnal range (Figure 2).

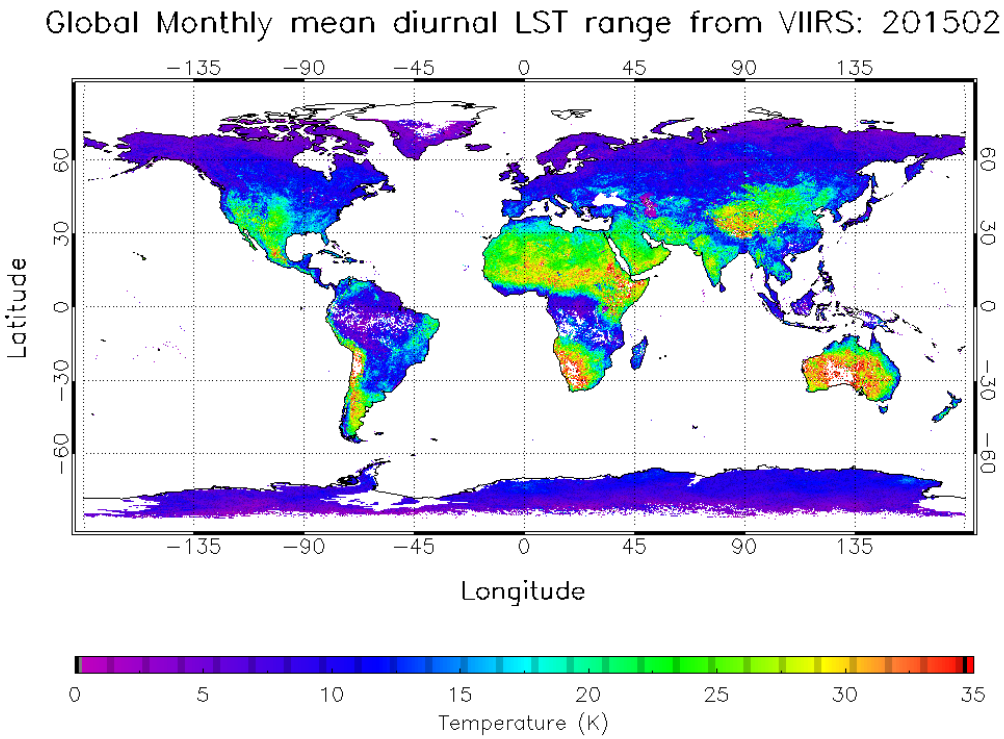

Figure 2. Global monthly mean diurnal LST range from VIIRS for February 2012.

Since Himawari-8 AHI sensor is very similar to the future ABI, it is important to include the AHI data as the ABI proxy. We have been working closely with AIT group for this dataset. The algorithm and the reader package have been ready for testing this newly available data. It has also been included in the proxy list in the routine validation tool.

We have also worked on the error budge for the operational LST retrievals. Theoretical basis of this analysis has been established.

Planned work

- Continue to develop the routine validation tool with effective satellite to ground data match-up system and make it ready for GOES-R LST operational production validation
- 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
- Work closely with industrial contractors (the vender) for validating and maintaining the LST package that has been delivered to the vender
- Continue to work on different validation techniques, including the simultaneous multiple measurements technique recently studied
- Extend the multi-sensor LST monitoring and evaluation tool to other sensors
- Update corresponding documents related to the above tasks

Publications

Separate peer reviewed from non-peer reviewed –only for period covered in report

Products

New version regression package to generate retrieval coefficients for different algorithms;
New version validation tool with enriched features have been delivered and incorporated with the validation tool.
A new operational system to produce global daily LST composites are completed.

Presentations

Peng Yu, Yunyue Yu, Yuling Liu, and Zhuo Wang, Towards Monitoring Satellite Land Surface Temperature Production, 2014 CICS Science Meeting

Yuling Liu, Yunyue Yu, Zhuo Wang, Peng Yu, Suomi NPP VIIRS Land Surface Temperature Product Quality Assessment toward Validated Maturity, 2014 CICS Science Meeting

Zhuo Wang, Yunyue Yu, Peng Yu, Yuling Liu, Mike Ek, and Yihua Wu, Using VIIRS Land Surface Temperature to evaluate NCEP North American Mesoscale Model (NAM) forecast, 2014 CICS Science Meeting

Peng Yu, Yunyue Yu, Yuling Liu, Zhuo Wang, and Xiangyang Zhang, Towards Monitoring Satellite Land Surface Temperature Production, AGU Fall 2014

JPSS LST EDR Team, Long Term Monitoring, JPSS LTM Workshop

Yunyue Yu, Yuling Liu, Peng Yu, Zhuo Wang, and Ivan Csiszar, Issues in Developing and Validating Satellite Land Surface Temperature Product, 2015 AMS Meeting

Yuling Liu, Yunyue Yu, Zhuo Wang, Peng Yu, Concerns on cross comparison of satellite land surface temperature retrievals, a case between VIIRS and MODIS LST product, 2015 AMS Meeting

Other

I started to advise a graduate student, Mr. Yuhann Rao, from the department of geography since Dec. 2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**3**
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	

Validating GOES-R Land Surface Temperature Product Using Ground Campaign and Station Data

Task Leader: Peng Yu
Task Code: PYPY_VGLS_14
NOAA Sponsor: Yunyue Yu
NOAA Office: NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%): Theme 1: 30%; Theme 2: 70%; 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: Retrieval algorithm for AHI has been generated and the validation tool has been updated to include the AHI data.

Background

This report summarizes the ongoing NOAA project entitled "Validating GOES-R Land Surface Temperature Product Using Ground Campaign and Station Data". The goal of this work is to perform the tasks determined at land team LST schedule and Validation Plan. The major works for FY14 is on the pre-launch validation for the GOES-R LST product, including the ground station LST data collection and calibration via national and international collaboration and ground campaign and the improvement on current validation method. The validation method improvement includes the investigation of up-scaling model and two-measurement analysis. The ground/field campaign data will be compared to Himawari AHI data in the GOES-R LST validation tool environment.

The focus of this period of time has been on the test of ABI algorithm using Himawari-8 AHI data as proxy. Since the sensor characteristics of this sensor is very similar to the one from the future GOES-R ABI, it is expected to be extensively used as the best test bed for ABI LST retrieval algorithm.

Accomplishments

The group has been closely collaborating with AIT group to work with the AHI data. Its naming convention and data format have been understood. As a result the AHI data reader was completed and it has been included as one of the proxy options for the LST routine validation system. Figure 1 shows the AHI full disk BT15 (~12 micro meter).

We have collaborated with scientists from CMA to collect in-situ observations in areas covered by Himawari-8 AHI. The mechanism to bring these datasets from CMA to STAR has been discussed. As a result, in-site from Huailai China for the period of June 2013-November 2014 has been obtained. The data have been converted to a uniform format which the validation tool can read. These data were studied and tested to get ready for the ABI algorithm evaluation with AHI proxy data. Due to its station design (six sites within very small area), we consider to use it for the study of up-scaling model. In situ data will be routinely collected and processed.

Since emissivity data are not available for near-real-time LST retrieval, we used the global emissivity data set from CIMSS. The emissivity has been analyzed and converted for AHI LST retrieval.

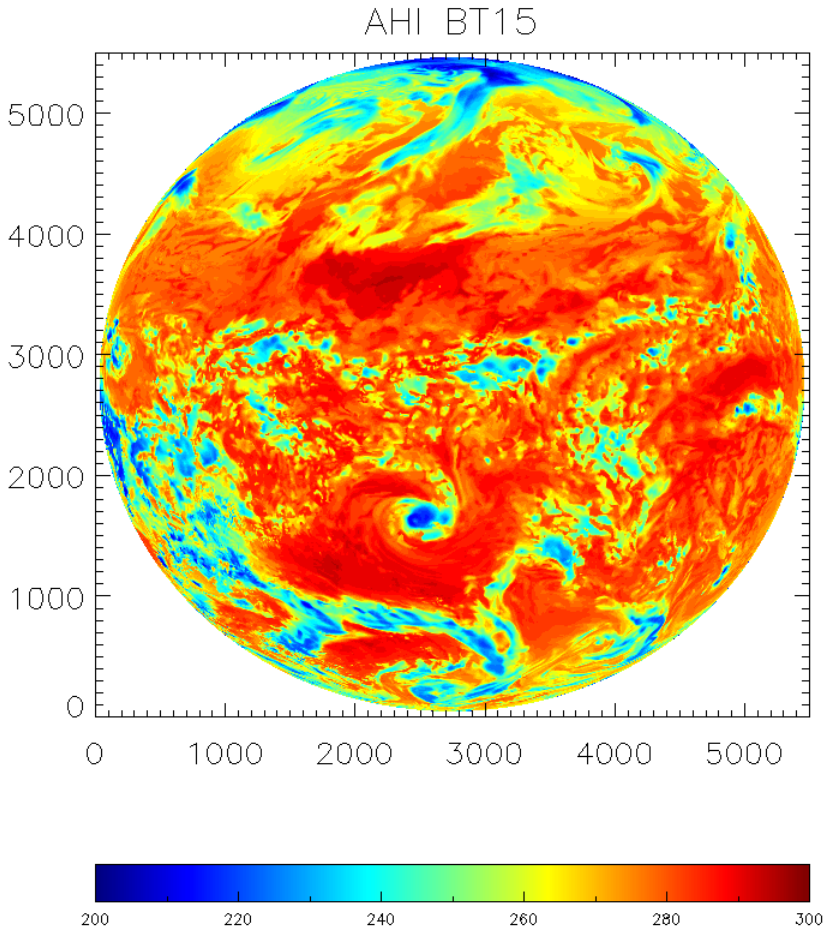

Figure 1 AHI BT15 (~12 micron meter) full disk image from its sample data.

Total precipitable water product from NOAA NCEP weather forecast model has been processed to be used as ancillary data for AHI LST retrieval.

The retrieval coefficients for ABI algorithm applicable to AHI proxy data have been generated. Scripts of processing AHI standard data have been completed and added to the routine validation tool. These scripts include calculating geo-location and solar zenith angles for each AHI pixel based on data projection information, getting emissivity data and TPW data from ancillary datasets for each AHI pixel, calculating brightness temperature from AHI standard data and calculating land surface temperature based on ABI LST algorithm. These scripts have been tested using AHI standard data in NESDIS/STAR, and can be successfully run automatically. Figure 2 presents the sample LST image generated from AHI standard data in Dec 27th, 2014.

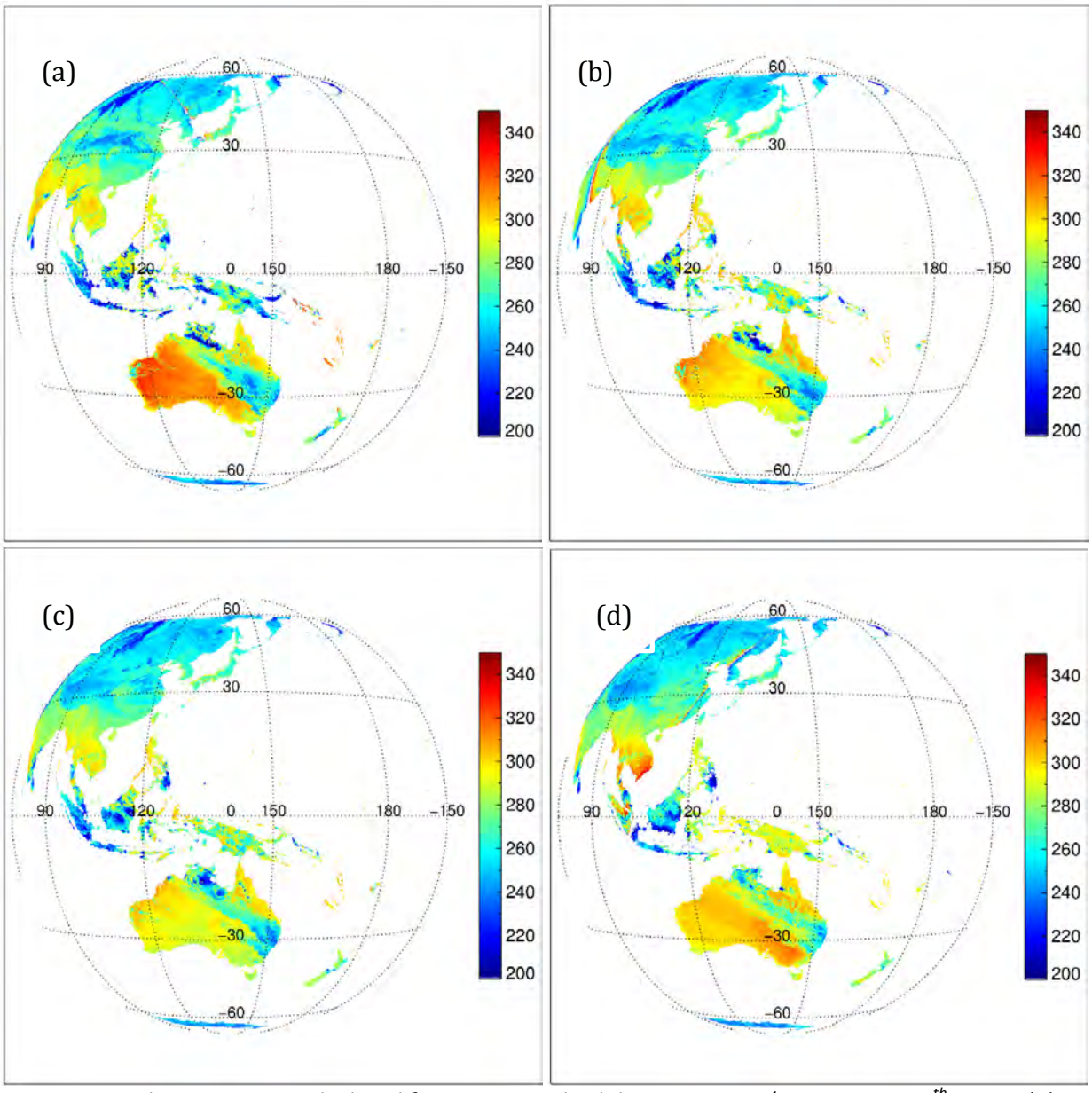

Figure 2. Sample LST images calculated from AHI standard data in NESDIS/STAR at Dec 27th, 2014. (a) 08:00, (b) 12:00, (c) 16:00, (d) 23:00 (all times are UTC time).

Planned work

- Collect and process ground station data managed by Chinese Meteorological Administration (CMA); collect and process the corresponding JMA/AHI data
- Participate field campaign, collaborating with the CMA scientists, to measure the in-situ data which will be used for calibrating the CMA ground station data
- Apply up-scaling model that converts ground *in situ* LST data to the equivalent satellite pixel LST data
- Apply the two-noise measurements analysis method on the satellite and ground LST statistical comparisons; explore a method for estimating noise of the ground LST measurement

- Evaluate the ABI LST algorithm through comparisons of the AHI LST (conducted from the ABL LST algorithm) and the calibrated CMA ground station data

Publications

Separate peer reviewed from non-peer reviewed –only for period covered in report

Products

An LST routine validation tool which incorporated the AHI data.
Retrieval algorithm for AHI data.

Other

I started to advise a graduate student, Mr. Yuhann Rao, from the department of geography since Dec. 2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	

The LST validation tool incorporating AHI data and the retrieval algorithm for AHI data have been completed. A graduate student, Mr. Yuhan Rao, has been supported by this project and is being advised to carry out the validation.

Development of Algorithms for Shortwave Radiation Budget from GOES-R

Task Leader Rachel Pinker
Task Code RPRP_DASR_14
NOAA Sponsor **Jaime Daniels**
NOAA Office **NOAA/STAR**
Contribution to CICS Research Themes (%) Theme 2: 100%
Main CICS Research Topic Future Satellite Programs: Scientific Support for GOES-R Mission
Contribution to NOAA goals (%) Goal 1: 100%
Highlight: We have developed new narrow-to-broadband transformation coefficients based on the newly-available spectral response functions for ABI.

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

We updated the previously-delivered NTB transformation coefficients by regenerating them using the newly available spectral response functions (SRFs) for ABI. We calculated the new NTB coefficients for clear-sky conditions with 12 surface types and for 3 types of clouds over 4 surface types with up to 11 cloud optical depths (CODs), as outlined in the "Products" section below.

We are verifying the quality of the new NTB coefficients by using them to compute TOA shortwave radiative fluxes with simulated ABI data available at ftp://ftp.ssec.wisc.edu/ABI/REALTIME_PROXY. We have built the framework for utilizing the new data source and applying the coefficients. We are currently working out issues of separating clear and cloudy-sky conditions in the data. An example of simulated ABI radiances from 1800 UTC on 12/24/14 is shown in Figure 1.

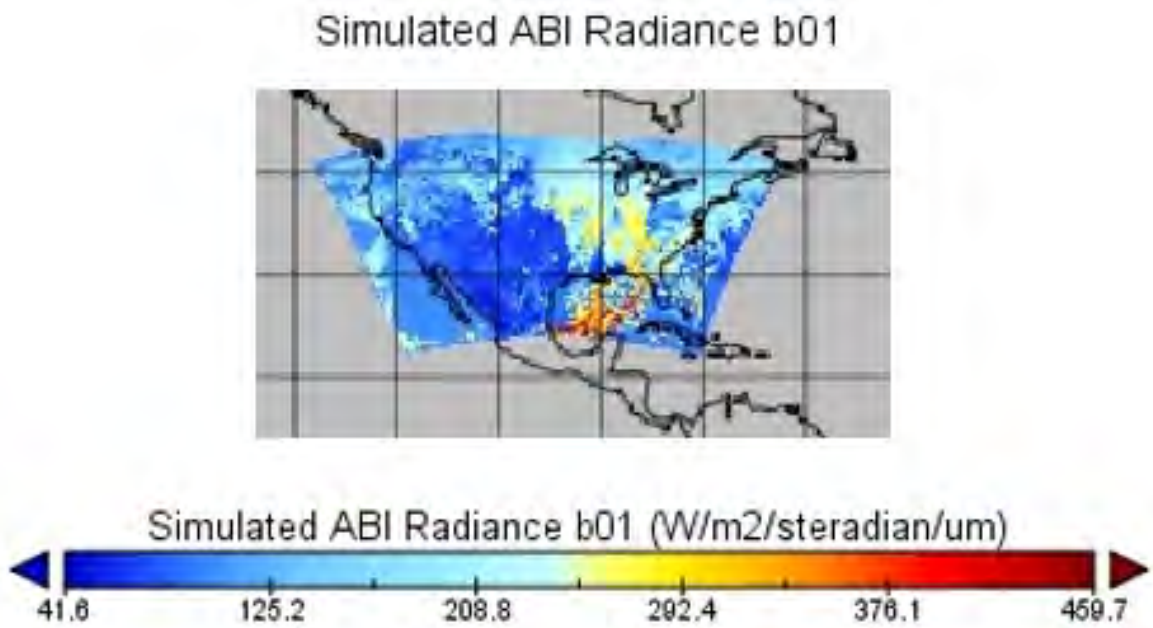

Figure 1. Simulated ABI radiances from 1800 UTC on 12/24/14.

Planned Work

- Select an appropriate cloud screening technique and apply it to calculate TOA shortwave fluxes with the newly developed NTB transformation coefficients
- Determine the quality of the TOA shortwave fluxes through comparison with estimates derived from CERES
- Determine the optimal channel combinations to use in calculating shortwave radiative fluxes from ABI; there are 6 visible and near-IR ABI channels that can be used, but previous experience with MODIS observations showed that better results were obtained when using only 3 of the 6 available channels.

Products

Narrow-to-broadband transformation coefficients derived with ABI spectral response functions for the following conditions:

- Water clouds for 4 surface types (water, land, desert, and snow/ice) at 11 cloud optical depths (CODs)
- Altostratus clouds for 4 surface types (water, land, desert, and snow/ice) at 5 CODs
- Cirrus clouds for 4 surface types (water, land, desert, and snow/ice) at 5 CODs
- Clear-sky for 12 surface types (water, needleleaf forest, wooded grassland, closed shrub land, open shrub land, broadleaf forest, mixed forest, woodland, grasslands, cropland, desert, and snow/ice)

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**1**

We produced a new set of NTB transformation coefficients for multiple sky conditions, surface types, and cloud optical depths using the spectral response functions provided for ABI.

1.4b Scientific Support for the JPSS Mission

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

Task Leader Louis Giglio, Wilfrid Schroeder, Christopher Justice
Task Code CJWS_VIIRS_14
NOAA Sponsor Lihang Zhou
NOAA Office NOAA JPSS, Center for Satellite Applications and Research (STAR)
Contribution to CICS Research Themes (%) Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic Scientific Support for the JPSS Mission
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%; Goal 3: 0%
Highlight: This task supports the operational implementation of the Suomi-NPP/VIIRS Active Fire algorithm at NOAA. The input SDR data are routinely monitored, and reactive fire algorithm maintenance implemented in order to ensure highest product quality. Science algorithm updates are also ported into the operational system. Additional programmatic tasks (e.g., product maturity assessment/review) and algorithm/user guide documentation are regularly addressed.

Background

The Active Fire (AF) product 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]. The MODIS algorithm has since evolved, incorporating additional tests to minimize potential false alarms, implementing a dynamic background characterization, and expanded processing of offshore pixels to allow detection of gas flares. Those changes are included in the MODIS Collection 6 algorithm, which is being ported to the revised Joint Polar Satellite System (JPSS) AF algorithm. This new AF algorithm also incorporates new output layers in response to the user community demand, namely a 2-D image classification product (fire mask) and sub-pixel fire characterization retrievals (fire radiative power [FRP]).

Accomplishments

During this funding cycle our team performed routine diagnostics of updated SDR processing packages (Mx builds) implemented at IDPS. Some of the SDR processing updates targeted the VIIRS dual-gain channel calibration, in particular channel M13 driving the fire algorithm. Reactive algorithm maintenance was performed in order to address changes observed in the quality flag (QF1) information associated with the SDR input data feeding the fire algorithm (Figure 1). Additional SDR anomalies were attributed to lunar intrusion affecting the on-board calibration of VIIRS dual-band infrared channels. Those episodes result in anomalous M13 brightness temperatures that propagate into the fire algorithm leading to bands of spurious fire detections (Figure 2). Our team has communicated those anomalies to the VIIRS calibration team and since engaged in several telecons and panel discussions aiming to address the problem. Lastly, our team worked with the Algorithm Implementation Team (AIT) at NESDIS/STAR on the implementation of the revised VIIRS AF algorithm into the Suomi NPP Data Exploitation (NDE) data processing environment. The revised algorithm was delivered to NESDIS, following extensive review of the new product characteristics and processing requirements.

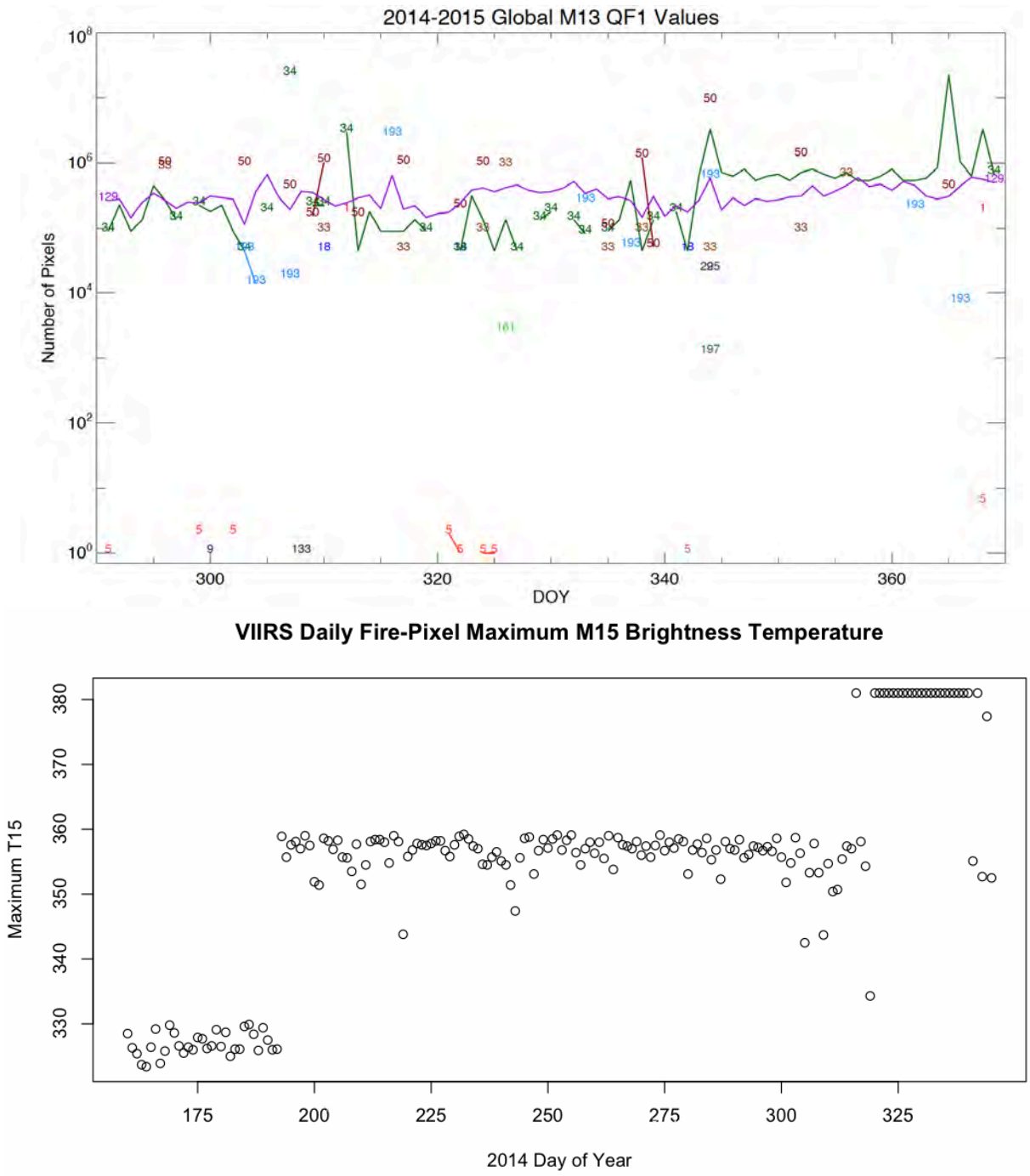

Figure 1: Daily summary statistics for the VIIRS primary fire algorithm input M13 channel quality flag (QF1)(top), and daily fire-pixel maximum observed brightness temperature on channel M15. Discontinuities on both data series were related to new SDR data processing package implementations.

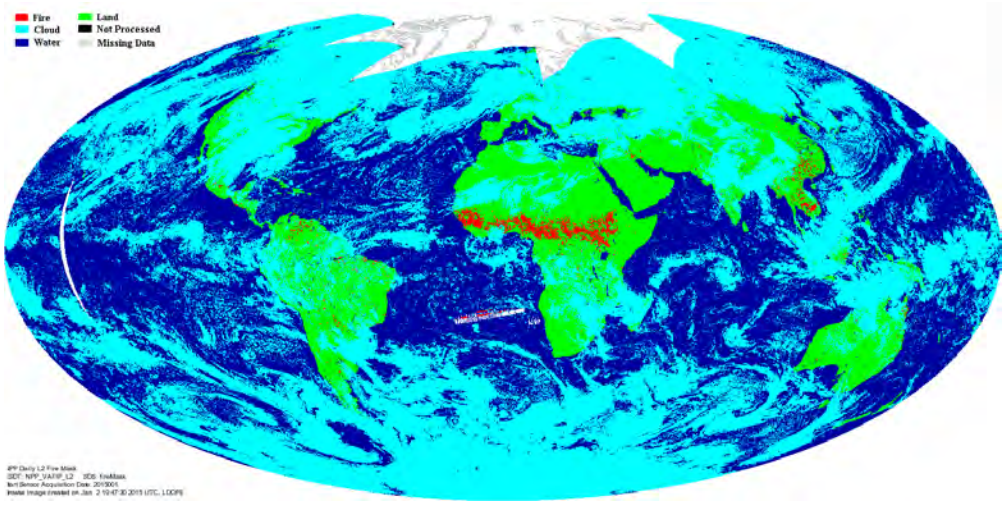

Figure 2: S-NPP/VIIRS active fire algorithm output showing band of spurious detections off the south-western coast of Africa. That anomaly was associated with lunar intrusion impacting the quality of channel M13.

Planned work

- Support the transition of VIIRS AF algorithm updates into NDE operations
- Work with AIT team members in the assessment and verification of VIIRS AF outputs from NDE
- Investigate and report data anomalies & discrepancies to appropriate AIT and VIIRS SDR teams
- Assist in the preparation of algorithm theoretical basis document and user's guide

Products

A revised VIIRS AF algorithm was delivered to AIT for subsequent implementation at NDE.

Presentations

Csiszar, I., E. Ellicott, L. Giglio, W. Schroeder, M. Ruminski, Recent advances in the development and applications of VIIRS active fire products, 2015 NOAA Satellite Science Week, Boulder, CO, 23-27 February 2015.
http://www.star.nesdis.noaa.gov/jpss/documents/meetings/2015/NSSW/Csiszar_fire_022015.pdf

Csiszar, I., S. Kondragunta, E. Ellicott, L. Giglio, W. Schroeder, C. O. Justice, M. Ruminski, Active fire data from Suomi NPP to serve end user applications, 2015 Annual Meeting of the American Meteorological Society, Phoenix, AZ, 4-8 January 2015.
http://www.star.nesdis.noaa.gov/jpss/documents/meetings/2015/AMS/Csiszar_fire_010615.pdf

Csiszar, I., X. Zhan, M. Vargas, Y. Yu, F. Kogan, M. Ek, M. Román, Suomi NPP Terrestrial Data Products and Their Use in NOAA Operations, 2015 Annual Meeting of the American Meteorological Society, Phoenix, AZ, 4-8 January 2015.
http://www.star.nesdis.noaa.gov/jpss/documents/meetings/2015/AMS/Csiszar_land_011415.pdf

Csiszar, I., JPSS Land Product Overview, Status and Near-term Plans. 1st Suomi NPP Land Workshop, NASA Goddard Space Flight Center, Greenbelt, MD, 3-4 December 2014.

Csiszar, I., Long Term Monitoring: JPSS Active Fire. NOAA JPSS Long Term Monitoring Workshop, NOAA Center for Weather and Climate Prediction (NCWCP), College Park, Maryland, October 28, 2014.

Csiszar, I., Land Products from the Suomi NPP VIIRS Instrument, International Land Cover Land Use Change Regional Science Meeting, Sopron, Hungary, October 16-18, 2014. http://lcluc.umd.edu/Documents/ScienceTeamMtg/2014_OCT/25_Csiszar_land_102714.pdf

Csiszar, I., L. Giglio, W. Schroeder, E. Ellicott, K. Vadrevu and C. O. Justice, Recent results from the development and evaluation of active fire products from Suomi NPP VIIRS, 2014 EUMETSAT Meteorological Satellite Conference, Geneva, Switzerland, 22-26 September 2014.

Csiszar, I., Validated Stage 1 Science Maturity Review for Active Fire, Suomi NPP EDR Validated 1 Maturity Readiness Review, NOAA Center for Weather and Climate Prediction (NCWCP), College Park, Maryland, September 3-4, 2014. http://www.star.nesdis.noaa.gov/jpss/documents/meetings/2014/EDRVal1/07-ActiveFries.pdf

Csiszar, I., Declaring S-NPP Active Fires Operational, Satellite Products and Services (SPSRB) Decision Brief, NOAA Center for Weather and Climate Prediction (NCWCP), College Park, Maryland, August 20, 2014.

Giglio, L., Schroeder, W., Ellicott, E., Walsh, W., and Justice, C. (2014). VIIRS M-Band Active Fire Products. Global Observation of Forest and Land Cover Dynamics Fire Mapping and Monitoring Implementation Team Meeting NOAA Center for Weather and Climate Prediction (NCWCP), College Park, Maryland, USA July 29-31, 2014 http://gofc-fire.umd.edu/meeting/static/GOFC_Fire_IT_2014/index.php

Goldberg, M. and I. Csiszar, The Suomi NPP Mission and the VIIRS Fire Detection Capability, Global Observation of Forest and Land Cover Dynamics Fire Mapping and Monitoring Implementation Team Meeting NOAA Center for Weather and Climate Prediction (NCWCP), College Park, Maryland, USA July 29-31, 2014 http://gofc-fire.umd.edu/meeting/static/GOFC_Fire_IT_2014/index.php

Csiszar, I., L. Zhou, R. Godin, T. Atkins, M. Divakarla, X. Liu, Suomi NPP EDR Performance. International Geoscience and Remote Sensing Symposium (IGARSS 2014), Quebec City, Canada, July 13-18, 2014.

Csiszar, I., Suomi NPP Land Product Status Overview, STAR JPSS Annual Science Team Meeting, NOAA Center for Weather and Climate Prediction (NCWCP), College Park, Maryland, USA May 12-16, 2014. http://www.star.nesdis.noaa.gov/star/documents/meetings/2014JPSSAnnual/dayTwo/07_Session3_Csiszar_Plenary_land_051314.pdf

Giglio, L., W. Schroeder, E. Ellicott, W. Walsh and I. Csiszar, Active fires: SDR quality, replacement code and I-band product. STAR JPSS Annual Science Team Meeting, NOAA Center for Weather and Climate Prediction (NCWCP), College Park, Maryland, USA May 12-16, 2014. http://www.star.nesdis.noaa.gov/star/documents/meetings/2014JPSSAnnual/dayThree/10_Session5a_Giglio_Fire.pdf

Csiszar, I., E. Ellicott, C. Schmidt, JPSS and GOES-R activities supporting 2013 fire outbreaks. JPSS Science Seminar, NOAA JPSS Office, Lanham, MD, 21 April 2014. http://www.jpss.noaa.gov/science_seminars/Presentations/SSP17-Fire_Outbreaks.pdf

References

Giglio, L., Descloitres, J., Justice, C. O., and Kaufman, Y.J. (2003). An enhanced contextual fire detection algorithm for MODIS. *Remote Sensing of Environment*, 87, 273-282.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**6**
# 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**

Revised VIIRS active fire algorithm being implemented at NDE

Validation of Cryospheric EDRs GCOM AMSR2

Task Leader Kongoli
Task Code CKCK_AMSR_14
NOAA Sponsor JPSS
NOAA OFFICE NESDIS/STAR
Main CICS Research Topic b. Scientific Support for the Future Satellite Missions: (i) Scientific support for the JPSS Mission
Percent contribution to CICS Themes Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Percent contribution to NOAA Goals Goal 1: 20%; Goal 2: 80%
Highlight: The Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument launched on May 18, 2012 onboard the Global Change Observation Mission 1st - Water "SHIZUKU" (GCOM-W1) satellite. A suite of AMSR2 operational algorithms have been developed for the retrieval of snow cover, snow depth and Snow Water Equivalent using heritage AMSR-E data as proxy and transitioned to operations.

Background

A suite of operational snow algorithms have been developed for the new AMSR2 instrument and are being tested for operational implementation at NOAA as Option 2 products. The suite of snow products includes snow cover, snow depth and Snow Water Equivalent (SWE). The snow cover algorithm is a decision tree classification scheme originally developed for the SSM/I instrument. The algorithm is enhanced with a climatology test which applies snow cover climatology derived from the Interactive MultiSensor Snow and Ice Mapping Unit (IMS). The snow depth algorithm is based on the NASA AMSR-E empirical dynamical approach whereby algorithm regression coefficients are dynamically adjusted (computed from brightness temperatures). SWE is derived from the retrieved SD and climatologically determined snow density.

	STD (cm)	Bias (cm)	Number of samples
All data	17.97	0.39	130,036
ff=0	17.20	-3.69	69,139
0.0<ff<=0.5	18.26	6.14	35,232
ff>0.5	16.78	3.46	25,665

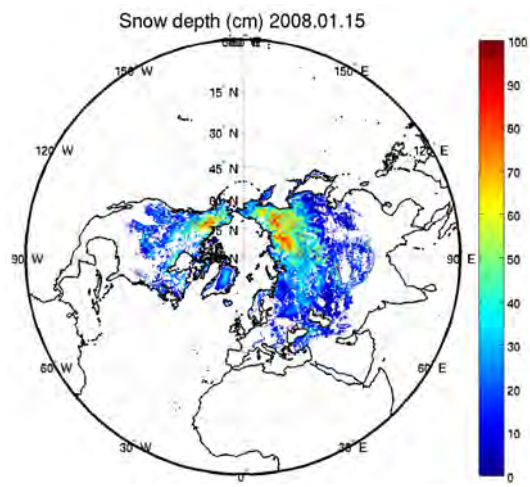

Figure 1. Snow Depth algorithm statistics with respect to in-situ stations (left) and a map of retrieved Snow Depth (right)

Accomplishments

The three snow algorithms – snow cover extent, sow depth and sow water equivalent – have been developed and code transitioned to operations. Figure 1 presents statistical measures of accuracy for the snow depth product with respect to in-situ data.

Planned Work

Improve snow depth retrievals by adjusting coefficients and removing regional biases with respect to climatology
Improve snow water equivalent product

Publications

Lee, Y. C. Kongoli and J. Key, 2014, Evaluation of NOAA's AMSR2 Snow Algorithms, submitted to Remote Sensing of Environment

Presentations

Lee, J-K, C.Kongoli, and J.Key "Snow cover detection and snow depth algorithms for the Global Change Observation Mission (GCOM) AMSR2 instrument using AMSR-E/AMSR2 measurements", submitted to the 2014 AGU Fall Meeting, San Francisco, CA

Performance Metrics	
# of new or improved products developed (please identify below the table)	**3**
# of products or techniques submitted to NOAA for consideration in operations use	**3**
# of peer reviewed papers	**1**
# 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	**N/A**
# of undergraduate students mentored during the year	**0**

This year, three AMSR2 snow products have been improved (3) and transitioned to operations (3). One peer reviewed paper is under review (1) and one presentation has been made (1)

Improvement of Cloud Ice Microphysics for ATMS Snowfall Rate Retrievals

Task Leader Cezar Kongoli
Task Code CKCK_EOY_14
NOAA SPONSOR JPSS PGRR
NOAA Office **NESDIS/STAR**
Main CICS Research Topic b. Scientific Support for the Future Satellite Missions (i) Scientific support for the JPSS Mission
Percent contribution to CICS Themes Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Percent contribution to NOAA Goals Goal 1: 20%; Goal 2: 80%
Highlight: This project has just started and will enhance the ATMS SFR product by incorporation of advanced microphysics in radiative transfer model calculations

Background

The ATMS Snowfall Rate algorithm computes ice cloud properties of falling snow using an inversion method involving the simulation of brightness temperatures with a radiative transfer model, followed by calculation of SFR from the retrieved ice cloud properties. The SFR and snowfall detection (SD) algorithms have been extended to colder climate with encouraging results. Testing shows that the algorithms have skill in capturing snowfall in variable weather conditions including colder weather.
To estimate snowfall rate, the SFR algorithm retrieves cloud properties - ice water path and ice particle effective diameter - based on the radiative scattering effect of ice particles which for computational efficiency are assumed spherical in shape. However, snowfall ice particles are typically non-spherical and their microphysics including habit shape can have a considerable impact on the accuracy of the retrieved cloud parameters and snowfall rate. This project will incorporate non-spherical ice particle shapes in radiative transfer and SFR calculations.

Accomplishments

This project is in its initial stages.

Planned Work

- Determine the appropriate particle shapes to use depending on atmospheric conditions (temperature and water vapor profiles) and cloud type (stratiform or convective);
- Adopt an existing scattering property database for non-spherical ice particles;
- Modify the SFR algorithm for non-spherical ice particle shapes; and
- Carry out case studies to derive SFR with the original and the modified algorithms.

Science and Managerial Support to Global Space-Based Inter-Calibration System (GSICS)

Task Leader Hu (Tiger) Yang
Task Code HYHY_GSICS_14
Reporting Period April 1, 2014 ~ March 31, 2015
NOAA Sponsor Fuzhong Weng
NOAA Office NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%) Theme 1: 100%
Main CICS Research Topic Future Satellite Programs: Scientific Support for the JPSS Mission
Contribution to NOAA goals (%) Goal 5: 100%
Highlight : The Backus-Gilbert method is used for optimally remapping the ATMS FOVs to AMSU-A like FOVs. Differences in ATMS brightness temperatures introduced by remapping are firstly illustrated over the region of Hurricane Sandy which occurred in October 2012. Using the simultaneous nadir overpass (SNO) method, AMSU and ATMS remap observations are then collocated in space and time and the inter-sensor biases are derived for each pair of channels. It is shown that the brightness temperatures from SNPP ATMS are now well merged into the AMSU data family after remap and cross-calibration.

Background

The cross-calibrated measurements from Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit-A (AMSU-A) on board different NOAA polar-orbiting satellites have been extensively used for detecting atmospheric temperature trend during the last several decades. AMSU-A observations from NOAA satellites will soon be replaced by the Advanced Technology Microwave Sounder (ATMS) with the launch of Suomi National Polar-orbiting Partnership (SNPP) satellite. ATMS inherited most of the sounding channels from its predecessor AMSU. It is important to extend AMSU data records with ATMS observations. However, the ATMS field of view is different from that of AMSU. In this study, the Backus-Gilbert method is used for optimally remapping the ATMS FOVs to AMSU-A like FOVs. Differences in ATMS brightness temperatures introduced by remapping are firstly illustrated over the region of Hurricane Sandy which occurred in October 2012. Using the simultaneous nadir overpass (SNO) method, AMSU and ATMS remap observations are then collocated in space and time and the inter-sensor biases are derived for each pair of channels. It is shown that the brightness temperatures from SNPP ATMS are now well merged into the AMSU data family after remap and cross-calibration.

Accomplishments

1. **OPTIMAL ATMS REMAPPING ALGORITHM**

The cross-calibrated measurements from Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit-A (AMSU-A) on board different NOAA polar-orbiting satellites have been extensively used for detecting atmospheric temperature trends during the last several decades. AMSU-A observations from NOAA satellites will soon be replaced by the Advanced Technology Microwave Sounder (ATMS) with the launch of Suomi National Polar-orbiting Partnership (SNPP) satellite. ATMS inherited most of the sounding channels from its predecessor AMSU. It is important to extend AMSU data records with ATMS observations. However, the ATMS field of view (FOV) is different from that of AMSU. In this study, the Backus-Gilbert method was used to optimally remap the ATMS FOVs to AMSU-A like FOVs. Using the simultaneous nadir overpass method, AMSU and ATMS remap observations are then collocated in space and time and the inter-sensor biases are derived for each pair of channels. The brightness tem-

peratures from SNPP ATMS are now well merged into the AMSU data family after remap and cross-calibration.

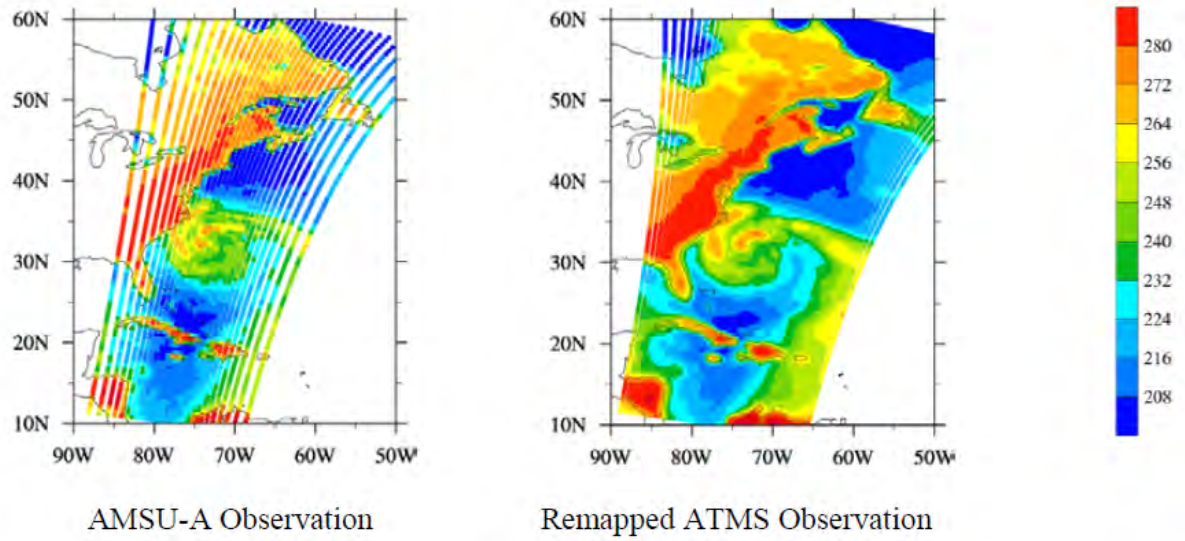

Figure 1: Comparison of AMSU-A observation and remapped ATMS observation for typhoon "Sandy". The observation is in brightness temperature, color from blue to red indicate scene temperature is from cold to warm. The spatial resolution of ATMS is enhanced from 75 Km to 47Km in nadir after remapping process.

2. Cross Calibration between ATMS Resample and AMSU-A Data

The cross-calibrated measurements from Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit-A (AMSU-A) on board different NOAA polar-orbiting satellites have been extensively used for detecting atmospheric temperature trend during the last several decades. AMSU-A observations from NOAA satellites will soon be replaced by the Advanced Technology Microwave Sounder (ATMS) with the launch of Suomi National Polar-orbiting Partnership (SNPP) satellite. ATMS inherited most of the sounding channels from its predecessor AMSU. It is important to extend AMSU data records with ATMS observations. However, the ATMS field of view is different from that of AMSU. In this study, the Backus-Gilbert method is used for optimally remapping the ATMS FOVs to AMSU-A like FOVs. Using the simultaneous nadir overpass (SNO) method, AMSU and ATMS remap observations are then collocated in space and time and the inter-sensor biases are derived for each pair of channels. It is shown that the brightness temperatures from SNPP ATMS are now well merged into the AMSU data family after remap and cross-calibration.

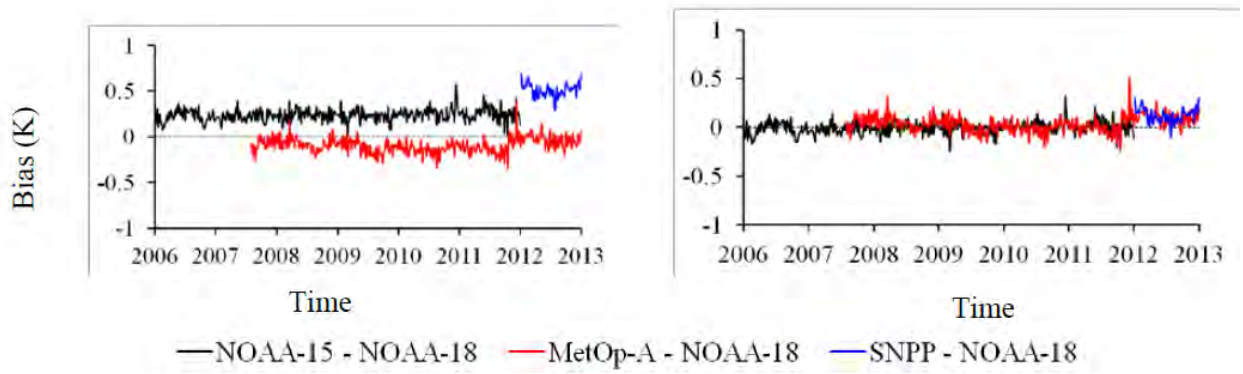

Figure 2: Intersatellite difference time series of the ocean mean clear-sky brightness temperature of AMSU-A channel 8 within ±30° latitude before (left panels) and after (right panels) intersatellite bias correction.

Outreach to International Scientists

In May 2015, *GSICS Quarterly Letter Special Issue on microwave was published*. This special issue was edited by Manik Bali and have 10 research articles included in it with authors from NESDIS, UMD, NASA, JPSS Program office. Copies were distributed to GSICS working group satellite scientists distributed in USA, Japan, Korea, France, Germany and China.

GSICS Global Space-based Inter-Calibration System

Quarterly

Newsletter – Spring 2014 Issue

Volume 8 Number 1 2014

Manik Bali, Editor

CMA • CNES • EUMETSAT • IMD • ISRO • JAXA • JMA • KMA • NASA • NIST • NOAA • ROSHYDROMET • USGS • WMO

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Special Issue on Microwave

In This Issue

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GPM Microwave Radiometer Inter-Calibration using Vicarious Cold Calibration

On-Orbit ATMS Lunar Contamination Corrections

Identifying AMSR2 Oceanic Calibration Biases

Inter-calibration of Observations from SAPHIR and ATMS Instruments

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Inter-Calibration of AMSU-A Window Channels

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News in This Quarter

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2014 Annual Meeting of GSICS Research and Data Working Groups

Microwave Inter-calibration Activities Reported at MicroRad 2014

Meet GSICS Members

Announcements

Dr. Peng Zhang Accepts Chair of Executive Panel

Dr. Ken Holmlund Accepts Vice Chair of Executive Panel

GSICS-Related Publications

Inter-calibration of Microwave Satellite Data: An Ongoing Challenge

by Isaac Moradi ESSIC/CICS, University of Maryland and Ralph Ferraro, NOAA

Passive microwave (MW) satellite measurements and derived products play a very important role in weather forecasting, data assimilation, and also in climate monitoring and assessment. MSU was the first operational MW radiometer flown on the TIROS-N satellite and subsequently on NOAA-6 to -14 from 1978 to 2007.

AMSU-A/-B and MHS flown on NOAA-15 through NOAA-19 and EUMETSAT MetOp (-A and –B) satellites since 1998 formed the next generation of operational MW instruments. Most recently, ATMS combined the capabilities of both AMSU and MHS and was initially flown on Soumi-NPP in 2011, and is planned to be flown on JPSS-1 and -2. DMSP also operated a series of operational MW radiometers including SSM/T initially flown in 1979 onboard DMSP F04 to F15, SSM/I onboard F08 to F15, SSM/T-2 onboard F11 to F15, and currently, SSMI/S onboard F16 to F19. Finally, many MW instruments have been in recent years flown on different research satellites (WMO, 2013).

Spaceborne MW measurements, like any other physical measurements, are subject to errors and uncertainties. The errors can be classified into radiometric and geometric errors. Radiometric errors are caused by several sources including drift in sensor calibration, imperfect antenna and local electronics, Radio Frequency Interference (RFI), uncertainty temperatures of hot and cold (space-view) targets, and non-linearity in the calibration. Due to the lack of reference datasets, alternative methods are used to quantify the radiometric errors. These methods include validation using airborne observations; inter-calibration with similar spaceborne instruments, inter-comparison with brightness tem-

Planned Work

The planned work includes both continued support for monitoring and inter-satellite calibration for operational NOAA satellite:

1) Develop monitoring system for AMSU instrument onboard NOAA operational satellite NOAA-15,NOAA-18/19.
2) Agenda for GSICS working group meetings at NOAA and EUMETSAT conferences
3) Publish GSICS quarterly newsletter

Publications

Peer-Reviewed

Yang, Hu, and Xiaolei Zou. "Optimal ATMS Remapping Algorithm for Climate Research." IEEE Transactions on Geoscience and Remote Sensing 52 (2014): 7290-7296

Zou, Xiaolei, Fuzhong Wang, and Hu Yang, 2014: Connecting the Time Series of Microwave Sounding Observations from AMSU to ATMS for Long-Term Monitoring of Climate, *J. Atmos. Oceanic Technol.*, **31**, 2206-2222, doi: 10.1175/JTECH-D-13-00232.1

Non-Peer-Reviewed

Yang, Hu, and Fuzhong Weng, 2014: On-Orbit ATMS Lunar Contamination Corrections, *GSICS Quarterly*, **8**, 7-9, doi: 10.7289/V55H7D64

Products

GSICS Quarterly Letter

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**1**
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	**2**
# of undergraduate students mentored during the year	

Advanced Radiance Transformation System (ARTS) for JPSS ATMS Calibration

Task Leader Hu (Tiger) Yang
Task Code HYHY_JPSS_14
Reporting Period April 1, 2014 ~ March 31, 2015
NOAA Sponsor Fuzhong Weng
NOAA Office NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%) Theme 1: 100%
Main CICS Research Topic Future Satellite Programs: Scientific Support for the JPSS Mission
Contribution to NOAA goals (%) Goal 5: 100%
Highlight : For JPSS ATMS TDR processing, a full radiance transformation system (ARTS) is being developed. From the lessons studied from Suomi-NPP ATMS calibration, several major improvements are also made for ARTS, which include FFT-based destriping algorithm for warm and cold calibration counts, scan bias correction for warm target and cold space radiance, and refined lunar contamination correction for cold space calibration counts. Using RDR as inputs to ARTS, TDR and SDR can be generated directly with a high quality for many applications such as radiance assimilation in NWP system.

Background

In history, NOAA operational calibration for microwave instruments was derived in radiance. In general, the radiance describes the amount of electromagnetic energy radiated by a blackbody in a thermal equilibrium as a function of its temperature and wavenumber through Planck's function. In the current IDPS, Suomi NPP ATMS calibration is derived in brightness temperature through Rayleigh–Jeans approximation which has biases in cold temperature and high frequencies. ARTS is a module based microwave calibration system. The main function module include raw level 0 data decode, GPS and two line elements (TLE) based geolocation, antenna correction, non-linear calibration and lunar contamination correction. From the lessons studied from Suomi-NPP ATMS calibration, several major improvements are also made for ARTS, which include FFT-based destriping algorithm for warm and cold calibration counts, scan bias correction for warm target and cold space radiance, and refined lunar contamination correction for cold space calibration counts. Using RDR as inputs to ARTS, TDR and SDR can be generated directly with a high quality for many applications such as radiance assimilation in NWP system.

Accomplishments

1. Scan Bias Correction

An analysis of the ATMS antenna gain measurements reveals that the efficiencies of both ATMS antenna side lobes and cross polarization are frequency-dependent. From the ATMS pitch-over maneuver data, it is found that the contributions of spacecraft radiation through the near-field side lobes are significant and dominates the scan angle dependent features in the ATMS antenna temperatures. A theoretical model is developed for the conversion from antenna to sensor brightness temperatures, which incorporates the angular dependent terms derived from the pitch-over maneuver data .

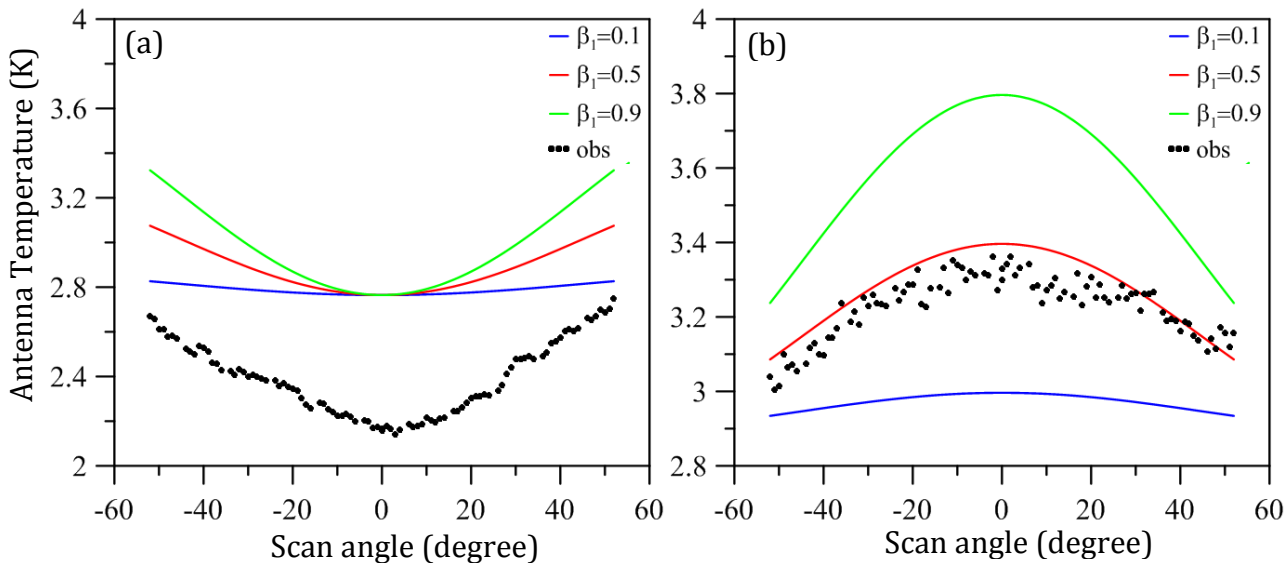


Figure.1 Variation of the model-simulated antenna temperature with respect to scan angle (curves) for a typical ATMS (a) quasi-vertical polarization channel (channel 1) and (b) quasi-horizontal polarization channel (channel 4) for three specified values of β_1. The ATMS measured antenna temperatures for the same channels during pitch-over maneuver are shown in black.

2. Destriping Algorithm for Calibration Counts

Based on the frequency spectrum analysis of receiver output calibration counts, we introduce a "accurate" low-pass filter in frequency domain, which can be used to effectively remove the high-frequency component (short term fluctuation) in the signal while kept the low–frequency component (gain variation) being unchanged. The filter was applied to raw calibration counts and then new calibrated antenna temperature was derived through two-point calibration. Figure.2 shows the calibrated antenna temperature at channel 14 with/without calibration counts filtering processing and the difference between them. It is shown that by applying new designed low pass filter to calibration counts, the striping noise is effectively removed from the calibrated antenna temperature.

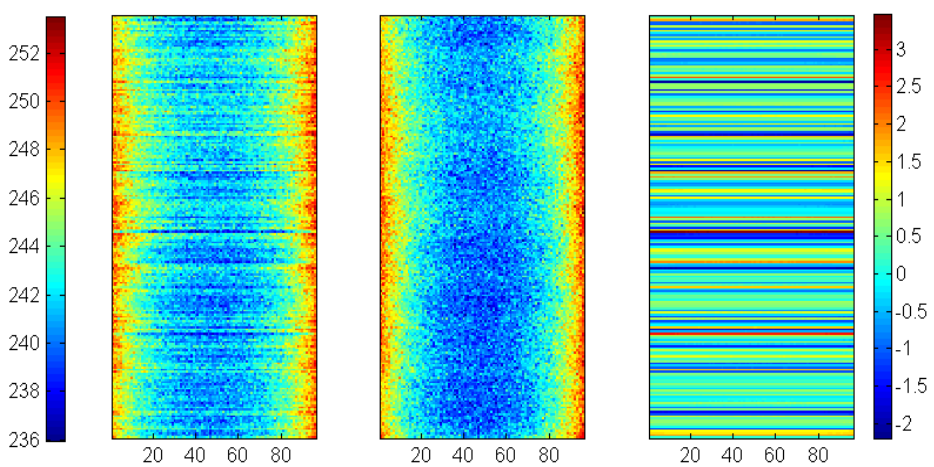


Figure.2. The calibrated antenna temperature at channel 14 without calibration counts filtering(left), with 0.1 cut off frequency filtering (middle) and the difference between them.

3. Lunar Contamination Correction

The lunar intrusion becomes significant when its radiation appears in the antenna main beam. In general, the cold count anomaly is detected when the angle between antenna space view and lunar observation vector exceeds a certain threshold. The lunar radiation can be also included in the calibration. In doing so, a lunar radiation term is derived as a function of antenna gain, the solid angle of Moon and the brightness temperature of full Moon disk. This algorithm is applied for ATMS on-orbit data processing and shows a successful removal of all the lunar contamination on the earth-scene brightness temperature.

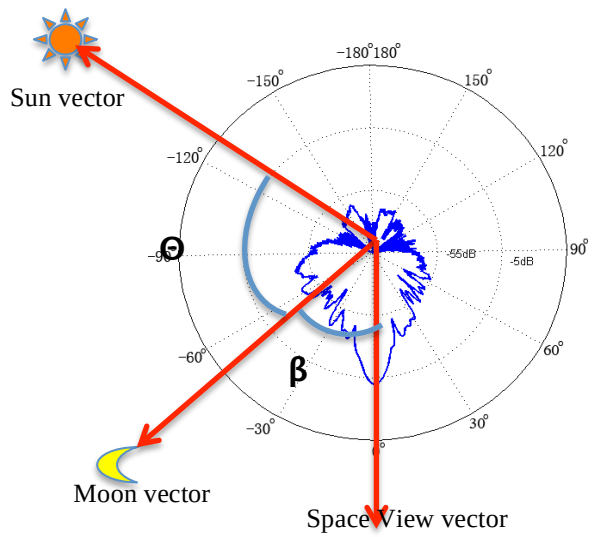


Figure.3 A schematic diagram shows the lunar contamination when the radiation from the moon is received through the antenna main beam. The blue curve corresponds to ATMS antenna pattern at 23.8 GHz in polar coordinate system.

Planned Work

The planned work includes both continued support for on-orbit calibration and validation of the ATMS instrument on-board the Suomi NPP and develop new science and techniques for the future JPSS-1 and JPSS-2 satellites:

1) Develop physical based antenna emissivity correction algorithm. Apply the correction model to on-orbit TDR calibration and SDR conversion to improve the products accuracy
2) Develop an operational geolocation evaluation algorithm, transfer the geolocation bias on Earth surface to satellite attitude error, build the correction matrix to improve the geolocation accuracy
3) Develop a radiative transfer model with full polarimetric capability, by which to evaluate the microwave window channel calibration accuracy

Publications

Peer-Reviewed

Yang, Hu, and Xiaolei Zou. "Optimal ATMS Remapping Algorithm for Climate Research." IEEE Transactions on Geoscience and Remote Sensing 52 (2014): 7290-7296

Zou, Xiaolei, Fuzhong Wang, and Hu Yang, 2014: Connecting the Time Series of Microwave Sounding Observations from AMSU to ATMS for Long-Term Monitoring of Climate, *J. Atmos. Oceanic Technol.*, **31**, 2206-2222, doi: 10.1175/JTECH-D-13-00232.1

Non-Peer-Reviewed

Yang, Hu, and Fuzhong Weng, 2014: On-Orbit ATMS Lunar Contamination Corrections, *GSICS Quarterly*, **8**, 7-9, doi: 10.7289/V55H7D64

Products

ARTS calibratin/geolocation software

Presentations

Yang, Hu, and Miao Tian, Nonlinearity Analysis for JPSS-1 ATMS Instrument, *AMS Annual Meeting*, Phoenix, AZ (1/4 to 1/8/2015)

Yang, Hu, Introduction of an Advanced Radiance Transformation System (ARTS) , *CICS-MD Science Meeting*, College Park, MD (11/12 to 11/13/2014)

Other

Outreach to International Scientists: In January 2015,CICS-MD mailed out 60 hard copies of the *Journal of Geophysical Research (Atmospheres) Special Issue on Suomi National Polar-Orbiting Partnership Satellite Calibration, Validation, And Applications* (2014). This special issue was edited by Fuzhong Weng and has an introduction by Al Powell. Out of the 35 articles in the issue, 14 are coauthored by CICS scientists and another three by CICS sponsors. Copies were sent to satellite scientists in Argentina, Belgium, Canada, China, Czech Republic, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, Poland, Portugal, Romania, Russia, Spain, Sweden, and the United States.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1***
# of products or techniques submitted to NOAA for consideration in operations use	**2†**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**1**
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	**2**
# of undergraduate students mentored during the year	

*1. Improved ATMS SDR products

†1.ATMS TDR to SDR conversion algorithm

2. ATMS lunar contamination correction algorithm

Technical Support of JPSS Land Surface Temperature and Albedo EDR evaluation and improvement

Task Leader	Yuling Liu
Task Code	YLYL_TSJL_14
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Scientific support for the JPSS Mission
Contribution to NOAA goals (%)	Goal1:20%; Goal 2: 80%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Background

This report summarizes the ongoing Joint Polar-Orbiting Satellite System (JPSS) project "Satellite Land Surface Temperature (LST) and Albedo". LST is a critical parameter in the weather and climate system controlling surface heat and water exchange with the atmosphere. The NPP satellite has been launched on October 28, 2011. The Visible Infrared Imaging Radiometer Suite (VIIRS) provides a majority of the Environmental Data Records (EDR) from the S-NPP satellite. VIIRS Land Surface Temperature (LST), one of the EDRs, is derived from the VIIRS data collection using baseline split-window regression algorithms. The coefficients of the LST algorithm are surface type dependent, referring the International Geosphere-Biosphere Programme (IGBP) types, separating day and night conditions.

This project is to provide scientific and technical support on this effort, meanwhile to provide a testbed base for future JPSS satellite series, e.g. the first JPSS satellite will be launched in 2016. The ultimate objective of this project is to generate high quality LST product for the JPSS mission, through algorithm refinement and improvement, algorithm and product evaluation, long-term monitoring and algorithm maintenance.

Accomplishments

The JPSS Algorithm Engineering Review Board (AERB) released the VIIRS Land Surface Temperature Environmental Data Record (EDR) to the public with a Stage 1 Validation level maturity with an ef-fective date of December 2014. This assessment is based on both qualitative and quantitative anal-ysis of the VIIRS LST EDR. The VIIRS LST EDR has been compared with U.S. SURFRAD, CRN observations and some other available ground measurements such as those in Africa and China. In addition the radiance based validation at granule level and the cross satellite comparisons with MODIS LST, SEVIRI LST products etc. have been performed. All together build up the extensive evaluation and validation structure for VIIRS LST product.

In detail, the accomplishments include

1) Improvements of the LST EDR product for the NPP/JPSS mission, making it meet the product milestone and mission requirements. This is the main accomplishment within this time peri-od.

We used three approaches in validating the VIIRS LST product: one is temperature based method (T-based) and the second is radiance based validation method (R-based) and the method of cross-comparison with heritage satellite LST product.

- The T-based method is performed with the data from Surface Radiation Budget Network (SURFRAD), U.S. Climate Reference Network (CRN), as well as ground ob-servations from Africa and China. Related results have been presented in the con-ference or included in publications. We have been collecting ground data as a routine task and actively involved in the international co-operation of LST validation work with the scientist from Europe and China.

- The R-based method used the radiative transfer simulations from MODTRAN, to cal-culate the spectral radiance at the top of atmosphere for the LST retrieval. The anal-ysis is done at global scale with total 9 areas including North America(Multiple loca-tions), Africa, Australia, China, Brazil, Greenland. Considering that some IGBP types particularly vegetation types may have sea-sonal variability, granules representing each season are selected for this study.
- The cross comparison with heritage satellite LST product is mainly between VIIRS LST and equiv-alent MODIS LST products , at various spatial and temporal frame over the Simultaneous Nadir Overpasses (SNO) and near SNO pass. The analysis is done at global scale, regional scale and sin-gle granule scale for the whole year and repre-sentative months of each season. In addition, we also include the cross comparison with SEVIRI LST product over Iberian Peninsula area. This work has been extended to AATSR and other satellite products.

2) The product uncertainty analysis has been performed to quantify the LST error from the input data, algorithm itself and other factors.

3) The comprehensive simulation database is built up, which covers wide spatial and temporal dis-tribution, a variety of atmospheric conditions and wide LST range, to support scientific study related to VIIRS LST product, e.g. algorithm coefficients derivation, algo-rithm test and uncertainty analysis etc.

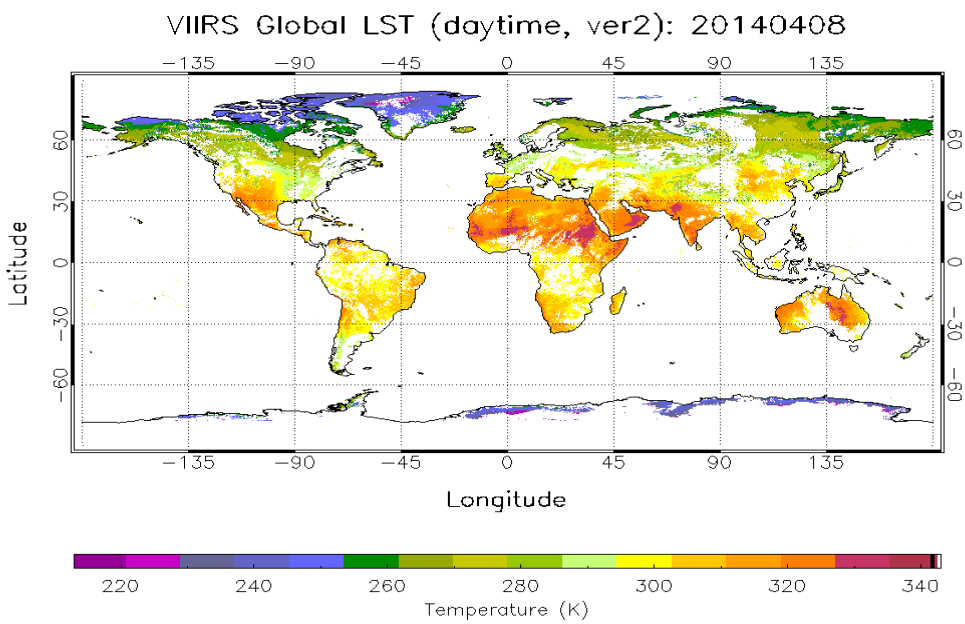


Figure 1. An example of the Global daily composite LST map, on April 8, 2014. The global composite data is archived daily using the validation tool system.

4) The VIIRS LST product has been compared with numerical model output to promote the uses of the LST data in operational weather forecast. This study reveals the difference between satellite LST es-timation and model LST estimation, in spatial distribution, temporal pattern etc.

5) Validation tool development. Related Tools are developed to support LST evaluation and calibra-tion work including the regression package for algorithm coefficient, the routine vali-dation and deep-dive system, and a prototype long term monitoring (LTM). While each tool package is a stand-alone sys-

tem and has its own application, a merged system combining the three will better and more efficiently serve the need of the LST retrieval. The regression package includes a comprehensive simulation database from MODTRAN and generates the coefficients for different algorithms, which will be evaluated by the validation tool software. The LTM system monitors LST production from multiple satellites in near real time, including SNPP-VIIRS and MODIS-AQUA. Meanwhile, it produces the proxy data set from these satellite sensors, which will be used by the validation system for algorithm evaluation.

6) Maintain the software package and related documentations
   - Support the actions taken for LST related DRAT. Attended DRAT meeting and the land team EDR/CalVal meetings.
   - Maintenance of the LST source code, ADL update, ATBD, OAD and some other related documentations update. Particularly, for validated stage 1 maturity release, the readme file as well as ATBD is updated by providing details of this post-launch vali-dation efforts and known issues.

Planned Work

- Continue to work on the evaluation and validation of the current LST production
- An emissivity explicit algorithm will be developed and tested for J-1 mission, and possibly for the S-NPP mission at STAR operational environment
- Supporting the long term monitoring tool development
- Update LST software code and ATBD documentation and support the NPP/JPSS Mission Management

Publications

Manuscript:

Yuling Liu, Yunyue Yu, Peng Yu and Ivan Ciszar, "Quality Assessment of V1 S-NPP VIIRS Land Surface Temperature Product", plan to submit it to IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing

Products

JPSS VIIRS Land Surface Temperature EDR product.

Presentations

1. Yuling Liu, Yunyu Yu, Peng Yu, and Zhuo Wang, "Concerns on cross comparison of satellite land surface temperature retrievals, a case study between VIIRS and MODIS LST product", AMS 95th Annual Meeting on Jan. 4-8th, 2015, Phoenix, AZ.
2. Yunyue Yu, Yuling Liu, Peng Yu, Zhuo Wang and Ivan Csiszar, "Issues in Developing and Validating Satellite Land Surface Temperature Product", AMS 95th Annual Meeting on Jan. 4-8th, 2015, Phoenix, AZ.
3. Yuling Liu, Yunyue Yu, Zhuo Wang and Peng Yu, "Evaluation of the SNPP VIIRS Land Surface Temperature Product: Provisional Maturity", 2014 STAR JPSS Science Teams Annual Meeting, May 12-16, 2014, College Park, MD
4. Yuling Liu, Yunyue Yu, Peng Yu and Zhuo Wang, "Quality Assessment of Suomi NPP VIIRS Land Surface temperature Product", NOAA Satellite Science Week meeting, February 23 - 27, 2015, Boulder, Colorado.

5. Yuling Liu, Yunyue Yu, Zhuo Wang and Peng Yu, "Suomi NPP VIIRS Land Surface Temperature Product Quality Assessment toward Validated Maturity", CICS science meeting, November 12-13, 2014, College Park, MD
6. Peng Yu, Yunyue Yu,Yuling Liu and Zhuo Wang,"Towards Monitoring Satellite Land Surface Temperature Production", AGU fall meeting, December 2014, San Francisco, CA
7. Peng Yu , Yunyue Yu, Yuling Liu and Zhuo Wang, " The tool for the VIIRS LST Product monitoring and validation", 2014 STAR JPSS Science Teams Annual Meeting, May 12-16, 2014, College Park, MD
8. Zhuo Wang, , Yunyue Yu, Yuling Liu and Peng Yu, " Revealing Issues for Improving VIIRS Land Surface Temperature Retrieval", 2014 STAR JPSS Science Teams Annual Meeting, May 12-16, 2014, College Park, MD
9. Zhuo Wang, Yunyue Yu, Peng Yu, Yuling Liu, Michael Ek and Yihua Wu, "Using VIIRS Land Surface Temperature to Evaluate NCEP North American Mesoscale Model(NAM) Forecast", CICS science meeting, November 12-13, 2014, College Park, MD
10. Peng Yu, Yunyue Yu, Zhuo Wang and Yuling Liu, "A system for satellite LST product monitoring and retrieval algorithm evaluation", CICS science meeting, November 12-13, 2014, College Park, MD
11. Yunyue Yu, Yuling Liu, Peng Yu and Jaime Daniels, "Land Surface temperature Production for GOES-R and JPSS Missions", NOAA Satellite Science Week meeting, February 23 - 27, 2015, Boulder, Colorado.
12. Peng Yu , Yunyue Yu, Yuling Liu and Zhuo Wang, "Testing of Emissivity Explicit Retrieval Algorithms for VIIRS Land Surface temperature ", NOAA Satellite Science Week meeting, February 23 - 27, 2015, Boulder, Colorado.
13. Yunyue Yu, Yuling Liu, Ivan Csiszar, "Production of Land Surface Temperature for JPSS Mission", International Geoscience and Remote Sensing Symposium (IGARSS) 35th Canadian Symposium on Remote Sensing (CSRS), July 13-18th, 2014, Québec , Canada

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**13**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

1.5 Climate Research, Data Assimilation, and Modeling

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

Task Leader:	Christopher Hain
Task Code	CHCH_JPSS_14
NOAA Sponsor	Xiwu Zhan
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 20; Theme 2: 20; Theme 3: 60
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 55%; Goal 2: 45%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: We have produced the global drought maps using or without using near real time green vegetation frac- tion (GVF). The quality control procedures and parameters for Soil Moisture Operational Product System (SMOPS) soil moisture (SM) product are established using real time GVF and newer surface type prod- ucts. In addition, we assessed the improvement of assimilating SMOPS-blended SM on Noah model per- formances in both sparsely and densely vegetated areas.

Background

The soil moisture statuses at various soil layers are the most important indicator of agricultural drought. This project is to demonstrate the value of NPP/JPSS land observations (i.e. green vegetation fraction, albedo, soil moisture and surface type) in improving the estimates of soil moisture status by assimilating NPP/JPSS land EDRs in North American Land Data Assimilation System (NLDAS) and Global Land Data Assimilation System (GLDAS) implemented via NASA's Land Information System (LIS).

Accomplishments

We have produced the global drought maps using or without using near real time green vegetation fraction (GVF). Figure 1 shows the difference between the global root-zone soil moisture anomalies generated from GLDAS with (DA03 case) and without (OLP case) using near real time GVF. It is evident that using the near-real-time weekly GVF lead to improvements in the specification of the 2010 drought over Russia: less severe drought was observed in western Russia, while more severe drought was observed in eastern Russia.

In addition, quality control rules of satellite soil moisture data product from NOAA-NESDIS Soil Moisture Product System (SMOPS) have been established for their assimilation into the Noah land surface model using vegetation fraction criteria. Figure 2 denotes the averaged time series of daily surface layer (0-10 cm) and root zone layer (60-100 cm) SM RMSE for OLP (without the benefit of data assimilation), DA01 (assimilating SMOPS soil moisture without the benefit of quality control), DA02 (assimilating SMOPS soil moisture with the benefit of the satellite data removed under GVF exceeding 0.70) and DA03 (assimilating SMOPS and benefited from our quality control parameters) cases during the 2010-2011 analysis period. According to the in situ observations, for the surface and root zone layers, the time series of USA domain-averaged root mean square error (RMSE) for each of the three assimilation cases are all reduced in comparison with the case without data assimilation, and the assimilation case with quality control procedures and parameters established by us exhibits larger improvements.

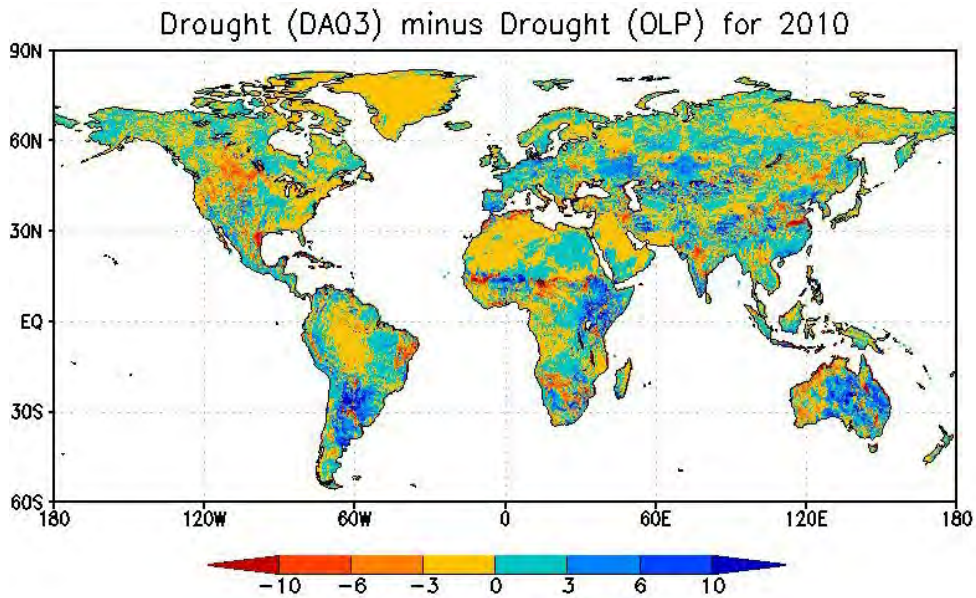


Figure 1. Differences (DA03-OLP) of the root-zone soil moisture anomalies of 2010 between OLP and DA03 runs of GLDAS. The redder (bluer) color indicates severer (lighter) drought using near-real-time VIIRS GVF than using the multiyear average of MODIS GVF.

Planned Work

1) Assess the performances of global drought monitoring product using real time GVF in comparison
2) with using static GVF;
3) Assess the performances of global drought monitoring product using real time GVF in comparison with other dataset (i.e. vegetation health index, drought severity index, etc);
4) Establish the optimal ensemble size of Ensemble Kalman Filter (EnKF) and verify it using the example experiments.

Publications

1) Yin, J., X. Zhan, Y. Zheng, J. Liu, C. R. Hain, and L. Fang (2014), Impact of quality control of satellite soil
2) moisture data on their assimilation into land surface model, Geophys. Res. Lett., 41, 7159–7166, doi:10.1002/2014GL060659
3) Yin, J., X. Zhan, Y. Zheng, J. Liu, L. Fang, and C. Hain, 2014: Enhancing Model Skill by Assimilating SMOPS Blended Soil Moisture Product into Noah Land Surface Model. J. Hydrometeor. doi:10.1175/JHM-D-14-0070.1
4) Yin, J., X. Zhan, Y. Zheng, L. Fang, J. Liu and C. R. Hain, An assessment of impacts of surface type changes on drought monitoring. International Journal of Remote Sensing, under review.
5) Yin, J., X. Zhan, Y. Zheng, C. R. Hain , L. Fang and J. Liu. Improve drought monitoring using real time albedo and green vegetation fraction from satellite observations. To be submitted to Remote Sensing of Environment.

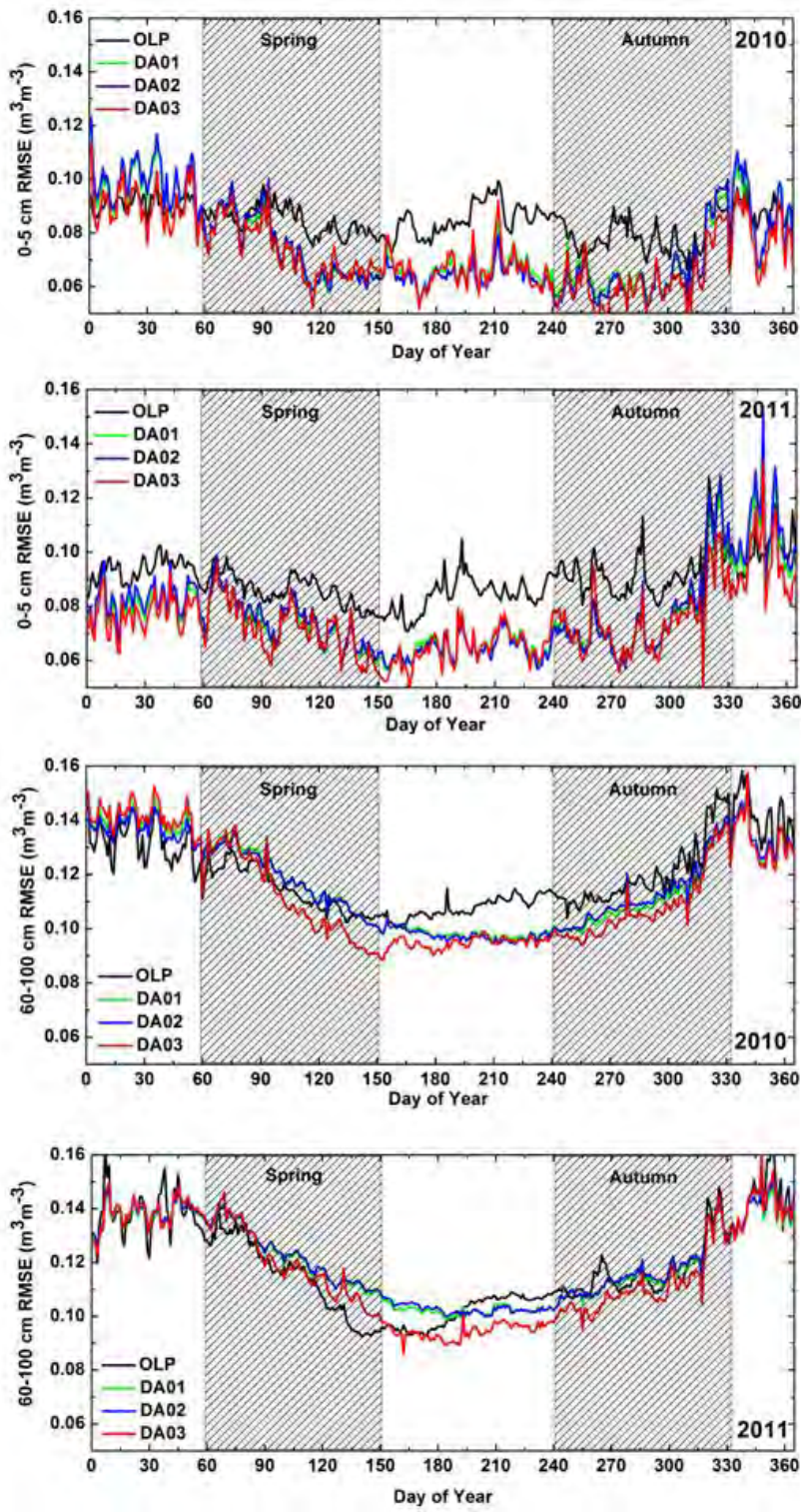


Figure 2. Based on the in-situ observations from 179 USDA Soil Climate Analysis Network (SCAN) sites, the averaged time series of daily surface layer (0-10 cm) and root zone layer (60-100 cm) SM RMSE for OLP (black), DA01 (green), DA02 (blue) and DA03 (red) case during the 2010-2011 analysis period.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**3**
# 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	**0**

This project accesses the impact of JPSS EDR products in land data assimilation systems, such as NLDAS and GLDAS. The techniques submitted to NOAA for consideration in future operational use include (1) real time GVF insertion component into NLDAS/GLDAS and (2) assimilation of SMOPS soil moisture into NLDAS/GLDAS. Three peer-reviewed papers (2 published,1 in review) have been completed based on this work.

Enhancing NCEP-NAM Weather Forecasts via Assimilating Real-time GOES-R Observa- tions of Land Surface Temperature and Green Vegetation Fraction

Task Leader Christopher Hain
Task Code CHCH_NCEP_14
NOAA Sponsor Xiwu Zhan
NOAA Office NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%) Theme 1: 50; Theme 2: 10; Theme 3: 40
Main CICS Research Topic Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%) Goal 1: 35%; Goal 2: 65%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%
Highlight: We have prepared the GOES-based input data sets for data assimilation (DA) experiments. In addition, a fully coupled NASA LIS and WRF assimilation system (NU-WRF) have been set up on S4 supercomputer in which EnKF DA algorithm is implemented to assimilate multiple land observations (SM and LST) into NWP model. The NU-WRF system will be used to test the impact of assimilating real-time GOES-R LST and GVF observations on NCEP-NAM forecasts.

Background

Accurate forecasts of temperature and precipitation from numerical weather prediction (NWP) models rely on the quality of the initialization of land surface state variables (e.g. soil moisture(SM)) and the representativeness of parameters that describe the current land surface (e.g. green vegetation fraction (GVF)). Real time satellite-based land surface products are capable of providing spatially continuous observations of surface parameters while accurately capturing the dynamics of surface conditions. With enhanced observations from the GOES-R, the assimilation of real time GOES-R green vegetation fraction, land surface temperature (LST), and a LST-based SM proxy are expected improve temperature and precipitation forecasts from NWP models.

The exchange of energy and water fluxes in operational NWP models is very sensitive to GVF, an important weighting coefficient in partitioning total evapotranspiration into the three components of evaporation. GVF is also a highly variable parameter annually and seasonally (Chen et al. 2001). More importantly, a successful assimilation of LST information into land surface models (LSMs) is dependent on a consistent representation of the observed vegetation fraction. However, the current Noah LSM within the NCEP North American Mesoscale Forecast System (NAM) utilizes a multi-year climatology of GVF. Climatological GVF maps are not always representative of the actual condition observed on the ground (e.g., in regions of drought; early or late emergence/senescence), especially in agricultural areas of the central and eastern U.S., where temporal variability in GVF can be significant.

It has been found that a LST-based SM signal is particularly advantageous because it is able to provide SM information over moderate to dense vegetation, a capability that is limited with microwave sensors (Hain et al. 2011). Meanwhile, several satellite LST data products are operationally available for use in the NWP models (e.g. GOES LST; MSG LST; GSIP LST). However, a direct application of LST data products

through data assimilation in NWP operations has not been well demonstrated. Even as current studies have shown some success in directly assimilating LST into LSMs, significant shortcomings have been found. One challenge comes from the absolute biases between satellite-based LST and modeled surface temperature due to the inconsistencies of satellite LST retrieval algorithms and model physics and parameterizations used to predict LST within LSMs. These biases need careful consideration for the direct assimilation of satellite-based LST to avoid unrealistic estimation of sensible and latent heat fluxes. An

additional challenge is that surface skin temperature exhibits a very short memory as a model state variable. If the biases and inconsistencies of LST observations are not fully addressed (between model and observation), the model state will quickly return to its pre-assimilation state which will ultimately limit the impact of a direct LST assimilation.

Therefore, there are compelling reasons to test alternative approaches to assimilating pertinent information from GOES-R LST into operational NWP models. Our team has outlined a technique for simulating the effects of SM on latent heat estimates from the Atmosphere-Land Exchange Inversion model (ALEXI) model, which is forced with an observation of the morning change in LST, using a stress function relating the value of the fraction of actual to potential evapotranspiration (fPET) to soil moisture. Anderson et al. (2007; 2011) demonstrated that spatial distributions in the fraction of actual to potential ET correlate well with patterns in precipitation-based indices, responding to rainfall events at monthly time steps. The ALEXI fPET product has been utilized as a thermal infrared (TIR)-based SM proxy signal for assimilation using an EnKF into the Noah LSM. Importantly, the assimilation of TIR-based SM retrievals from ALEXI is able to avoid some of the issues that can hamper the direct assimilation of LST. For instance, the biases in absolute values of satellite-based LST retrievals are effectively circumvented by ALEXI because it is sensitive only to the time rate of change of mid-morning LST (Anderson et al. 1997). The assimilation of ALEXI SM retrievals also circumvents the difficulties in comparing satellite-based and model-based LST, which is an inevitable and complicated step in approaches for direct assimilation of satellite-based LST. Finally, the updating of soil moisture state variables has been shown to be a more stable state for data assimilation than LST.

Based on our past research results using GOES LST, we therefore hypothesize that using the LST-driven ALEXI model as a “forward model” to assimilate LST information into NWP models can be more effective and efficient than direct LST assimilation. Data assimilation (DA) tests will be set up to assimilate both direct GOES LST observations and ALEXI SM retrievals into the NCEP NAM and evaluate the effect of the two approaches on NCEP NAM weather forecasts. Building on our previous work on DA, a simplified ensemble Kalman filter (an EnKF without large matrix operation) in NCEP GFS for assimilating microwave satellite SM data products. A similar EnKF data assimilation utility will be implemented in the NCEP NAM to carry out assimilation of GOES/GOES-R LST and LST-based ALEXI soil moisture proxy data.

Accomplishments

We worked on the preparation of GOES-based input data sets for data assimilation (DA) experiments. Three key GOES/GOES-R satellite-based data sets are collected and processed for the DA experiments, including the GOES-R GVF proxy from MODIS, GOES LST and GOES-R LST proxy products, and GOES/GOES-R LST-based ALEXI soil moisture retrievals. The collection and pre-process of GVF proxy has been completed and a sample of 1-km global MODIS-based GVF on June 26th, 2013 is shown in Figure 1. In addition, ground SM measurements over more than one thousand sites from 21 networks over the period of 2000 to present are collected (Figure 2). A fully coupled NASA LIS and WRF assimilation system (NU-WRF) has been set up in which EnKF DA algorithm is implemented to assimilate multiple land observations (SM and LST) into NWP model.

Two simulation domains have been set up: (1) a parent domain which covers much of North America (see Fig. 3) at a spatial resolution of 12 km and (2) a nest domain which covers much of the contiguous United States at a spatial resolution of 4 km. These will serve as the initial testing domains for the first set of simulations. Once the evaluation of each assimilation technique is assessed, the spatial domains will be updated to closely match that of the operational NAM.

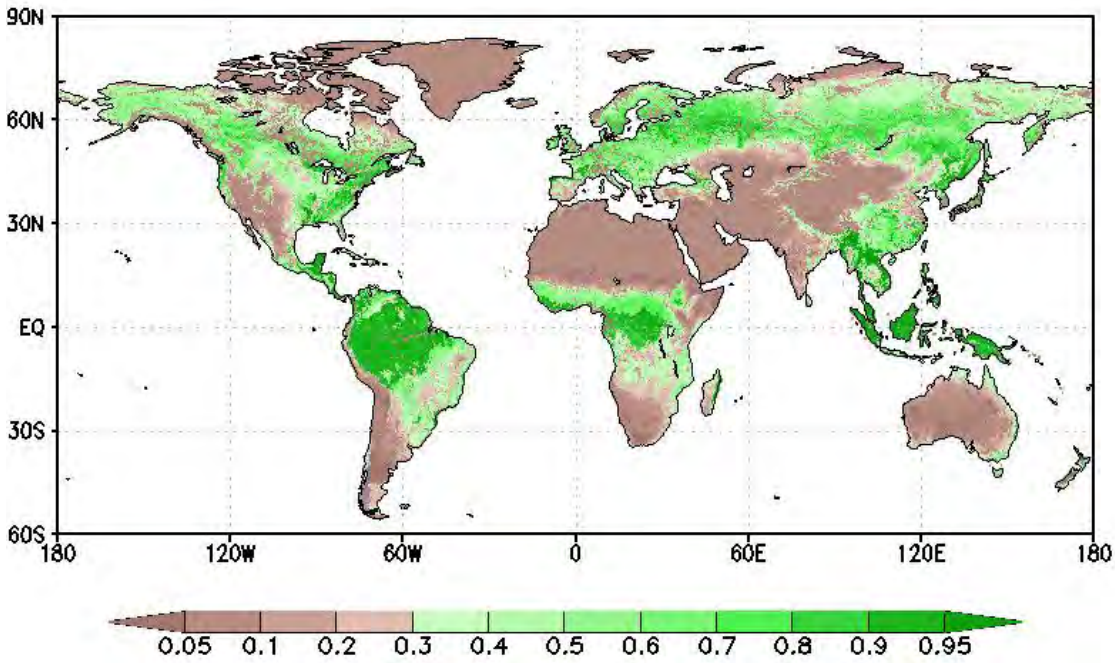


Figure 1: 1-km global MODIS-based GVF on June 26th, 2013

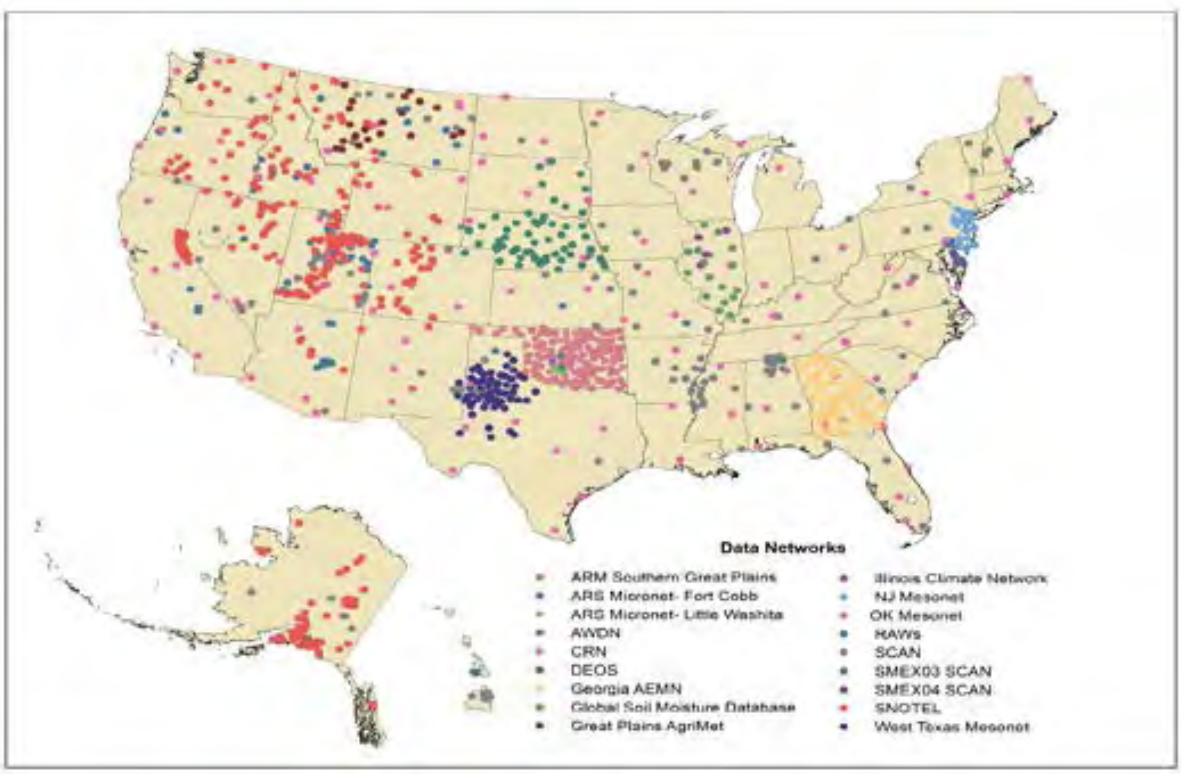


Figure 2: Collected ground based SM measurements networks (data source: NASMD soilmoisturemaps.tamu.edu)

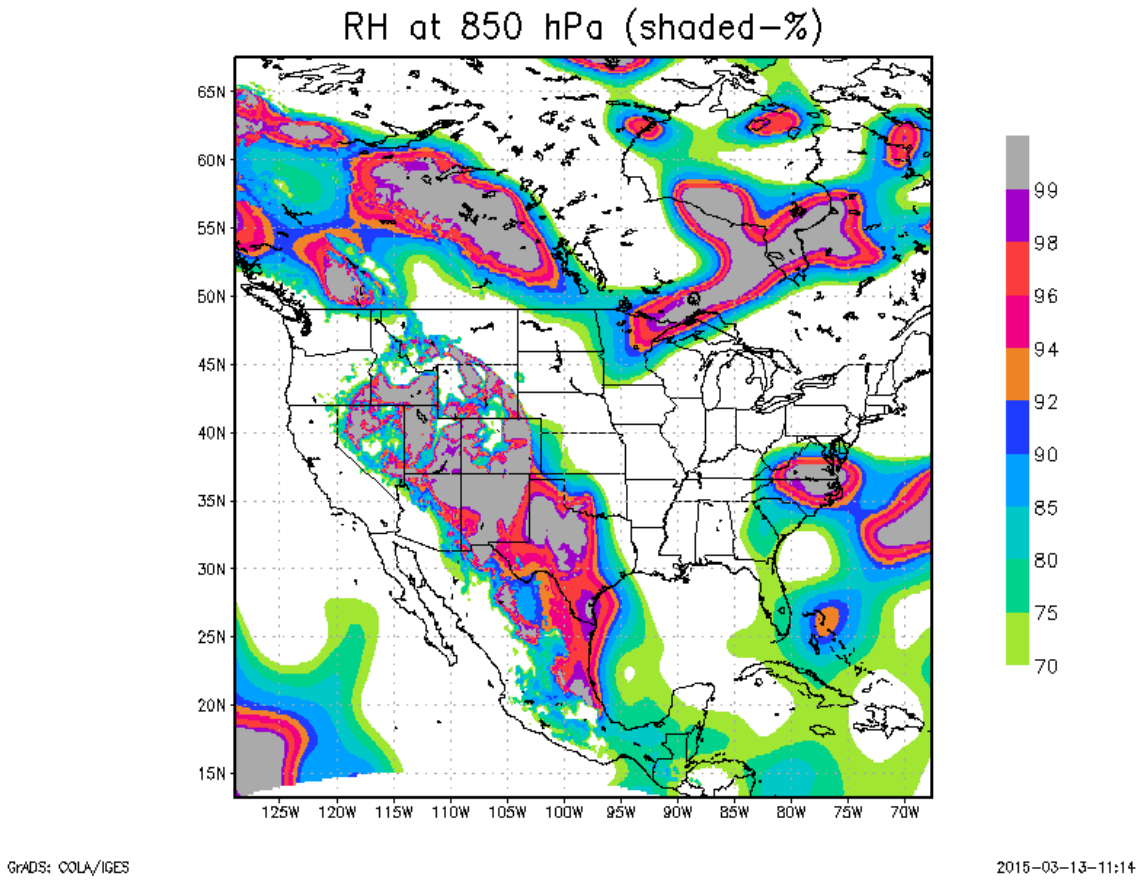


Figure 3. Parent simulation domain over North America at a spatial resolution of 12 km.

Planned Work

1) Complete the pre-processing of GOES based input data sets
2) Complete the test of NU-WRF system and conduct real NU-WRF simulation over the NAM domain
3) Ingest real time GOES/GOES-R GVF proxy data in NCEP-NAM

Publications

Fang, L., C. R. Hain, X. Zhan and J. Yin, 2014: Impact of near-real-time satellite observations of solar insolation, green vegetation fraction and albedo on soil moisture estimates from the Noah land surface model. To be submitted to J. Hydrometeor.

Fang, L., C. R. Hain and X. Zhan, 2014, Impact of GVF derivation methods on Noah land sur- face model performance. To be submitted to J. Hydrometeor.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**2**
# 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**

This project accesses the impact of near-real time GOES-R LST and GVF observations on NCEP NAM forecasts. The techniques submitted to NOAA for consideration in future operational use include (1) real time GVF insertion component in NCEP NAM and (2) land satellite data assimilation utility in NAM. There are total of 2 journal papers have been prepared and ready to submit.

Student Support for NOAA's Climate Prediction Center

Task Leader	E. Hugo Berbery (Katherine Lukens)
Task Code	EBEB_CPC_13
NOAA Sponsor	Mike Halpert
NOAA Office	NWS/CPC
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%;
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 25%; Goal 3: 25%; Goal 4: 0%; Goal 5: 0%

Highlight: Over the last two years, graduate student Katherine Lukens, under the advisement of Dr. E. Hugo Berbery, focused on ascertaining the characteristics and behaviors of seasonal storm over North America for her PhD thesis on "The interconnectivity of extreme precipitation events, storm tracks, and modes of variability via the applications of large-scale global climate dynamics."

Background

This report summarizes the research conducted from April 2014 to September 2014 by Katherine E. Lukens, GRA II with the working title of "The interconnectivity of extreme precipitation events, storm tracks, and modes of variability via the applications of large-scale global climate dynamics."

Katherine focused on the completion of her coursework required for the doctoral program in the Department of Atmospheric and Oceanic Science at the University of Maryland until May 2014; this final course was entitled Climate System Modeling.

During and after the completion of this course, Katherine continued to conduct research. She read the literature to inform herself of the results, methods, and background needed to explore storm tracks and extreme precipitation events (droughts and wet periods). She also explored the use and relevance of a Lagrangian storm track diagnostic employed by Hoskins and Hodges (2002) and Woolings et al. (2009). This method is very involved computationally, but in general it examines the full, non-anomalous vorticity field at 850hPa. Cyclones are represented by vorticity maxima and are tracked. A track density is calculated and plotted to visually describe the general position and intensity of storm tracks at this level. Other statistics are computed to further examine the characteristics and behaviors of storm tracks.

Berbery and Vera (1996) provided a basis upon which to formally begin her research encompassing precipitation and climate dynamics at CICS-MD and the University of Maryland.

Accomplishments

Under the advisement of Dr. E. Hugo Berbery, Katherine continued to analyze vorticity at 850hPa and surface precipitation over North America. She performed single-point regressions of the Eulerian filtered vorticity at 850hPa onto the precipitation rate field, which produced wave trains representing individual storms; these wave trains resemble those found in Wallace et al. (1988), Chang and Orlanski (1993), and others.

Katherine then studied the methods and uses of a Lagrangian-inspired storm tracking program entitled *TRACK*. After a few months of installation and test runs, she applied low-level vorticity data to the program and produced a variety of storm track statistics, including storm track density, mean storm intensity, cyclogenesis density, and cyclolysis density.

The track density (Fig. 1a) represents the storm track pattern for the Northern Hemisphere DJF season. It pictures four separate and distinct tracks, which are concentrated to the mid-latitudes and expose small-scale features such as the lower latitude extensions of the Mediterranean track and the eastern Pacific storm track. The mean intensity (Fig. 1b), or average strength, reveals that peak mean intensities of storms are reached slightly northward but still within the Pacific and Atlantic track patterns over the western halves of their respective ocean basins. Because low-level vorticity is smaller in scale, this storm tracking program is able to easily extract small-scale features like regions of cyclogenesis and cyclolysis (Figs. 1c and 1d, respectively).

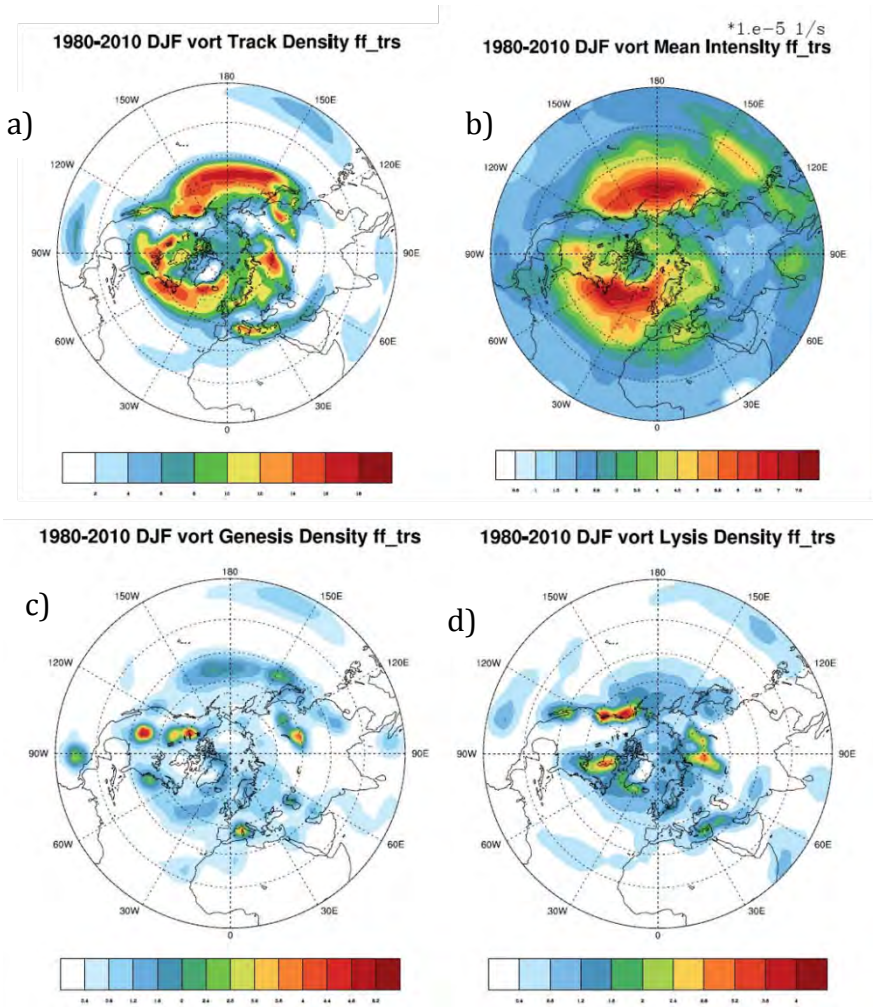


Figure 1: Lagrangian statistics using the vorticity field at 850hPa for the DJF season for 1980-2010. a) storm track density; b) mean intensity, units of 10-5 s-1; c) cyclogenesis density; and d) cyclolysis density. Figs. 1a, 1c, and 1d have units of number of storms per month with a unit area of 106 km2 (5° spherical cap).

Fig. 2 shows an example of the storms identified and tracked via this storm tracking approach.

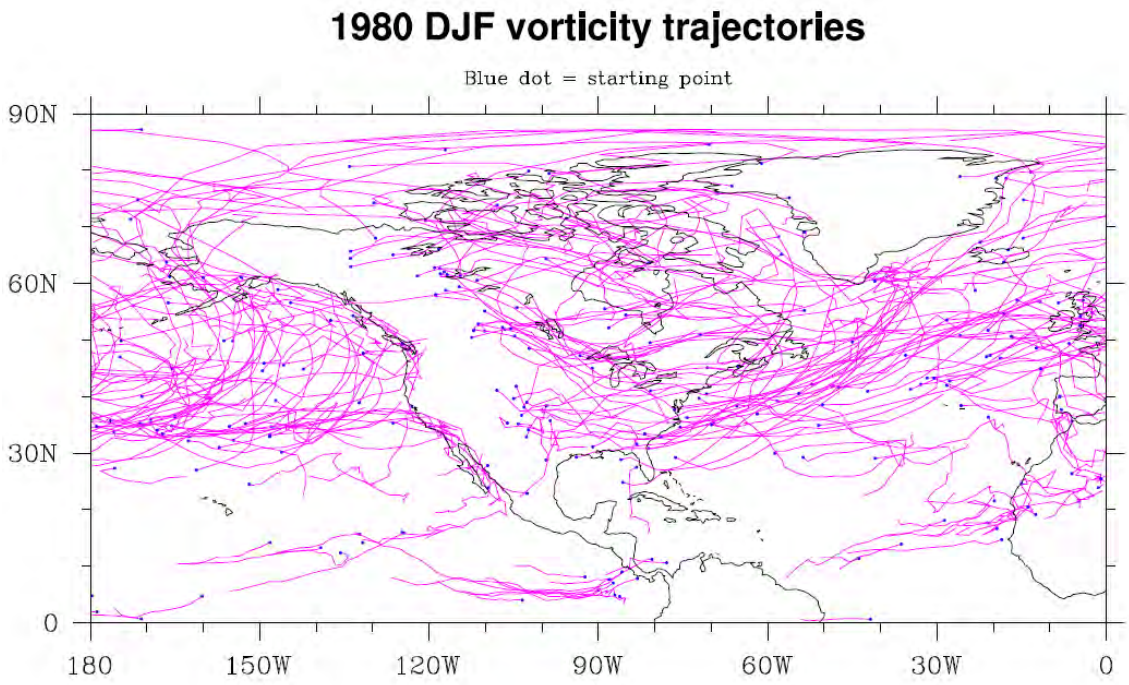


Fig. 2: Individual storm tracks that last longer than 2 days and travel further than 1000 km for the DJF season of 1980. Blue dots mark the starting points of each track.

Katherine primarily programs using the NCAR Command Language (NCL) and continues to expand her knowledge of this language and sharpen her programming skills.

The data used in all of the abovementioned calculations comes from NCEP's Climate Forecast System Reanalysis (CFSR) product. For more information, visit: https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr.

Presentations

Lukens, K. E. and E. H. Berbery, 2014: On the Relation Between North American Winter Precipitation and Storm Tracks, abstract submitted to *95th AMS Annual Conference,* 4-8 January 2015, Phoenix, AZ.

Lukens, K. E. and E. H. Berbery, 2014: On the Relation Between North American Winter Precipitation and Storm Tracks, abstract submitted to *39th Annual Climate Diagnostics & Prediction Workshop,* 20-23 October 2014, St. Louis, MO.

Other

- Green Fund Award recipient for outstanding academic excellence – *University of Maryland, Spring 2014*
- Served as an extra resource for the CICS-MD summer internship undergraduates – *CICS-MD, summer of 2014*
- Vice President of MetoGrads (the graduate student organization for the Department of Atmospheric and Oceanic Science) - *University of Maryland, April 2014 to June 2014*

Performance Metrics	
# of new or improved products developed (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	1
# of undergraduate students mentored during the year	0

CICS Support for NOAA's Climate Prediction Center

Task Leader	E. Hugo Berbery (tasks performed by Li-Chuan Chen)
Task Code	EBEB_CSCPC_14
NOAA Sponsor	Huug van den Dool
NOAA Office	NWS/NCEP/CPC
Contribution to CICS Themes (%)	Theme 2: 25%; Theme 3: 75%
Main CICS Research Topic	Climate Research and Modeling; Land and Hydrology
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%

Highlight: CICS researcher constructed ENSO composites based on the North American Multi-Model Ensemble (NMME) forecasts and found discrepancies between the model temperature composites and the observed.

Background

This work is to support NOAA/NCEP Climate Prediction Center's (CPC's) efforts on North American Multi-Model Ensemble (NMME) forecasts and evaluations. NMME is an experimental multi-model forecasting system consisting of coupled climate models from U.S. modeling centers (including NCEP, GFDL, NASA, and NCAR) and Canadian Meteorological Centre (CMC), aimed at improving intraseasonal to interannual prediction capability. Tasks include (1) developing algorithms and techniques for multi-model ensemble forecasts and evaluations, (2) working on research to advance the science and technology necessary for subseasonal to seasonal prediction, and (3) assisting in NMME system upgrades/transition/maintenance, including pre-processing and post-processing hindcasts and real-time forecasts, migrating the codes for running at alternative platform, and updating hindcast archive (originally 1982-2010) with real-time forecasts.

Accomplishments

In 2014, I started a new project with my colleagues at CPC to examine the simulations of El Nino/Southern Oscillation (ENSO) events in six NMME models, including the CFSv2, CM2.1, GEOS5, CCSM3, CanCM3, and CanCM4 models, by comparing the model-based ENSO composites to the observed in the same period. The composite analysis is conducted using the 1982-2010 hindcasts for each of the six models with selected ENSO episodes based on the seasonal Ocean Nino Index (ONI) just prior to the date the forecasts were initiated. The composites apply to monthly mean conditions in November, December, January, February, and March, respectively, as well as to the five-month aggregates representing the winter conditions. We found that all NMME models simulate ENSO precipitation patterns well during wintertime (Figure 1); however, some models have difficulties in capturing the warming trends of temperature (and their teleconnections), resulting in large discrepancies between the model temperature composites and the observed (Figure 2). The results of this research was presented in the 3rd Annual CICS-MD Science Meeting and NMME monthly telecon on November 10, and received great response. I was invited to give a presentation in the NOAA/CPO/MAPP Climate Prediction Task Force telecon on November 20. A manuscript based on this research results is in preparation for submission to a peer-reviewed journal.

Prior to this project, I worked on research to advance the science and technology for drought prediction and monitoring in the last three years. Along with CPC's collaborators, I have conducted an assessment of meteorological drought predictability using the retrospective NMME forecasts for the period from 1982 to 2010. Two performance measures, the anomaly correlation coefficient and root-mean-square errors against the observations, are used to evaluate forecast skill.

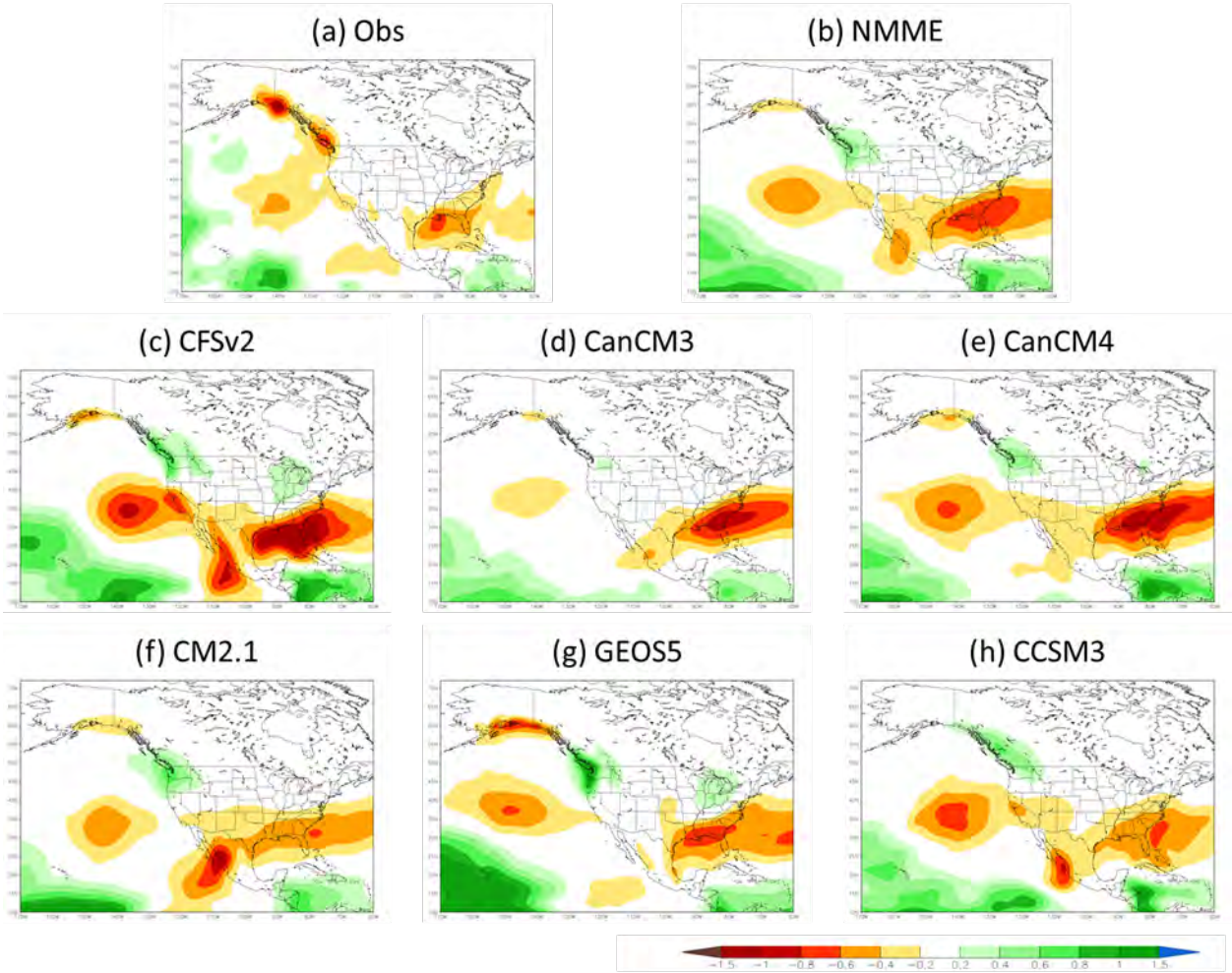


Figure 1 La Nina composites for NDJFM precipitation anomaly based on (a) observations, (b) NMME, (c) CFSv2, (d) CanCM3, (e) CanCM4, (f) CM2.1, (g) GEOS5, and (h) CCSM3 forecasts over the North American domain. The anomaly unit is mm/day.

For precipitation (P) forecasts, errors vary among models and predictive skill is generally low after the second month. All model P forecasts have higher skill in winter and lower skill in summer. Although P forecast skill is not large and quickly drops after one month, predictive skill of standardized precipitation index (SPI), a drought index, is high and the differences among models are small. Generally, model with lower P forecast skill has lower SPI forecast skill. The skill mainly comes from the P observations appended to the model forecasts. This factor also contributes to the similarity of SPI prediction among the six models. Still, NMME SPI ensemble forecasts have higher skill than those based on individual models or persistence. Overall, SPI predictive skill is regionally and seasonally dependent, and the six-month SPI forecasts are skillful out to four months. SPI forecast skill at a region corresponds to local rainfall climatology and variability. Dynamical models improve SPI predictive skill from baseline skill when and where P forecasts are skillful. The improved skill of SPI prediction during the wet seasons spanning roughly from late autumn to early spring over the Southwest and Gulf Coast region is attributed to the known impacts of ENSO signals on these regions' cold-season precipitation. These findings were presented in several conferences and meetings, including the 38th CDPW Workshop and 2013 AGU Fall Meeting. A manuscript is in preparation for submission to a peer-reviewed journal.

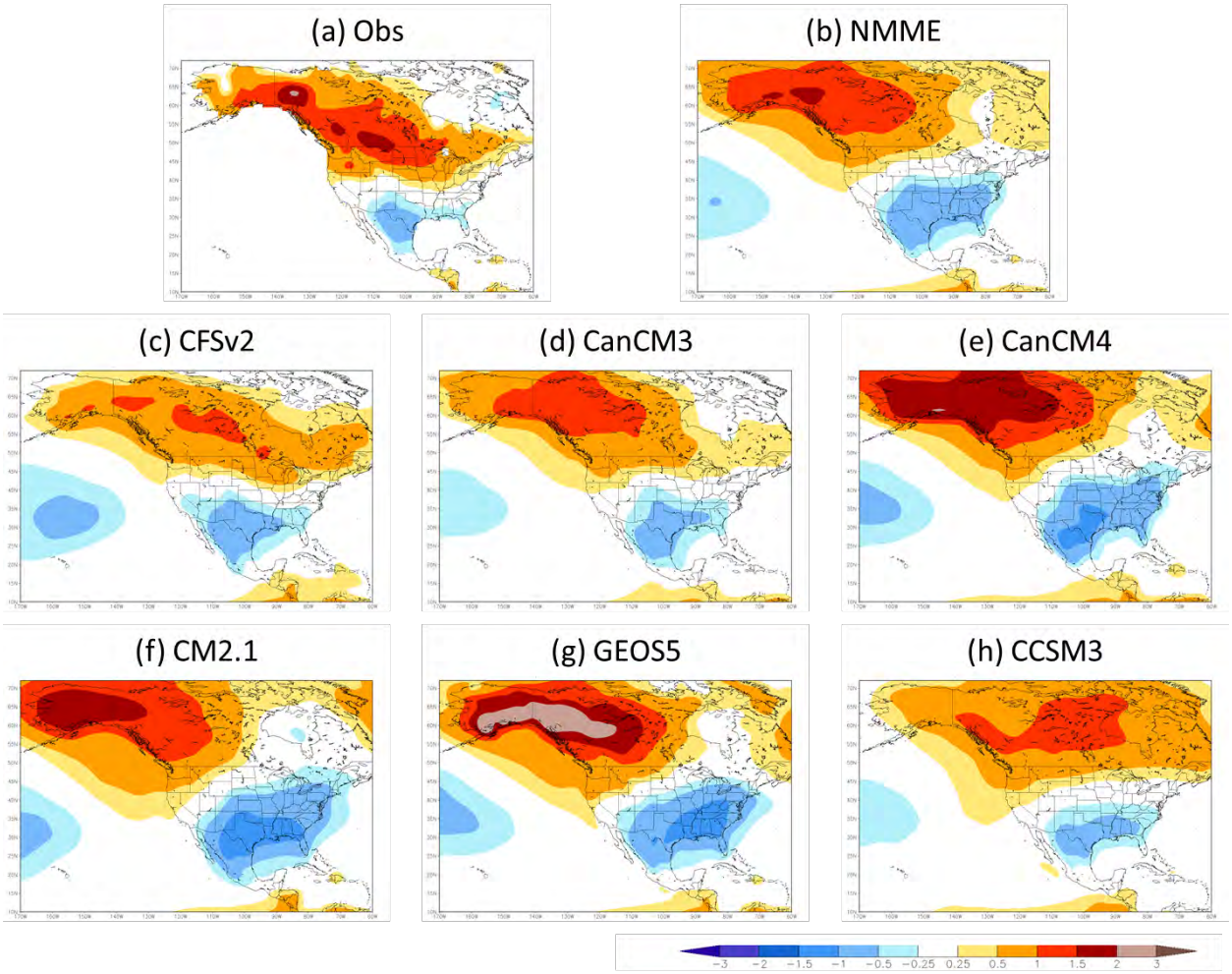


Figure 2 El Nino composites for NDJFM temperature anomaly based on (a) observations, (b) NMME, (c) CFSv2, (d) CanCM3, (e) CanCM4, (f) CM2.1, (g) GEOS5, and (h) CCSM3 forecasts over the North American domain. The anomaly unit is ^{o}C.

In addition to the hindcast evaluation, I have examined the predictive skill of real-time NMME SPI forecasts for the period from May 2012 to May 2014. Similar to the assessment based on NMME retrospective forecasts, predictive skill of monthly-mean P forecasts is generally low after the second month and errors vary among models. Although P forecast skill is not large, SPI predictive skill is high and the differences among models are small. The skill mainly comes from the P observations appended to the model forecasts. This factor also contributes to the similarity of SPI prediction among the six models. Still, NMME SPI ensemble forecasts have higher skill than those based on individual models or persistence, and the six-month SPI forecasts are skillful out to four months. The three major drought events occurred during the 2012-2014 period, the 2012 Central Great Plains drought, the 2013 Upper Midwest flash drought, and 2013-2014 California drought, are used as examples to illustrate the system's strength and weakness. For precipitation-driven drought events, such as the 2012 Central Great Plains drought, NMME SPI forecasts perform well in predicting drought severity and spatial patterns. For fast-developing drought events, such as the 2013 Upper Midwest flash drought, the system failed to capture the onset of the drought. The results of this study was presented in the 2014 AGU Fall Meeting.

Planned Work

- Analysis of choice, request, or opportunity (such as NAO performance, model produced ENSO composites, global change trends in each model, drought, initial soil moisture anomaly etc.)
- Basic evaluation of a candidate new model (climatological analysis, skill assessment etc.)
- Development of additional real-time verification products and assessment of real-time forecast skill of current events.
- Design of different approaches to accomplish systematic error correction, both in the mean and higher moments.
- Development of weighting scheme of N models to optimize skill in a consolidation, both deterministically and probabilistically.

Products

- NMME ENSO Composites available at http://www.cpc.ncep.noaa.gov/products/NMME/enso/

Presentations

Chen, L.-C., K. C. Mo, Q. Zhang, and J. Huang (2014), Predictive Skill of Meteorological Drought Based on Multi-Model Ensemble Forecasts: A Real-Time Assessment, Abstract H23N-1074 presented at 2014 Fall Meeting, American Geophysical Union, San Francisco, CA, 15-19 Dec.

Chen, L.-C., H. van den Dool, E. Becker, Q. Zhang, and J. Huang (2014), ENSO Simulations in the North American Multi-Model Ensemble: A First Look, NOAA/CPO/MAPP Climate Prediction Task Force Telecon, 20 November 2014.

Chen, L.-C., H. van den Dool, E. Becker, Q. Zhang, and J. Huang (2014), ENSO Simulations in the North American Multi-Model Ensemble: A First Look, 3rd Annual CICS-MD Science Meeting, College Park, MD, 12-13 Nov.

Chen, L.-C. (2014), Operational Drought Monitoring and Prediction in the U.S., National Ilan University, Ilan, Taiwan, 22 July 2014.

Chen, L.-C. (2014), Predictability of Objective Drought Indices Based on Multi-Model Ensemble and Hydroclimate Forecasts, Taiwan Typhoon and Flood Research Institute, Taichung, Taiwan, 14 July 2014.

Chen, L.-C., K. C. Mo, Q. Zhang, and J. Huang (2014), Meteorological Drought Prediction Using a Multi-Model Ensemble Approach, World Environmental & Water Resources Congress, Portland, OR, 1-5 June.

Other

Chen, Li-Chuan (Primary Convenor and Chair), Hydroclimatic Extremes: Drought, 2014 Fall Meeting, American Geophysical Union, San Francisco, CA, 15-19 Dec.

Performance Metrics	
# of new or improved products developed (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	6
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Science Support for Mesoscale Data Assimilation at EMC & JCSDA

Task Leader	E. Hugo Berbery (Xiaoyan Zhang)
Task Code	EBXZ_MDA2_14
NOAA Sponsor	Steven Goodman
NOAA Office	GOES-R Program
Contribution to CICS Research Themes (%)	Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 2: 100%

Highlight: An hourly-updated version of the NAM, called the NAM Rapid Refresh was built and placed over Europe and Africa. The month-long experiment was completed for clear-sky SEVIRI radiance data. The SEVIRI cloudy radiance data assimilation algorithm has been developed in GSI, and the initial single observation test has been completed.

Background

This report summarized the year-2 work of onging GOES-R project entitled "GOES-R Cloudy Radiance Data Assimilation in Mesoscale Model". Before GOES-R launched, Meteosat SEVIRI (Spinning Enhanced Visible and Infrared Imager) is treated as the proxy data of GOES-R ABI. The 1-month control run without SEVIRI radiance data and the baseline experiment with SEVIRI clear sky radiance has been done with the 12km resolution the hourly-updated NAM, known as NAM Rapid Refresh (NAMRR) system. The domain covered Atlantic Ocean, Europe and Africa (Figure 1). Beyond that, the initial development and testing of SEVIRI cloudy radiance has been finished.

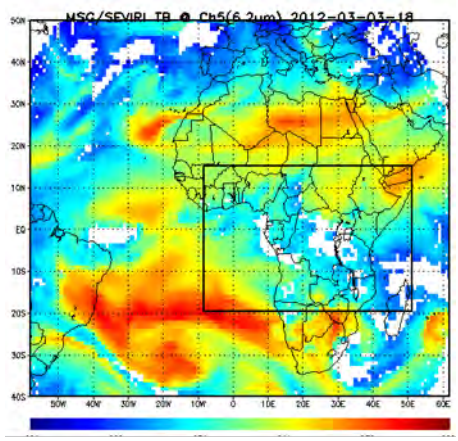


Figure 1: Model domain location, shaded color is SEVIRI brightness temperature that has been covered in each domain. The black rectangle shows the nested 4km domain in shifted domain, which still covered Lake Victoria.

Accomplishments

The control run and baseline experiment were conducted over the period of 1 March – 1 April, 2012, before the assimilation of cloudy SEVIRI radiance data in regional model. The control run experiment assimilated conventional data and satellite radiance data, including AMSUA from METOP-a, NOAA-15, NOAA-18 and NOAA-19; AMSUB from NOAA-17; HIRS3 from NOAA-17; HIRS4 from METOP-a and NOAA-19; IASI from METOP-a; AIRS from AQUA; and MHS from METOP-a and NOAA-19. In the baseline experiment assimilate SEVIRI clear-sky radiance, besides all the data that assimilated in control run. These two experiments were conducted with the NCEP regional operational forecast model NMM-B and the data

assimilation system NDAS with the domain configuration of Europe and Africa, including Lake Victoria. An hourly-updated version of the NAM, called the NAM Rapid Refresh was built and placed over Europe and Africa. The NAMRR includes the NMMB model, the NCEP-GSI data assimilation system, as well as pre- and post-processing procedures. The model grid-spacing is 12-km for the parent domain and 4-km for the nested domain (Fig.1). The hourly update advantage of NAMRR is adopted in this system, which assimilates observations every. This system is suitable for quickly evolving, high-impact events due to its hourly-update capability. The system is also suitable for short- to medium-range timescales due the fact that it makes 18 hr forecasts every hour while also conducting 84 hr forecasts at 00Z, 06Z, 12Z, and 18Z. In order to verify the forecast skill, NCEP gdas analysis was selected as the truth to do the verification. A grid-to-grid verification package was build up specifically for this region. The overall performance for SEVIRI clear-sky radiance for the 84-h forest is natural (Figure 2).

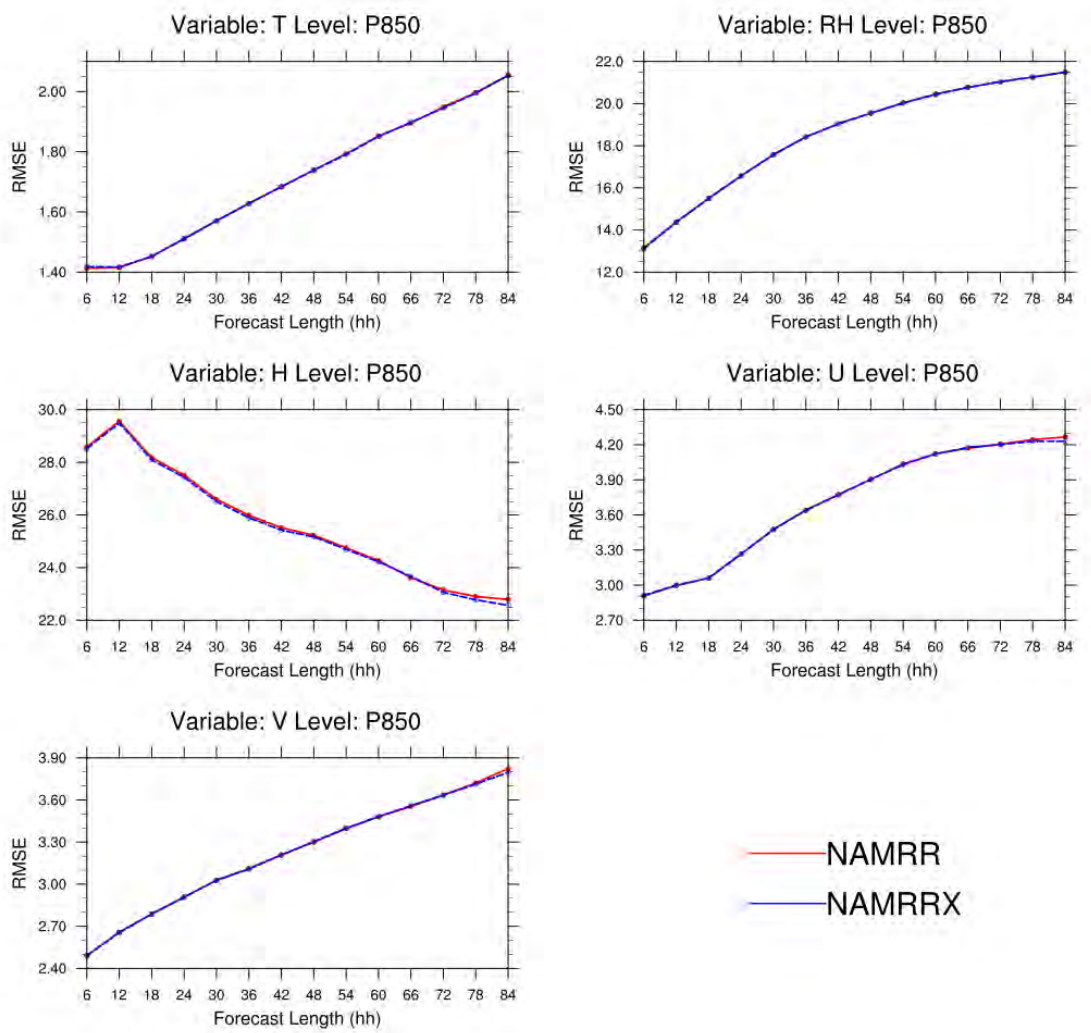


Figure 2. Time Averaged (1 MAR – 1 April, 2012) RMSE at 850hPa along with the forecast length for Control Run Experiment (NAMRRS, blue line) and Baseline Experiment (NAMRR, red line).

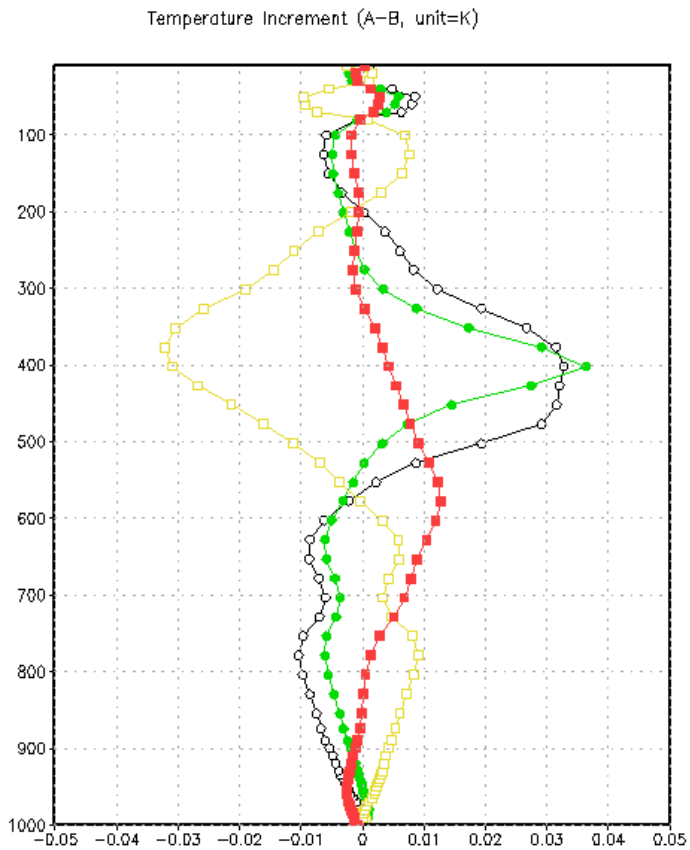


Figure 3. Increment of temperature (unit: K) with the single footprint radiance data under the condition of clear-sky (yellow line), low cloud (red line), middle cloud (black line), and high cloud (green line).

The SEVIRI cloudy radiance assimilation in GSI was developed and ongoing test. The algorithm for this research is treated cloud top height as an extra control variable (Lupu, 2012) at the observation space, which will be adjusted along with the minimization. The cloudy data source are EUMETSAT all-sky 16x16 products, including three cloud type of data, the low cloud radiance (900-600 hPa), middle cloud (600-300 hPa), and high cloud above 300 hpa. The cloud detection scheme (Eyre,1989) in GSI presented a relative similar cloud amount and reasonable cloud top height as that provided in EUMSAT product for low, middle, and high cloud. The channels are used to define background estimates of cloud parameters are 6.2, 7.4, 8.7, 10.8, 12.0 and 13.4 µm in the cloud detection scheme. Two water vapor channels (at 6.2, 7.4 µm) are assimilated, which keeps the consistent channel selection with clear-sky radiance assimilation. Figure 3 provides the single footprint test of cloudy radiance assimilation. The temperature of analysis was adjusted differently among four types of radiance data. The temperature above cloud top increased with the maximum value of 0.01K for low cloud, 0.032 K for middle cloud, and 0.038 K for high cloud. Obviously, the clear-sky data points brings opposite increment for the analysis. This result shows the cloudy radiance data was assimilated correctly, and ready to move forward to test the full data.

Planned work

- Continue work to access the performance of cloudy radiance in mesoscale model, and compare the forecast skill with the control run and baseline experiments
- Investigate more severe storm case study over Lake Victoria
- Work on the observation error tuning and bias correction for cloudy radiance
- Work on the data thinning algorithm for high resolution mesoscale model

Presentations

Xiaoyan Z., A. Collard J. Carley and G. DiMego, 2014: SEVIRI Radiance Data Impact to Regional Forecast using NAMRR , 3rd Annual CICS-MD Science Meeting, 12-13 November, 2014, College Park, MD

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**2**
# of invited presentations	**N/A**
# 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**

Use of LETKF sensitivity to improve QC of data from JPSS polar orbiting instruments and to detect the origin of the NCEP "5-day forecast skill dropouts"

Task Leader	Eugenia Kalnay
Task Code	EKEK_LETK_14
NOAA Sponsor	Mitch Goldberg
NOAA Office	JPSS/NESDIS
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: We succeeded and are working now to do final tests for operational implementation

Link to a research web page https://www.dropbox.com/s/ba69hh38ayx97av/Hotta-Dissertation-revised-after-defense.pdf?dl=0

Background

"5-day skill dropouts" at NCEP have been linked to the initial conditions, not the model. Although they are fewer after the implementation of the hybrid EnKF-3DVar (Kleist, 2015) they still take place and presumably are due to flawed observations that passed the standard QC. We developed Ensemble Forecast Sensitivity to Observations (EFSO) that allows to accurately estimate the impact of EACH observation on the forecast. Hotta (2014) showed that it can be used even with 6hr forecasts, opening the way to the application of Proactive QC (identifying and removing flawed observations that make the 6hr forecast worse).

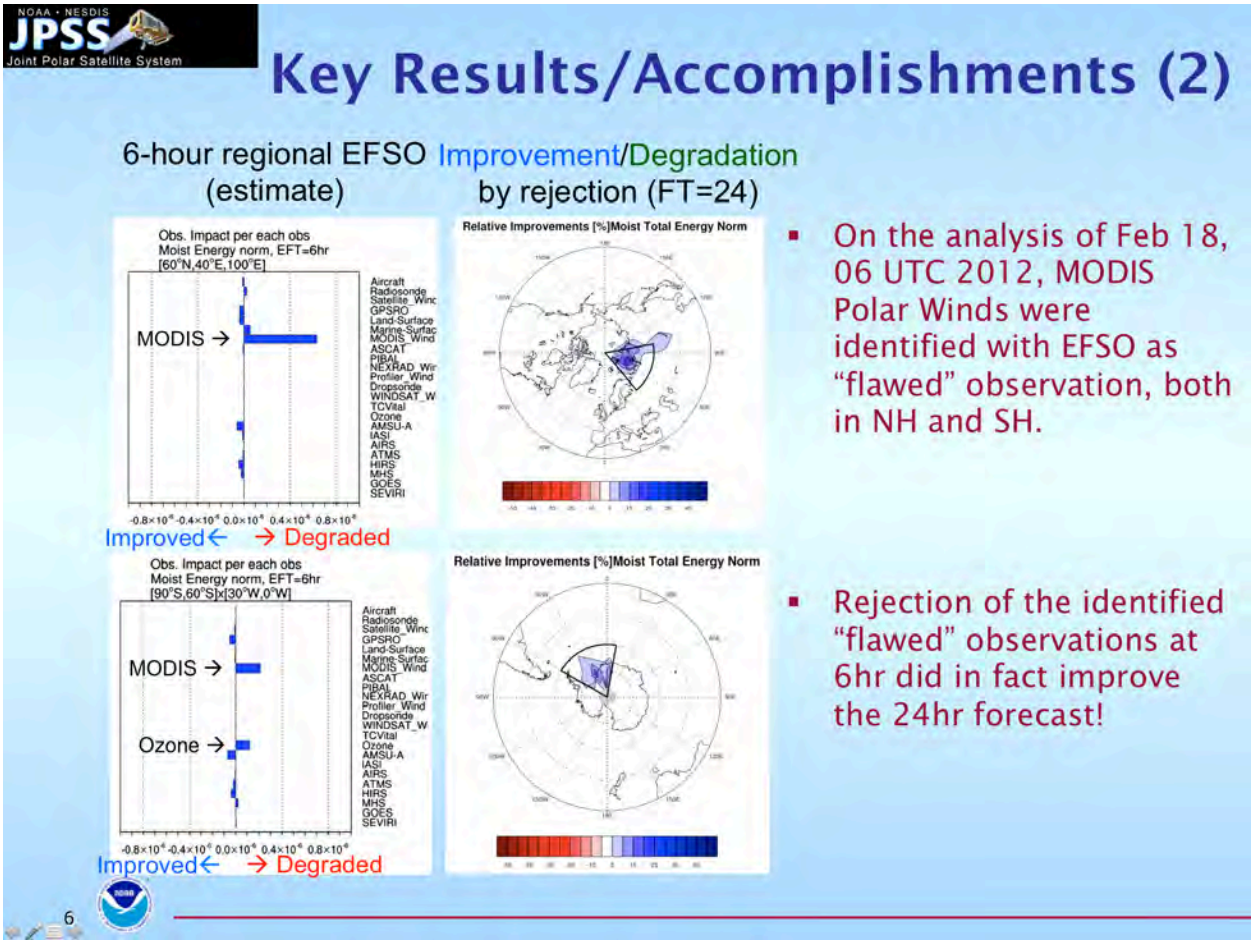
Accomplishments

We succeeded! Hotta (2014) tested these ideas on the JSDA test bed on a lower resolution GFS model with a hybrid LETKF/GSI data assimilation and showed that it was possible to identify flawed observations (in this case high latitude MODIS winds) by their impact on the moist total energy of the error (which is increased by the flawed observation).

As shown in the figure, 24hr forecasts with the observations identified as flawed by EFSO after 6hr withdrawn do indeed show a significant improvement both in the NH and in the SH.

In addition, Dr. Hotta develop the Ensemble Forecast Sensitivity to R, the observations error covariance denoted EFSR and showed it can be used to Tune R. For example reducing the error variances of AMSU, as suggested by EFSR, reduced the forecast error.

After Dr. Daisuke Hotta completed his PhD on Proactive QC and returned to the JMA, student Tse-Cun Chen took over the project and is performing all the necessary experiments testing EFSO in order to implement it operationally at NCEP, a task that will be directed by Prof. Daryl Kleist.



Planned work

- In order to go R2O student Tse-Chun Chen is carrying out experiments in order to show:
  - the forecasts without the flawed obs give an overall positive impact (first results indicate that the reduction of error continues for 3 days or more),
  - the EFSO approximation to the analysis change from withdrawing the flawed observations is fairly accurate;
  - the online (accumulated) impact is at least as good as the average individual impact;
  - estimate the maximum impact by doing the full analysis correction online.

- After this is completed, Prof. Darryl Kleist has kindly offered to direct the NCEP implementation.

- In addition to the improvement of the forecasts, we plan to save all the flawed observations together with all the needed metadata from the analysis (e.g., location, background forecast, etc.) and provide this information to NESDIS scientists familiar with the observation forward model in order to improve the algorithm and eliminate the source of the observation deficiency.

- Another application is testing new observing systems, whose impact on the 6 or 24hr forecasts can be easily computed for each observations. Similarly, the R of the new system can be tuned with EFSR.

Publications

Kalnay, E., Y. Ota, T. Miyoshi, and J. Liu, 2012: A simpler formulation of forecast sensitivity to observations: application to ensemble Kalman filters. Tellus A, 64, 18 462.

Ota, Y., J. C. Derber, T. Miyoshi, and E. Kalnay, 2013: Ensemble-based observation impact estimates using the NCEP GFS. Tellus A, 65, 20 038.

Hotta, Daisuke, 2014: PROACTIVE QUALITY CONTROL BASED ON ENSEMBLE FORECAST SENSITIVITY TO OBSERVATIONS, Ph. D. Thesis, U of Maryland

Products

See discussion above

Presentations

This work was presented in more than 6 national and international data assimilation Symposia. The last one was on March 17, 2015 at NCEP (EMC). We were invited to give a similar seminar at the Climate Test Bed at NCEP on May 18 at 10am. These include:

Chen, Tse-Chun, Daisuke Hotta and Eugenia Kalnay, 899: "No-cost" Proactive Quality Control (PQC) by the use of linearly approximated analysis *AMS Annual Meeting*, Phoenix, AZ (1/4 to 1/8/2015)

Hotta, Daisuke and Eugenia Kalnay, Proactive QC based on Ensemble Forecast Sensitivity to Observations (EFSO) and Ensemble Forecast Sensitivity to observation error covariance matrix R (EFSR)), *AMS Annual Meeting*, Phoenix, AZ (1/4 to 1/8/2015)

Kalnay, Eugenia and Tse-Chun Chen, Efficient Assimilation of Precipitation: Results with TRMM/TMPA and Plans for GPM , *AGU Fall Meeting*, San Francisco, CA (12/15 to 12/19/2014)

Chen, Tse-Chun, No-cost" Proactive Quality Control (PQC) by the Use of Linearly Approximated Analysis, *CICS-MD Science Meeting*, College Park, MD (11/12 to 11/13/2014)

Hotta, Daisuke, Proactive Quality Control based on Ensemble Forecast Sensitivity to Observation (EFSO), *Environmental Modeling Center Seminar* , College Park, MD (7/16/2014)

Kalnay, Eugenia, Daisuke Hotta, Yoichiro Ot, and Guo-Yuan Lien, Use of LETKF sensitivity to improve QC of data from JPSS polar orbiting instruments and to detect the origin of the NCEP "5-day forecast skill dropouts," *JPSS PGRR Science Review*, College Park, MD (4/29/14 to 5/1/2014)

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**5**
# of invited presentations	**8**
# of graduate students supported by a CICS task	**2**
# of graduate students formally advised	**3**
# of undergraduate students mentored during the year	

Scientific support for an updated analysis of global stratospheric temperature observations during the satellite era

Task Leader Isaac Moradi
Task Code IMIM_GSTO_14
NOAA Sponsor Richard Artz Richard.Artz@NOAA.gov
NOAA Office: ARL
Contribution to CICS Research : Themes (%) Theme 1 - 80%, theme 2 - 20%
Main CICS Research Topic : Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%): Goal 1 (100%)
Highlight: the main purpose of the work was to determine the changes in stratospheric temperature
Link to a research web page

Background

This project is in the support of the work of Stratosphere-troposphere Processes and their Role in Climate (SPARC) programme. SPARC is a core project of the World Climate Research Programme (WCRP) and coordinates international efforts to enhance our knowledge of the stratosphere to bear on relevant issues in climate variability and prediction [see http://www.sparc-climate.org/]

The main goal of the task was to assist in the analysis of global stratospheric temperature observations from multiple datasets, including observations from

- Stratospheric Sounding Unit (SSU)
- Microwave Sounding Unit (MSU) and Advanced MSU (AMSU)

In each case, multiple version of the data, from different research teams, are used.

Accomplishments

The main accomplashiments of the project include:

- Collecting available datasets of stratospheric temperature from NOAA, UK MetOffice, RSS, and UAH
- Analyzing homogenized time series of these datasets from several instruments including SSU, MSU, and AMSU – the SSU data were available from UK MetOffice, NOAA, RSS and UAH – the MSU data were only available from NOAA and UK MetOffice and the AMSU data were only available from NOAA
- Analyzing the datasets using empirical orthogonal function. The leading mode showed a decrease in stratospheric temperature until around 1995 then almost a constant period for the stratospheric temperature
- Although the time series of homogenized datasets agree to some extent after recent homogenization but still some noticeable difference exist among different datasets
- Multiple regression analysis showed that the solar, ENSO, QBO and aerosols play a role in the trend in stratospheric temperature. Figure 1 shows the time series of these variables that were used for multiple regression anomaly analysis

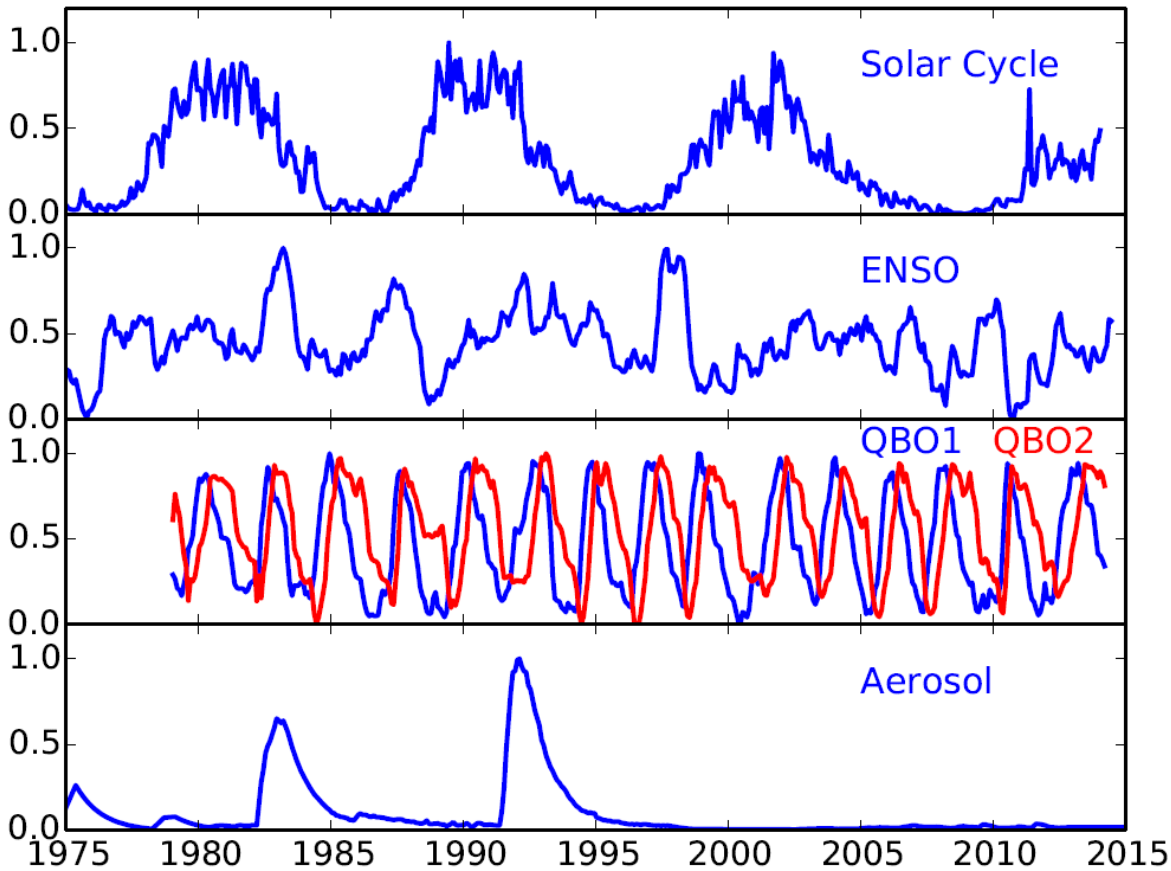


Figure 1: time series of different variables that were used for the multiple regression analysis.

Planned work

The final paper is under preparation. In addition the dataset will be provided to the community.

Publications

A paper titled "Observed Stratospheric Temperature Changes during the Satellite Era" to be submitted in Spring 2015.

Products

In addition to the analysis and corresponding results that will be provided to the community, the datasets are also planned to be available upon request.

Presentations

Observed Stratospheric Temperature Changes during the Satellite Era, 18th Conference on Middle Atmosphere, AMS Annual Meeting, Phoenix, AZ

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	**1**
# of non-peered reviewed papers	
# of invited presentations	**2**
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

This project helps improving the current CDR's of stratospheric temperature through intercomparison. A paper is under preparation that will be submitted soon. Two talks have been presented at the SPARC meeting as well as AMS annual meeting.

Graduate Student Support: ENSO-related Precipitation In 20th Century Reanalysis, Reconstructed Precipitation and CMIP5 Models

Task Leader Phil Arkin/Fernando Miralles Wilhelm
Task Code CICS Base
NOAA Sponsor N/A
NOAA Office N/A
Contribution to CICS Research Themes (%) Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%) Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%
Highlight CMIP5 models are able to simulate not only similar mean state of ENSO-related precipitation but also its seasonal evolution and transition as the observations, though detailed spatial patterns vary, though ENSO-related precipitation signals and asymmetry are weaker in models especially those models with the most severe biases in their precipitation mean state. The mean extreme of ENSO-related precipitation anomalies in 20CR, REC and some CMIP5 models are significant larger (on a significant level of 98%) in the 2nd half of 20th century than the 1st half.

Background

This task began in 2013 as part of my PhD degree research. The goal of this task is to investigating CMIP5 (Coupled Model Intercomparison Project Phase 5) models' simulation of ENSO (El Niño/Southern Oscillation) and the related precipitation. ENSO is the most significant interannual climate phenomenon, and is associated with large-scale changes in sea surface temperature (SST), surface pressure and atmospheric circulation. As a result, ENSO is the single most important determinant of variability in global precipitation fields on seasonal to interannual time scales. It is important to understand and predict ENSO and ENSO-related precipitation due to its connection with many environmental and societal problems. However, since ENSO is associated with complex atmosphere-ocean coupling, it is still difficult for models to accurately represent its behavior, as well as the related precipitation. The Coupled Model Intercomparison Project Phase 5 (CMIP5) collects most of the current state-of-the-art GCMs global wide, providing excellent opportunities to compare inter-model diversity of the ENSO-related precipitation and to further understanding ENSO. We compare ENSO-related precipitation in the whole 20th century among 20th Century Reanalysis (20CR), Reconstructed Precipitation (REC) and 9 Coupled Model Intercomparison Project Phase 5 (CMIP5) models (CCCma.CanESM2, CNRM-CERFACS.CNRM-CM5, CSIRO-QCCCE.CSIRO-Mk3-6-0, IPSL.IPSL-CM5A-LR, MIROC.MIROC5, MOHC.HadCM3, NASA-GISS.GISS-E2-R, NCAR.CCSM4 and NOAA-GFDL.GFDL-CM3) in both spatial and temporal perspective. Precipitation climatology, Empirical Orthogonal Function (EOF) and extended-EOF analysis, as well as ENSO-related precipitation composites results based on SST-constructed ENSO index are employed to present precipitation background and to extract ENSO-related precipitation signals in each data.

Out specific objectives for this task are:

1) To examine the ability of CMIP5 models to simulate ENSO-related precipitation variability during the 20th century;
2) To investigate how ENSO-related precipitation changes in the 20th century;
3) To further study how the atmospheric and oceanic circulation biases in models affect the resulted ENSO-related precipitation biases.

Accomplishments

We compare the spatial patterns of precipitation climatology, precipitation EOF and EEOF results, as well as the ENSO precipitation composites results among 20CR, REC and 9 CMIP5 models. The precipitation climatology results show that though REC is drier than 20CR on a level of 0.50mm/day, their seasonal- and annual-averaged precipitation patterns are alike. The 9 CMIP5 models all have good spatial correlation with the two observations, but biases such as the 'Double-ITCZs' in eastern tropical Pacific, an overly zonal and eastward-extended SPCZ and dry equator are quite obvious. The "Double-ITCZs" problem is most severe in DJF due to the strong and eastward-extended SPCZ. In MAM, models' "southern-ITCZ" biases in the eastern Pacific reach the peak, and in SON, the "northern-ITCZ" biases become the largest. There are other shared precipitation biases existing among the models comparing to 20CR and REC, e.g. overestimated precipitation over the tropical Atlantic and Indian Ocean, Maritime Continent, northern Pacific subtropical high region, central and southern Africa and Australia; underestimated rainfall over northern extra-tropical storm track region, central America and tropical South America and central United States.

EOF and EEOF results show that the spatial fields of the two observations correlate with each other very well and they display same seasonal evolution of ENSO. The 9 CMIP5 models also show ability to reproduce ENSO-like features of precipitation anomalies that is similar to the observations, in both annually and seasonally averaged perspectives. All of them can simulate similar seasonal evolution of ENSO and transition of ENSO phases as the observations. However, positive anomalies over Pacific Ocean in most of the models extend too far west and meridionally confined. The biases in the precipitation climatology results also influence the spatial patterns of the EOF and EEOF results. The four models (CSIRO-Mk3-6-0, IPSL-CM5A-LR, MOHC-HadCM3 and NOAA-GFDL-CM3) with the most severe dry equator or "Double-ITCZs" problem in their precipitation climatology also exhibit these problems in their ENSO-related precipitation pattern. These models perform poorest in the EOF and EEOF results, as well as having the weaker ENSO signals and asymmetry than the other models. The 9 CMIP5 models in general correlates better with 20CR than REC since 20CR has stronger ENSO-related rainfall in the "Double-ITCZs" region and weaker SPCZ.

In seasonal revolution of ENSO, some models and 20CR are more "ITCZ-dominant", with the maximum positive anomalies centers shift to northern ITCZ region in JJA, while REC and the other models are "center-fixed", that is, with the maximum center fixed in the western/central Pacific throughout the seasons. In addition, the results show that transition from one ENSO phase to the other (EOF/EEOF second mode) is different among datasets and is more difficult to simulate than the seasonal mean or evolution of ENSO (EOF/EEOF first mode). Different models might have different periods of ENSO transition cycles.

ENSO composites results show that models have weaker ENSO-related precipitation signals than the observations. CMIP5 models also have smaller seasonal variation of ENSO non-linearity than the observations, and present weaker asymmetry in the eastern Pacific. ENSO-related precipitation extremes (both maximum and minimum) is likely to become significantly larger in the second half of last century than the first half, as suggesting by 20CR, REC and MIROC5 results (on a significant level of 98%). The EOF time series results indicate the increase of the ENSO-related precipitation extremes in REC resides in its classic ENSO variability (2-7 year period) while 20CR is affected by both classic ENSO variability and decadal ENSO variability (7-15 year period).

Planned work

- Continue to investigate how the atmospheric and oceanic circulation biases in models affect the resulted ENSO-related precipitation biases, starting from the atmospheric adiabatic heating and vertical tendency;
- Investigate why each model's ENSO-related precipitation behaves in its own way.

Publications

Ni Dai and Phil Arkin, 20th Century ENSO-related Precipitation in 20th Century Reanalysis, Reconstructed Precipitation and CMIP5 Models (draft paper)

Products

Re-gridded CMIP5 monthly precipitation, sea surface temperature and adiabatic heating (2.5 by 2.5 degree, historical runs)

Presentations

- Ni Dai and Phil Arkin, 2015: ENSO-related Precipitation Change in 20th Century (oral), Graduate Research Interaction Day 2015 at University of Maryland – College Park (8 April)
- Ni Dai, 2015: ENSO-related Precipitation in CMIP5 Models and Change of ENSO-related Precipitation in 20th Century (student seminar), Dept. of Atmospheric and Oceanic Science, University of Maryland (31 March)
- Ni Dai and Phil Arkin, 2014: ENSO-related Precipitation Representation in CMIP5 Models (poster), 7th International Scientific Conference on the Global Energy and Water Cycle, Hague, Netherlands (14-17 July)

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**1**
# of invited presentations	**2**
# of graduate students supported by a CICS task	**1**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

NOAA Air Quality Forecasting Research and Operational Support (GMU)

Task Leader Daniel Tong
Task Code QTQT_AQFR_14
Main CICS Research Topic Climate Research, Data Assimilation and Modeling
Percent contribution to CICS Themes Theme 3, 100%
Percent contribution to NOAA Goals Theme 3, 100%
Highlight: 1) CICS scientists have Validated MODIS-based marine isoprene retrieval algorithm; 2) CICS scientists have Compared MODIS and VIIRS based marine isoprene products; and 3) Prepare to integrate and test the new Soumi-NPP VIIRS marine product in the NAQFC system.

Background

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

Accomplishments

1. Validate MODIS-based marine isoprene retrieval algorithm

A box model has been built to simulate the response of isoprene emission to changes in key variables. Six variables, including chlorophyll-a (Chl-a) concentration, emission factors, $K_d(490)$, sea surface temperature (SST), radiation, and wind speed, are examined with model simulations in which isoprene emission is calculated by changing the value of one parameter while holding constant the others (Figure 1). Simulation results reveal various sensitivity of isoprene emission to these parameters, changing linearly or semi-linearly with Chl-a, EF and SST, but nonlinearly with $K_d(490)$, wind speed, and irradiance. Among these parameters, isoprene emission is the least sensitive to change in SST. By changing SST from 0°C to 30°C, the estimated isoprene emission increases only by two-fold, suggesting that the effect of SST on air-sea gas exchange coefficient is small (Wanninkhof, 1992). Note that the effect of SST on isoprene emission is not only limited to air-sea exchange process, but also the production rates by different phytoplankton groups. For instance, Shaw et al. (2003) demonstrated that *Prochlorococcus* shows peak isoprene production rate near 23°C, and lowers values at higher or lower temperatures. This is consistent with the response in terrestrial isoprene emission, which show an increase with higher temperature until a maximum rate is reached, after which the rate will decrease with temperature (Guenther et al., 1993). Recent laboratory studies (e.g., Meskhidze et al., 2014) provided more evidence of a terrestrial plant-like response of isoprene emission to temperature change. Future studies need to consider the direct effect of SST on isoprene production rate.

The box model simulations show that isoprene emission displays much larger variability in response to other variables, in the order of 10^7-10^8 moles m^{-2} s^{-1}. In the tested irradiance range, isoprene emission changes from 0 to 2×10^7 moles m^{-2} s^{-1}. The emission increases rapidly when irradiance reaches 100 W m^{-2}, and then becomes steady at higher light intensity. This shape mimics the observed isoprene emission response to light sensitivity (Shaw et al., 2003; Columb et al. 2008), suggesting that the light dependence formula (Gantt et al., 2009) is able to capture the expected pattern of phytoplankton photoinhibition (Platt et al., 1980; Shaw et al., 2003). This result suggests that emission algorithm needs to consider the temporal variation of light intensity in order to capture the variability in marine isoprene emission to better support high temporal resolution model simulations.

Isoprene emission increases exponentially with wind speed, which dominates the mass transfer coefficient. Isoprene emission rate is low under calm condition (0.5 m/s or lower), but quickly increases to 5.6×10^5 moles m^{-2} s^{-1} at 1m/s wind speed. The emission flux increases 20-fold at 5m/s and more than 100 times at 10m/s wind speed from the 1m/s level (Fig. 1). This trend appears consistent with the observed emission fluxes that show higher values at high wind speed (Fig. 1). Note the mass transfer equation here assumes a steady-state between isoprene emissions and removal through outflow into the air. At constant high wind area, isoprene could be depleted and the mass-transfer based mechanism could cause over-estimation of isoprene emission over these regions.

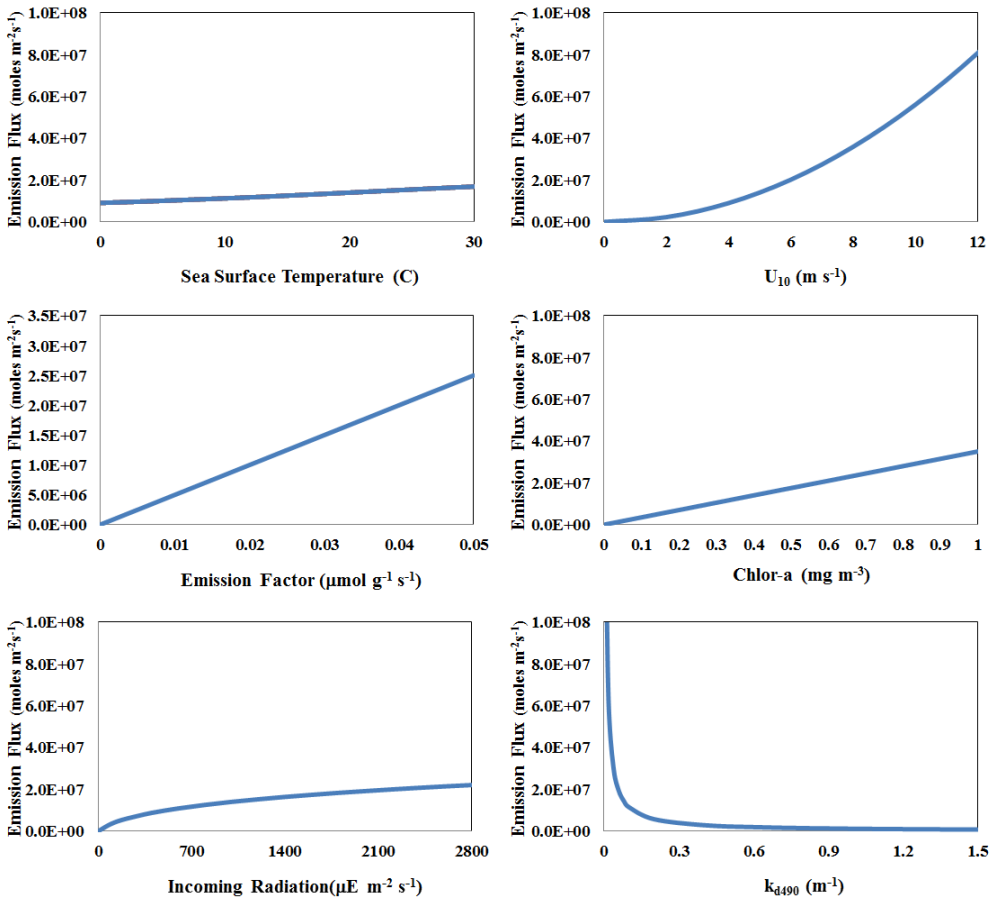


Figure 1. Sensitivity of derived isoprene emission flux to environmental parameters in the emission algorithm. Except the varying parameters, the inputs are kept constant with the following designated values: SST at 20°C, U_{10} at 5 m s^{-1}, EF at 0.028 mmol $g^{-1}d^{-1}$, Chlor-a at 0.4 mg m^{-3}, radiation at 500 Wm^{-2}, and kd490 at 0.06 m^{-1}.

Isoprene is very sensitive to chlorophyll-a concentrations and emission factors. There are large uncertainties in both the type of phytoplankton and the emission factors associated with each type. WE are currently analyzing the emission factors in literature. The most sensitive environmental factor, however, is $K_d(490)$. This is because $K_d(490)$ determines the euphotic zone height and hence the total . It is very sensitive to the low values of $K_d(490)$. In some algorithm, there is no limit of the $K_d(490)$ values, causing problems in the Hmax and the isoprene emissions. Isoprene algorithm needs to consider the low values or a cutoff value must be enhanced to avoid unrealistic high isoprene values. Other studies have used

the climatological depth. Our team is currently comparing the effect of using the H_{max} algorithm from Gantt et al. (2009) with that using the mixed layer depth from climatology on the isoprene retrieval.

2. Compare MODIS and VIIRS based isoprene products

Another major progress during the past period is to conduct a throughout comparison between MODIS isoprene and VIIRS isoprene to understand the difference between these products over time and space, as well as the underlying factors that contribute to the difference. The emission flux based on MODIS and VIIRS satellite products are shown on Figures 2 and 3. It is noted that the spatial pattern for two emission datasets are similar. MODIS data show a relatively stronger overall emission than the VIIRS product. The zonal averaged emission rates (Fig. 3) show that the MODIS emission is higher over the middle latitude in both hemispheres while the VIIRS emission is stronger in tropical regions. Total isoprene emissions estimated from MODIS are approximately 20% higher than from VIIRS.

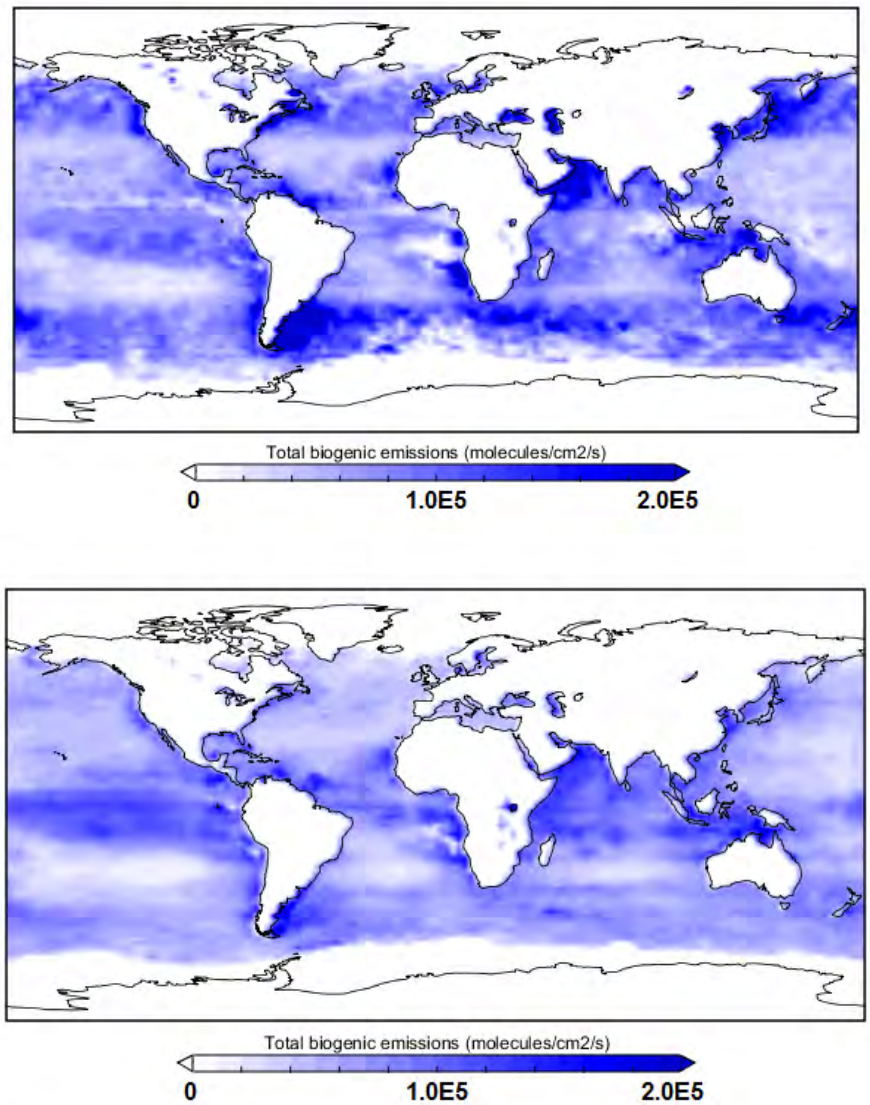


Figure 2. The spatial distribution of estimated isoprene emissions over ocean in October, 2013 from MODIS (up) versus JPSS VIIRS (down).

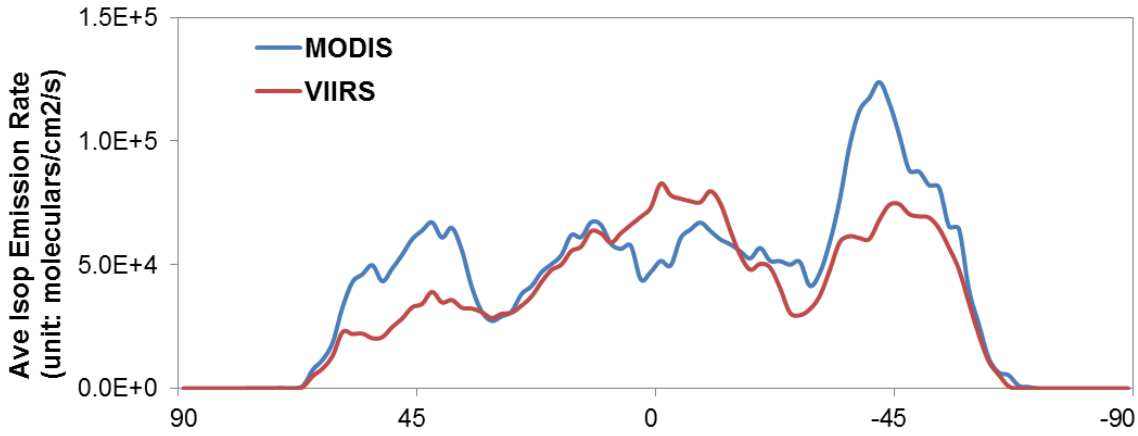


Figure 3. Zonal average of estimated isoprene emission flux.

In order to further understand the difference in emission datasets, we compare the spatial variation of chlorophyll-α concentrations and kd490 values derived from MODIS and VIIRS. Figure 4 shows the zonal average of chlorophyll- α concentrations from both sensors. The VIIRS concentrations on the north hemispheric ocean are noticeablely higher than that from MODIS. In other regions, both concentrations are comparable in magnitude. Figure 5 shows the variation of the diffuse attenuation coefficients of downwelling irradiance at 490-nm (kd490) along the latitude. The VIIRS observations are overall higher than MODIS observations. The largest difference occurs over the north hemispheric ocean. Usually, a large diffuse attenuation coefficient means that the beam is quickly "attenuated" (weakened) as it passes through the ocean. According to the algorithm that we used in this emission estimate, the isoprene emission is linearly proportional to the chlorophyll-α concentration [Chl- α] and the maximum height of possible extent of the planktonic euphotic zone [Hmax].

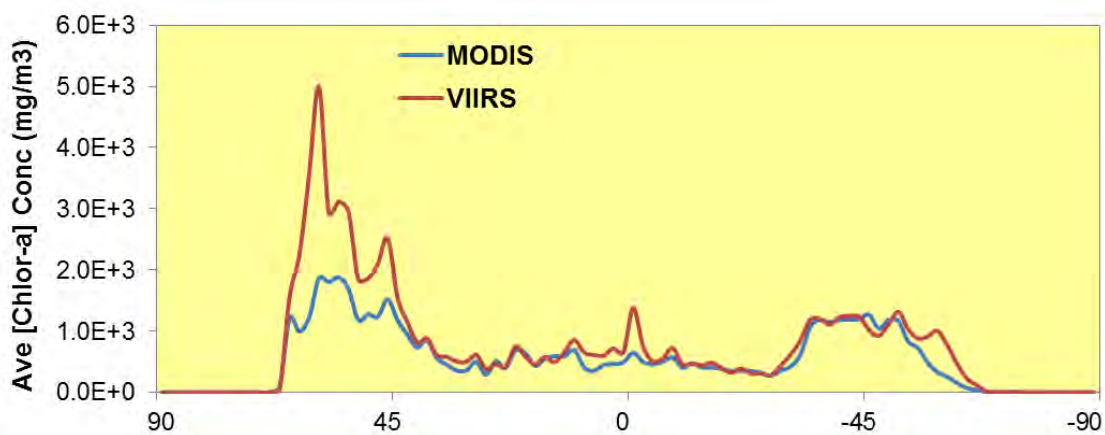


Figure 3. Zonal average of chlorophyll- α concentrations based on MODIS and VIIRS satellite observations.

The higher concentration of chlorophyll-α in VIIRS data positively contribute to the isoprene emissions over ocean, while the higher values of Kd-490 negatively affect the isoprene emission. Because the iso-

prene algorithm designates that the emission is exponentially related to the inverse of Kd490, the isoprene product is more sensitive to the change in kd490 than [Chl-a]. Consequently, the isoprene emissions estimated based on VIIRS is smaller than that based on MODIS.

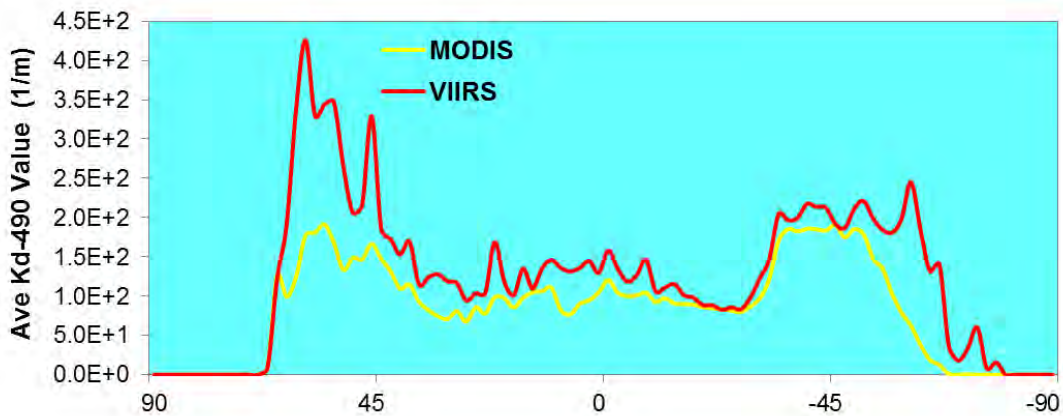


Figure 4. Zonal average of Kd-490 values based on MODIS and VIIRS satellite observations.

3. Prepare to integrate and test the new Soumi-NPP VIIRS marine product in the NAQFC system

While the team is working on further understanding of the uncertainties of the VIIRS isoprene product, the NOAA NAQFC modeling system has been prepared for testing the beta version of the product. A NAQFC-b (Lee et al., 2009; 2010), a research version of NAQFC system with a simulation domain covering the CONUS at 12 km horizontal grid spacing was constructed for this study. This system is similar to the coupled NAM-CMAQ modeling system used in the NAQFC, but CMAQ (version 4.7.1) was used. CMAQ 4.7.1 is a newer version than that currently used in the NAQFC. PREMAQ (Otte et al., 2005), an interface processor that provides the means for data exchange from NAM to CMAQ, was used to generate the CMAQ model-ready meteorological input. This processor remaps the meteorology data from a rotated latitude-longitude map projection on an Arakawa-B staggered grid to a Lambert conformal map projection onto an Arakawa-C staggered grid. Horizontally, PREMAQ subsets and transforms the meteorological fields from NAM so that they are ready to be inputted into CMAQ's CONUS domain. Vertically, PREMAQ interpolates NAM's 60 hybrid (top 18 isobaric levels and 42 sigma-p levels) layers to CMAQ's 22 terrains following sigma-p layers with uneven grid spacing. There are 14 layers below 2 km. The model top is 200 pa. The dry deposition velocities for gas and particulate species were also calculated in PREMAQ. Two treatments were used to prepare the model-ready emissions data. For emissions sources that are independent of meteorological influence, emissions projections were processed as a "pre-simulation generated CMAQ input" by using a tool called SMOKE (Sparse Matrix Operator Kennel Emissions) (Houyoux et al., 2000) in order to account for temporal and holiday/non-holiday variations that are year-specific. On the other hand, for those sources influenced by meteorology, their projected rates were generated by using PREMAQ and the forecasted meteorological fields from the NMM model.

Planned Work

1. Support ARL Observational System Simulation Experiments (OSSEs) Project

The Observational System Simulation Experiments (OSSEs) project is a NOAA Research Office's multiple line offices effort to evaluate the potential impact of proposed new observing systems. OSSEs have proven its value by having determined correctly the quantitative potential for several proposed satellite

observing systems in recent past prior to their launches; evaluated trade-offs in orbits, coverage and accuracy for space-based wind lidars; and were used in the development of the methodology that led to the first beneficial impacts of satellite surface winds on numerical weather prediction. ARL attempts to apply the concept to air quality observation systems. Space-based and high-altitude airborne-based meteorological measurements offer an effective way to supplement the conventional observations not only in the traditionally data poor regions, but also at higher spatial and temporal resolution than are available from the conventional observations. This is also true for air quality related measurements. Satellite-based and high-altitude airborne-based remotely sensed air quality data supplement land-based data and routinely commercial-flight-based and other measurement-campaign acquired remotely sensed and in-situ observations. It is important to optimize the proportionality, mix and placement of these wide ranges of measurements and data acquisition options for cost-effectiveness. To achieve this, GMU will assist ARL scientists to conduct OSSEs with NCEP's GSI and 3DVar data assimilation protocol to accelerate the transition from research to operation.

2. Integrate and test Soumi-NPP VIIRS marine emission product into NAQFC

ARL is working with the National Weather Service to develop and maintain the National Air Quality Forecast Capability (NAQFC) modeling system. Currently NAQFC includes isoprene emission from terrestrial sources (trees and grass), but not marine phytoplankton. GMU will work with ARL to integrate the marine isoprene emission developed by GMU into NAQFC CONUS domain. The GMU staff will work onsite within ARL facility to bring in the isoprene data, process the data into the right data format (IOAPI with NAQFC) and projection (Lambert Conformal Conic), so that NAQFC can readily take the data with minimum extra burden to the operational team if the new product is promoted into the operational mode later. This task is a continuation of the ongoing JPSS isoprene project (funding support from JPSS office).

Publications

Tong D., H. Lei, L. Pan, T. Chai, H. Kim, P. Lee, R. Saylor, M. Wang, and S Kondragunta. (2014). Assimilation of satellite oceanic and atmospheric products to improve emission forecasting, Air Pollution Modeling and its Application XXIII, D. Steyn and R. Mathur (eds.), Springer Proceedings in Complexity, pp. 563-569, doi:10.1007/978-3-319-04379-1_93.

Lei, H., D. J. Wuebbles, X.Z. Liang, Z. Tao, S. Olsen, R. Artz, X. Ren, and M. Cohen. (2014). Projections of atmospheric mercury levels and their effect on air quality in the United States. *Atmospheric Chemistry & Physics.* 14(2): 783-795. doi:10.5194/acp-14-783-2014

Lei, H. and J. X. L. Wang (2014). Sensitivities of NOx transformation and the effects on surface ozone and nitrate. *Atmospheric Chemistry & Physics.* 14(3): 1385-1396. doi: 10.5194/acp-14-1385-2014

Lei, H. and J. X. L. Wang (2014). Observed characteristics of dust storm events over the western United States using meteorological, satellite, and air quality measurements. *Atmospheric Chemistry and Physics*. 14(15): 7847-7857. doi:10.5194/acp-14-7847-2014.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**4**
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Evaluation of Ozone and PM2.5 Forecasting with NO_2 Emission Data Assimilation (Nina Randazzo)

Task Leader Daniel Tong
Task Code QTQT_EOPM_14
Main CICS Research Topic Climate Research, Data Assimilation and Modeling
Percent contribution to CICS Themes Theme 3, 100%
Percent contribution to NOAA Goals Theme 3, 100%
Highlight: 1) CICS Intern Nina Randazzo

Background

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

Accomplishments

Nina Randazzo worked with Dr. Daniel Tong at ARL to study carbon monoxide (CO) trends over several United States Urban areas in July from 2005 through 2012 (before, during, and after the economic recession). She examined both total column CO from the AIRS instrument and ground-level CO from the EPA AQS network. We observed a trend seemingly related to the recession in the ground-level CO but many disparities with the total column CO. The AIRS total column measurements are most sensitive at a 500-mb level, an area where the trace gas concentration may be more influenced by long-range transport rather than local emissions. For this reason, she ran 48-hour back trajectories at a 500-mb level using the HYSPLIT meteorological model. She also obtained maps of biomass burning events from NASA's FIRMS Fire Mapper, which uses fire detection data from MODIS. The focus of this part of the research was on Atlanta because this city showed strong disparities between ground-level CO and because Atlanta receives upper-level transport sometimes from the ocean and sometimes from inland (a disparity that would be interesting for comparison). This research showed at least qualitative evidence that upper-level transport from inland, especially during times of large amounts of regional biomass burning, resulted in a greater total column CO measurement, while these factors did not seem to have an effect on ground-level CO. I presented these results as a poster at the Community Modeling and Analysis Systems (CMAS) conference at the University of North Carolina in October 2014.

After that conference, Nina began focusing on quantitative analysis. First, she began looking at case studies of days in July with different amounts of regional biomass burning and different upper-level transport regimes for the southeast United States. In addition to the years previously mentioned, she also looked at July 2013 at the suggestion of Dr. Li Pan, an ARL scientist who has examined United States biomass burning during this time period. After finding several days with strong contrasts in terms of these factors, she began the process of examining CMAQ model predictions of CO at various altitudes for the Atlanta area for these days. The purpose of this part of the project is both to the effects of such factors in the model and to compare these effects to observed values. After experiencing many technical difficulties with CMAS's AMET model evaluation software, I have begun to copy and alter code from Dr. Pan (with his permission) to avoid the use of AMET.

Throughout this time, she has also been doing programmatic work with NOAA Climate Program Office (CPO) Atmospheric Chemistry, Climate, and Carbon Cycle (AC4). She has summarized progress reports of funded projects, and edited the program website and written website content. She also assisted in the

organization of the CrIS user workshop, which took place in September 2014. She also helped to put together and proofread the document that summarized the findings of that workshop.

Presentations

1. Nina Randazzo, Daniel Tong, Pius Lee, Xiaozhen Xiong, Feng Ding, Juying Warner, Monika Kopacz, 2014. Comparisons of CO emission trends over US large cities observed by satellite remote sensing and ground observations during the 2008 Great Recession. The **13th Annual CMAS Conference,** October 27-29, 2014, Chapel Hill, NC.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	**1**

Understanding the Impact of AMSU Derived Orbital Hydrological Products on Global, Merged Precipitation Products

Task Leader Ralph Ferraro; Wenze Yang; Tom Smith; Huan Meng
Task Code RFWY_CDR_14
Main CICS Research Topic Climate Research, Data Assimilation, and Modeling
Percent contribution to CICS Themes Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Percent contribution to NOAA Goals Goal 1: 50%; Goal 2: 50%
Highlight: Initial assessment study displays promising results.

Background

For the past two decades, several global precipitation products have been developed through the utilization of passive microwave (MW) rainfall retrievals which are then merged together with satellite infrared (IR) measurements and then surface rain gauges (the latter of which is primarily done on monthly time scales). It has been demonstrated that the primary error source in these products stems from the number of satellite overpasses from the MW measurements over a given time period – the strong diurnal cycle of rainfall can only be captured by frequent MW observations. With the advent of the first Advanced Microwave Sounding Unit (AMSU) on NOAA polar orbiting satellites in 1998 (and subsequent sensors in operation on seven additional satellites), the diurnal cycle of precipitation can be captured on a global scale every 3 hours or less. This has reduced the error magnitudes in the blended precipitation products, although no specific quantification of this impact has been documented. Thus, the primary goal of the this project is to demonstrate the importance of the "AMSU Hydrological CDR Bundle" (level 2, L2 products) in the broader based, "blended" product suite (level 3, L3) of precipitation and possibly, other parameters such as total precipitable water (TPW).

Accomplishments

A. Perform Initial Assessment of L3 Rain Product Using the CONUS as a Focus Area

A set of observing system simulation experiments (OSSEs) was performed using AMSU precipitation data from five satellites for November 2008. The satellites are NOAA 15 (N15), NOAA 16 (N16), NOAA 17 (N17), NOAA 18 (N18) and MetOp-A (MOA). Data used for the experiments are roughly over the contiguous US, 125°W-65°W by 25°N-60°N. Data over this domain are binned into a daily and 1° spatial grid. Binning is done by averaging all data for the day and 1° region. Comparisons are against the GPCP 1° daily estimates. Two sets of comparisons were done, one for daily averages and another for monthly averages. Monthly averages were computed for 1° regions with data for at least 10 days of the month. Experiments were done by averaging subsets of the five satellites and comparing the results to the average of all five for a day or the month. We evaluated individual satellites and combinations of two, three, and four satellites for our testing. This gives a total of 30 different subsets to test.

As a first test we consider changes in sampling and spatial correlation against GPCP, for both monthly and daily averages. Monthly statistics are given in Table 1, which also defines the subset of satellite data used for each test number. We assigned lowest test numbers to subsets with the fewest satellites and highest numbers to subsets with the most satellites. As expected, correlations generally increase as CDR Quarterly Status Report Template NESDIS/NCDC CDR Program the number of satellites increases. We further evaluated test 25 (3 satellites), 27 (4 satellites), and 31 (all 5 satellites), using comparisons against GPCP for daily and monthly averages.

Table 1. Statistics for monthly averaged satellite data using the satellites identified by number: 1) N15, 2) N16, 3) N17, 4) N18, and 5) MOA. Under Test the 5 columns correspond to the 5 satellites in the order indicated here, and a 1 indicates that the satellite is used. Spatial correlation is relative to the average of all five. Highest correlations for each set (1, 2, 3, and 4 satellites) are in bold and lowest correlations for each set are underlined.

Test Number	Satellite 1 2 3 4 5	Sampling Fraction	Spatial Correlation
1	1 0 0 0 0	1.000	0.614
2	0 1 0 0 0	0.957	0.586
3	0 0 1 0 0	0.000	-----
4	0 0 0 1 0	1.000	**0.672**
5	0 0 0 0 1	1.000	0.620
6	1 1 0 0 0	1.000	0.630
7	1 0 1 0 0	1.000	0.614
8	1 0 0 1 0	1.000	0.691
9	1 0 0 0 1	1.000	0.676
10	0 1 1 0 0	0.957	0.586
11	0 1 0 1 0	1.000	0.682
12	0 1 0 0 1	1.000	0.660
13	0 0 1 1 0	1.000	0.672
14	0 0 1 0 1	1.000	0.620
15	0 0 0 1 1	1.000	**0.703**
16	1 1 1 0 0	1.000	0.630
17	1 1 0 1 0	1.000	0.683
18	1 1 0 0 1	1.000	0.673
19	1 0 1 1 0	1.000	0.691
20	1 0 1 0 1	1.000	0.676
21	1 0 0 1 1	1.000	**0.712**
22	0 1 1 1 0	1.000	0.682
23	0 1 1 0 1	1.000	0.660
24	0 1 0 1 1	1.000	0.704
25	0 0 1 1 1	1.000	0.703
26	1 1 1 1 0	1.000	0.683
27	1 1 1 0 1	1.000	0.673
28	1 1 0 1 1	1.000	0.703
29	1 0 1 1 1	1.000	**0.712**
30	0 1 1 1 1	1.000	0.704
31	1 1 1 1 1	1.000	0.703

Considering the daily averages (Fig. 1), the precipitation patterns are all similar but the influence of increased sampling is clear. In particular, greater sampling is able to resolve some small-scale daily variations present in GPCP. Sampling is less of a problem for the monthly averages, reflected in the similarity of the monthly maps (Fig. 2). Thus, for short term hydrological applications like river flow models, having multiple satellites is clearly beneficial to a more accurate precipitation product and resulting river flow and discharge.

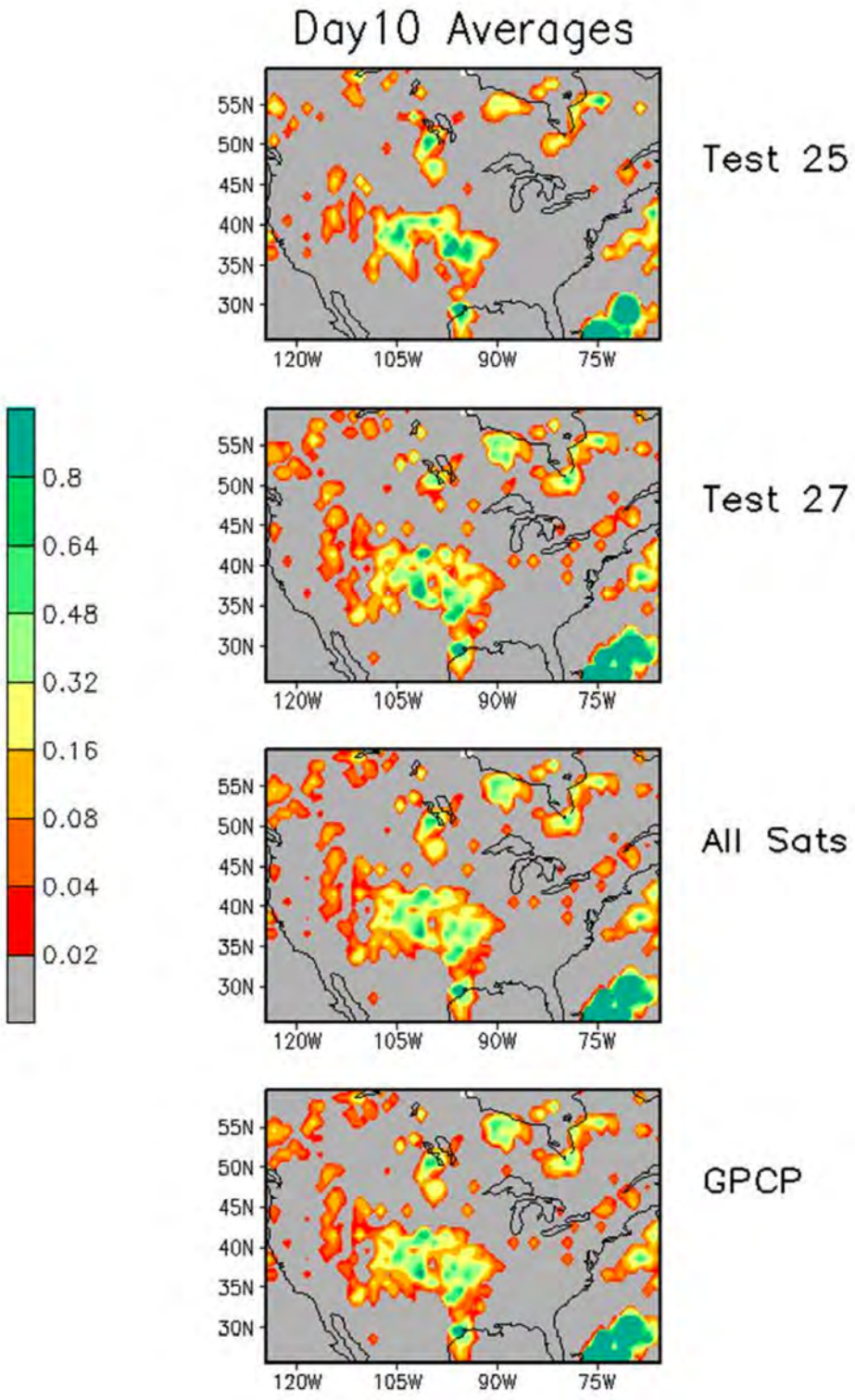


Figure 1. Daily precipitation averages (mm/hr) for 10 November 2008. Test 25 is for N17, N18 and MOA combined; Test 27 is for N15, N16, N17 and MOA combined; All satellites is for N15, N16, N17, N18 and MOA combined; GPCP is the 1 degree daily satellite product (normalized by monthly gauges).

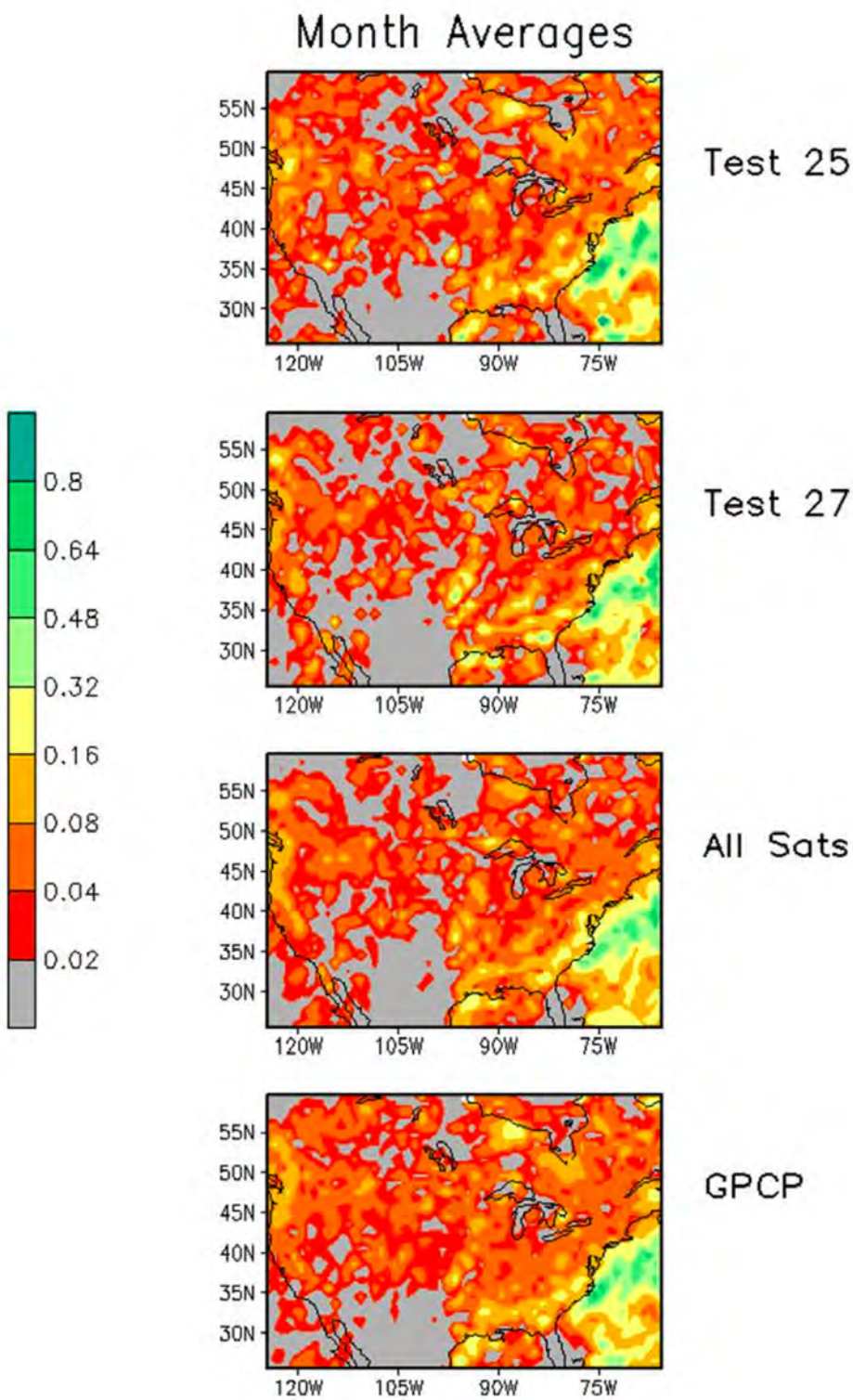


Figure 2. As in figure 1, but for the entire month of November 2008.

B. Devise Impact Study Parameters with End Users

We had several telecons and communications with P. Xie (CMORPH), G. Huffman (TMPA) and J. McCollum (FM Global) on devising and impact study for use with the FM Global Hydrological Model that

is used as part of the hazards assessment team; FM Global examines insurance risks for their reinsurance program. It was decided that 5-years of data were required to accurately spin up the hydrological model (more than we initially thought; they changed their model and how it's used after we spun up this project). It's unlikely that the CMORPH data set could be reprocessed in a timely manner without the AMSU TCDR's, however, the TMPA product does exist with and without AMSU rainfall (pre-TCDR), so most likely, and we'll utilize these data sets for the FM Global study. Furthermore, we'll focus on two river basins: Susquehanna and Ogeechee.

Planned Work

The planned work is scheduled as following:

- Expand domain to global and work with end users on specific time periods; potentially include other satellites in new product;
- Devise impact study parameters with end users.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

Subseasonal Tropical-Extratropical Interaction

Task Leader:	Sumant Nigam
Task Code:	SNSN_STEI_14
NOAA Sponsor:	Mike Halpert
NOAA Office:	NWS/CPC
Contribution to CICS Research Themes (%):	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%):	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: The graduate student has been reading background material and learning GrADS while completing her coursework.

Background

Recent studies suggest that during meteorological summer (JJA) the interannual variability of North American precipitation has been increasing over the last 6 decades. However, upon closer examination it is evident that changes in this variability are more nuanced than previously thought. During the warm half of the year (i.e., April-September) changes in the variability of North American precipitation are sensitive to both the choice of region and definition of season. During spring (AMJ) both the Great Plains and Southeast show increases in interannual variability of precipitation, however, neither region shows a significant increase during summer (JAS).

Accomplishments

So far, Natalie Thomas, a first-year graduate student, has spent her time on the project reading background reference papers on the topic assigned by Dr. Scott Weaver and Prof. Sumant Nigam. She is also becoming familiar with GrADS software via the online tutorial. Most recently, she has been working with sample data provided by Dr. Weaver to practice with GrADS scripting and plotting and to learn how to create anomaly data sets using the software.

Planned work

Natalie Thomas will start out the new fiscal year by focusing on precipitation in the time window of longer than two weeks but shorter than seasonal.

Other

Natalie Thomas is completing her first-year graduate coursework at UMD AOSC.

Performance Metrics	
# of new or improved products developed (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	
# of graduate students formally advised	1
# of undergraduate students mentored during the year	

Professor Nigam and Dr. Weaver are the advisors for graduate student Natalie Thomas.

1.6 Climate Data & Information Records/Scientific Data Stewardship

CICS Support for the National Oceanographic Data Center

Task Leader: Hugo Berbery
Task Codes: EBEB_AOML_14, EBEB_NJGS_14, EBEB_NODC_14, EBEB_OADS_14, EBEB_OSSI_14, EBEB_PSST_14, EBEB_SARS_14, EBEB_VDMS_14, EBEB_WOD_14
NOAA Sponsor: Dr. Krisa Arzayus
NOAA Office: NOAA/NESDIS/NODC (now NOAA/NESDIS/NCEI)
Contribution to CICS Research Themes (%): Theme 1: 17% Theme 2: 32% Theme 3: 51%
Main CICS Research Topic: Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%): Goal 1: 33% Goal 2: 5% Goal 3: 40% Goal 4: 8% Goal 5: 14%
Highlights: In 2014, CICS played a significant role in the development of improved satellite data products, working with the ocean science community to provide global and regional ocean data, and by validating new space-based ocean observing technologies. CICS enhanced NOAA's ability to understand, predict and communicate climate variability by data distribution and education through web based satellite data, detailed descriptions of these data, and the continued enhancement of the World Ocean Database.
Link to a research web page: www.nodc.noaa.gov

Background

Archival of oceanographic data at NODC for long-term preservation; Coral Reef Temperature Anomaly Database (CoRTAD) Version 5 Development; Processing and Merging of hydrographic data into the World Ocean Database (WOD); Quality Control and Application of Global Temperature and Salinity Anomaly Fields derived from WOD; National Oceanographic Data Center Satellite Support; Bodega Marine Lab in-situ buoy observations; IOOS Regional Association (RA) Southeast Coastal Ocean Observing Regional Association (SECOORA), IOOS Regional Association (RA) Great Lakes Observing System (GLOS); NOAA Rolling Deck to Repository (R2R) from the NOAA Office of Marine and Aviation Operations (OMAO); Stewardship of thermosalinograph data; Quality control of Regional Climatologies; Development of the data distribution, archive and quality monitoring systems for Jason-2/3 products; Development of the Gridded level-3 products from SMOS and Aquarius satellites; Development of the archive appraisals and technical solutions designed to improve archive, disseminate and access to NOAA's Ocean Color products; Ocean acidification data management project development; NODC online submission system (Send2NODC) development; Transfer of data from the Carbon Dioxide Information Analysis Center (CDIAC) to NODC; Transfer of data from the Biological and Chemical Oceanography Data Management Office (BCO-DMO); Global carbonate saturation states (Omega) data processing; eXpendable BathyThermograph (XBT) Bias Correction Availability; Extended Pathfinder V5.2 SST through 2012; Generate/improve software necessary for Group for High Resolution Sea Surface Temperature (GHRSST) data archiving and ensure the quality assurance for the archive; Generate software to create browse images for the GHRSST SSTs in near-real time; Archiving of the NESDIS/STAR generated SAR-Wind product from the Canadian RADARSAT-2 satellite; Participate in Amazon cloud pilot project to carry out pathfinder 5.3 analysis; Process ~30 years (1981-2012) of pathfinder 5.3 in cloud environment.

Dr. Sheekela Baker-Yeboah (NOAA Collaborators: Dr. Krisa Arzayus); Mathew Biddle (NOAA Collaborators: Dr. Krisa Arzayus, Steven Rutz, Dr. Deirdre Byrne); Liqing Jiang (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons); Alexey Mishonov (NOAA Collaborators: Dr. Krisa Arzayus, Tim Boyer); James Reagan (NOAA Collaborators: Dr. Krisa Arzayus, Tim Boyer); Korak Saha (NOAA Collaborators: Kenneth

Casey, John Relph, Thomas Ryan, Deirdre Byrne, John Sapper, William G. Pichel); Yongsheng Zhang (NOAA Collaborators: Dr. Deirdre Byrne, Dr. Eric Bayler)

NOAA's National Oceanographic Data Center (NODC) is an organization (http://www.nodc.noaa.gov/) that provides scientific and public stewardship for national and international marine, environmental, and ecosystem data and information. With its regional branch assets and divisions (http://www.nodc.noaa.gov/General/NODC-About/orgchart.html), NODC is integrated to provide access to the world's most comprehensive sources of marine environmental data and information. NODC maintains and updates a national ocean archive with environmental data acquired from domestic and foreign activities and produces products and research from these data which help monitor global environmental changes. In January 2015, with the passing of the FY2015 budget, the consolidation of the National Oceanographic Data Center, National Climatic Data Center, and the National Geophysical Data Center into the National Centers for Environmental Information (NCEI) was approved. Thus, moving forward the three national data centers will all be called NCEI.

In January 2015, Dr. Sheekela Baker-Yeboah joined CICS-MD and leads the satellite team at NODC. The satellite team is responsible for the archiving and delivery of ocean data products that are derived from sensors operating in space. These include sea surface temperature, ocean altimetry, ocean vector winds and other products derived from these measurements. The satellite team adds value by providing metadata, making the data discoverable, performing quality assurance and providing scientific and technical support to users of these data (http://www.nodc.noaa.gov/SatelliteData/). The ongoing satellite data products are all automatically ingested and placed in the NODC public data area. Here they are made available to the public with an array of online tools including ftp, http, OPeNDAP, THREDDS and our geoportal.

The Coral Reef Temperature Anomaly Database (CoRTAD) product is designed to quantify global-scale stressors that are widely deemed responsible for the decline of coral reefs. A likely candidate is rising sea surface temperature (SST) in much of the tropics. CoRTAD, funded by the NOAA Coral Reef Conservation Program uses SST from NOAA's Pathfinder program to develop weekly SST averages, thermal stress metrics, SST anomalies (SSTA), SSTA frequencies, SST Degree heating weeks and climatologies (http://www.nodc.noaa.gov/SatelliteData/Cortad/).

The World Ocean Database (WOD) is one of the most requested products from the NODC (http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html). It is a vast hydrographic database that includes nearly 14 million profiles dating back to the late 18th century. In order for the WOD to keep growing, and to keep being used by the public for a multitude of different ocean and climate studies, data from the NODC archive must be continually processed and merged into the WOD. This requires that the data be converted into a common format, checked for uniqueness and quality, and merged into the WOD. WOD also offers a multitude of different XBT biased corrected data based on various XBT bias correction algorithms that have been published in the literature.
The WOD is also used in calculating gridded climatologies of the ocean. The World Ocean Atlas as well as a multitude of regional climatologies (http://www.nodc.noaa.gov/OC5/indprod.html) have been created from the WOD. The climatologies require extensive amounts of quality control to ensure an accurate product. More recently, since the introduction of Argo floats, gridded temperature and salinity anomaly products have also been able to be produced.

The regional climatologies are created based on the public's need and additionally constrained by the regional hydrographic data distribution. Because regional climatologies are only calculated in regions of

high data distribution, vertical resolutions of 102 standard levels and horizontal resolutions up to 1/10th degree are attainable. The World Ocean Atlas 2013 also increased, at least for some variables and time periods, its vertical resolution to 102 standard levels and horizontal resolution to a quarter-degree. The movement to higher vertical and horizontal resolutions in both regional and global climatologies is important for resolving small scale structures (i.e. fronts) and usage in ocean and climate models, among others.

NODC has automated several in-situ datasets as well. CICS staff members have negotiated with the Integrated Observing Systems (IOOS) Regional Associations SECOORA and GLOS to automate the full archive of in-situ data. Once the agreement was defined, CICS staff worked with NODC IT staff to implement the automation and archive while providing public access to the in-situ data. These three RA's will be used as test beds and use cases for the remaining 9 observing systems. Through direct work with the IOOS Program Office, CICS staff was elected to be the lead for NODC in developing requirements to enable a smooth transfer of data from the remaining IOOS RAs to the archive.

In addition to the SECOORA and GLOS automations, CICS staff members have developed two other automated data streams. One data stream is from the Bodega Marine Laboratory, in-situ buoy observations. The other data stream is directly from the NOAA Vessels through the NOAA Office of Marine and Aviation Operations (OMAO). The OMAO data stream consists of the data that is sent through Scientific Computer System, packaged up and submitted directly to NODC. This data varies by submission, but it typically consists of thermosalinograph and surface meteorological data.

One of the roles of the National Oceanographic Data Center is to fully steward environmental data, which consist of converting and applying quality control tests as applicable. Currently at the NODC, there is a significant amount of thermosalinograph (TSG) data that comes in through various pathways and in various file formats. CICS staff worked with NODC to steward the TSG data and provide various reformatted aggregations of the Shipboard Automated Meteorological and Oceanographic System (SAMOS) data sets submitted to the archive.

In its role as the US archive for oceanographic data, NODC provides near real-time and delayed-mode product distribution, rigorous archive services, and long-term data stewardship for the JASON-2/Ocean Surface Topography Mission (OSTM) and future JASON-3 products. JASON-3 is designed to ensure continuity of high quality measurements of sea surface heights for determining ocean circulation, climate change and sea-level rise. NOAA Jason Ground System (NJGS) is developed for supporting the simultaneous operation of the Jason-2 and Jason-3 Ocean Surface Topography Missions.

Cooperation with STAR/NESDIS, NODC works to produce gridded level-3 data from SMOS and Aquarius satellites level-2 granules by applying data quality flags and a simple interpolation method (e.g., box average). The outputs cover various time scales from swath to 3-day, 7-day and monthly mean. NODC also works to establish and operationally implement of data quality monitoring on the level-2 sea surface salinity (SSS) products from SMOS and Aquarius satellites. The QA statistics (observation number, mean, standard deviation, minimum, maximum, and number over 3-sigma edited) have been calculated in each level-2 granule and saved into NetCDF format. The visualization of the QA statistics and the data will be published through a web interface. The data process and visualization generation are made to be updated in automation in a time-length consistent with the data latency. An important component of NODC's data stewardship for the Aquarius, SMOS, and Jason-2/3 products is to develop a data quality monitoring system known as the Rich Inventory which provides an important tool to monitor and track the data assurance statistics and metadata attributes in each granule, and to provide those results to

the public. This system improves the integrity of these satellite missions thereby enhancing the usefulness and deepening the understanding of the data for climate and other long-term applications.

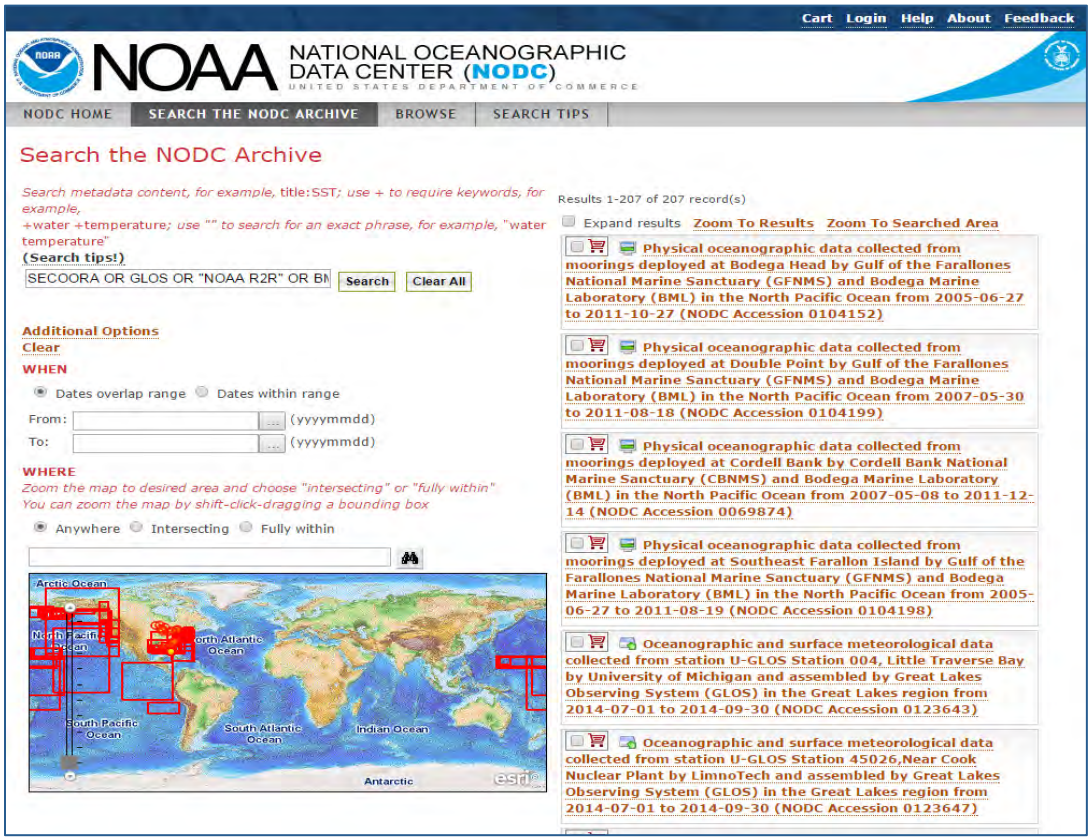


Figure 1: Geoportal screenshot for the NODC Geoportal response to a query for the BML, NOAA's OMAO (R2R), SECOORA, and GLOS data streams. Here is the url to that prequeried webpage http://data.nodc.noaa.gov/geoportal/rest/find/document?searchText=SECOORA%20OR%20GLOS%20OR%20%22NOAA%20R2R%22%20OR%20BML&start=1&max=2500&contentOption=intersecting&f=searchPage .

NODC was funded by NOAA's Ocean Acidification Program to manage their data through the Ocean Acidification Data Stewardship (OADS) project. The overarching goal of the OADS project is to serve the OA community by providing dedicated online data discovery, access to NODC-hosted and distributed authoritative data sources, long-term archival, coordinated data flow, and scientific stewardship for a diverse range of OA and other chemical, physical, and biological oceanographic data.

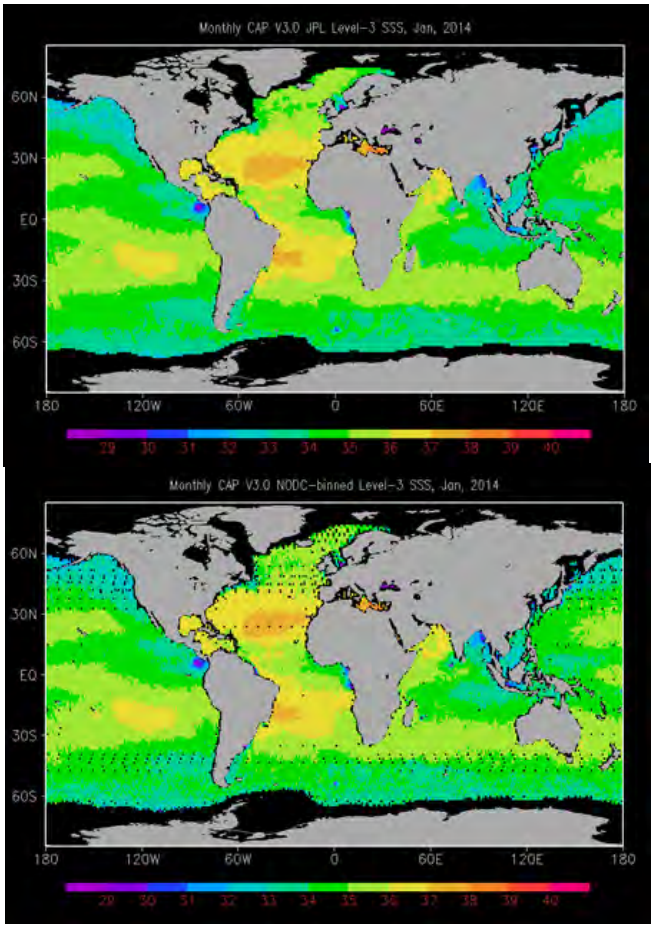


Figure 2: Monthly JPL Aquarius Level-3 V3.0 (top panel) and NODC-binned Level-3 sea surface salinity from JPL Aquarius Level-2 products in January 2014 in unit of PSU.

Accomplishments

1. Archiving of in situ data

One of the primary focuses of CICS staff at NODC is timely archiving of various hydrographic data sets received from a multitude of sources. CICS staff archived numerous accessions over the 2011-2015 time period. For example, CICS staff archived over 700 accessions from just the Carbon Dioxide Information Analysis Center (CDIAC) alone. In addition, CICS staff archived over 120 accession from the Biological and Chemical Oceanography Data Management Office (BCO-DMO). CICS staff have also been instrumental in establishing relationships with various institutes and setting up automatic archiving of their data. For example, we set up separate agreements with Bodega Marine Lab (BML), NOAA's OMAO (R2R), IOOS RA SECOORA, and IOOS RA GLOS to automatically archive their in-situ data and provide robust metadata to facilitate discovery through various web portals. All of which are now fully operational (approximately 207 records and continually increasing).

2. Archive, Access, and Distribution of Satellite Data

CICS staff developed data archive, access, distribution and data quality monitoring systems for NOAA Jason Ground System (NJGS). We finalized and signed off on NOAA Jason-3 supplemental requirements for those being responsible for fulfilling at NODC in the development of data archive, access, distribution and quality monitoring system in NJGS. We developed real-time dashboard data quality monitoring for Jason-2&3 Level-2 products and improved codes in data processing and visualization and generated highly comprehensive ISO 19115 metadata for Jason-2/3 and chlorophyll frontal products. We completed NODC archive system for Jason-2&3 products and developed NASA and NOAA collaborative altimetry data information and access webpage. Finally, we supported end-to-end testing of Jason-3 data archive, access and distribution.

CICS staff developed NODC-binned level-3 7-day and monthly mean sea surface salinity (SSS) data from Level-2 Aquarius V3.0 and CAPv3.0 products. Furthermore, we developed a Rich Inventory (QA statistics data) for SMOS, Aquarius V3.0, CAP V3.0, and AVHRR Pathfinder v5.2 SSS and SST products. We also developed a NODC data quality monitoring homepage for SMOS and Aquarius level-2 SSS products.

CICS staff completed documentation, work plan, cost appraisals and technical solutions for archiving NOAA ocean color frontal, VIIS ocean color reprocess, altimeter sea level rise, satellite ocean heat content and synthetic aperture radar ocean products. We implemented management of GHRSST data archive and implemented routine data archive, access and distribution tasks for Jason-2 products.

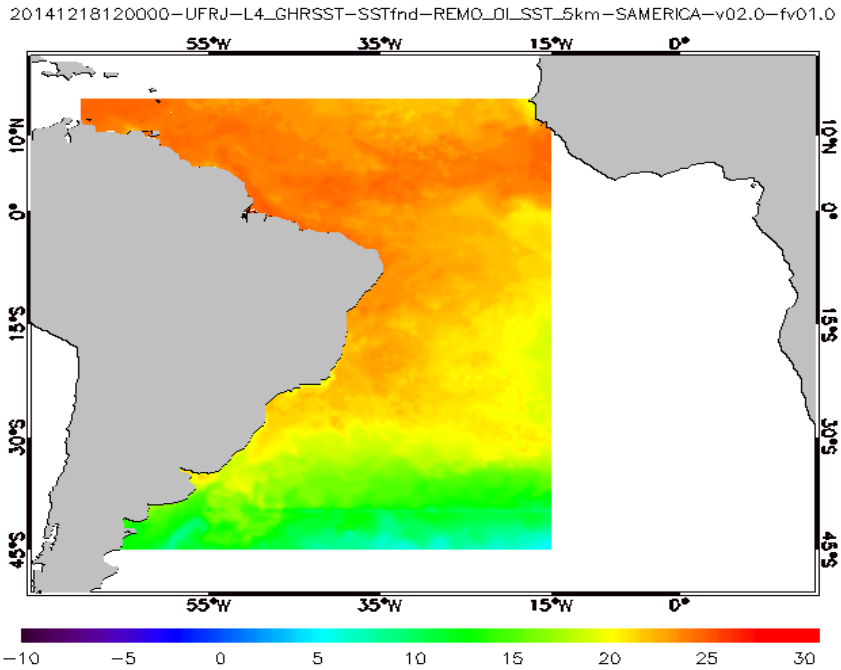


Figure 3: GHRSST Level 4 REMO_OI_SST_5km Regional Foundation Sea Surface Temperature

The goal is to maintain a leading role in the world's SST community by operating the Group for High Resolution SST (GHRSST) Long Term Stewardship and Reanalysis Facility (LTSRF). The NCEI-SS GHRSST LTSRF archives over 50GB of SST data each day. These data are created by various Regional Data Assembly Centers (RDAC) globally. There are 70 plus GHRRST products from these RDACS that are archived each day using a very robust automation system. CICS affiliates in the satellite oceanography team are responsible for generating/improving software necessary for archive process and ensure the quality as-

surance for the archive and generate software to create images for these GHRSST L2 and L3 products in near-real time and to implement general GHRSST archive management. During the previous year almost 10 new GHRSST SSTs were successfully archived.

Under GHRSST LTSRF operations:

- Developed IDL codes and scripts to generate GHRSST Level 2P, Level 3 and Level 4 browse images in near real time (Fig. 3 is an example of a Level 4 browse graphic for the Brazilian REMO SST 5 Km data). The scripts to run these codes in near-real time are also generated and being run regularly.
- A documentation only accession was created for all the GHRSST products.

SAR archive implementation:

- SAR wind data from RADARSAT-2 is regularly downloaded from the OSPO via the NODC DDS account.
- Automation SOP wiki page set up for archiving the RADARSAT-2 data was started.
- "RADARSAT-2" as a platform and "Synthetic Aperture Radar" as a sensor are added in the common vocabulary of Archive Management database

3. Ocean Acidification

CS staff developed the first ever metadata template for the documentation of experimental ocean acidification (OA) studies. In addition, a rich OA metadata XML blob to store OA metadata elements in a standardized format was created. Furthermore, we created an XSLT program to display the information in the XML blobs in a user-friendly html web page format. Please see the OA website at NODC for further information (http://www.nodc.noaa.gov/oceanacidification/).

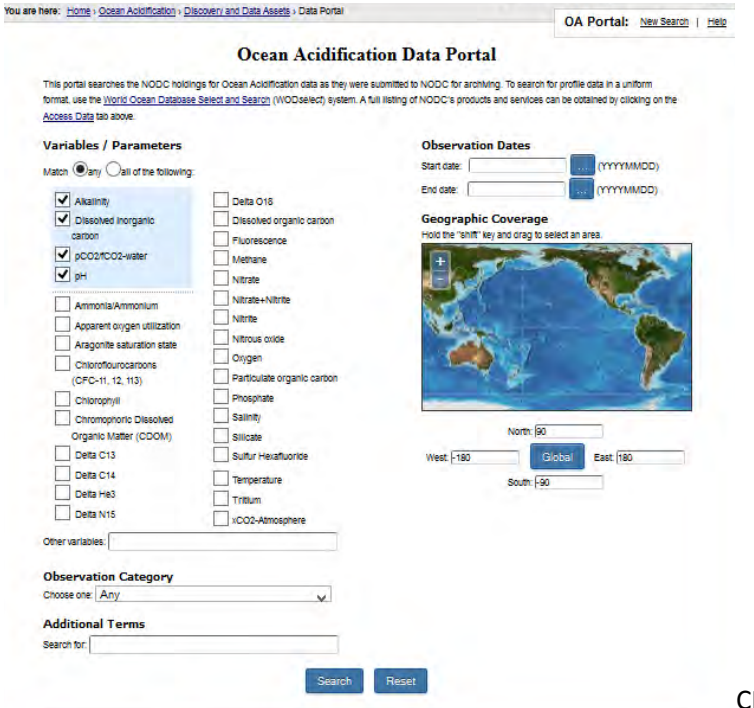


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Figure 4: Ocean Acidification Data Access Portal

CICS staff designed and worked with the NODC IT department to develop the Ocean Acidification Data Access Portal. The OA Data Portal allows a user to search for OA data based on criteria of "Variables", "Observation type", "Spatial coverage" and "Temporal coverage". This tool makes data searching much easier by creating a user-friendly interface. The OA Data Portal was launched in September 2014 and is now fully functional. Please see it at:
http://www.nodc.noaa.gov/oceanacidification/stewardship/data_portal.html .

4. Send2NCEI (Formerly Send2NODC)

CICS staff played a major role in designing and coordinating the development of the Send2NCEI online data submission tool. The Beta version of the tool was launched in 2014 where users were given the opportunity to use the tool and provide feedback. The official version is set to be released in 2015. The tool will be located at: http://www.nodc.noaa.gov/submit/index.html

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5. Aragonite Saturation State Climatology

CICS staff gathered all the available ocean station data with both dissolved inorganic carbon and total alkalinity measured and estimated aragonite saturation states, and along with colleagues from PMEL, AOML, and Princeton University, computed climatological distributions of aragonite saturation states of the surface and subsurface layers of the global ocean. A manuscript in preparation has examined mechanisms controlling the aragonite saturation state, seasonal variations of aragonite saturation, and decadal changes of aragonite saturation states.

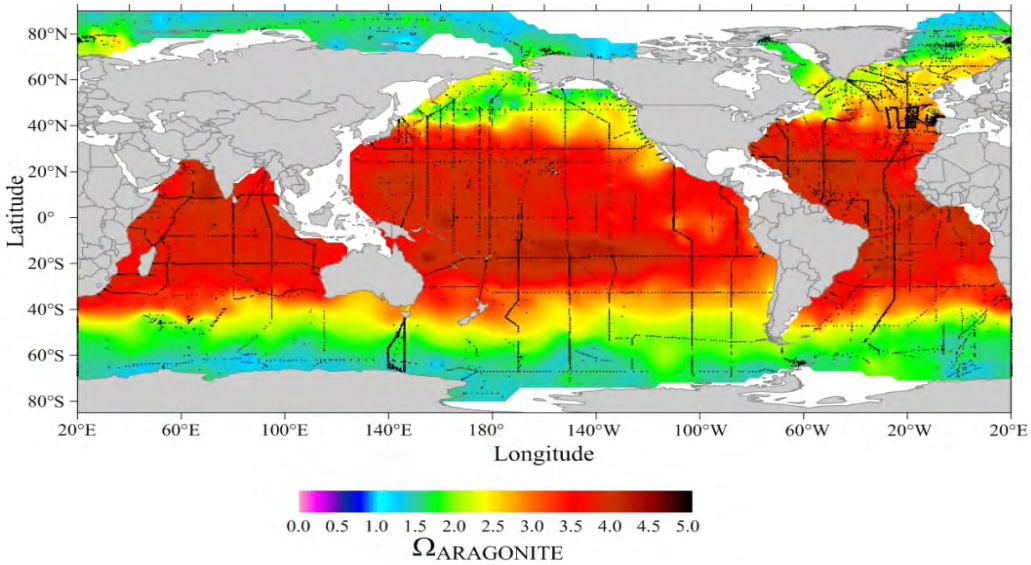

Figure 5: Spatial distributions of aragonite saturation state (Ωarag) in surface waters of the global oceans

6. World Ocean Database/World Ocean Atlas

The WOD is updated quarterly every year. In addition, major releases occur every ~4 years. CICS staff members were heavily involved in the last major release of the World Ocean Database which occurred in 2013 (WOD13). Major releases differ from quarterly updates in that major releases provide supporting documentation, and in this case contained more standard depths (137 as compared to 40 in the previous release (WOD09)). Constant data updates to WOD are needed to maintain and enhance the database. CICS staff's responsibility is to populate WOD on a quarterly basis with bottle and CTD data from the CLIVAR & Carbon Hydrographic Data Office (CCHDO) and the International Council for the Explora-

tion of the Sea (ICES). We also perform annual updates of CTD data from the Northeast Fisheries Science Center (NEFSC). Furthermore, over the past year, NODC has received a large increase in glider data that were archived and processed for inclusion in WOD. These streams of glider data continue

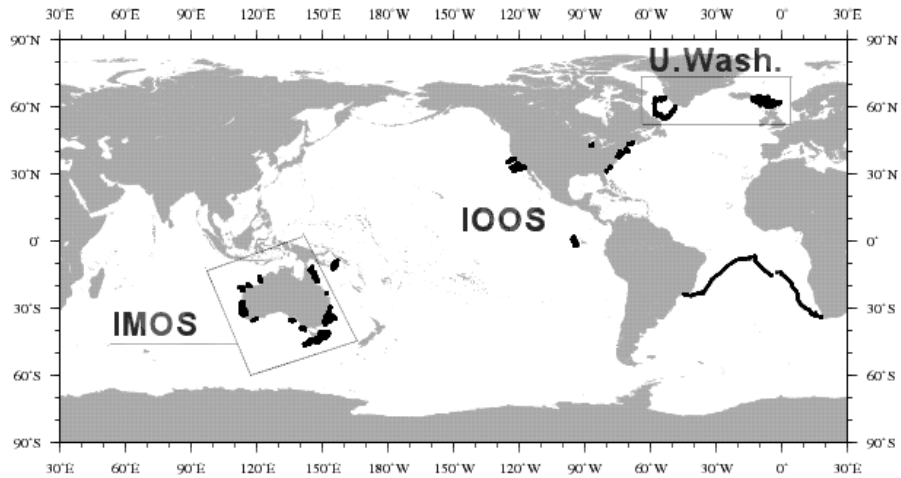

Figure 6: Glider data added to WOD from various institutions.

and have become a valuable dataset within WOD. CICS staff also processed and continues to process other miscellaneous data sets that come in from a variety of sources.

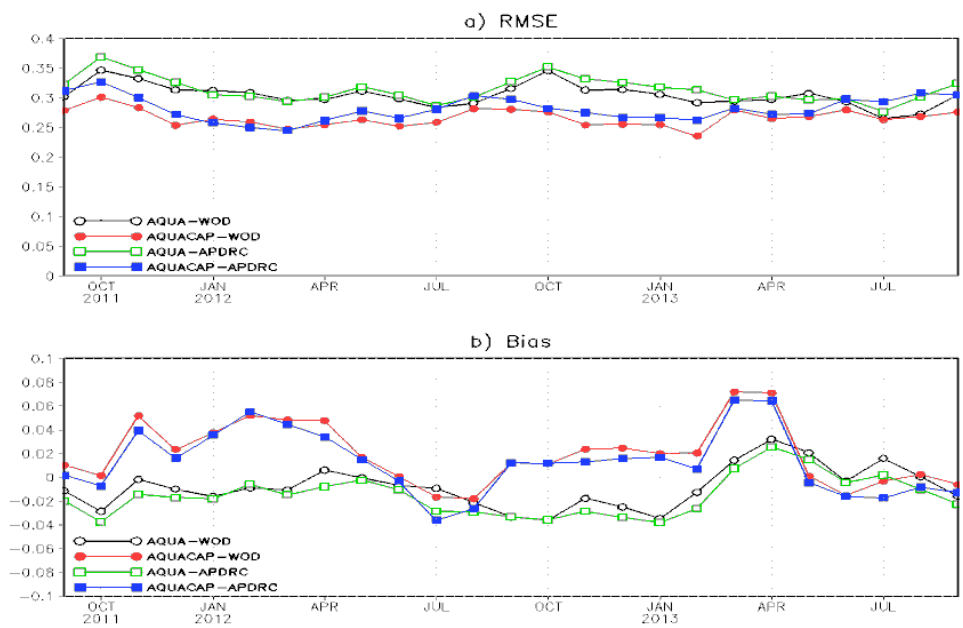

Figure 7: Monthly time series plots for September 2011 – September 2013 of a) root-mean-square error (RMSE) and b) bias for Aquarius v2.5.1(AQ251)-WOD derived SSS (WODSSS), AQ251-APDRC, Aquarius CAP v2.5.1(AQCAP251) -WODSSS, and AQCAP251-APDRC over the ocean from 60°S-60°N (from Reagan et al., 2014).

Data from WOD is used to calculate pentadal, annual, seasonal, and monthly gridded temperature and salinity anomaly products. CICS staff is involved in the creation and quality control of these products. Quality control consists of removing "bullseyes" from the gridded fields. The "bullseyes" are seen as

concentric circles emanating from a specific location. The monthly salinity anomaly products were used extensively in a manuscript published by CICS staff and NOAA collaborators that compared these salinity anomaly products to Aquarius SSS. They are also being used in a manuscript that is in preparation in which recent near-surface salinity trends over the global ocean are being analyzed and compared to long-term trends.

After release of WOA13 (global ocean climatology of temperature, salinity, oxygen, and nutrients) in early 2014, some users noted some strange features in the temperature and salinity climatologies. CICS staff helped resolve these features through additional QC work. In addition, CICS staff created and re-created web-based maps to help assist the additional QC efforts as well as prepare for final public release of version 2. WOA13 version 2 is slated to be released in 2015. ODselect they have the option of selecting which XBT fall rate equation they would like to use.

7. Regional Climatology

CICS staff were involved with the creation and quality control of numerous high-resolution regional climatologies. CICS staff were directly involved with the creation and quality control of the Arctic, Greenland-Iceland-Norwegian Seas, and the Gulf of Mexico regional climatologies. Furthermore, they also assisted in data preparation and quality control of the Northwest Atlantic (NWA). Multiple sets of maps were created and re-created for different oceanographic variables on varying spatial grids (one-degree, quarter-degree & tenth-degree) for the NWA.

8. Cloud Pilot Project and Pathfinder 5.3 statistical characterization

- Set up environment to run instances in Amazon Web services (AWS) Elastic Compute Cloud (EC2).
- Running the Pathfinder V5.3 in AWS Amazon Machine Images (AMI) with various combinations of virtual CPUs (2, 4, 8, 32, 64 etc). This exercise was done to optimize and set up the environment for future processing.
- The sample output from these test runs are analyzed for validation, browse images are created and comparison with outputs from Pathfinder 5.2 was generated.

Planned work

- Continue to discover, assess, acquire and archive the wide array of new ocean data as they become available.
- Migrate all current services which have been developed at NODC for NJGS (web pages, file systems, process and visualization codes and scripts in generation of data quality statistics, and metadata templates) into NJGS.
- Support NJGS project during Jason-3 LEOP.
- Continue production of NODC satellite sea surface salinity (SSS) products for SMOS, Aquarius ADPS v3.0, and Aquarius CAP v3.0.
- Complete comparison study amongst SMOS Level-3 binned monthly data, Aquarius monthly Level-2 data, NASA's Aquarius Level-3 data, and conventional observations from NODC World Ocean Database, applying results to improve the 3-day, 7-day and monthly binned datasets.
- Evaluate the impact of choices of data quality and scientific flags in SMOS and Aquarius level-2 data and apply to improve the gridded binned data products.
- Conduct SSS comparison study among SMOS (3 models), Aquarius (v3 and CAPv3) and NODC World Ocean Database products.

- Continuously develop technical solutions designed to archive NOAA ocean color satellite products.
- Continuously develop tools for improving satellite data quality monitoring, access, search and discovery.
- Working with international OA data management community on unifying OA data managing practices.
- Synthesis efforts on coral reef carbonate data.
- Restarting CDIAC data transfer based on comments from the science community.
- Regional Climatology of Northwest Atlantic (NWA)
  - Quality Control of climatological fields for NWA area on decadal time-scales.
  - Re-calculating updated climatological fields for NWA area on different stages of QC.
  - Creating updated version of maps for different oceanographic variables.
  - Analyses of the climatic long-term changes in NWA area.
- Continue to participate in Ocean Heat Content research.
- Continue working with partners to provide global and regional products and climatologies identified as high priority by users, particularly users within NOAA.
- Continue to process data for the WOD. This includes CCHDO, ICES, NEFSC, and Glider data, as well as other data sets received by NODC.
- Continue to QC monthly, seasonal, annual, and pentadal temperature and salinity anomaly fields derived from the WOD.
- Develop climatological fields of mixed layer depths, as well as other related variables, as a first step in monitoring seasonal/interannual changes in mixed layer depth
- Continue to analyze near-surface salinity variability through satellite and in situ data
- Continue working towards archiving of upcoming GHRSST data and maintaining the ongoing archiving system.
- Generating climatological data for the pathfinder 5.3 (1981-2012) running it in the Amazon Cloud.
- Archive the pathfinder 5.3 climatological data.
- Archiving the RADARSAT-2 SAR-wind data generated by NOAA/NESDIS/STAR.
- Archiving the Sentinal SAR-wind data.
- Working for the development of SST coefficients for Pathfinder 6.
- Act as the lead for NODC to work with the IOOS Program Office to interact with the RAs and enable smooth transfer of data into the archives.

Publications

Peer-reviewed:

1. Boyer, T., J. Antonov, **J. Reagan**, C. Schmid, and R. Locarnini, 2014: [Subsurface Salinity] Global Oceans [in "State of the Climate in 2013"]. *Bull. Amer. Meteor. Soc*., **95** (7), S62–S65.
2. Boyer, T., J. Antonov**, J. Reagan**, C. Schmid, and R. Locarnini, 2015: [Subsurface Salinity] Global Oceans [in "State of the Climate in 2014"]. *Bull. Amer. Meteor. Soc*., submitted
3. Boyer, T.P., H. E. Garcia, R. A. Locarnini, M. M. Zweng, **A. V. Mishonov**, **J. R. Reagan**, J. I. Antonov, O. K. Baranova, **M. M. Biddle**, D. R. Johnson and C. R. Paver (2014): 2013 World Ocean Atlas Aids High-Resolution Climate Studies, *Eos, Transactions American Geophysical Union*, 95(41), 369-370, doi: 10.1002/2014EO410002.

4. **Reagan, J.**, T. Boyer, J. Antonov, and M. Zweng, 2014: Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity, *J. Geophys. Res. Oceans*, 119, 8122-8140, doi:10.1002/2014JC009961.
5. Seidov, D., J. I. Antonov, K. M. Arzayus, O. K. Baranova, **M. Biddle**, T. P. Boyer, D. R. Johnson, **A. V. Mishonov**, C. Paver and M. M. Zweng (2015): Oceanography North of 60°N from World Ocean Database, *Progress in Oceanography*, Vol. 132, pp. 153-173. doi:10.1016/j.pocean.2014.02.003
6. Xie, P., T. Boyer, E. Bayler, Y. Xue, D. Byrne, **J. Reagan**, R. Locarnini, F. Sun, R. Joyce, and A. Kumar, 2014: An in situ-satellite blended analysis of global sea surface salinity, *J. Geophys. Res. Oceans*, 119, 6140–6160, doi:10.1002/2014JC010046.
7. Xue, L., W. Yu, H. Wang**, L.-Q. Jiang**, L. Feng, L. Gao, K. Li, Z. Li, Q. Wei, and C. Ning. 2014. Temporal changes in surface partial pressure of carbon dioxide and carbonate saturation state in the eastern equatorial Indian Ocean during the 1962–2012 period. *Biogeosciences*, 11: 6293-6305, doi:10.5194/bg-11-6293-2014.
8. Xue, L., W. Yu, H. Wang, **L.-Q. Jiang**, W.-J. Cai, Q. Wei, H. Song, L. Liu. 2015. Aragonite saturation state in a monsoonal upwelling system off Java, Indonesia. *Journal of Marine systems*, submitted.
9. Xue, L., W.-J. Cai, X. Hu, C. Sabine, S. Jones, A. J. Sutton**, L.-Q. Jiang**, and J. Reimber. 2015. Sea surface carbon dioxide at the Georgia time series site (2006-2007): air-sea flux and controlling processes. *Progress in Oceanography*, under review.

Not Peer-Reviewed.

1. **Jiang, L.-Q.**, R. A. Feely, D. J. Greeley, B. Carter, R. Wanninkhof, R. Key, and K. M. Arzayus. 2015. Climatological distributions of aragonite saturation state in the global oceans. *Global Biogeochemical Cycles*, in preparation.
2. **Jiang, L.-Q**., S. A. O'Connor, K. M. Arzayus, A. Kozyr, and A. R. Parsons. 2015. A metadata template for ocean acidification data, Earth Syst. Sci. Data Discuss., 8: 1-21, doi:10.5194/essdd-8-1-2015.
3. Johnson, D.R., Boyer, T.P. (2014): *Regional Climatology of the East Asian Seas: An Introduction*. NOAA Atlas NESDIS ##, Tech Ed. **A. Mishonov**, Silver Spring, MD, 40 pp.
4. **Reagan, J.**, T. Boyer, J. Antonov, and M. Zweng: Changes in Near-Surface Salinity from 2005-2014, *J. Geophys. Res. Oceans*, in preparation.

Products

1. NODC-binned level-3 1x1 degree 7-day and monthly mean sea surface salinity data from Level-2 Aquarius V3.0;
2. NODC-binned level-3 1x1 degree 7-day and monthly mean sea surface salinity data from Level-2 Aquarius CAPv3.0.
3. Ocean Acidification Data Access Portal
4. Send2NCEI online data submission tool
5. OA Metadata Template
6. Aragonite Saturation State Climatology – Release 2015
7. World Ocean Database – Quarterly Updates/Releases
8. World Ocean Atlas 2013 Version 2 – Release 2015
9. Atlas on Northwest Atlantic Regional Climatology – Release 2015
10. Most recent release of pentadal (2009-2014), annual (2014), seasonal (2014), and monthly (2014) temperature and salinity anomaly gridded products

Presentations

- **Biddle, M.** OMAO-NODC archive process and updates. NOAA Rolling Deck 2 Repository Meeting. Boulder, CO. 13-14 May 2014.
- Byrne, D. and **Y. Zhang**: NOAA archive and access services for Jason-2/3 products, Annual OSTST meeting, Oct 28-31, 2014, Constance, Germany.
- Hausman, J., **Y. Zhang** and Deirdre A. Byrne: NASA and NOAA Collaborative Altimetry Data Information and Access Webpage. Annual Ocean Surface Topography Science Team (OSTST) Meeting, Oct 28-31, 2014, Constance, Germany.
- **Jiang, L. -Q.**, S. O'Connor, K. M. Arzayus, A. Kozyr, A. R. Parsons, and **J. Reagan**. A metadata template for ocean acidification data. 2014 AGU Fall Meeting. San Francisco, CA. 15-19 December 2014.
- Parsons, R., S. Cross, D. Seidov, **A. Mishonov**, and **J. Reagan**, 2014. Coupling analyses of new high-resolution regional ocean climatologies and ocean model output in relation to long-term AMOC fluctuations, 2014 AGU Fall Meeting, San Francisco, CA, 15-19 December 2014.
- **Reagan, J.**, T. Boyer, J. Antonov, and M. Zweng. Changes in the Seasonal Cycle of Sea Surface Salinity during the Argo-era (2004-2013). 2014 AGU Fall Meeting. San Francisco, CA. 15-19 December 2014.
- **Reagan, J.**, T. Boyer, J. Antonov, and M. Zweng. Changes in the Seasonal Cycle of Sea Surface Salinity from 2005-2013. Ocean Salinity Science and Salinity Remote Sensing Workshop. Exeter, UK. 26-28 November 2014.
- **Reagan, J.**, T. Boyer, J. Antonov, and M. Zweng. Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity. NODC/NCDC/NGDC Branch Overview Seminar. Silver Spring, MD. 9 September 2014.
- **Reagan, J.**, T. Boyer, J. Antonov, and M. Zweng. Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity. Aquarius/SAC-D Science Team Meeting. Seattle, WA. 11-14 November 2014.
- **Reagan, J.**, T. Boyer, J. Antonov, M. Zweng. Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity. 2014 Ocean Sciences Meeting. Honolulu, HI. 23-28 February 2014.
- **Zhang, Y.** and D. Byrne: Development of NODC Satellite Data Quality Monitoring System, 3rd Annual CICS-MD Science Meeting, Nov 12-13, 2014, College Park, MD.

Other

- M. Biddle received NODC recognition award for his contribution to the successful establishment of the first automated archive process with the Southeast Coastal Ocean Observing Regional Association (SECOORA), an IOOS Regional Association (2014).
- M. Biddle received a nomination for National Oceanic and Atmospheric Administration's (NOAA) Team Member of the Month award for his work in automating the archival of NOAA Office of Marine and Aviation Operations (OMAO) Scientific Computer System (SCS) data directly from the NOAA fleet (2014).
- L. Jiang received NODC Director's award for the development of the Ocean Acidification Data Access Portal.
- A. Mishonov has a proposal pending: Quantifying oceanographic variability in the NW Atlantic, # 00024511; submitted to NOAA Climate Program Office, call: Understanding Climate Impacts on Fish Stocks and Fisheries to Inform Sustainable Management

Performance Metrics	
# of new or improved products developed (please identify below the table)	10
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	9
# of non-peered reviewed papers	4
# of invited presentations	1
# 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

Climate Data Record for HIRS-OLR – Gauge Blended Analysis of Global Daily Precipitation

Task Leader Hai-Tien Lee
Task Code HLHL_HIRS_14
Main CICS Research Topic A: 10%; B: 5%; E: 15%; F: 60%; G: 5%
(F) Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to CICS Themes Theme 1: 10%; Theme 2: 90%
Percent contribution to NOAA Goals Goal 1: 100%
Highlight: HIRS OLR retrievals are used in a gauge-satellite blended system to generate high-resolution analysis of precipitation estimate over land globally on a daily basis at CPC (POC: Pingping Xie). This precipitation estimation system has been evaluated with very favorable performance that CPC plans to derive a long time series of OLR-based precipitation record as well as putting this system into operational mode in the near future.

Background

Many precipitation data sets have been produced in the past two decades based on gauge measurements, satellite observations and their combinations. Their applications in hydro-climate applications, however, are restricted by a number of shortcomings in long-term homogeneity, quantitative accuracy, and time/space resolution. The objective of this work is to construct a homogenous analysis of daily precipitation on a 0.25°lat/lon grid over the global land for a 35-year period from 1979 to the present through combining information from satellite observed outgoing longwave radiation (OLR), as well as daily and monthly gauge analyses.

Accomplishments

Gauge-OLR Blended Precipitation Estimation

CPC unified daily gauge analysis is calibrated against the GPCC monthly gauge data set to correct the under-estimates in the daily gauge analysis caused by the negatively biased daily station reports. The resulting adjusted daily gauge analysis presents improved quantitative accuracy over regions with reasonable gauge coverage.

A new technique is then developed to derive precipitation estimates from the OLR data observed by HIRS aboard NOAA polar orbiting satellites. To this end, probability density function (PDF) tables are created for the HIRS OLR and matched against those for the collocated CMORPH satellite precipitation estimates using data for a 15-year period from 1998 to the present. An observed HIRS OLR value is converted to precipitation through the matched OLR and precipitation PDF tables. The PDF tables are constructed for each pentad period and for each land grid box of 1olat/lon to account for the seasonal variations and regional dependence of the OLR-precipitation relationship. The technique is applied to generate precipitation estimates on a 0.25°lat/lon grid over the globe for the entire HIRS OLR data period from 1979.

The adjusted daily gauge analysis and the HIRS OLR-based precipitation estimates are blended through the optimal interpolation (OI) technique. The OLR based precipitation estimates are used as the first guess, while the gauge analysis is utilized as the observation to update the first guess. The gauge-OLR blended analysis of daily precipitation analysis is dominated by the gauge analysis over regions of dense station networks, while the OLR-based estimates play an important role over regions of sparse surface observations.

Transition from Research to Operation

CICS is delivering the orbital HIRS OLR retrievals to CPC on the daily basis, meanwhile, the HIRS OLR retrieval production code package has been transferred to CPC for operational implementation.

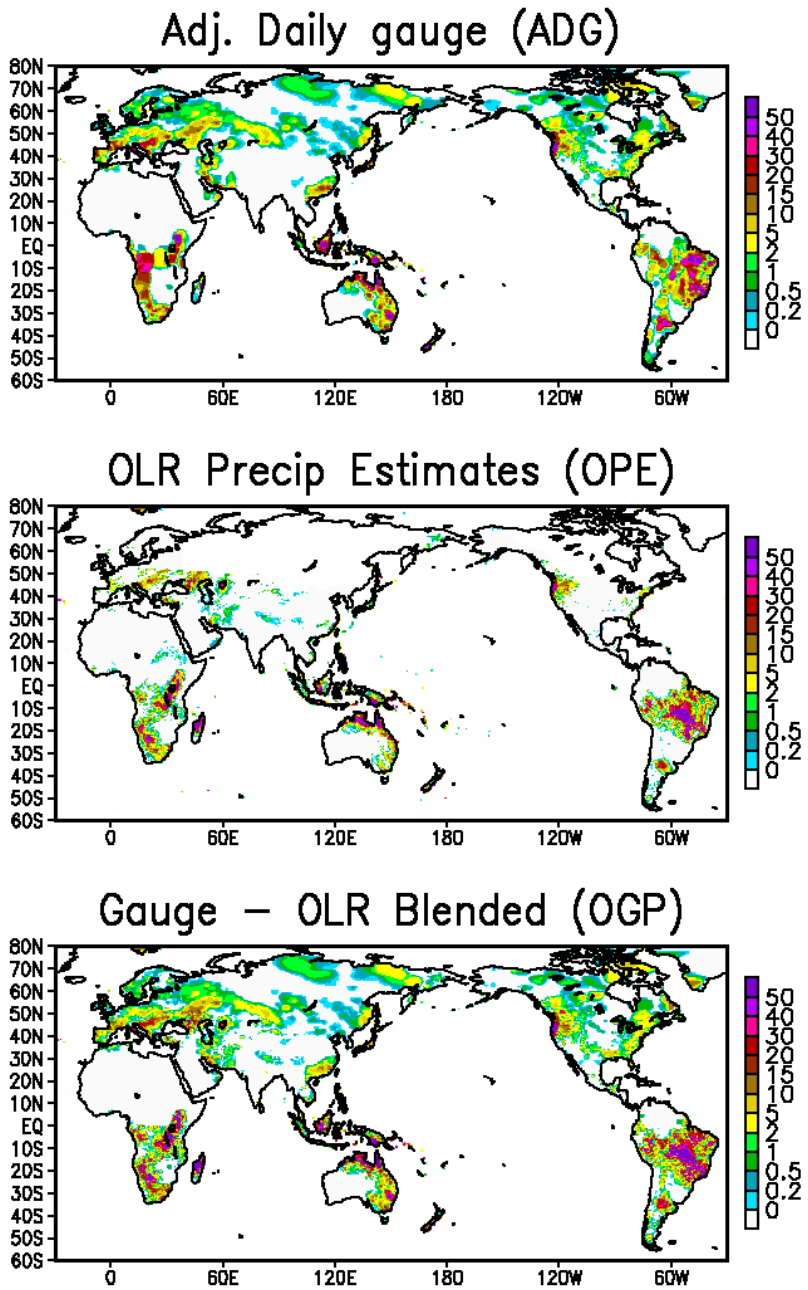

Figure 1. Daily precipitation for January 1, 2010, from (top) adjusted daily gauge analysis, (middle) OLR-based precipitation estimates, and (bottom) gauge-OLR blended analysis. The original OLR-based precipitation estimate (OPE) misses some of the precipitation patterns shown in the gauge analysis. In contrast, the Gauge-OLR blended (OGP) product is in very good agreement with the gauge analysis, while providing complete coverage over land.

Planned Work

- Generation of long time series (1979-present) of 0.25° precipitation estimate over global land
- Operational OLR retrieval at CPC

Products

1. HIRS Daily OLR field of view retrievals
2. HIRS OLR retrieval production package

Presentations

Xie, Pingping, Hai-Tien Lee, Jesse Meng, Kingtse Mo, and Michael Ek, 2014: A 35-Year Analysis of Global Daily Precipitation for Improved Hydro-climate Monitoring and Modeling. NOAA's 39th Climate Diagnostics and Prediction Workshop. 20-23 October 2014, St. Louis, Missouri.

H.-T. Lee and Pingping Xie, 2014: A 35-Year Daily Precipitation Analysis for Hydro-climate Applications. 28th Conference on Hydrology / 94th American Meteorological Society Annual Meeting. Feb 2-6, 2014. Atlanta, GA. (Oral)

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# 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**

The Global Precipitation Climatology Project (GPCP) Data Products—Transfer to Operations at NCDC

Task Leader	Robert Adler
Task Code	RARA_GPCP_14
NOAA Sponsor	Xuepeng Zhao
NOAA Office	NCDC
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight The routine production of monthly, pentad and daily products from the Global Precipitation Climatology Project (GPCP) products will be transferred to NCDC for archival and dissemination. The GPCP codes are being organized, streamlined, updated and documented for product production from the level of the satellite-calibrated radiances to the final merged products at NCDC.

Link to a research web page http://eagle1.umd.edu/GPCP_ICDR/index.htm

Background

The objective of this work is to successfully transfer the routine production of (GPCP) products to NCDC from the ad-hoc processing at the current GPCP centers. The current monthly (1979-present), pentad (1979-present) and daily products (1997-present) have been developed by research groups over the last 15 years and are produced by a consortium of those groups, funded by various agencies. Transfer of the routine processing of the GPCP products to an operational entity will ensure continuation of these important data analysis sets. This activity involves the development of a detailed strategy for transfer of scientific knowledge, satellite and other data source accesses, and processing code for successful implementation of an end-to-end processing system that would routinely produce the GPCP current (Version 2) products for archival and dissemination. Initial data processing with the new system will take place at University of Maryland CICS.

Accomplishments

The focus for the past year has been on resolving the shift in GPCP precipitation caused by the transition from SSM/I to SSMIS. The GPCP monthly product uses precipitation obtained form the METH algorithm over the tropical oceans. From 1987 to 2008, this was based on RSS SSM/I Tb and switched to the RSS SSMIS Tb in 2009. A possible discontinuity in the microwave record created by the switch to SSMIS was found that lead to a shift of around -.36 in GPCP tropical rainfall and -0.4 METH tropical rainfall. The cause of this discrepancy has now been identified as an error in the way the freezing level was calculated in the METH code. The SSMIS METH algorithm originally included an adjustment to the calculation of the freezing level, which was applied erroneously. With this removed, the difference between SSM/I and SSMIS rainfall is reduced in magnitude by around 0.026. In addition to this, a minor change was made by GMU to the convergence threshold used in the METH algorithm. A chi-squared statistic is used to assess convergence, with lower values indicating more accurate results. For SSM/I, the threshold was set at 5 000. The original METH code used a value of 15 000, but this was changed in November 2014 to 25 000 to be more consistent with the SSM/I threshold based on the increased sampling of SSMIS. The increased threshold does not affect the mean rainfall.

Table 1 shows the bias for SSM/I F13 minus SSMIS F17 from the CDR and GMU METH estimates using two different land masks and three different latitude bands. The CDR and GMU estimates should be consistent, and are indeed so, but there are differences depending on the land mask and latitude band used for calculating the average. The rows showing the comparison that used TMI as a transfer show slightly different values between 40S/N (the TMI transfer data is ~0.005 lower), and larger values for the 20S/N latitude band. At present, there is no suggestion that these relatively small differences come from the METH algorithm, so it is assumed that these are sensor differences.

Land Mask	F13-F17 (No T0 offset)	90S/N	40S/N	20S/N
Normal	F13-F17 CDR METH Combined 2.5°+5°	0.041	0.027	-0.042
	F13-F17 GMU METH Combined 2.5°+5°	0.039	0.024	-0.047
	F13-F17 CDR METH Com 2.5+5 via TMI		0.017	-0.006
+1 gridbox	F13-F17 CDR METH Combined 2.5°+5°	0.051	0.039	-0.029
	F13-F17 GMU METH Combined 2.5°+5°	0.05	0.037	-0.033
	F13-F17 CDR METH Comb 2.5+5 via TMI		0.032	0.011

Table 1. F13-F17 bias for CDR and GMU (combined 2.5°+5°) for normal and conservative land masks for three different latitude bands. F17 data has no Tzero offset applied. Rows 1, 2, 4 and 5 are direct overlaps for 2008, where as lines 4 and 6 use TMI data as a transfer with F13 data from 2003-2007 and F17 data from 2009-2014.

Planned work

- Continue work on the one degree daily version of GPCP. Some progress has already been made with the transition of this code, but much is still to be done.
- Continue to produce the monthly CDR and ICDR make these available to the community.
- There are several issues that may force an upgrade to the GPCP Version 2 system within the coming months including the changes to the METH algorithm; differences between RSS binary file Tb used at NASA Goddard to and the RSS NetCDF Tb supplied by NCDC; and a new version of the GPCC gauge analysis. There is still uncertainty over the timing of any reprocessing of GPCP, but we will keep NCDC updated as we learn more about the expected timetable for GPCC reprocessing.

Products

Each month for the past year, the Interim Climate Data Record (ICDR) of the monthly GPCP has been produced in near real time, as well as the final CDR 2 months after real time.

Presentations

Adler, R.; M. Sapiano, G. Huffman, D. Bolvin, L. Chiu The Global Precipitation Climatology Project (GPCP) CDR: Research to Real-time Climate Monitoring, AMS Meeting, Phoenix, AZ, Jan. 2015

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**1**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

This year, the new datasets developed were the monthly CDR using the CDR code and the near real time ICDR.

The Development of AMSU Climate Data Records (CDR's)

Task Leader	Ralph Ferraro; Huan Meng; Wenze Yang; Isaac Moradi; Jim Beauchamp; Tom Smith
Task Code	RFWY_AMSU_14
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to CICS Themes	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Percent contribution to NOAA Goals	Goal 1: 50%; Goal 2: 50%

Highlight: TCDR's of AMSU-A has been assessed.

Background

Current passive microwave sounder data, used in hydrological applications, are derived from POES satellites for which the primary mission is operational weather prediction. These data are not calibrated with sufficient stability for climate applications. A properly calibrated FCDR needs to be developed to enable the utilization of these data for TCDR and Climate Information Records and to extend their application into the JPSS era (e.g., POES/AMSU to NPP/ATMS to JPSS/ATMS). Once developed, TCDR's for water cycle applications (precipitation, water vapor, clouds, etc.) will be developed for use as key components in international programs such as GEWEX, CEOS and GPM.

Passive microwave sounder data have proven their worth in more than just tropospheric temperature and moisture monitoring. NOAA/NESDIS generates operational products from the Advanced Microwave Sounding Unit (AMSU) focused on the hydrological cycle (e.g., rainfall, precipitable water, cloud water, ice water, etc.) through two product systems known as the Microwave Surface and Precipitation Products Systems (MSPPS) and the Microwave Integrated Retrieval System (MIRS) since the launch of NOAA-15 in 1998. These data offer the unique opportunity to develop CDR's that can contribute to other satellite time series with similar capabilities such as the DMSP SSM/I and SSMIS, the TRMM TMI, and Aqua AMSR-E. This project will focus on the development of AMSU FCDR's for the AMSU-A window channels (e.g., 23, 31, 50 and 89 GHz) and the AMSU-B/MHS sensor.

Accomplishments

During the fifth year of the project, we continue to make progress towards the creation and evaluation of AMSU-A and AMSUB/MHS FCDR's and TCDR's.

A. Assessment of AMSU-A asymmetry correction and inter-satellite correction for all satellites;

After the calculation of the AMSU-A asymmetry coefficients for all on-board satellites in the previous report period, the performance of these coefficients was assessed in the current report period. To do this, we first generated the TCDR product for all satellites, and picked five days of cloud liquid water (CLW) over tropical ocean, binned them according to local zenith angle (LZA), as shown in Figure 1. It shows that the asymmetry problem has been solved for all satellites.

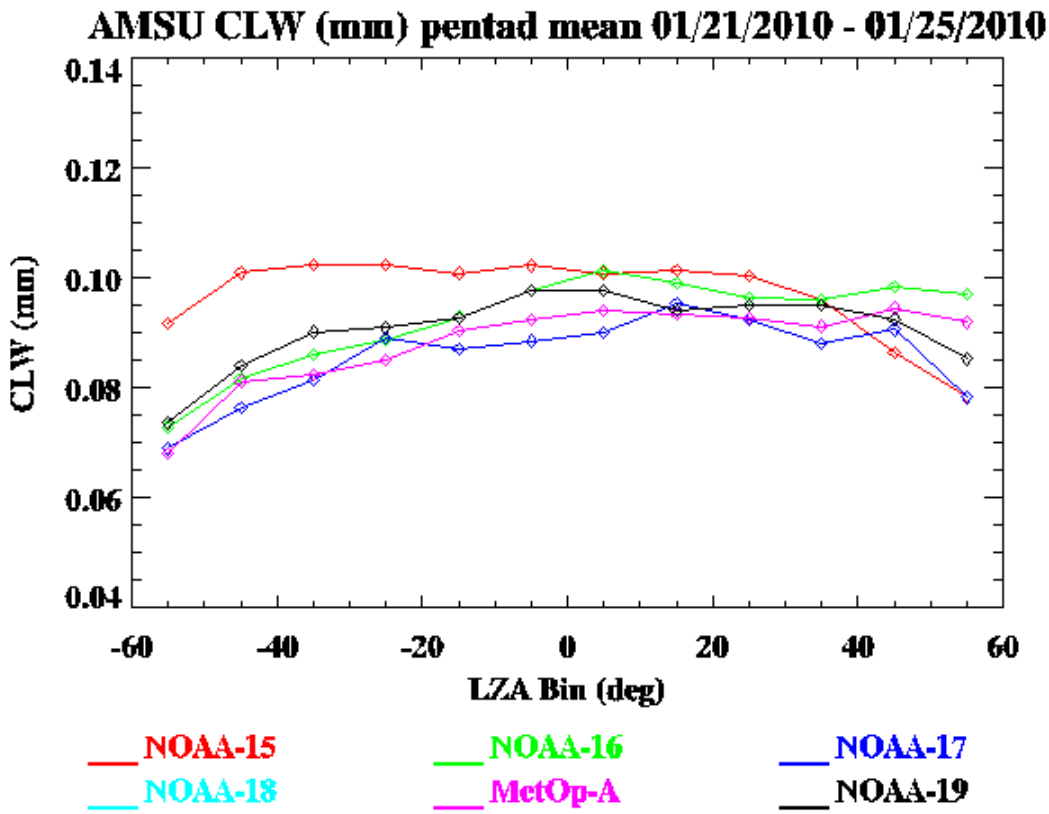

Figure 1. Angular distribution of AMSU-A cloud liquid water (CLW) pentad mean over tropical ocean for all on-board satellites.

We also revamped the AMSU-A TCDR processing system during this reporting period. The previous system took AMSU-A 1b data as input, and generated FCDR and TCDR in one execution. The long production chain proved to be somewhat cumbersome and error-prone. The revamped system separates the FCDR and TCDR production into two subsystems and avoids some of the issues we noticed in the older system. A set of AMSU-A TCDR data was generated using the new production system. The products were assessed for inter-satellite consistency as shown below.

Ocean products, including total precipitable water (TPW) and CLW, were averaged over tropical ocean (30°S to 30°N), from satellite launch time to the end of 2010, and the time series were compared between the operational MSPPS and the TCDR retrievals (Figure 2). Compared to the operational products, the TCDR products show better agreement among all satellites.

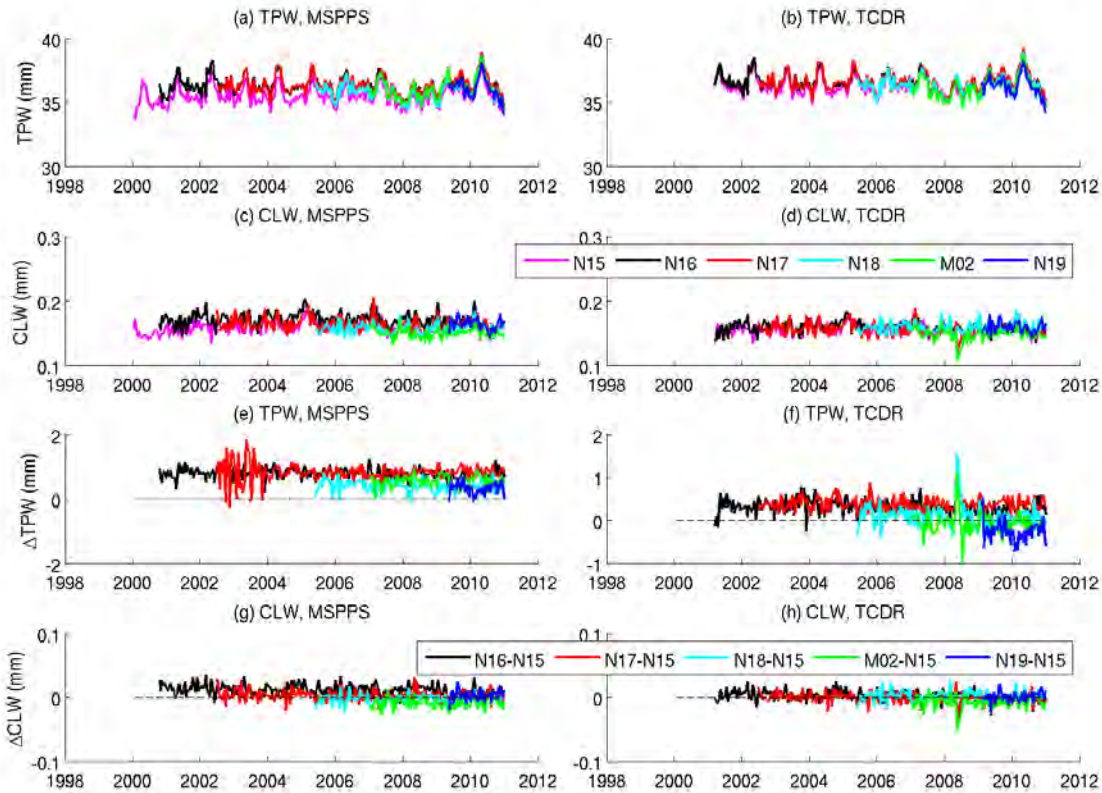

Figure 2. Comparison of ocean products (total precipitable water (TPW) and cloud liquid water (CLW)) time series between old MSPPS products (left column) and new TCDR products over tropical ocean.

Land products, including surface temperature (Ts) and surface emissivity at 50.3 GHz ($Emis_{50}$), were averaged over tropical land (30°S to 30°N), from satellite launch time to the end of 2010. Figure 3 compares the time series between MSPPS and TCDR. Note that the land products are impacted much more by diurnal cycle and seasonal cycle than ocean products do. Hence the land TCDR's display more differences among satellites compared to the ocean products.

To further examine the inter-satellite consistency of the land products, we repeated the above analysis (Figure 4) but limited the region to the Amazon, and selected only ascending node for improved telemetry homogeneity. The results show that the variation in surface temperature is much less both diurnally and seasonally compared to in the tropical region. The TCDR time series now display very nice agreement among satellites.

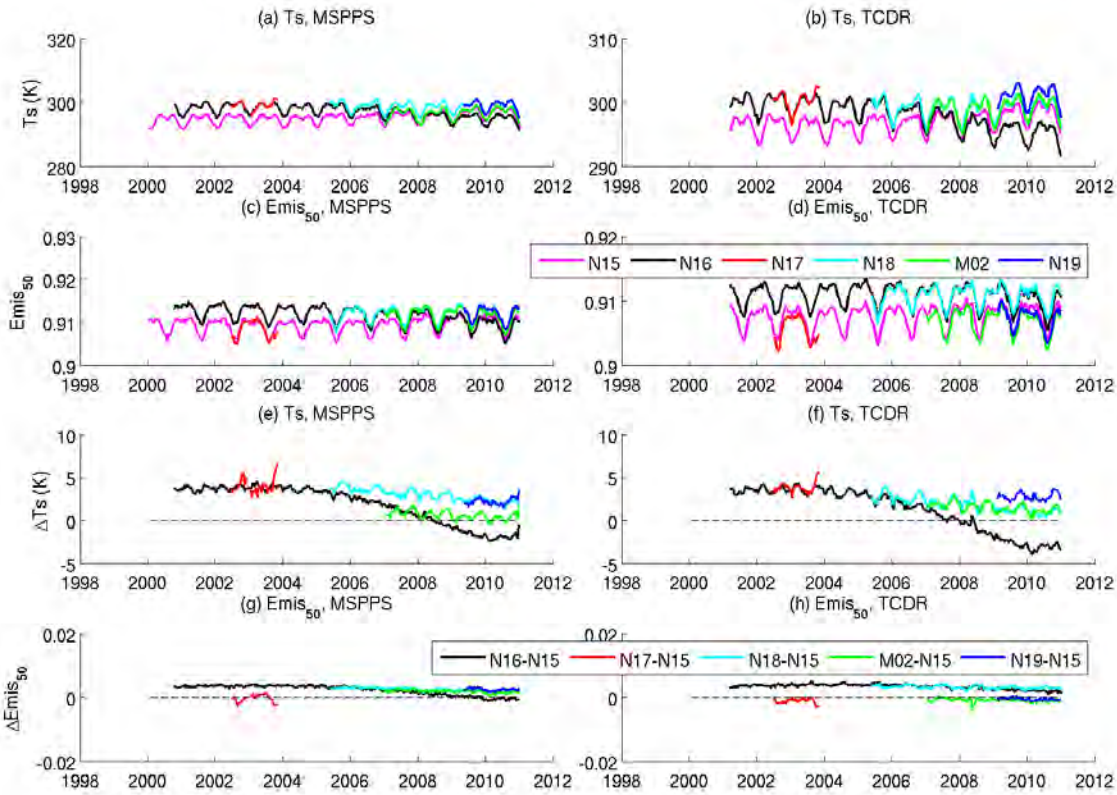

Figure 3. Comparison of land products (surface temperature (Ts) and surface emissivity at 50.3 GHz ($Emis_{50}$)) time series between old MSPPS products (left column) and new TCDR products over tropical land.

The AMSU-B and MHS TCDR processing systems were also developed during this reporting period. The TCDR's include rain rate, ice water path, snow cover, and snow water equivalent. The product algorithms are based on the MSPPS production system. The input to the systems include 1) AMSU-A FCDR for window channels, 2) AMSU-A TCDR for window channels, 3) AMSU-A FCDR for sounding channels, 4) AMSU-B/MHS FCDR, and 5) NOAA/NCEP GFS data. All input and output FCDR and TCDR data are in NetCDF4 format.

B. Inter-Satellite Calibration of AMSU-B/MHS Water Vapor Channels

Inter-satellite calibration of the AMSU-B (aboard NOAA-15, NOAA-16, and NOAA-17 satellites) and MHS (aboard NOAA-18, NOAA-19, and MetOp-A satellites) water vapor and window channels was completed and level-Beta NetCDF4 format files were created from the corrected brightness temperatures. For the AMSU-B sensors, NOAA-17 (2002 – 2009) was used as the reference to correct values from NOAA-15 (2000 – 2010) and NOAA-16 (2001 – 2010). The same was done for the MHS, using NOAA-18 (2005 – 2010) as a reference to correct NOAA-19 (2009 – 2010) and MetOp-A (2007 – 2010). Since the intercalibration coefficients are scene dependent, thus the collocations between reference and target satellites are required to cover a wide range of brightness temperatures. We employed area averaged brightness temperature from Tropical region (tropical band expanding from 30°S to 30°N) as the warm end of the brightness temperature range, and also area averaged brightness temperatures from Antarctica (< 75°S) and Arctic (> 75°N) as the cold end of the brightness temperatures. Since over tropical regions, there is a

small diurnal veneration in cloud regimes, we used a cloud filter, which is based on the difference between brightness temperatures from different channels to filter out cloud-contaminated observations

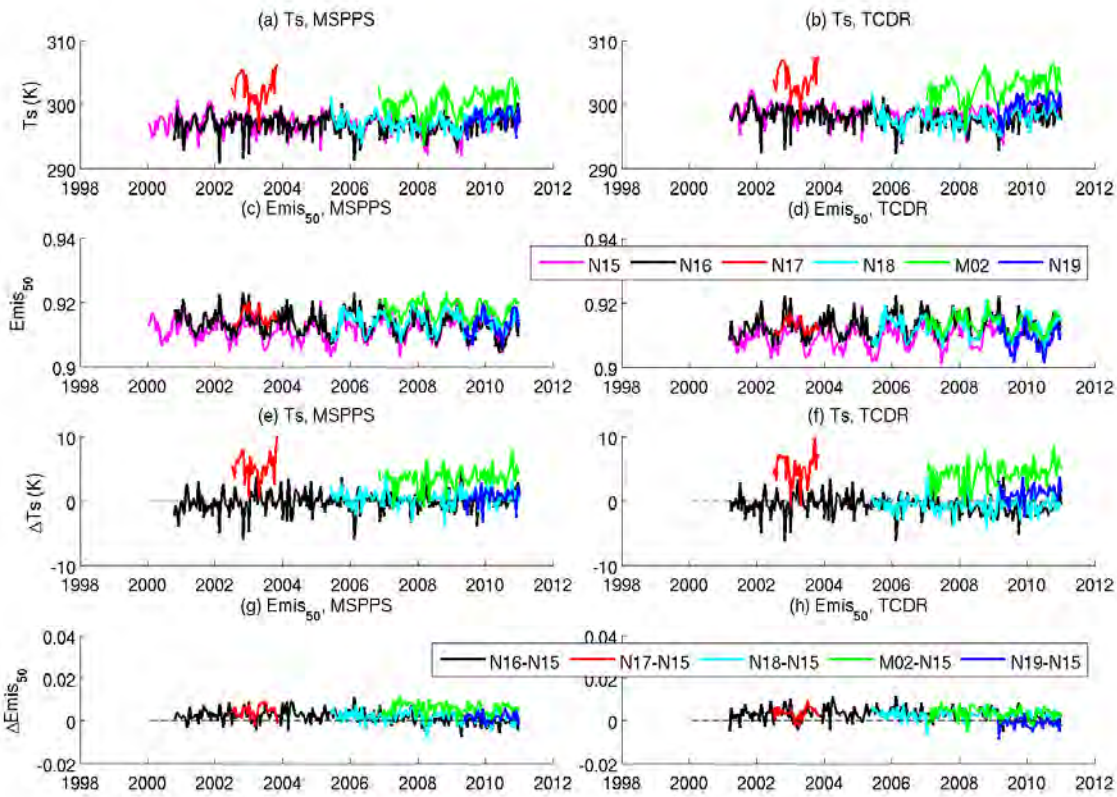

Figure 4. Similar to Figure 3, but over Amazon region.

Besides, since the satellites' overpass time is different, we only used the area-averaged data over ocean to eliminate the diurnal variation over land. Then we calculated the linear regression coefficients between the observations from the target satellites in a monthly period. These monthly values then were interpolated using a cubic-spline method to derive the daily values. It is preferred to calculate the coefficients in a monthly basis to avoid noise in the coefficients. Figure 5 shows an example of area averaged NOAA-15 versus NOAA-17 Channel 5 observations for 2003 and 2009. Figure 6 shows the time series of NOAA-15 Channel 5 corrected and un-corrected data along with NOAA-17 time series. Because NOAA-17 (reference satellite) does not cover the entire period of the target satellites, it was also necessary to extrapolate for January 2000 – June 2002 (NOAA-15) and for January 2001 – June 2002 (NOAA-16) as well as 2010 for both NOAA-15 and NOAA-16. However, validation is still underway to decide about the necessity of extrapolation and also the results of that.

These daily inter-calibration coefficients were then applied to level -1b data to create NetCDF4 format level-Beta files. Orbital node (ascending or descending node) was also applied to the corrected geolocations so that this information is also included in the final product.

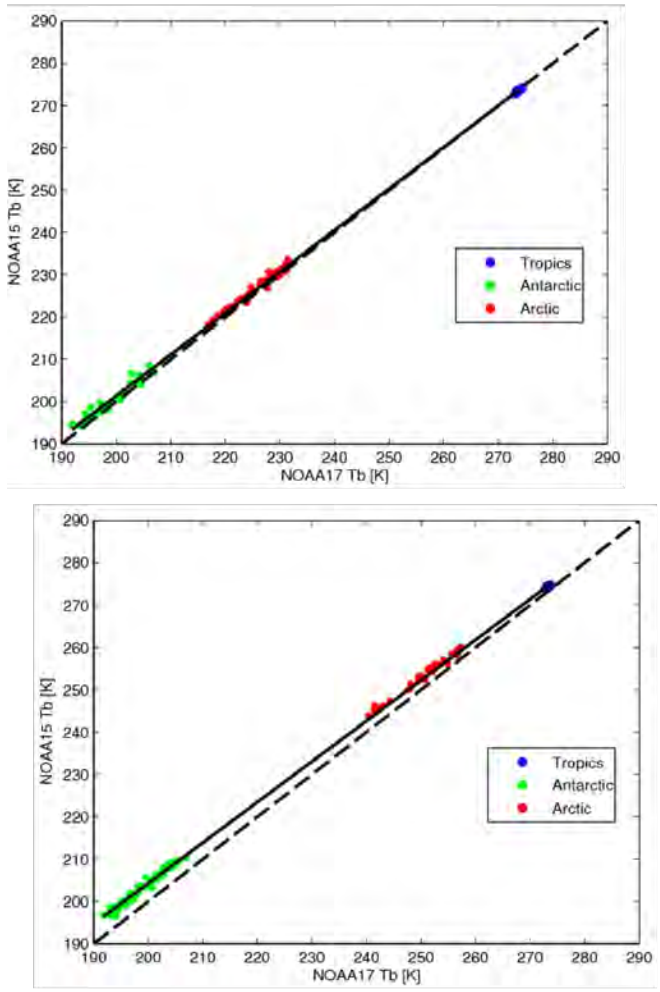

Figure 5: Area averaged NOAA-15 versus NOAA-17 Channel 5 observations for (top) 2003 and (bottom) 2009

C. Data Generation and Distribution

All of our data generated to date can be accessed through our project web site – http://cics.umd.edu/AMSU-CDR/home.html - which was updated during the reporting period.

D. C-ATBD Delivery

The AMSU-A, and AMSU-B/MHS C-ATBD for the FCDR's was delivered to NCDC, along with sample files.

Planned Work

The planned work is scheduled as following:

- For AMSU-A window channels, we plan to quantify frequency shift of 89 GHz, NOAA 15.
- Migration of the data to NCDC is not expected until FY2016 to sync with their transition schedule.

Publications

Moradi, I. and R. Ferraro, 2014: Intercalibration of microwave satellite data: an ongoing challenge. GSICS Quarterly, 8, 1-2, doi: 10.7289/V55H7D64

Yang, W., H. Meng, and R. Ferraro, 2015, Inter-Calibration of AMSU-A Window Channels, IEEE Trans. Geosci. Remote Sens. (to be submitted).

Yang, W., H. Meng, and R. Ferraro, 2014: Intercalibration of AMSU-A window channels, GSICS Quarterly, 8, 14-15, doi: 10.7289/V55H7D64.

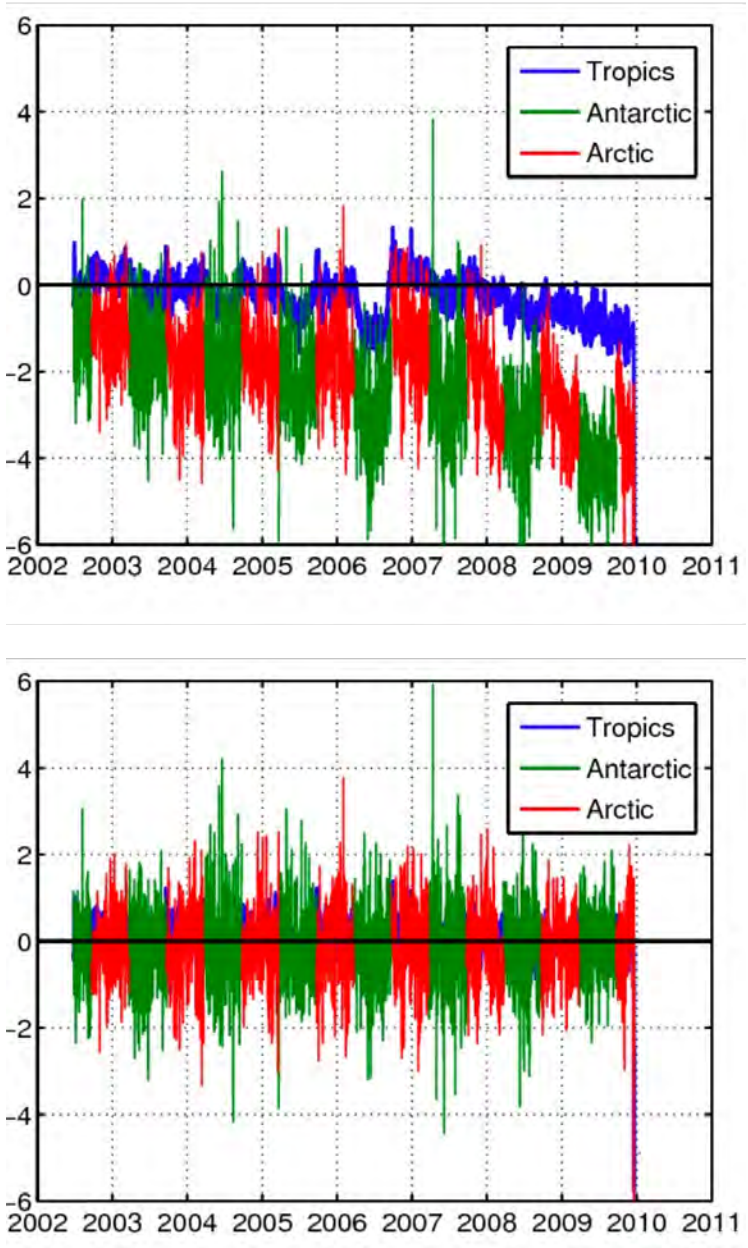

Figure 6: Time series of (top) uncorrected NOAA-15 channel 5 and (bottom) intercalibrated data along with NOAA-17 Level-1b data.

Presentations

Beauchamp, J., et al., 2015: The Development of AMSU-B/MHS FCDR's and TCDR's for Hydrological Applications, Second Annual CICS-MD Science Meeting, 2014, College Park, MD, November 2014.

Moradi, I, et al., 2014: Inter-Calibrating Observations from Microwave Humidity Sounders Onboard NOAA and Metop Satellites, AGU fall meeting, 2014, San Francisco, CA, December 2014.

Moradi, I., et al., 2015: Developing Climate Data Records from Microwave Water Vapor Channels, AMS 20th Conference on Satellite Meteorology and Oceanography, 2015 Phoenix, AZ, January 2015.

Yang, W., H. Meng, and R. Ferraro, Inter-Calibration of AMSU-A Window Channels, GPM XCal Meeting, Greenbelt, MD, Jul 9-10, 2014.

Yang, W., H. Meng and R. Ferraro, 2014: An Improved Microwave Satellite Data Set for Hydrological and Meteorological Applications, CICS-MD Science Meeting, College Park, MD, November 2014.

Yang, W., H. Meng and R. Ferraro, 2015: An Improved Microwave Satellite Data Set for Hydrological and Meteorological Applications, AMS Annual Meeting, Phoenix, AZ, January 2015.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**2**
# of invited presentations	**6**
# 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**

1.7 Land and Hydrology

Precipitation Research and Applications

Task Leader Yalei You
Task Code EBWY PRA_14
NOAA Sponsor Ralph Ferraro
NOAA Office NESDIS/STAR
Contribution to CICS Research Themes (%) Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic Land and Hydrology
Contribution to NOAA goals (%) Goal 1: 25%; Goal 2: 75%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%
Highlight A prototype precipitation retrieval algorithm is developed for passive microwave radiometers. The essential idea is to stratify the single data base into many smaller but more homogeneous databases by considering both surface condition and precipitation vertical structure information. We have implemented this algorithm using collocated SSMIS and ground based radar observations. Much improved precipitation detection and retrieval result have been obtained from this prototype algorithm.

Background

This work is to develop a prototype precipitation retrieval algorithm for passive microwave radiometers. The fundamental idea is to stratify the single database into many smaller but more homogeneous databases, in which both the surface condition and precipitation vertical structure are similar. Four ancillary parameters have been used in the stratification process, including surface type, surface temperature, land elevation and ice layer thickness. Three major statistical approaches are utilized for precipitation detection and retrieval, i.e., Linear Discriminant Analysis (LDA), Principal Component Analysis (PCA) and Bayes' theorem.

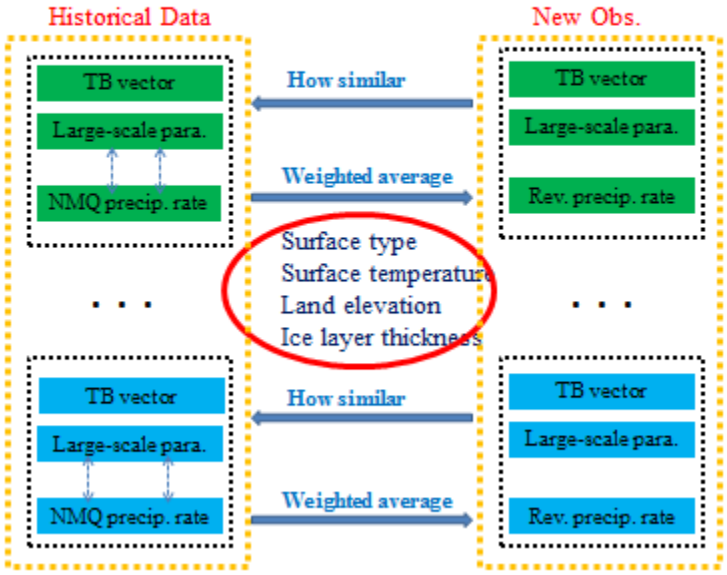

Figure 1. Flow chart for the prototype precipitation retrieval algorithm.

Accomplishments

The first objective of this work was to search the ancillary parameters, which can be used to stratify the single database, therefore alleviate the ill-posed retrieval issue. We found that four parameters (surface type, surface temperature, land elevation and ice layer thickness) can significantly reduce the brightness temperature (TB) variation corresponding to same surface precipitation rate. Next, these four parameters were utilized to stratify the single database into many smaller but more homogeneous databases. (Figure 1).

Using collocated Special Sensor Microwave Imager/Sounder (SSMIS) and ground radar observations over United States, we demonstrated that the probability of detection (POD) increases about 8% and 12% by using stratified databases for rainfall and snowfall detection, respectively. In addition, by considering the relative humidity at lower troposphere and the vertical velocity at 700 hPa in the precipitation detection process, the POD for snowfall detection is further increased by 20.4% from 56.0% to 76.4%. (Tables 1 and 2).

Table 1. Probability of detection (POD, %) for rainfall from the single database or stratified database, and with/without considering the vertical velocity (w) at 700 hPa and the relative humidity (rh) at the lower troposphere.

	Without (*w, rh*)	With (*w, rh*)
Singe database	75.9	78.5
Stratified database	84.0	85.1

Table 2. Same as table 2 except for snowfall.

	Without (*w, rh*)	With (*w, rh*)
Singe database	56.0	67.2
Stratified database	68.0	76.4

The better result from stratified databases is evident in both ends of the retrieved rainrate when the stratified databases are used, especially when the rainrate is greater than 30 mm/hr. Similarly, the retrieved snowfall rate using stratified databases also outperform that using single database. The correlation between retrieved and observed rainrates from stratified databases is 0.63 while it is 0.42 using the single database. The root mean square error is reduced by 50.3% from 2.07 to 0.98 by using stratified databases. The retrieved snowrate from stratified database are also better correlated with observations and possess smaller root mean square error. (Figure 2).

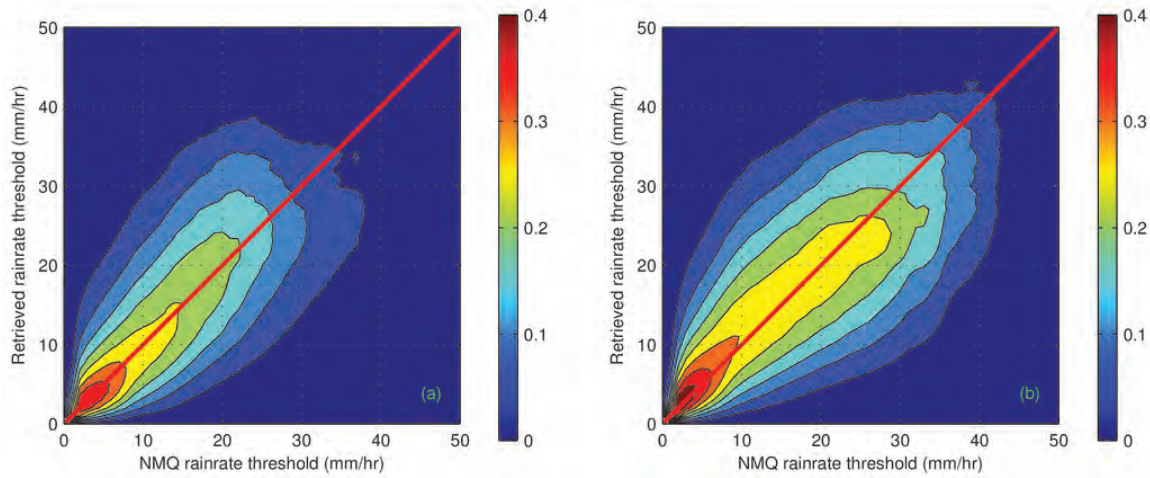

Figure 2. Two dimensional Heidke skill score (HSS) plot. (a) The rainrates are estimated from the single dtabase. (b) The rainrates are estimated from stratified databases.

Planned work

- Use better quality controlled ground radar observations to construct the database.
- Apply this framework to sounders, e.g., ATMS.
- Employ new rain/snow separation scheme.

Publications

You, Yalei, Nai-Yu Wang and Ralph Ferraro, 2014: A prototype precipitation retrieval algorithm over land using passive microwave observations stratified by surface condition and precipitation vertical structure, *J. Geophys. Res.: Atmos*. (conditionally accepted).

Presentations

Wang, Nai-Yu, Yalei You and Ralph Ferraro, et al., Towards the Consideration of Surface and Environment variables for a Microwave Precipitation Algorithm Over Land, *AGU Fall Meeting*, San Francisco. CA (12/15 to 12/19/2014)

You, Yalei, A Bayesian precipitation retrieval algorithm for the Advanced Technology Microwave Sounder (ATMS) , *CICS-MD Science Meeting*, College Park, MD (11/12 to 11/13/2014)

You, Yalei, Nai-Yu Wang, and Ralph Ferraro, A Prototype Precipitation Retrieval Algorithm Over Land Using Passive Microwave Observations Stratified by Surface Condition and Precipitation Vertical Structure, *AMS Annual Meeting*, Phoenix, AZ (1/4 to 1/8/2015)

You, Yalei, and Nai-Yu Wang, Poster: Microwave Remote Sensing of Lake-Effect Snow in the GPM Era, *AMS Annual Meeting*, Phoenix, AZ (1/4 to 1/8/2015)

Other

Collaboration with Yudong Tian et al. for the land surface emissivity work. A paper regarding this work is submitted to JGR.

Performance Metrics	
# of new or improved products developed (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	4
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

1.8 Earth System Monitoring from Satellites

Utilization of M-T SAPHIR to monitor S-NPP ATMS and MiRS products

Task Leader Isaac Moradi
Task Code IMIM_ATMS_14
NOAA Sponsor Fuzhong Weng fuzhong.weng@noaa.gov
NOAA Office: NOAA/STAR
Contribution to CICS Research : Theme 1 -20% Theme 2 - 60%, theme 2 - 20%
Main CICS Research Topic : Earth System Monitoring from Satellites
Contribution to NOAA goals (%): Goal 1 (100%)
Highlight: ATMS and SAPHIR data were intercompared and validated using radiosonde and GPS-RO data
Link to a research web page

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. These data are subject to errors and uncertainties after launch due to several reasons including drift in calibration. However, there is a lack of a perfect ground-based method to validate and monitor the accuracy of these observations. This project focuses on monitoring the accuracy of ATMS and SAPHIR observations with respect to each other as well as ground based radiosonde data. SAPHIR is a microwave humidity sounder onboard Megha-Tropiques (M-T) – a joint research mission between India and France (launched in October 2011) – and ATMS is the microwave instrument onboard S-NPP and future JPSS satellites.

The SAPHIR sensor on the M-T satellite has shown to be very accurate and can be utilized to cross-validate ATMS measurements in the 183 GHz water vapor bands. MiRS will also be generating TPW and rain rate products from SAPHIR.

Accomplishments

The main accomplishments of the project include:

- Inter-comparing similar channels from ATMS and SAPHIR
- Validating SAPHIR channels using observations simulated from radiosonde data
- Validating mid-upper tropospheric and lower stratospheric ATMS temperature sounding channels using simulated observations from radiosonde data
- Validating ATMS water vapor channels using simulated observations using radiosonde data
- Validating ATMS temperature sounding channels using observations simulated using a RT model and GPS-RO profiles

We evaluated the accuracy of ATMS and SAPHIR observations using several methods including inter-comparing observations from similar channels taking into account difference between the channels caused by small frequency difference, validating ATMS temperature and water vapor sounding channels using radiosonde data and validating ATMS stratospheric sounding channels using GPS-RO observations. The difference between SAPHIR and ATMS channels because of the frequency difference was simulated using CRTM and was subtracted from the difference between SAPHIR and ATMS observations. This difference, often referred to as double difference, varies from 0.3 K to 0.7 K, which shows a good consistency between the instruments. Figure 1 shows an example for the comparison of collocated SAPHIR and ATMS observations.

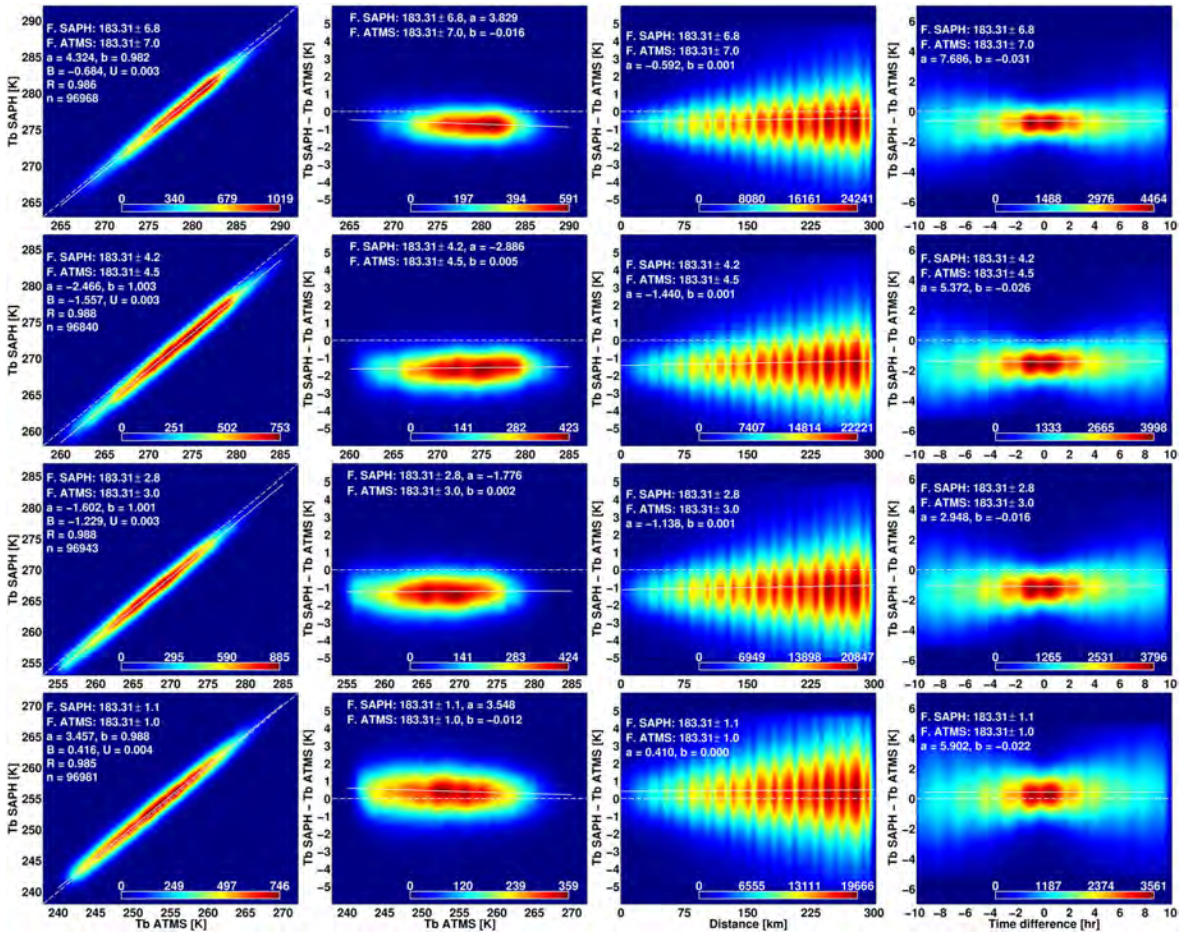

Fig. 3. Collocated SAPHIR and ATMS observations. Rows indicate results for different channels (frequencies of both ATMS and SAPHIR channels are printed on the plots). First column shows SAPHIR Tb's versus collocated ATMS Tb's, and second to fourth columns show the difference between SAPHIR and ATMS Tb's (SAPHIR minus ATMS) as a function of ATMS Tb (scene temperature), distance between collocated SAPHIR and ATMS data, and time difference between collocated SAPHIR and ATMS data, respectively. F indicates frequency of the channels, a and b indicate the offset and slope of the fitted line, B indicates the mean difference between SAPHIR and ATMS Tb's in Kelvin, U is uncertainty of the bias in Kelvin, R indicates the correlation coefficient, and n indicates number of collocations..

Then, the ATMS and SAPHIR observations were simulated using radiosonde profiles and an RT model. The difference between radiosonde and ATMS Tb's for the middle and upper tropospheric temperature sounding channels was less than 0.5 K at most stations, but the difference between radiosonde and ATMS/SAPHIR Tb's for water vapor channels was between 0.5 K and 2.0 K. The larger bias for the WV channels is attributed to a larger error in radiosonde humidity data and should not be counted as error in satellite data. The mean difference between ATMS observations and the Tb's simulated using GPS-RO profiles was 0.2, 0.3, 0.4, 0.2, and -0.2 K for channels 10-14, respectively, and the uncertainty increases from 0.02 K for channel 10 to 0.07 K for channel 14.

Planned Work

Inter-comparing and validation results are planned to be delivered to NOAA.

Publications

Moradi, I., Ferraro, R, Eriksson, P., Weng, F., Inter-calibration and validation of observationsfrom ATMS and SAPHIR microwave sounders. IEEE TGRS – under revision.

Moradi, I., Ferraro, R., 2014. Intercalibrating and Validating Saphir and Atms Observations. AGU Fall Meeting, San Francisco, CA

Products

The main products include interomparison results for ATMS and SAPHIR water channels and also validation using radiosonde and GPS-RO profiles

Presentations

Moradi, I., Ferraro, R., 2015. Inter-calibration and validation of observations from modern satellite microwave humidity and temperature sounders. AMS Annual Meeting and 11th Annual Symposium on New Generation Operational Environmental Satellite Systems, Phoenix, AZ.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	
# of invited presentations	**2**
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Towards Operational Arctic Snow and Sea ice Thickness Products

Task Leader Sinéad Louise Farrell
Task Code SFSF_IOAS_14
NOAA Sponsor Laury Miller
NOAA Office NOAA/NESDIS/STAR/SOCD/OPB Laboratory for Satellite Altimetry
Contribution to CICS Research Themes (%) Theme 1: 30%; Theme 2: 60%; Theme 3: 10%
Main CICS Research Topic Earth System Monitoring from Satellites; Calibration and Validation
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%
Highlight A novel technique to process snow radar data collected on airborne platforms over Arctic sea ice was developed resulting in a new snow on sea ice product. Snow depth on ice was analyzed as a function of ice type and surface roughness and compared with climatological values. Mean snow depth is thinner over first-year Arctic sea ice (~ 20 cm) than over multi-year ice (~ 35 cm).
Link to a research web page http://ibis.grdl.noaa.gov/SAT/SeaIce/index.php

Background

Improving our knowledge of the nature, and variability, of the sea ice cover is critical in order to advance our capabilities to predict future Arctic state, on seasonal to decadal time-scales. The thickness and volume of the Arctic sea ice pack are key components of the polar climate system. Ongoing loss of the ice pack has serious implications for climate change, but also has ecological and socio-economic impacts on the Arctic region. Satellite altimetry observations from ICESat and CryoSat-2 indicate a decline in the thickness of the ice pack over the last decade. The latest results from NASA's IceBridge mission show that following the precipitous drop in multi-year ice in 2007-2008, the central Arctic remains dominated by multi-year ice just over 3 m thick, while ice thickness in the Beaufort and Chukchi Seas continues to decline. Extensive, and continued, monitoring of the Arctic sea ice pack using satellite altimetry is necessary to determine whether recent observations are part of a sustained negative trend, or a reflection of the natural, interannual variability of the system. Altimetry data from the Envisat, ICESat, CryoSat-2, IceBridge and ICESat-2 missions provide almost two full decades of measurements of the Arctic ice pack. The goal of this investigation is to assess how well Arctic sea ice elevation, ice freeboard, snow depth, and ice thickness can be mapped using satellite and airborne altimeters. We validate the capabilities of the various altimeter systems, using independent aircraft and field measurements.

Accomplishments

CICS scientists, Dr. Sinéad L. Farrell, Dr. Thomas Newman, Dr. D. McAdoo, and Dr. A. Petty, along with scientists at the NOAA Lab. for Satellite Altimetry participated in the NASA Operation IceBridge (OIB) Mission's Arctic 2014 Spring Campaign, the ARISE Summer 2014 Campaign, and the NASA OIB 2014 Fall Campaign. Fifteen of the seventeen planed Arctic 2014 sea ice surveys were successfully conducted from Thule, Greenland and Fairbanks, AK during March and April 2014 (Figure 1). CICS and NOAA sea ice scientists collaborate closely with the NASA OIB Science Team on flight planning to acquire an optimal set of sea ice thickness and snow depth measurements across the ice pack of the western Arctic. Specifically the CICS/NOAA sea ice team designed airborne survey lines, provided advice on the collection of cal/val data below altimetry satellites (e.g. ESA's CryoSat-2 and SARAL/AltiKa), and assisted in designing OIB flights above in situ field sites to better quantify the accuracy of the airborne instrumentation. IceBridge conducted over-flights of multiple field sites in the Beaufort Sea and central Arctic Ocean (Figure 1), while teams on the ice obtained direct measurements of snow and sea ice conditions. These field activities were conducted in collaboration with CRREL, the European Space Agency (ESA) CryoVex

campaign, the US Office of Naval Research (ONR) Marginal Ice Zone (MIZ) DRI, and the Naval Research Laboratory's (NRL) DISTANCE program.

The CICS/NOAA sea ice team presented their recommendations and recent research at the IceBridge Sea Ice Working Group Meeting, 27 Jan. 2015, held at the NASA Goddard Space Flight Center (GSFC), Greenbelt, MD and the IceBridge Science Team Meeting, on 28 Jan. 2014, also at NASA GSFC. An Arctic 2014 field planning meeting was convened at NCWCP, College Park on 31 Jan. 2014, with sea ice scientists attending from NOAA, University of Maryland, CREEL and York University, Canada. A "Sea Ice Radar Altimetry Meeting" was convened at NCWCP on 23 Jan. 2014, with scientists attending from NOAA, University of Maryland, and NRL-DC.

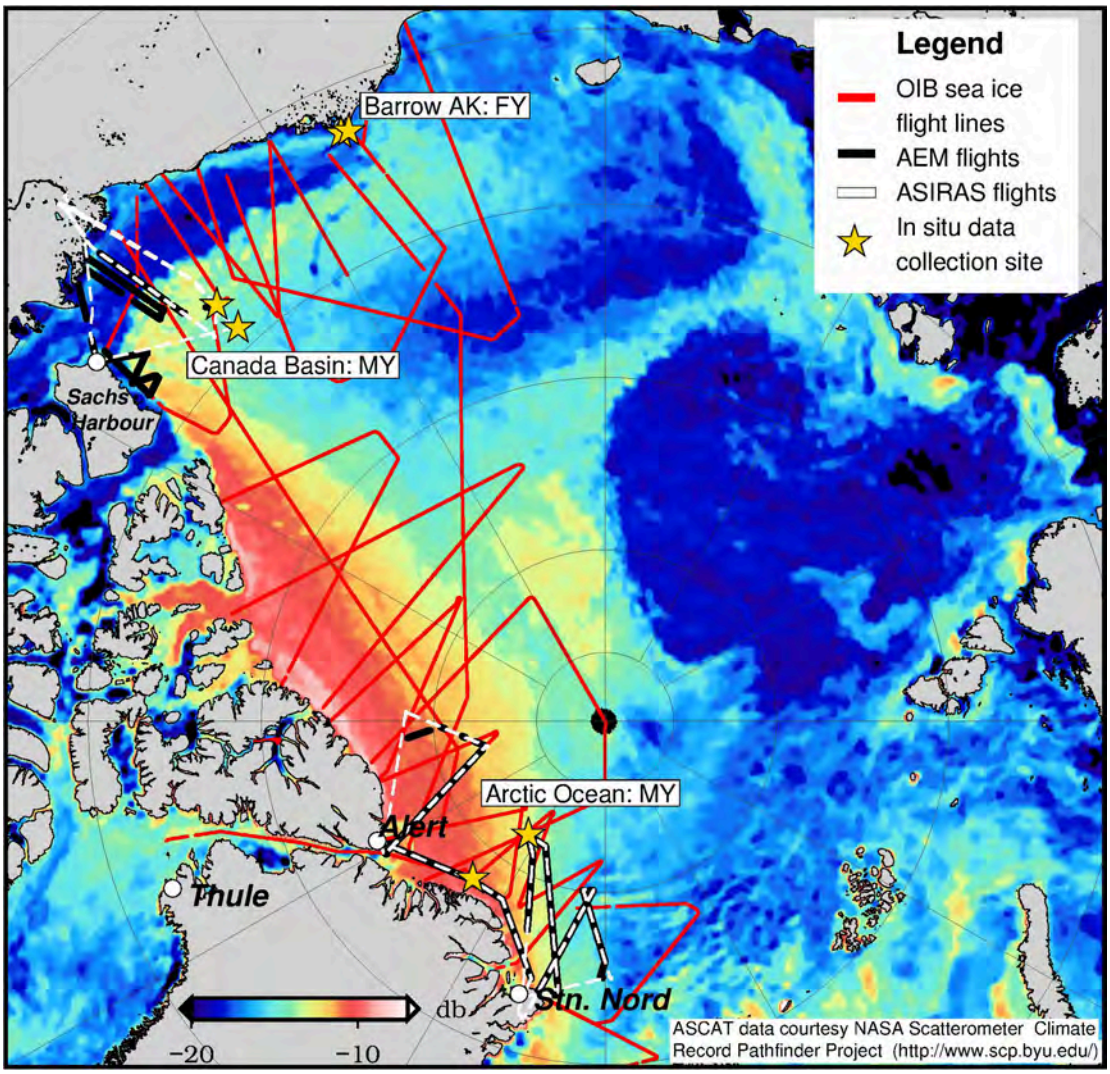

Figure 1. Coordinated in situ and airborne sea ice campaign in the western Arctic in March/April 2014. Fifteen of the seventeen planned NASA Operation IceBridge Arctic 2014 sea ice surveys (red lines) were successfully completed across the Arctic Ocean. The location of field camps (yellow stars), CryoVex2014 sea ice flights, including AEM (black lines) and ASIRAS (white lines), are also shown. The flight lines are over-laid on the contemporaneous sigma0 backscatter field derived from ASCAT. Figure credit: Richter-Menge et al., 2015, in prep.

Knowledge of contemporaneous snow depth on Arctic sea ice is important both to constrain the regional climatology and to improve the accuracy of satellite altimeter estimates of sea ice thickness. We assessed new data available from the NASA Operation IceBridge snow radar instrument and derived snow depth estimates across the western Arctic ice pack using a novel methodology based on wavelet techniques that define the primary reflecting surfaces within the snow pack (*Newman et al*., 2014). We assigned uncertainty to the snow depth estimates based upon both the radar system parameters and sea ice topographic variability. The accuracy of the airborne snow depth estimates was examined via comparison with coincident measurements gathered in situ across a range of ice types in the Beaufort Sea. We found that snow depths derived from the airborne snow radar using the wavelet-based technique are accurate to 1 cm over level sea ice. Over rougher surfaces including multiyear and ridged ice, the radar system is impacted by ice surface morphology.

Across basin scales, we found that the snow-radar-derived snow depth on first-year ice is thinner than on multiyear ice, at least 60% of the value reported in the snow climatology for the Beaufort Sea, Canada Basin, and parts of the central Arctic, since these regions were previously dominated by multiyear ice during the measurement period of the climatology. Snow on multiyear ice is more consistent with the climatology, on average ~ 35 cm thick. The results, published in *JGR-Oceans* in December 2014, were placed in the top 5 "most accessed articles" during the three-month period Dec. 2014 – Feb. 2015.

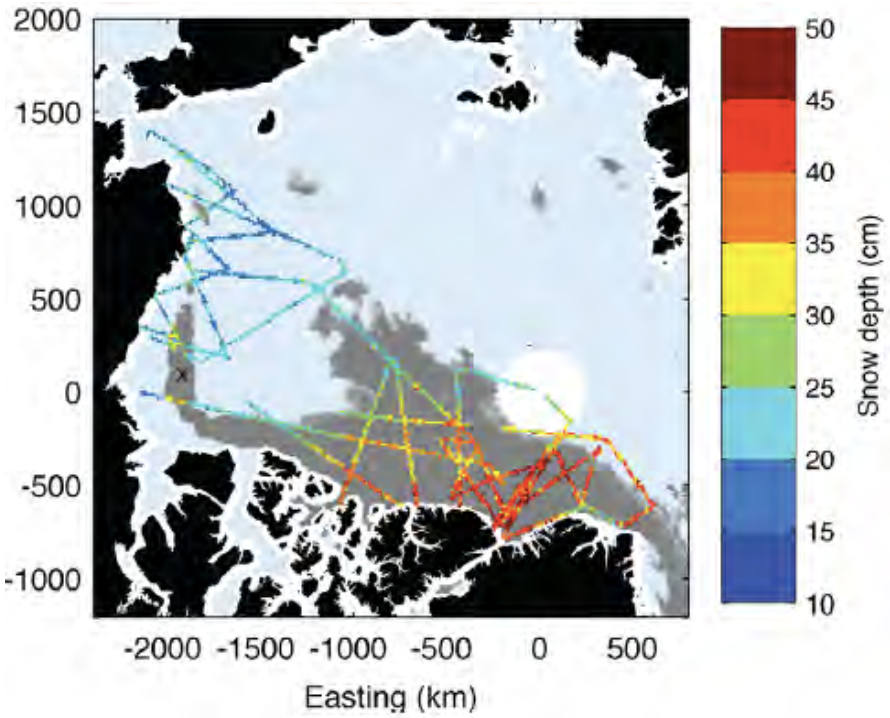

Figure 2. Polar stereographic mapping of snow depths (cm) obtained by applying the novel wavelet snow layer retrieval technique to Operation IceBridge (OIB) Snow-Radar data collected in March/April 2012. Dark gray shading shows the persistent multiyear ice region, derived from the EUMETSAT OSI SAF mask, for all the days that the OIB flights occurred, while lighter gray indicates areas of transient multiyear ice. Feature ''X'' is a tongue of multiyear ice that extended into a region of predominantly first-year ice in the southern Beaufort Sea in 2012. Figure credit: Newman et al., 2014.

Planned Work

- Participation in NASA Operation IceBridge Summer 2015, Antarctic 2015 and Arctic 2016 airborne campaigns: assist with definition of science objectives and flight-planning for successful completion.
- Extend results of Arctic snow depth assessment to rough/ridged sea ice surfaces via comparison of NASA IceBridge snow radar data with multiple validation data sets gathered in situ across a range of ice conditions in March 2014.
- Examine observed changes in the Arctic ice pack in the context of atmospheric forcing and ice drift.
- Examine sea ice dynamical change through assessment of the roughness and morphology of Arctic sea ice over a 6-year period (2009-2014) using high-resolution laser altimetry.
- Continue collaborations with the NOAA Laboratory for Satellite Altimetry, NASA GSFC, the Naval Research Laboratory (NRL), CRREL, University College London, and the European Space Agency on the assessment and inter-comparison of IceBridge and CryoSat-2 data products over Arctic sea ice.

Publications (1 April 2014 – 31 March 2015)

Richter-Menge, J., C. Haas and S. L. Farrell (2015), Arctic-wide airborne campaign to advance snow depth observations on sea ice, EOS Trans. AGU, in preparation.

Petty, A., J. Hutchings, S. L. Farrell, J. Richter-Menge and M. Tschudi (2015), Sea ice circulation around the Beaufort Gyre, *J. Geophys. Res*., in preparation.

Farrell, S. L., K. M. Brunt, J. M. Ruth, J. M. Kuhn, L. N. Connor and K. M. Walsh, 2015: Sea Ice Freeboard Retrieval using Digital Photon-counting Laser Altimetry, *Ann. Glaciol.*, *56*(69), 167–174, doi: 10.3189/2015AoG69A686.

Newman T., S. L. Farrell, J. Richter-Menge, B. Elder, L. Connor, N. Kurtz and D. McAdoo, 2014: Assessment of Radar-derived Snow Depth Measurements over Arctic sea ice, *J. Geophys. Res.*, *119*, 8578–8602, doi:10.1002/2014JC010284.

Webster, M. A., I. G. Rigor, S. V. Nghiem, N. T. Kurtz, S. L. Farrell, D. K. Perovich and M. Sturm, 2014: Interdecadal Changes in Snow Depth on Arctic Sea Ice, *J. Geophys Res.*, *119*, doi: 10.1002/2014JC009985.

Tsamados, M., D. Feltham, D. Schroeder, D. Flocco, S. Farrell, N. Kurtz, S. Laxon, and S. Bacon, 2014: Impact of atmospheric and oceanic form drag on simulations of Arctic sea ice, *J. Phys. Oceanog.*, *44*, 1329-1353, doi: 10.1175/JPO-D-13-0215.1.

Presentations (1 April 2014 – 31 March 2015)

Farrell, S. L., T. Newman, J. Richter-Menge, C. Haas, A. Petty, D. McAdoo, and L. Connor (2014), Recent Advances in Satellite and Airborne Altimetry over Arctic Sea Ice, Abstract C11D-04, *AGU Fall Meeting*, San Francisco. CA (12/15 to 12/19/2014)

Haas, C., J. Beckers, B. Elder, C. Hiemstra, M. Davidson, S. L. Farrell and J. Richter-Menge (2014), CryoVEx2014: Observations of Arctic Snow and Sea Ice Properties for Validation of CryoSat and IceBridge Retrievals (*Invited Presentation*), Abstract C24B-06, AGU Fall Meeting, San Francisco. CA (12/15 to 12/19/2014).

Hutchings, J., K. Martini, D. Perovich, I. Rigor, A. Petty, S. L. Farrell, R. Gens and E. Barker (2014), The Expansion of the Marginal Ice Zone in the Pacific Arctic (*Invited Presentation*), Abstract C13C-02, AGU Fall Meeting, San Francisco. CA (12/15 to 12/19/2014).

Hutchings, J., A. Petty, S. L. Farrell, J. Richter-Menge and M. Tschudi (2014), Sea ice dynamics and the role of wind forcing over the Beaufort Sea, Abstract OS51C-0988, AGU Fall Meeting, San Francisco. CA (12/15 to 12/19/2014).

Newman, T., S. L. Farrell, J. Richter-Menge, B. Elder, J. Ruth and L. Connor (2014), Advances in Airborne Altimetric Techniques for the Measurement of Snow on Arctic Sea Ice, Abstract C11D-06, AGU Fall Meeting, San Francisco. CA (12/15 to 12/19/2014).

Petty, A., S. L. Farrell, T. Newman, N. Kurtz, J. Richter-Menge, M. Tsamados and D. Feltham (2014), Characterizing sea ice surface morphology using high-resolution IceBridge data, Abstract C21A-0302, AGU Fall Meeting, San Francisco. CA (12/15 to 12/19/2014).

Richter-Menge, J. & S. L. Farrell (2014), NASA IceBridge: Airborne surveys of the polar sea ice covers (*Invited Presentation*), Abstract C14B-01, AGU Fall Meeting, San Francisco, CA (12/15 - 12/19/2014)

Thomas, S., D. McAdoo, S. L. Farrell, J. Brozena, V. Childers, M. Ziebart, and A. Shepherd (2014), Assessing performance of gravity models in the Arctic and the implications for polar oceanography, Abstract C21A-0313, AGU Fall Meeting, San Francisco. CA (12/15 to 12/19/2014).

Farrell, Sinead (Co-convenor and Chair), Advances in Altimetry of the Polar Regions, *AGU Fall Meeting*, San Francisco. CA (12/15 to 12/19/2014)

Farrell, Sinead, Interannual variability in Contemporaneous Measurements of Arctic Snow and Sea Ice Thickness, *CICS-MD Science Meeting*, College Park, MD (11/12 to 11/13/2014)

Petty, A. A., S. L. Farrell, J. K. Hutchings, J. A. Richter-Menge (2014), Seasonal trends in sea ice circulation and wind forcing over the Beaufort Sea, *Forum for Arctic Ocean Modeling and Observational Synthesis (FAMOS)*, Woods Hole Oceanographic Institute, Falmouth, MA (21-24 Oct. 2014).

Farrell, S. L., J. Richter-Menge, T. Newman, J. Ruth, B. Elder and J. M. Kuhn (2014), Interannual Variability in Arctic Snow and Sea Ice Thickness from Operation IceBridge, *The Royal Society "Arctic Sea Ice Reduction: the evidence, models and impacts, Satellite Meeting"*, Kavli Royal Society International Centre, Buckinghamshire, UK (24-25 Sept. 2014).

Farrell, S. L., J. Richter-Menge, T. Newman, N. T. Kurtz, B. C. Elder and L. N. Connor (2014), Airborne Observations of Snow on Sea Ice, IceBridge Science Team Meeting, University of California, Irvine, CA (24-25 June 2014).

Other

ICESat-2 Science Definition Team Member

In November 2014, Sinéad L. Farrell was selected to serve as a member of the NASA ICESat-2 Science Definition Team through her proposal "Preparing for Launch: Optimizing the Performance of ICESat-2 for Sea Ice. This is Farrell's second term as a member of the ICESat-2 science team. NASA plans to launch ICESat-2 in 2017.

IceBridge Science Team Member

Sinéad L. Farrell continues to serve as a member of the NASA IceBridge Team (2009 – present)
European Space Agency (ESA) CryoSat Sea Ice Product Validation ("CryoVal-SI") Investigator
Sinéad L. Farrell serves as International Investigator on the ESA CryoVal-SI project (2013 – present)
NOAA/NESDIS/STAR/SOCD Sea Ice Team
Drs. Farrell, Newman, McAdoo and Petty are members of the NOAA/NESDIS/STAR Sea Ice Team

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**4**
# of non-peered reviewed papers	**0**
# of invited presentations	**3**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**1**

A novel wavelet-based snow depth retrieval technique that has the ability to identify snow layer interfaces in NASA Operation IceBridge (OIB) snow radar echograms was developed (*Newman et al*., 2014). The technique does not rely on set thresholds or noise power statistics. Snow depth over Arctic sea ice is extracted on a waveform-by-waveform basis, without the need for spatial averaging. This results in a snow depth product (1) with approximately twice as many measurements as previously available in the OIB "IDCSI2" product. The methodology may be automated to obtain robust, and repeatable, snow depth estimates over sea ice. The results of our study were published in four (4) peer-review articles, and two (2) articles are in final preparation for submission to peer-reviewed journals. We presented our results at a number numerous national and international meetings, of which three (3) were invited. Dr. Farrell mentored one (1) University of Maryland undergraduate student.

Real-Time Monitoring and Short-term Forecasting of Phenology from GOES-R ABI for the Use in Numerical Weather Prediction Models

Task Leader Xiaoyang Zhang (South Dakota State University)
Task Code XZXZ_GOESR_14
NOAA Sponsor Yunyue Yu
NOAA Office **STAR**
Contribution to CICS Research Themes (%): Theme 1: 20%; Theme 2: 40%; Theme 3: 40%.
Main CICS Research Topic Earth System Monitoring from Satellites
Percent contribution to NOAA Goals Goal 1: 60%; Goal 2: 40%
Highlight: We developed a time series of angular corrected NDVI/EVI2 from SEVERI data. The SEVERI EVI2 was compared with MODIS EVI2 in the Congo Basin where cloud cover frequently occurs and the results show that SEVERI EVI2 significantly improves the data quality for tropical forest observations. The phenology detection algorithm was able to identify the vegetation phenology in the Sahara Desert although the vegetation growth was subtle.

Background

This project is to use GOES-R ABI data to build an operational system for monitoring and forecasting the seasonality of the green vegetation fraction and phenology in order to *improve NWS Operational Numerical Weather Prediction (NWP)*. In this context, phenology at the spatial resolutions relevant to NWP quantifies the seasonal progression of green vegetation fraction (GVF), especially its timing, magnitude, and variation across the vegetated land surface. Real-time monitoring and short-term forecasting of green vegetation fraction could greatly benefit numerical weather modeling by incorporating a key determinant in albedo, surface energy balance, and evapotranspiration. However, the timing of critical phenological events is not explicitly defined and spatiotemporally consistent GVF is actually not produced in GOES-R ABI Option 2 GVF product. Therefore, we will use the high frequency of diurnal observations from GOES-R ABI to generate daily cloud-free trajectories of the vegetation index (VI) for real-time monitoring and short-term forecasting of phenological metrics, including the timing and GVF magnitude in vegetation growth. The specific goals of this project are: (1) to monitor in real time and forecast in the short term phenological metrics using simulated ABI vegetation greenness trajectories; (2) to produce a daily enhanced GVF dataset that is free of gaps in real time and a week ahead, respectively; (3) to evaluate and validate the stability, precision, and accuracy of the proposed GOES-R phenological metrics; (4) to demonstrate the influence of the enhanced phenological metrics on improving NWP systems.

Accomplishments

- We investigated the half-hourly SEVERI data which are the proxy data of GOES-R ABI. To reduce the effects of solar zenith angle in the instantaneous SEVERI observations on vegetation detection, we used an angular anisotropy model based on the Kernel-driven model to adjust diurnal variation in NDVI/EVI2. After developing C codes and Perl scripts to process the half-hourly data, we tested the algorithm to generate daily NDVI/EVI2 using data covering the period of 2005-2014. Because of cloud cover is another major impact factor on vegetation index, we calculated cloud mask to explicitly remove cloud contamination. Computer C codes were further developed to generate 3-day composite based on cloud free and maximum vegetation index criteria. Finally, we generated 3-day time series of data from daily angularly observations during 2005-2014 which consists of NDVI, EVI, and cloud flag.

- We compared SEVERI data with MODIS observation in the Congo Basin. The Congo Basin is frequently covered by clouds. This results in the limited good quality observation from polar orbiting satellites, such as MODIS. SEVERI is expected to improve the time series of observations for surface detections. After comparing cloud free observations from SEVERI with MODIS data in the Congo Basin, we found that SEVERI data significantly improve the quality of land surface observations (Figure 1). This improved time series is expected to enhance the phenology detection in tropical rainforests.

- We also collected SEVERI LST data to remove irregular NDVI/EVI2 during winter in west Europe. The NDVI/EVI2 data during winter were frequently contaminated by snow cover. The LST was used to determine winter period within a year.

- We developed an algorithm for simulating trajectory of vegetation greenness (NDVI/EVI2) development. Because various approaches fail to explain well the physical development of vegetation growth, we decided to use the hybrid piecewise logistic model for the reconstruction of the daily temporal trajectory. We tested the hybrid piecewise logistic model using a set SEVERI data. We found the EVI2 data are very sensitive to the residual of cloud cover and snow cover. Therefore, after making a series of test, we decided to replace the EVI2 values using fill value if EVI2 is larger than 90% of NDVI.

- We developed the algorithm and computer codes to detect vegetation greenness phenology and tested the algorithm using data in the Sahara Desert which is an extreme case with very limited vegetation growth. The results show the SEVERI data were able to detect the vegetation growth in this dry area (Figure 2) although the green vegetation cover was very low and the seasonal variation was subtle.

- We developed an algorithm for calibrating climatology vegetation index to be comparable with GOES-R ABI vegetation index. The climatology data of phenology development is an important parameter in the algorithm of real-time monitoring. It was planned to calibrate MODIS-based phenology climatology to GOES-R ABI. The plan is to re-project MODIS data to GOES-R pixels and to establish pixel-based function to calibrate MODIS EVI2 to GOES-R EVI2. We were working on the development of a computer code for conducting the calibration. For Africa, we decided to establish phenology climatology using the SEVERI data from 2006-2013 because SEVERI data have been available since 2006.

- We started to process phenology detection from SEVERI data over entire Africa from 2006-2013. This process employed data of the daily datasets of angularly-corrected vegetation index, land surface temperature, and cloud mask. All data were prepared. The initial results were just produced.

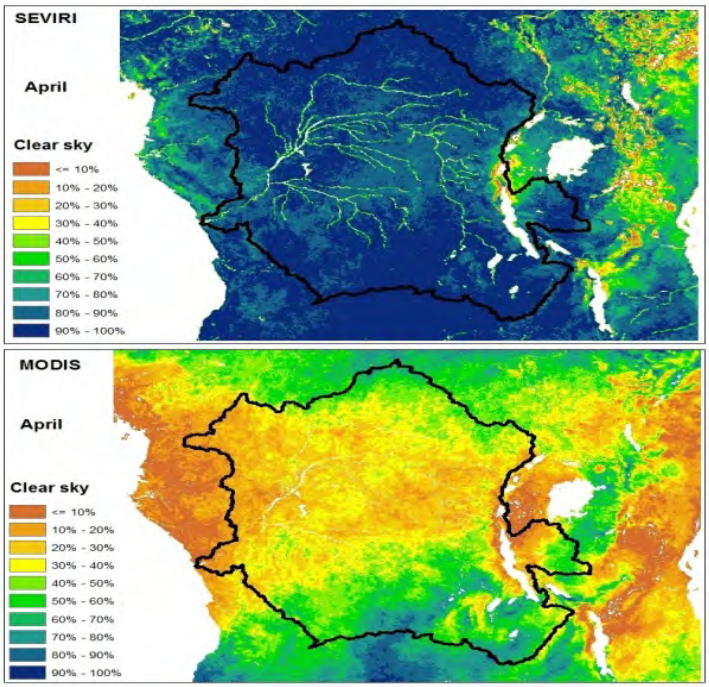

Figure 1. Comparison of the proportion of daily cloud free EVI2 between SEVERI observations and MODIS observations in the Congo Basin from 2005-2012.

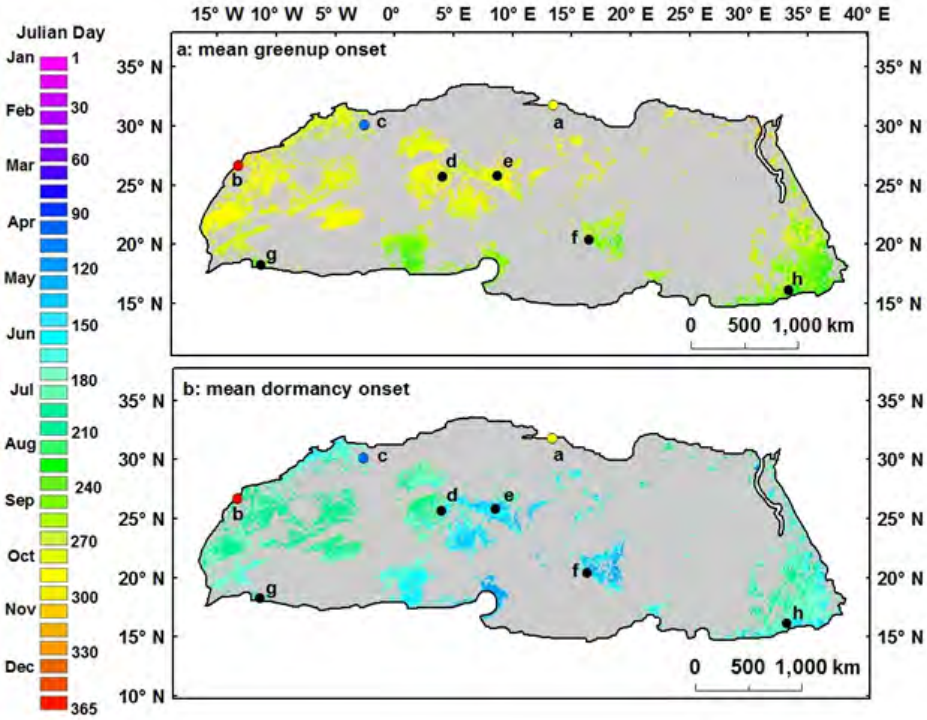

Figure 2. Green vegetation growth detected from SEVERI data in the Sahara Desert where (A) is the mean start of vegetation growth and (B) is the end of the growing season. The grey color represents the areas where no significant vegetation seasonality was detected.

Planned Work

- Investigate fire effects on phenology detection.
- Refine the algorithms and computer codes for monitoring in real time of phenological development.
- Prepare phenological data for Numerical Weather Prediction Systems (NWPS)

Presentations

Zhang, X., Yu, Y., 2014, Reconstructing daily Vegetation trajectory of vegetation index from AVHRR, MODIS, and VIIRS data, *2014 IGARSS and 35th Canadian Symposium on Remote Sensing*, July 13-18, 2014, Quebec City, Canada.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**1**
# 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**

Support transition of GSIP LST products to the Enterprise Processing System

Task Leader	Yuling Liu
Task Code	YLYL_GSIP_14
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic	Earth System Monitoring from Satellites
Contribution to NOAA goals (%)	Goal1:20%; Goal 2: 80%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Background

Information on land surface temperature (LST) is important for understanding climate change, modeling the hydrological and biogeochemical cycles, and is a prime candidate parameter for Numerical Weather Prediction assimilation models. The LST product from U.S. Geostationary satellite series is an important component of the global LST production at NOAA NESDIS. Cur-rent GOES LST is an independent product at OSPO which is proposed to be integrated into an enterprise operational system. This task is a part of the enterprise product development project which is going to merging the current GOES LST production into the system.

Accomplishments

1) Finished the modification of the GOES LST software package for making it adaptable to the change in GOES Surface and Insolation Product (GSIP) system.
    a. All related source code in GOES LST software package including the data reader and data process have been modified accordingly. The modified files include LST_Retrieval.h, LST_Retrieval.cpp, GOES_LST_MAIN.cpp, Para_define.h, Pa-ra_define.cpp and Make file etc. Corresponding configuration files have also been updated for both GOES 13 and GOES 15 LST.
    b. Performed unit test. The unit test includes the following items
        i. Test data preparation. The test data includes input from GOES 13 and GOES15 for both CONUS and full disk coverage.
        ii. Options for configuration file.
        iii. Developed a tool to check if the data is correctly read in for all variables such as BT, cloud mask, tpw, snow fraction etc.
        iv. Output verification
    c. Image display
    d. Downloaded a few more GSIP files and conducted the same test as explained above.
2) Provided support for new GLST code implementation in OSPO.
    a. The complete package including configuration files, updated readme file, source code and the unit test report has been delivered to OSPO.
    b. Provide support for investigating the difference observed between the two versions.
3) Emissivity update
    a. The emissivity data used as input for GOES LST retrieval are updated annually. The emis-sivity in 2014 has been included in the latest update.
4) Attended project progress meeting and provide support for scientific and engineering review

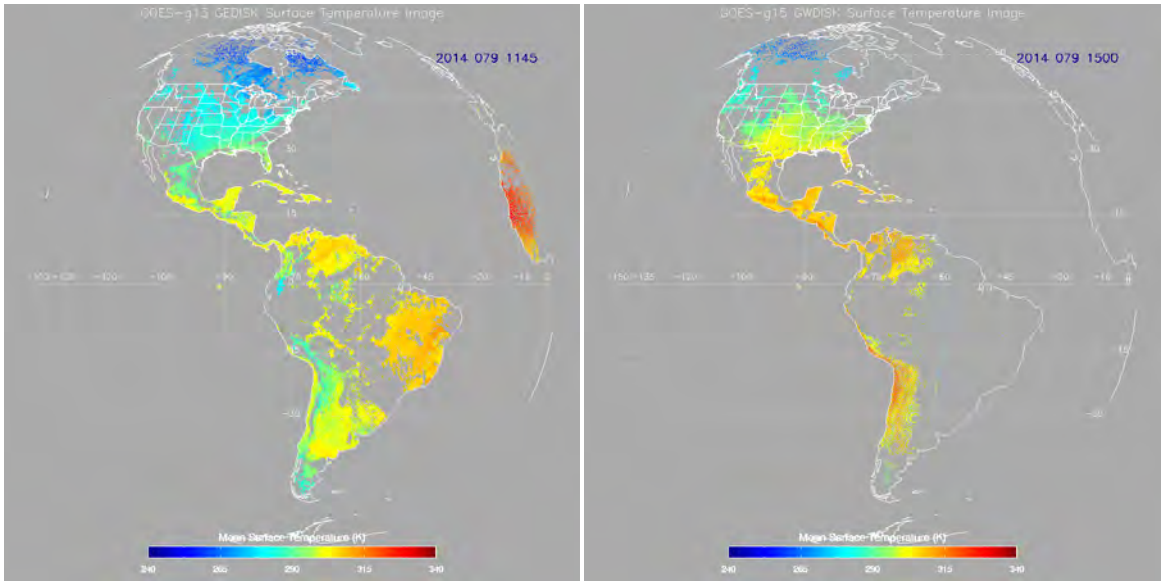

Figure 1. GOES LST Image (left: GOES13 at UTC 11:45 on March 20, 2014 and right: GOES 15 at UTC 15:00 on on March 20, 2014)

Planned Work

- Provide support for the LST software package
- Provide support for related scientific or engineering review of the project
- Provide support for the test related to transition, e.g. verification of the output before and after the transition

Products

GOES LST product version 2, corresponding to the GSIP V3 update

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

1.9 National Climate Assessments

CICS: Research, Development and Implementation of National and Regional Physical, Ecological, and Societal Climate Indicators for the NOAA and the USGCRP National Climate Assessment

Task Leader	Kenney, Melissa A.
Task Code	MKMK_RDIP_14
NOAA Sponsor	Eric Locklear
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 75%; Theme 2: 0%; Theme 3: 25% (estimated)
Main CICS Research Topic	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 85%; Goal 2: 5%; Goal 3: 5%; Goal 4: 5% (estimated)

Highlight: Kenney is leading the development of an interagency indicator system to bring together data, observations, and indicator products in innovative ways to better assess climate changes, impacts, vulnerabilities, and preparedness and move the research products into operations for decision support.

Link to a research web page http://tinyurl.com/melissakenney
http://www.globalchange.gov/what-we-do/assessment/indicators

Background

Indicators are essential elements of information systems, both to inform understanding and decisions about climate changes and impacts to diverse audiences. The National Oceanic and Atmospheric Administration (NOAA) has a number of monitoring, observation, and indicator efforts that provide critical insights and are integrated into information systems (e.g., National Climatic Data Center (NCDC; www.ncdc.noaa.gov/), National Integrated Drought Information System (NIDIS; www.drought.gov)). These NOAA initiatives are relevant to a new, national scale effort to develop an interagency indicator system for the U.S. Global Change Program (USGCRP), National Climate Assessment, described below. Given the benefits of indicators to NOAA, USGCRP, and the NCA, it is critical to understand and test the extent to which NOAA and other Federal agency indicator efforts and the development of additional indicators that would support ongoing NOAA information systems could additionally add value to a national interagency indicator platform.

This effort establishes a proof-of-concept system of indicators that communicates key aspects of the physical climate, climate impacts, vulnerabilities, and preparedness for the United States. We have brought together over 200 physical, natural, and social scientists, including NOAA experts, to develop pragmatic recommendations for a system of indicators. These collaborations will continue through the implementation of the prototype indicator system and associated scientific documents and manuscripts. The indicator system highlights critical NOAA and other Federal datasets and products, supports interagency collaboration, and is a fundamental element of the sustained USGCRP National Climate Assessment.

Accomplishments

We delivered on previous CICS task objective to provide a pilot indicator system as a prototype of the aspirational indicator system proposed through the NCADAC Indicators Report (Kenney et al., 2014). Since this delivery we have been helping facilitate the process of moving this research deliv-

erable into operations through the USGCRP and the associated Federal agencies. This has included consultations on the development of indicators through the USGCRP website, modifications to individual indicators (both graphics and text) and additional metadata information and collaboration with the Global Change Information Team to understand the modifications needed in the metadata model to accommodate the metadata needs of indicators. Additionally, we provided information upon request to support USGCRP's decision-making processes about the pilot indicator system release on the USGCRP website as a sustained assessment product and the development of a sustained governance structure for decision-making, prioritization, input from the scientific community, and actionable research to improve the system in real-time. The release of the pilot indicator system is likely in spring/summer 2015. The governance structure for a sustained indicator system was approved by the USGCRP Subcommittee on Global Change Research (USGCRP Principals) during their meeting in December 2014; the exact nature of the implementation of the governance structure will be decided partially through an adaptive management process in 2015.

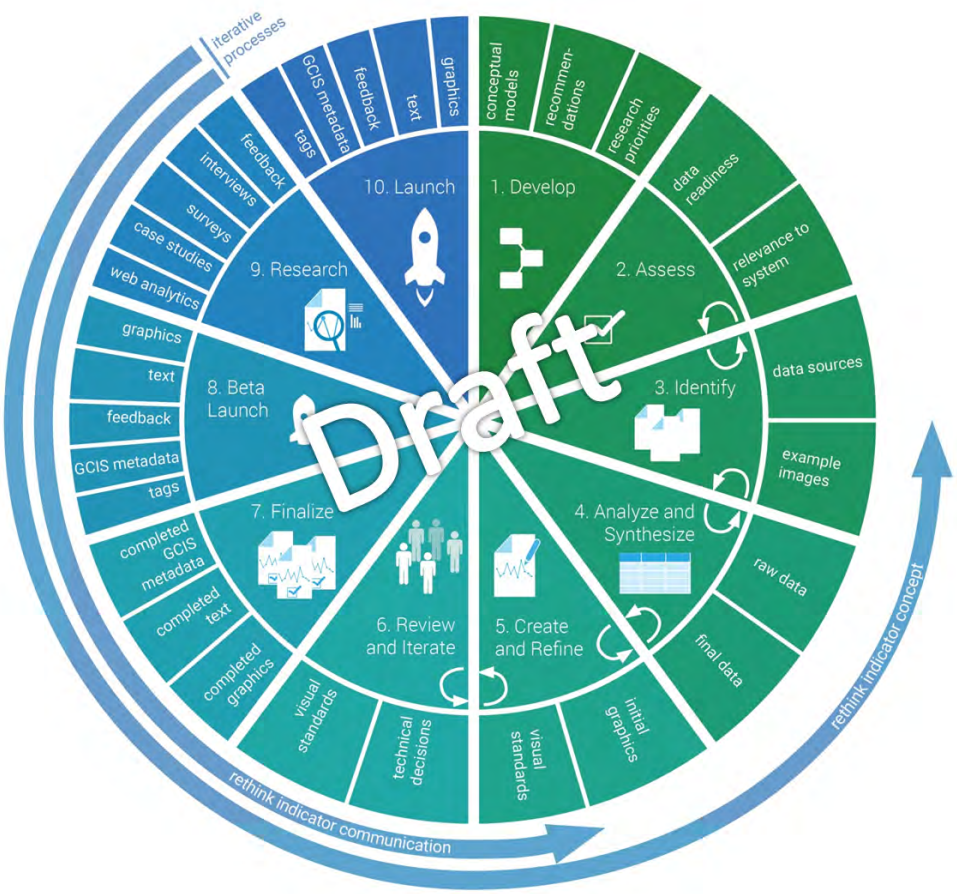

Figure 1. The process of moving from indicator recommendations through the development, design, review, evaluation, and implementation phases.

Over the past several models we developed a replicable process (Figure 1) to move from indicator recommendations through implementation. To this end, a project management tool was created with the intent to operationalize the graphic design process and facilitate efficiencies across the needed collaborations between the Indicators Team, NEMAC, USGCRP, GCIS, and others for the development, review, and release of indicators. The project management tool was developed by NEMAC in Drupal and thus can be transferred to other platforms in the future or to other organizations (such as USGCRP) if the implementation of indicators is taken over by a Federal agency or other group in the future. We also collaborated with the Global Change Information System team to develop an Indicators metadata model, which is still being built out and refined, to provide full traceability and transparency for the data and methods used to create the indicators published.

We proposed, in collaboration with our expert teams and appropriate agency subject matter experts, the development of indicator graphics and supporting key points and GCIS metadata traceability for those indicators proposed in the NCADAC Indicators Report (Kenney et al., 2014). We anticipate 14 indicators for pilot release; another 29 indicators are in various stage of development and will be presented for consideration when the new indicators governance structures are established.

In addition, we created graphic design guidance for a consistent color pallet, text size, and general look and feel of all the indicators included in the Indicator System. This approach is being formalized into guidance this spring that can be shared with agencies or scientists who would like to develop indicators consistent with the visuals for the Indicator System. We worked with USGCRP Communications to develop the lowest cost implementation of the pilot indicator system using existing USGCRP website templates updated for the basic needs of the pilot. More sophisticated website features will be revisited as social science research, planned for study when the pilot indicator system is released, proves them to be critical for the use of the indicators by user communities.

We also developed the protocol for an online survey testing the understandability and usefulness of indicator graphics and text to their intended audience (Figure 2). The survey will go active as soon as the pilot indicator system is officially released. Survey results will be used to determine if there is a systematic misunderstanding with any candidate indicators for both simple and complex indicators. If so, we will determine whether this is a result of a systematic bias by a subpopulation of the users and experiment to determine whether different presentation methods or translation of the information can remove the systematic misunderstanding.

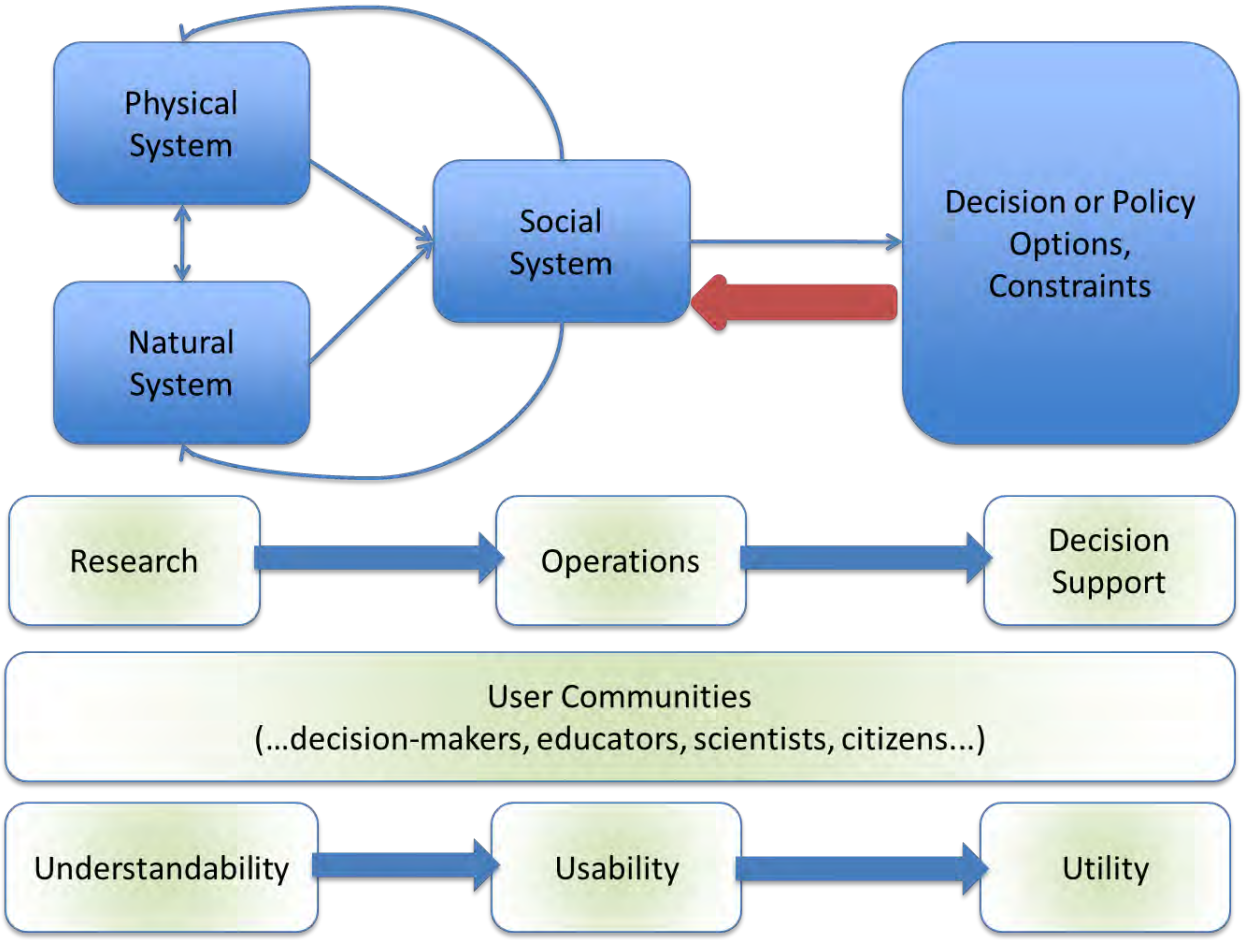

Figure 2. The integrated socio-physical-ecological systems approach to indicators with a focus on moving research to operations to decision support for a range of user communities. As the work moves more into social science evaluative research, we will take a multi-phase approach to move from understandability to potential usability for particular contexts, to actual use (utility) in various decision contexts.

Planned work

Note: This includes both work under this task as well as what is planned given additional funding.

Moving from the proof-of-concept indicator system to a fuller implementation of the National Climate Indicator System (NCIS), there are a number of research priorities that are necessary to develop the system interface, improve the indicators communication, develop and include new indicators, and understand and increase the use of indicators for multiple audiences and user communities. Specifically, the near-term research priorities include:

- **Development of Additional Indicators Recommended:** It is important to expand the initial proof-of-concept to include additional indicators recommended through the technical teams. Developing some of the recommendations will require data synthesis and visualization experimentation to assure that it communicates effectively to the intended audiences.

- **Development of New Indicators:** To meet the vision of the NCIS, additional indicators that have not been developed yet will need to be created. This is an opportunity for the research community to participate through identification of what is possible given existing understanding and datasets, as well as through development of prototype indicators for the NCIS that will be vetted through the peer-reviewed literature. This process has been partially modeled through the development of RFPs from NASA and NOAA related to the NCIS, but additional funding mechanisms are needed for the expansion of multi-stressor natural system and human sector impact and vulnerability indicators. This also includes the development of new technical teams to identify suites of indicators, such as biodiversity indicators, that are viewed as important by both the scientific and user communities.
- **Publications of Indicators Research:** Several research publications are planned given our current work including:
    - Coding indicator and climate decision support literature to have comprehensive review that can be empirically synthesized and published in an appropriate journal.
    - Special issue of journal, journal TBD late winter, for the development and recommendations of the Indicator System. Anticipate an overarching article on the indicator system, 12-13 articles from each of the technical teams, and an article with future directions and research priorities. NEMAC will be facilitating webinars with the technical teams in early 2015 to refine the draft conceptual models into something that the team views as final, is consistent with the conceptual modeling basis for this effort, and is scientifically rigorous and publishable in a top journal**.** Anticipate drafts of articles summer for internal review with articles submitted in fall 2015 for anticipated publication in 2016. This timeline would provide articles that could support the 4th NCA.
- **Development of Global Change Information System Metadata Guidance**: Develop guidance and processes to facilitate better development of the metadata with our experts so that expectations and needs for the Global Change Information System metadata are clear.
- **Social Science Evaluation Research:** There are a number of research studies that need to be conducted in order improve knowledge of the whole indicator development cycle, from indicator understanding to utility to use. The goal is to translate the scientific information in a manner that is correctly understood by non-scientists, such that a practical use for such information in their decision-making processes, communication and education goals, and scientific assessments can be seen. The research methods for this topic includes surveys, web analytics, focus groups, semi-structured cognitive interviews, and case studies.
- **Leading Indicators Priorities, Development, and Implementation:** To support decision-making it is critical to provide indicators that are predictive of future conditions. These indicators can be early warning indicators, meaning that we observe something now that gives us an indication of what will happen in the future, or predictive indicators, where we use models or expert judgment developed in a reproducible, verifiable manner to develop predictions of key changes or impacts. We would propose developing an expert workshop on the topic, conducted in two phases, that would then lead to the development of several prototype leading indicators that would be tested with user communities.
- **Adaptation and Mitigation Indicators:** Adaptation and mitigation indicators can take the form of both accounting indicators and effectiveness indicators. Accounting indicators assess whether a group has done certain types of adaptation or mitigation planning and implementation activities. These indicators give a sense of whether there is increased activity related to climate

resiliency. Adaptation and mitigation effectiveness indicators determine the degree of achievement relative to a counterfactual baseline (i.e., what would have occurred if the policy did not go into place). These indicators are difficult to develop, as determining what to measure (especially for adaptation indicators) and development of the counterfactual baseline can be contentious. Development of such indicators requires development of datasets and research, as there is nothing that is systematically established.

Publications

Peer Reviewed

Janetos, A.C., and M.A. Kenney, 2015: Indicators of change and consequence are unmet needs for Climate Change Assessments, *Nat. Climate Change* (in revision).

Kenney, M.A., E.M. Hamin, and T.C. Sheahan, 2014: Reconceptualizing the Role of Infrastructure in Resilience, *Eos, Transactions American Geophysical Union* , doi: 10.1002/2014EO330006

Prava, V., R.T. Clemen, B.F. Hobbs, and M.A. Kenney. 2015: Partition dependence and carryover biases in subjective probability assessment surveys for continuous variables: Model-based estimation and correction, *Decis. Anal*. (resubmitted)

Weaver, C. P., S. Mooney, D. Allen, N. Beller-Simms, T. Fish, A. E. Grambsch, W. Hohenstein, K. Jacobs, M. Kenney, M. A. Lane, L. Langner, E. Larson, D. L. McGinnis, R. H. Moss, L. G Nichols, C. Nierenberg, E. A. Seyller, P. C. Stern, R. Winthrop, 2014: From global change science to action with social sciences, *Nat. Climate Change*, **4**, 656–659

Kenney, M.A., A.C. Janetos, et al., 2014: *National Climate Indicators System Report*, National Climate Assessment and Development Advisory Committee.

Moss, R., P. L. Scarlett, M. A. Kenney, H. Kunreuther, R. Lempert, J. Manning, B. K. Williams, J. W. Boyd, E. T. Cloyd, L. Kaatz, and L. Patton, 2014: Ch. 26: Decision Support: Connecting Science, Risk Perception, and Decisions, in *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 620-647, doi:10.7930/J0H12ZXG.

Van Houtven, George, Carol Mansfield, Daniel J Phaneuf, Roger von Haefen, Bryan Milstead, Melissa A. Kenney, Kenneth H. Reckhow, 2014: Combining expert elicitation and stated preference methods to value ecosystem services from improved lake water quality, *Ecol. Econ*., **99**, 40–52, http://dx.doi.org/10.1016/j.ecolecon.2013.12.018

Non-Peer Reviewed

Vickerman, Sara, James S. Kagan et al., 2014: *Assessing Ecological Integrity across Jurisdiction and Scales*, http://www.defenders.org/publication/eco-integrity-measures-across-jurisdictions-and-scales

Products

- The proof-of-concept, a promised deliverable from the previous CICS task, was provided to USGCRP in summer 2014 and underwent review for consideration of both placing the pilot indicator system on the USGCRP website an setting up a long-term sustained governance structure for the development of a fuller implementation of the indicator system that would expand the indicators included, updates to the system, and refinements to meet the needs of multiple user communities. In December of 2014 the USGCRP SGCR approved the development of an indicators governance structure, the exact nature of which will be determined in 2015. Though multiple conversations have occurred to review and consider the pros/cons of a sustained indicator

system, the final approval and release of the pilot indicator system by USGCRP is anticipated in 2015.

  - Since the delivery of the prototype, requested changes and requests for information from USGCRP were prioritized to facilitate the process of moving the research product into interagency governance and operations.

- Created 43 climate change indicators that are in various stages of development (bolded indicators are finalized and will be part of the pilot indicator system release)
  - Annual and Monthly Precipitation
  - **Annual Greenhouse Gas Index**
  - **Arctic Sea Ice Extent**
  - Beef Cattle
  - **Carbon Dioxide Concentrations**
  - Coral Thermal Stress
  - Crop Yields
  - Disaster and Emergency Declarations by FEMA
  - Dissolved Oxygen
  - **Forest Cover**
  - Forest Growth / Productivity
  - Fossil and Industrial CO_2 Emissions
  - Freshwater Temperature
  - Global Emissions by Gas
  - Global Sea Level
  - **Global Surface Temperature**
  - **Grassland, Rangeland, and Pasture Cover**
  - **Heating and Cooling Degree Days**
  - Heavy Precipitation
  - Lake Ice
  - Livestock Deaths Due to Thermal Stress
  - Lyme Disease
  - Ocean Chemistry and Acidification (Aragonite Saturation State)
  - **Ocean Chlorophyll Concentrations**
  - **Onset of Spring**
  - Palmer Drought Severity Index
  - **Potential Growing Season (Frost-Free Season)**
  - Rainfall Erosivity
  - Rates of Heat Related Mortality
  - Regional and Local Sea Level Rise
  - **Sea Surface Temperature**
  - Seasonal Climate Indicators
  - Snow Cover Extent
  - Snowmelt Runoff
  - Status of the Nation's Infrastructure
  - Streamflow Indicators
  - Stress Index of Electricity Generation
  - **Terrestrial Carbon Storage**

  - Total GH Emissions by Source and Gas
  - **U.S. Surface Temperature**
  - Urban Area Extent
  - **Vibrio Infections**
  - Wildfire Effects – Burned Area
- Development of an Indicator Project Management System (indicators.nemac.gov) to facilitate collaboration and operationalize graphic design process and facilitate efficiencies across the needed collaborations between the Indicators Team, our subcontractor the National Environmental Modeling and Analysis Center (NEMAC), the Global Change Information System, and the USGCRP to make the decisions completely transparent and formalize the process and of moving from a indicator category recommendation to a fully-documented and indicator ready for review and delivery to USGCRP
- Created graphic design guidance document for a consistent color pallet, text size, and general look and feel of all the indicators included in the Indicator System.
- Developed a replicable process (Figure 1) to move from indicator recommendations through implementation that has been formalized through a document and the project management system.

Presentations

Kenney, Melissa, The Benefits of Water Quality Improvements and Restoration (Invited Presentation), *Virginia Lakes and Watershed Association (VLWA) Conference*, Richmond, VA (3/8 to 3/9/2015)

Kenney, Melissa (Invited Participant), *Communicating Climate Science Workshop*, AAAS, Washington, DC (3/4/2015).

Kenney, Melissa (Invited Participant), *S3 RCN Scenarios to Simulation Workshop*, Dartmouth College, Hanover, NH (2/26 to 2/27/2015)

Kenney, Melissa, Supporting and Informing Decisions through Assessment and Indicators, *AAAS Annual Meeting*, San Jose, CA (CA (2/12 to 2/16/2015)

Kenney, M.A., A.C. Janetos, R.V. Pouyat, R.J. AIcher, A. Lloyd, Poster: Developing a U.S. Interagency Pilot Indicator System to Support Climate Resilience, *AAAS Annual Meeting*, San Jose, CA (2/12 to 2/16/2015)

Cloyd, E.T. and M.A. Kenney, Poster: Tracking a changing climate: citizen science contributions to climate change indicator systems, *Citizen Science Association Conference*, San Jose, CA (2/11 to 2/12/2015)

Kenney, Melissa, Poster: Citizen science can support development of physical, natural, and societal indicators for the U.S. National Climate Indicator System, *Citizen Science Association Conference*, San Jose, CA (2/11 to 2/12/2015)

Kenney, Melissa, Climate Indicators? Or Farmer's Almanac? Weather-Water-Science-Policy (Invited Presentation), *DC Chapter of Sigma Xi and Rockville Science Café,* Rockville, MD (1/20/2015)

Kenney, Melissa, Indicators for the National Climate Assessment (Invited Presentation), *AMS Annual Meeting*, Phoenix, AZ (1/4 to 1/8/2015)

Kenney, Melissa, Opportunities and Examples for Integration of Socio-environmental Approaches to Support Climate-informed Decisions, *AGU Fall Meeting*, San Francisco, CA (12/15 to 12/19/2014)

Lloyd, Ainsley, Melissa Kenney, A.C. Janetos, R.V. Pouyat, R.J. AIcher, Poster: Developing a Pilot Indicator System for U.S. Climate Changes, Impacts, Vulnerabilities, and Responses, *AGU Fall Meeting*, San Francisco. CA (12/15 to 12/19/2014)

Kenney, Melissa (Co-convenir and Chair), Climate Indicators: Developing and Testing Indicators to Convey Information to Support Decisions, *AGU Fall Meeting*, San Francisco. CA (12/15 to 12/19/2014)

Kenney, Melissa, Applying an Ecosystem Services Framework to Climate Change Adaptation (Invited Presentation), *ACES 2014: Linking Science, Practice and Decision Making*, Washington, DC (12/8 to 12/12/2014)

Kenney, Melissa, Biodiversity and Ecosystem Services: Partners or Competitors? (Invited Presentation), *ACES 2014: Linking Science, Practice and Decision Making*, Washington, DC (12/8 to 12/12/2014)

Kenney, Melissa, The National Climate Assessment: The Role of Anthropologists in Building Assessment Capacity and Implementing a Sustained Assessment Process (Invited Presentation), *American Anthropological Association Annual Meeting*, Washington, DC (12/3 to 12/7/2014)

Kenney, Melissa, and Emily Cloyd, Plenary Panel on National Climate Indicators System (Invited Presentation), *Tracking a Changing Climate: Citizen Science Contributions to the National Climate Assessment* , Washington, DC (11/18 to 11/19/2014)

Kenney, Melissa (Invited Participant), *The Economic and Financial Risks of a Changing Climate*, Washington, DC (11/12/2014)

Kenney, Melissa, Future of Decision Analysis, *INFORMS Decision Analysis 50th Anniversary Gala Event,* San Francisco, CA (11/8/2014).

Kenney, Melissa (Invited Participant), *Measures of Community Resilience: From Lessons Learned to Lessons Applied*, Washington, DC (9/5/2014)

Kenney, Melissa A., Anthony C. Janetos, Richard V. Pouyat, Rebecca Aicher, Ainsley Lloyd, Poster: Developing a pilot system for national climate change, impact, vulnerability, and response indicators, *Ecological Society of America Annual Meeting*, Sacramento, CA (8/10 to 8/15/2014)

Kenney,Melissa, Anthony Janetos, Richard V. Pouyat, Rebecca J. Aicher, Ainsley Lloyd, Andrea J. Maguire, Indicators of climate changes and impacts for the National Climate Assessment (Invited Presentation) , *Ecological Society of America Annual Meeting*, Sacramento, CA (8/10 to 8/15/2014)

Kenney, Melissa (Invited Participant), *Next Steps for Implementing Ecosystem Services Approaches*, Washington, DC (7/21/2014)

Kenney, Melissa, National Climate Indicator System (Invited Presentation)*, Interagency Forum on Climate Change Impacts and Adaptation*, NASA HQ, Washington, DC (6/25/2014)

Kenney, Melissa (Invited Participant), *Frameworks for Evaluating the National Climate Assessment*, Washington, DC (6/19 to 6/20/2014)

Kenney, Melissa (Invited Participant), *Measurement Science for Sustainable Construction and Manufacturing*, Reston, VA (6/12 to 6/13/2014)

Kenney, Melissa, National Climate Indicators System: Sustained Actionable Science (Invited Presentation) , *Safeguarding Wildlife from Climate Change Webinar* (6/3/2014)

Kenney, M.A. and A.C. Janetos, Developing a system of national climate assessment indicators and Challenges with the Development of Adaptation Indicators (Invited Presentation*), USGCRP Adaptation Science Interagency Work Group*, Washington, DC (4/17/2014)

Kenney, M.A. and A.C. Janetos, National Climate Indicators System and Inclusion of Promising Research from NASA PIs (Invited Presentation), *NASA National Climate Assessment Center Call and Indicators Team Meeting*, NASA Headquarters, Washington, DC (4/8 to 4/9/2014)

Other

Kenney wins Young Investigator Award, 12/17/2014

CICS-MD Scientist Melissa Kenney has been selected to receive the 2015 Young Investigator Award from the Sigma Xi, the Scientific Research Society. The award comes with a guest lecture at the Sigma Xi Annual Meeting and an honorarium. The award recognizes researchers in the early stages of their careers whose outstanding contributions best exemplify the ideals of Sigma Xi.

Kenney Wins Editors' Choice Award, 7/21/14

The *Water Resources Research* journal has just announced that a 2013 "Editor's Choice Award" will go to an article by lead author Melissa Kenney, an ESSIC/CICS-MD Scientist. Editors' Choice Awards are given to about 1% of published articles in any calendar year to provide professional recognition to scientists and students for their outstanding work. The selection is made by the Editors of *WRR* based on technical significance, novelty, originality, presentation, and broader implications of the publication. The award will be presented in December at the AGU Fall Meeting. The winning article is: Kenney, M. A., B. F. Hobbs, D. Mohrig, H. Huang, J. A. Nittrouer, W. Kim, and G. Parker (2013), Cost analysis of water and sediment diversions to optimize land building in the Mississippi River delta, *Water Resour. Res*., **49**, 3388–3405, doi:10.1002/wrcr.20139. See CICS-MD Website Announcement at http://cicsmd.umd.edu/kenney-wins-editors-choice-award/.

Third National Climate Assessment Released, 5/9/2014

CICS Scientist Melissa Kenney attended the White House launch of the Third National Climate Assessment. The key message of her chapter on Decision Support in the Assessment is: "Steps to improve collaborative decision processes include developing new decision support tools and building human capacity to bridge science and decision-making."

Climate Voices is Rolling Out, 4/14/2014

CICS-MD Scientist Melissa Kenney is one of the "Climate Voices" in the new social media push by the United Nations Foundation and UCAR. The goal is to provide a registry of climate scientists that are available for discussions with local groups to spark community discussions about climate change. Check out the website at http://climatevoices.org/ . See CICS-MD Website Announcement at http://cicsmd.umd.edu/climate-voices-is-rolling-out-/

Performance Metrics	
# of new or improved products developed (please identify below the table)	**20**
# of products or techniques submitted to NOAA for consideration in operations use	**17**
# of peer reviewed papers	**7**
# of non-peered reviewed papers	**1**
# of invited presentations	**28**
# of graduate students supported by a CICS task	**NA**
# of graduate students formally advised	**3**
# of undergraduate students mentored during the year	**14**

Products

- The proof-of-concept, a promised deliverable from the previous CICS task, was provided to USGCRP in summer 2014 and underwent review for consideration of both placing the pilot indicator system on the USGCRP website an setting up a long-term sustained governance structure for the development of a fuller implementation of the indicator system that would expand the indicators included, updates to the system, and refinements to meet the needs of multiple user communities. In December of 2014 the USGCRP SGCR approved the development of an indicators governance structure, the exact nature of which will be determined in 2015. Though multiple conversations have occurred to review and consider the pros/cons of a sustained indicator system, the final approval and release of the pilot indicator system by USGCRP is anticipated in 2015.
    - Since the delivery of the prototype, requested changes and requests for information from USGCRP were prioritized to facilitate the process of moving the research product into interagency governance and operations.
- Individual indicators with developed for the pilot indicator system, 16 indicators submitted final proposed graphics, website text, and full metadata for Global Change Information System
    - Grassland, rangeland, and pasture cover
    - Arctic Sea Ice Extent
    - Terrestrial Carbon Sequestration
    - US Surface Temperature
    - Annual Greenhouse Gas Index
    - Frost-free Season
    - Onset of Spring
    - Global Surface Temperature
    - Forest Cover
    - Beef Cattle
    - Carbon Dioxide Concentrations
    - Heating and Cooling Degree Days
    - Urban Area Extent
    - Sea Surface Temperature
    - *Vibrio* Infections
    - Ocean Chlorophyll Concentrations

- Development of an Indicator Project Management System (indicators.nemac.gov) to facilitate collaboration and operationalize graphic design process and facilitate efficiencies across the needed collaborations between the Indicators Team, our subcontractor the National Environmental Modeling and Analysis Center (NEMAC), the Global Change Information System, and the USGCRP to make the decisions completely transparent and formalize the process and of moving from a indicator category recommendation to a fully-documented and indicator ready for review and delivery to USGCRP
- Created graphic design guidance document for a consistent color pallet, text size, and general look and feel of all the indicators included in the Indicator System.
- Developed a replicable process (Figure 1) to move from indicator recommendations through implementation that has been formalized through a document and the project management system.

Advising and Mentoring: Graduate Students

1. Reyes, Julian, Washington State University (2014-present)
2. Anderson, Sarah, Washington State University (2013-present)
3. Clark, Ryan, University of Maryland (2013-2014)

Advising and Mentoring: Undergraduate Students

1. Robbins, Ariane, University of South Carolina, Columbia (NOAA Hollings Scholar Program) (2015-present)
2. McAdams, Jasmine, Brown University (NOAA Hollings Scholar Program) (2015-present)
3. Weeks, Deseret, University of California Los Angeles (NOAA Hollings Scholar Program) (2015-present)
4. Deng, Ying, University of Maryland (2015-present)
5. Sharova, Maria, University of Maryland (2014-present)
6. Penansky, Michael, University of Maryland (2014)
7. Poon, Olivia, City College of New York (NOAA Educational Partnership Program (EPP) Internship) (2014)
8. Shaifer, Justin, Hampton University (NOAA Educational Partnership Program (EPP) Internship) (2014)
9. Lamoureux, Amanda, University of Maryland (National Socio-Environmental Synthesis Center (SESYNC) Internship) (2014)
10. Bredder, Allison, University of Maryland (2014-present)
11. Clarke, Ella, University of Maryland (2013-2014)
12. Ardanuy, Jeremy, University of Maryland, College Park (2013)
13. Golman, Eric, University of Maryland, College Park (2013-2014)
14. Gilliam, Marques, University of Maryland, College Park (2012-2014)

1.10 Climate Science to Support Policy and Outreach

Program Management at the Climate Program Office

Task Leader	Daniel Barrie
Task Code	DBDB_COEC_14
NOAA Sponsor	Eric Locklear
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 10%; Theme 3: 90%.
Main CICS Research Topic	5. Climate Research, Data Assimilation, and Modeling; 7. Land and Hydrology; 9. National Climate Assessments; 10. National Climate Model Portal; 11. Climate Science to Support Policy and Outreach
Contribution to NOAA Goals (%)	Goal 1: 40%; Goal 2: 25%; Goal 3: 15%; Goal 4: 10%; Goal 5: 10%

Highlight: Through engagement and the fostering of collaboration in carried out in this task, the University community has been more effectively connected with the NOAA scientific community. The results of this increased connectivity has been improved NOAA products and services including climate projections for North America, model components and performance, drought information, and improved understanding of extremes. Scientific progress has been fostered through new digital outreach techniques in addition to traditional facilitated community meetings. This outreach effort has helped coordinate and maximize the federal climate and Earth system model effort.

Background

The NOAA Climate Program Office (CPO) focuses on developing a broader user community for climate products and services, provides NOAA a focal point for climate activities, leads NOAA climate education and outreach activities, and coordinates international climate activities. To achieve these goals, CPO will benefit significantly from a strong partnership with outside investigators. Building this partnership requires the involvement of personnel with strong backgrounds in scientific research in program management positions. This need for scientific expertise within CPO matches well with Dr. Barrie's training, talents, and career interests.

Accomplishments

Two representative highlights from the task leader's previous year of activity are described below: 1) leadership of the CMIP5 Task Force and publication of an assessment of climate model performance for North America in the CMIP5 archive and 2) leadership of the Drought task Force and a report on the 2011-2014 California Drought.

1) The task leader has led the coordination and execution of the CMIP5 Task Force from the management side in collaboration with the Task Force leaders Jim Kinter (Center for Ocean-Land-Atmosphere Studies), Eric Maloney (Colorado State University), and Justin Sheffield (Princeton University). This Task Force came to a conclusion during 2014 having completed its three-year term. The Task Force has a long list of accomplishments from its tenure, and in the last year, a major capstone accomplishment was the publication of a report analyzing performance of the CMIP5 models for North American climate and comparing CMIP5-era model performance with that for CMIP3-era models. This report came about as a result of a connection made between the Task Force and the National Climate Assessment (NCA) staff. The staff of the NCA proposed a series of questions to the Task Force requesting information about the performance of

CMIP5/CMIP3 models for certain aspects of North American climate. The Task Force, leveraging the participating investigators and their relevant funded projects, contributed to the report, comparing CMIP3 and CMIP5 models. The report will be passed formally to the NCA in spring 2015 and will help inform future climate assessments.

2) The task leader helped organize and foster the Drought Task Force's efforts in assessing and better understanding the 2011-2014 California Drought, its causal mechanisms, its predictability, and whether the climate change signal contributed significantly to the drought. Richard Seager of Columbia University led the report with significant co-authorship and involvement from a broad cross-slice of the university research community and federal researchers. The report received a significant amount of media attention, mostly focusing on the implied conclusion that climate change did not contribute significantly to the drought and that the primary hydrologic forcing of the drought was from natural variability, particularly a "ridiculously resilient ridge" which has been present particularly over 2013-2015 off the U.S. West Coast. The report found the ridge to be the result of tropical SST forcing, and the ridge has also caused a significant warm pool in the NE Pacific through reduced cloud cover and increased ocean heat uptake. There is some uncertainty over the contribution of climate change to the drought in the published literature with a number of groups finding no (or a small) link while other groups have posited a significant impact from elevated temperatures or that the meteorological forcing has a climate change influence.

Planned work

- Continue to build on the Task Force activities
- Found a new CMIP task force based on projects funded in the FY15 cycle
- A new MAPP webinar series for 2015-2016
- Hold quarterly meetings at NCEP to facilitate transition of research to operations from the university/external community to NCEP
- Work with NCEP on a plan and prototype for CFSv3

Products

- CMIP3/CMIP5 Technical Report (not yet publically available; Sheffield et al., 2014)
- 2011-2014 California Drought report (Seager et al., 2014)

Presentations

2015 Climate and Severe Weather Workshop – presentation on transition of research to applications

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**4**
# of peer reviewed papers	**0**
# 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**

A number of funded projects have transitioned to operations during the past year

Climate Outreach and Education at the Climate Program Office

Task Leader	Dan Barrie
Primary Scientist	Will Chong
Task Code	**DBWC_CPO_14**
NOAA Sponsor	Eric Locklear
NOAA Office	OAR/CPO/ASD
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Science to Support Policy and Outreach
Contribution to NOAA Goals (%)	Goal 1: 55%; Goal 2: 5%; Goal 3: 0%; Goal 4: 0%; Goal 5: 40%

Highlight: Increased collaboration and cooperation with scientist from NOAA, other agencies, Cooperative Institutes, and the external community fosters the net output of research for the general public. Outreach using web interface and communicative materials has helped maximize the promotion of scientific stewardship of climate related information.
Link: http://cpo.noaa.gov/MAPP

Background

The Climate Program Office (CPO) focuses on developing a broader user community for climate products and services, provides NOAA a focal point for climate activities, leads NOAA climate education and outreach activities, and coordinates international climate activities. To achieve these goals, CPO will benefit significantly from a strong partnership with outside investigators. Building this partnership requires the involvement of personnel with computational and organizational skills to assist with program management activities.

Accomplishments

In FY14, the primary scientist continued to manage the website on the web interface content management system (CMS). The old website was structured using basic HyperText Markup Language (HTML), something that limited how much information and the type of information that could be effectively communicated online. The previous migration and creation of the new CMS allowed for a more efficient way to display and communicate climate related research results to the public. This year, the primary scientist continued to manage and develop new content for the website to better communicate and distribute the program's research outcomes with the public. New pages and sections were created to represent new task forces, providing a space for the public to view descriptions, missions, participants, news items, publications, reports and other resources. Articles were continually developed throughout the year to highlight newsworthy program news and events. This work enabled scientists from NOAA, other agencies, Cooperative Institutes, and the external community to increase their collaboration and improve the public's knowledge of research activities across multiple sectors.

The primary scientist collaborated with the Climate Program Office's Communication and Education division and public sector communities for the development of material for the website and communication materials. Material for the website including images and graphics were used to increase the communication and distribution of research results reflected on the website. Physical materials such as informational business cards and program brochures were co-created by the physical scientist for the distribution at meetings and conferences, such as the 2014 American Geophysical Union Fall Meeting in San Francisco, California and the 2015 American Meteorological Society Annual Meeting in Phoenix, Arizona. Those materials allowed for more outreach to promote scientific stewardship of climate related information.

The primary scientist interacted with investigators funded by the grants program to better promote and communicate their research and to facilitate the integration of their research results into NOAA activities and products. A webpage was created on the website that displays the projects in an informal profile for those of the general public who are interested in learning more about current and past NOAA research activities. The primary scientist also archives progress reports and publications submitted by investigators throughout the year for program management to review.

The involvement of the primary scientist with computational and organizational skills to assist with program management activities has been essential to the success of his ability to provide climate outreach and education activities at CPO. The primary scientist has provided logistical and technical support for organized groups of federal, state, non-governmental organizations, and the broader academic research community. Examples of this include successfully scheduling and organizing monthly teleconferencing events, virtual meetings, in-person meetings and workshops to connect and engage research activities across sectors. The primary scientist also provides IT support during meetings to help ensure they run smoothly. Technical support includes running test on computers and software prior to meetings to ensure timely efficiency. Web conferencing tools have been utilized to allow for program management and scientist to more effectively communicate during virtual meetings. This has resulted in improved meeting engagement with participants.

Planned Work

- Continue to manage and develop content for the website
- Continue to serve as the logistical organizer for groups, meetings, and workshops
- Continue to develop communicative tools for outreach and education

PE

Performance Metrics	
# of new or improved products developed (please identify below the table)	**5**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**N/A**
# of invited presentations	**N/A**
# 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**

New and improved products are described in the accomplishments section. Papers and graduate students are not applicable to the task.

Interpretation of Climate Data for Spherical Displays

Task Leader Stephanie Schollaert Uz
Task Code NA10SEC0080013
NOAA Sponsor Carrie MacDougall
NOAA Office OED
Contribution to CICS Research Themes (%) Theme 1: 100%
Main CICS Research Topic Climate Science in Support of Policy and Outreach
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 25%
Highlight: This interagency collaboration develops ClimateBits videos to explain a variety of Earth science concepts to the general public on Science On a Sphere® and YouTube. This resource is increasingly requested for routine and special events around the world.
Link to a web page http://climatebits.umd.edu

Background

This report summarizes the year's progress on the informal education project funded by the NOAA Office of Education to interpret climate data for spherical displays. This project has evolved into a close collaboration with scientists and informal education specialists at NASA GSFC, scientists at NOAA and the University of Maryland. Additionally we collaborate with other education and outreach organizations to promote this product (e.g. Smithsonian, Climate Central). We have an ongoing partnership with the Maryland Science Center to evaluate SOS content and conduct case studies on how people learn climate content from the sphere. We use the results of these evaluations to develop best practices to fully utilize the strengths of spherical displays. In addition to publishing these to the 110 sites in the SOS network with an estimated total visitorship of 35M per year, we also announce and publish the videos to social media. Here we detail the accomplishments of the project this year and then list planned work for next year.

Accomplishments

CICS-MD continued developing ClimateBits as a Science On a Sphere® and web-based resource: http://climatebits.umd.edu. The website includes a brief explanation of these short videos that explain essential climate concepts, a page for more in-depth information including references and other resources, and a link to watch the videos on YouTube. In collaboration with NASA GSFC, we published Solar Radiation, Ozone Layer, Air Quality (narrated by UMD professor Russ Dickerson), UV Index (narrated by NASA atmospheric scientist Paul Newman), and Fast Carbon, Slow Carbon (narrated by NASA carbon scientist Peter Griffith) to the NOAA SOS catalog. The last one made its debut on the NASA GSFC Visitor's Center SOS on February 3rd for a 'Women in STEM' group hosted by the Dept. of State, including women from around the world (e.g. Papua New Guinea, Bangladesh, Russia, Botswana, Nigeria, El Salvador, Mexico, Hungary, Poland). Current ClimateBits videos in production include Ozone Hole, Carbon Dioxide (with NASA climatologist Claire Parkinson), Carbon Sources (with NASA fires scientist Doug Morton), Carbon Sinks (with NOAA blue carbon scientist Ariana Sutton-Grier).

In collaboration with NASA, we are conducting ongoing research on the best practices for SOS use, working closely with the Maryland Science Center (MSC) and a school group that takes regular field trips to MSC. School groups represent a convenient population because they are much easier to access on multiple days than individuals from the general public. According to MSC, fifth grade represents the typical science education level of the general public. Last year we delivered an SOS show to a group of 75 fifth graders and their adult chaperones, pre and post testing them to quantify what they gained from the

show and testing them a month later to quantify what they retained. This year, we've been testing an identical population of 80 students with same content as the SOS show delivered on a flat screen. From the evaluations we hope to discern whether the SOS conveys any advantage over flat screen displays, in terms of acquisition and/or long-term memory.

Figure 1: Schollaert Uz delivered a Science On a Sphere® show to Maryland Science Center visitors in Baltimore, MD on 4/22/15 as part of a study on what people learn on a sphere versus a flat screen.

The Smithsonian Science Education Academy for Teachers invited Schollaert Uz to train 22 K-12 educators from around the country on June 26th, 2014: 'Monitoring Earth's Biology from Space: Satellite Data and Spherical Displays'. Along with Maurice Henderson from NASA, she gave teachers an introduction to how satellites monitor Earth's biology and other variables that impact life, showed a variety of data sets (chlorophyll, NDVI, NPP, NO_2, ozone, CO_2, temperature), played the ClimateBits video on the ozone layer, and demonstrated NASA Earth & Space Observations (NESO) investigations. A NESO investigation of ozone followed the ClimateBits video, confirming the results published in peer-reviewed literature: globally averaged ozone is slowly recovering, evident in the slight upward trend in annual minimum values. If current trends continue, the ozone layer is anticipated to make a recovery to 1980's levels around 2070. The teachers were very interested in these results and in the Montreal Protocol from an interdisciplinary standpoint as well as the impact to life on Earth had the world not come together to limit the use of ozone-depleting chemicals. The teachers began accessing the ClimateBits website immediately and said they would use it as a resources with their classes.

We serve on the host committee planning the Weather+Climate Day contest for Maryland middle and high school students convened by Climate Central (http://www.aqua.org/weatherclimateday). We are assisting with finding scientists and UMD graduate student to judge student entries. Additionally, ClimateBits to Magic Planet format as they will be featured on the National Aquarium Magic Planet during the Weather+Climate Day culmination on May 16th.

Figure 2: Schollaert Uz presenting Magic Planet to visitors at the McKinley Science Fair in Arlington, VA on 2/19/15 during 'Ocean Color measured by satellites and you!' along with a hands-on activity.

Chinese translation of ClimateBits was requested by a museum in China for an event on March 23rd. We provided the English script for them to translate due to the short-term request. For the future, we are exploring having CICS-MD scientists narrate ClimateBits in Chinese and Spanish, as the latter has been requested by informal educators with the National Park Service.

Planned Work

- Continue to develop ClimateBits videos at CICS-MD in partnership with NASA, NOAA, others
- Collaborate with others to develop hands-on activities that enhance active learning of ClimateBits concepts
-
- Coordinate 2015 official press release of ClimateBits at the Maryland Science Center with UMD CMNS, NASA GSFC, NOAA OED
- Continue to work with Joe Witte and other climate communicators to develop ClimateBits videos that may enhance TV news segments (e.g. Zhou, Maibach, Gandy, Witte, Cullen, Klinger, Rowan, Witte and Pyle, 2014, Climate change education through TV weathercasts: results of a field experiment, BAMS)
- Increase outreach and collaboration on and off campus, e.g. present ClimateBits to the Climate Literacy and Energy Awareness Network (CLEAN)

Publications

Schollaert Uz, Stephanie, Wendy Ackerman, Jim O'Leary, Britta Culbertson, Patrick Rowley, and Phil Arkin, 2014: The effectiveness of Science On a Sphere® stories to improve climate literacy among the general public, *J. Geosci. Educ.*, **62**, 485-494

Brown, C.W., S. Schollaert Uz, and B. H. Corliss. 2014. Seasonality of oceanic primary production and its interannual variability from 1998 to 2007, *Deep Sea Res. I*, 90, doi:10.1016/j.dsr.2014.05.009.

Products

http://climatebits.umd.edu
https://youtu.be/D7ujMCzcVCk
https://youtu.be/kOpqK5d01Wg
https://youtu.be/3o41ntp7hAg
https://youtu.be/BlREDNU-7cA
https://youtu.be/_a10uLMrUN8

Presentations

Uz, Stephanie Schollaert , ClimateBits: essential Earth science concepts explained simply for everyone, *CICS-MD Science Meeting*, College Park, MD (11/13/2014)

Uz, Stephanie Schollaert, A 51-year reconstruction of ocean surface chlorophyll in the tropical Pacific, *CICS-MD Science Meeting*, College Park, MD (11/12/2014)

Uz, Stephanie Schollaert and Phillip Arkin, Using satellite data on Science On a Sphere® at museums to inform society through ClimateBits: short, engaging videos on essential Earth Science concepts, *CoRP Science Symposium*, New York City (9/10/2014)

Uz, Stephanie Schollaert, Maurice Henderson, Monitoring Earth's Biology from Space: Satellite Data and Spherical Displays, Smithsonian Science Education Academy for Teachers (6/26/2014)

Other

On March 4th, Stephanie gave an invited presentation to the NOAA SOS Network Education Forum on Hands-on Activities, 'Will people learn more if their SOS experience is not simply passive?' and summarized her recent journal article (http://nagt-jge.org/doi/abs/10.5408/13-075.1). *Webinar*

Performance Metrics	
# of new or improved products developed (please identify above the table)	**6**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**0**
# of invited presentations	**4**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Appendix 1: CICS-MD Performance Metrics

Performance Metrics	
# of new or improved products developed (please identify below the table)	103
# of products or techniques submitted to NOAA for consideration in operations use	82
# of peer reviewed papers	105
# of non-peered reviewed papers	34
# of invited presentations	165
# of graduate students supported by a CICS task	8
# of graduate students formally advised	17
# of undergraduate students mentored during the year	25

Appendix 2: CICS-MD Publications

Alsweiss, S., Z. Jelenak, P. Chang, J. Park, and P. Meyers, 2014: Inter-calibration results of the Advanced Microwave Scanning Radiometer-2 over ocean. *J. of Sel. Top. Earth Obs. Remote Sens.*, **99**.

Bai, Yan, Changyong Cao, Xi Shao, Wenhui Wang, "Suomi NPP VIIRS calibration knowledge base for SDR data quality assurance, anomaly investigation, and EDR applications", in Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, Xiaoxiong Xiong; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9264 (SPIE, Bellingham, WA 2014), 92641M.

Berndt, E.B., B.T. Zavodsky, M.J. Folmer, 2015: Development and Application of Atmospheric Infrared

Blonski, S., C. Cao. X. Shao, and S. Uprety, 2014: VIIRS reflective solar bands calibration changes and potential impacts on ocean color applications, *Proc. SPIE*, **9111**, 911106, doi:10.1117/12.2053315.

Boyer, T., J. Antonov, J. Reagan, C. Schmid, and R. Locarnini, 2014: [Subsurface Salinity] Global Oceans [in "State of the Climate in 2013"]. *Bull. Amer. Meteor. Soc*., **95** (7), S62–S65.

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