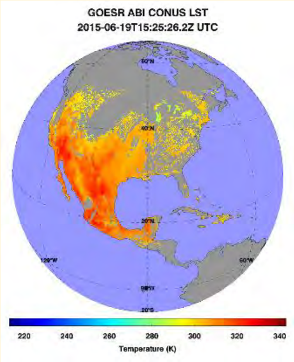

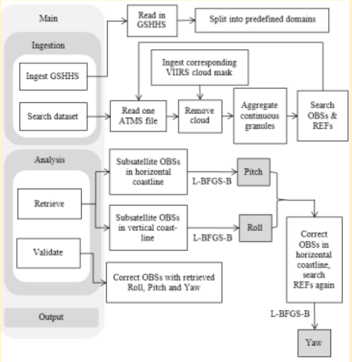

COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

Annual Scientific Report

VOLUME II: CICS-MD TASK REPORTS

For the period:
April 1, 2015 – March 31, 2016
NOAA Grant NA14NES4320003

Dr. Ernesto Hugo Berbery, CICS-MD Director
Compiled by Ms. Debra Baker, CICS-MD Coordinator

Dr. Fernando Miralles-Wilhelm, CICS Executive Director
April 30, 2016

Cooperative Institute for Climate and Satellites

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1 Data Fusion and Algorithm Development

Monitoring and Day-2 Algorithms of AMSR2 EDRs

Task Leader Patrick Meyers
Task Code EBPM_AMSR2_15
NOAA Sponsor Paul Chang and Ralph Ferraro
NOAA Office NESDIS/STAR/CRPD/SCSB
Contribution to CICS Research Themes (%) Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic Data Fusion and Algorithm Development
Contribution to NOAA goals (%) Goal 1: 70%; Goal 2: 30%; Goal 3: 0%
Highlight AMSR2 Environmental Data Records completed their initial evaluation and were declared operational by NESDIS
Links to a research web page:
http://manati.star.nesdis.noaa.gov/gcom/datasets/GCOM2Data.php
http://www.ospo.noaa.gov/Products/atmosphere/gpds/maps.html

Background

NOAA recently began producing environmental data records (EDRs) for the Advanced Scanning Microwave Radiometer 2 (AMSR2) aboard the Global Change Observation Mission – Water (GCOM-W) satellite. GCOM-W is part of the Joint Polar Satellite System (JPSS) mission in coordination with the Japanese Aerospace Exploration Agency, and is part of the A-Train constellation. AMSR2 replaces the AMSR-E sensor, which stopped routine operations in 2011.

AMSR2, launched in early 2012, had several calibration issues that delayed the release of operational products. CICS-MD contributed to the calibration of brightness temperatures, resulting in more radiometrically stable Level-1 brightness temperatures (TBs). CICS-MD is responsible for the rain rate environmental data record (EDR), as well as contributing to the sea surface temperature (SST), total precipitable water (TPW), cloud liquid water (CLW), wind speed (WSPD) algorithms. The Goddard Profiling Algorithm 2010 – Version 2 (GPROF2010V2) retrieves global rain rates. SST, TPW, CLW, and WSPD are calculated over oceans using a Bayesian framework which compares observed TBs to a database of collocated TBs and analysis fields.

Accomplishments

JAXA released an updated version of Level-1 TBs in March 2015. The new version was purported to correct some of the AMSR2 calibration issues, and required reanalysis by the NOAA GCOM-W team. AMSR2 was intercalibrated using collocations with the Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI). TBs were simulated by CRTM v2.1 over oceans and CSEM-MW over land, using ECMWF gridded atmospheric profiles and surface information as reference. Areas over oceans that were affected by rain, sun glint, and radio frequency interference were excluded in the calibration. The Amazon rain forest was the calibration target over land because of the regions high emissivity and non-polarized nature of surface emissions. The TB offsets were as high as 5 K over the ocean, and ±2 K over land. Theses corrections help to offset the receiver non-linearity, however JAXA is continuing efforts to understand and address the issue.

Consistent Level-1 TBs allowed for the training and validation of the EDR algorithms. The ocean EDRs match observed TBs to an a-priori database to find consistent geophysical scenes. CICS-MD scientists contributed to the construction of the database and performed validation of the retrievals using independent datasets (Fig. 1). Separately, GPROF2010V2 was further modified to address retrieval problems over snow-covered surfaces. A description of the algorithm and validation of the AMSR2 rain rate retrievals were published in *JSTARS*, and the surface screening results were described in detail in IGARSS conference proceedings. Most notably, the AMSR2 EDR production became operational at NOAA/OSPO.

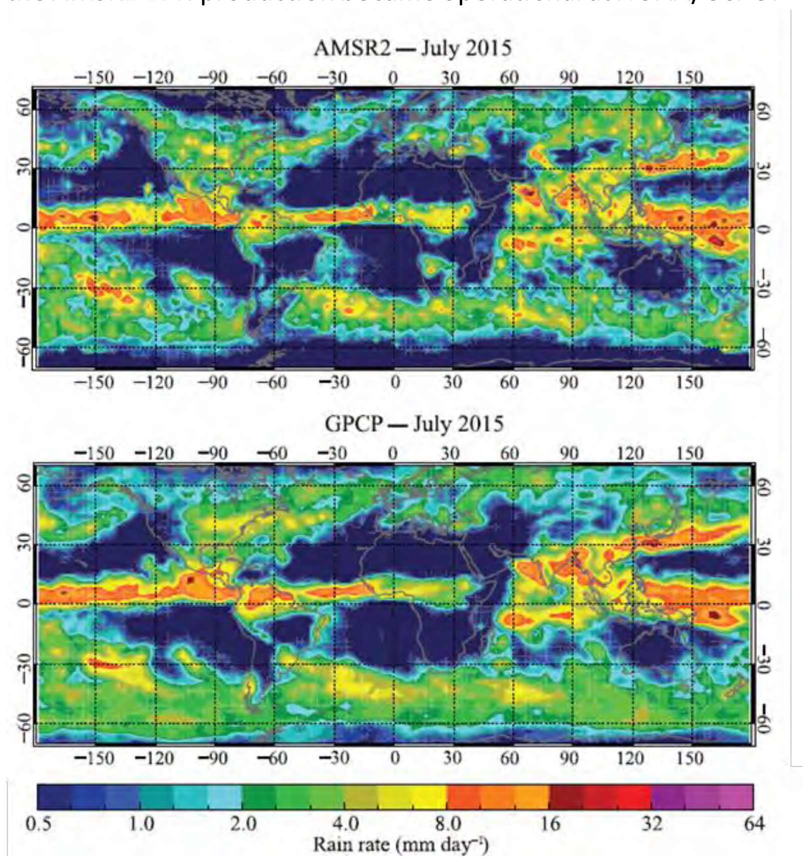


Fig. 1 – Comparison of daily AMSR2 precipitation retrievals (top) to the Global Precipitation Climatology Project (bottom) for July 2015.

As part of the NOAA mission requirements, CICS-MD scientists continue to monitor the AMSR2 data, ensuring continued quality (Fig. 2). After significant weather events, such as hurricanes and blizzards, we evaluate AMSR2's performance and disseminate relevant imagery and descriptions.

Initial efforts are underway to leverage other remotely sensed data, including geostationary IR and ground-based lightning networks, to improve the utility of AMSR2 retrievals in forecasting applications, as part of the CICS-MD Proving Ground and Training Center. Additionally, we are involved in collaboration with the NASA Precipitation Measurement Missions Science Team, on the project titled "NOAA's Continued Contributions to the Development and Utilization of NASA's Global Precipitation Measurement (GPM) Products".

Planned work

- Continue monitoring efforts of operational AMSR2 EDRs
- Continue product validation and identify algorithm deficiencies
- Collaboration with the NASA PMM Science Team
- Update GPROF2010V2 to incorporate the latest IMS snow analysis
- Merge AMSR2, lightning, and geostationary IR to improve situational awareness for forecasting

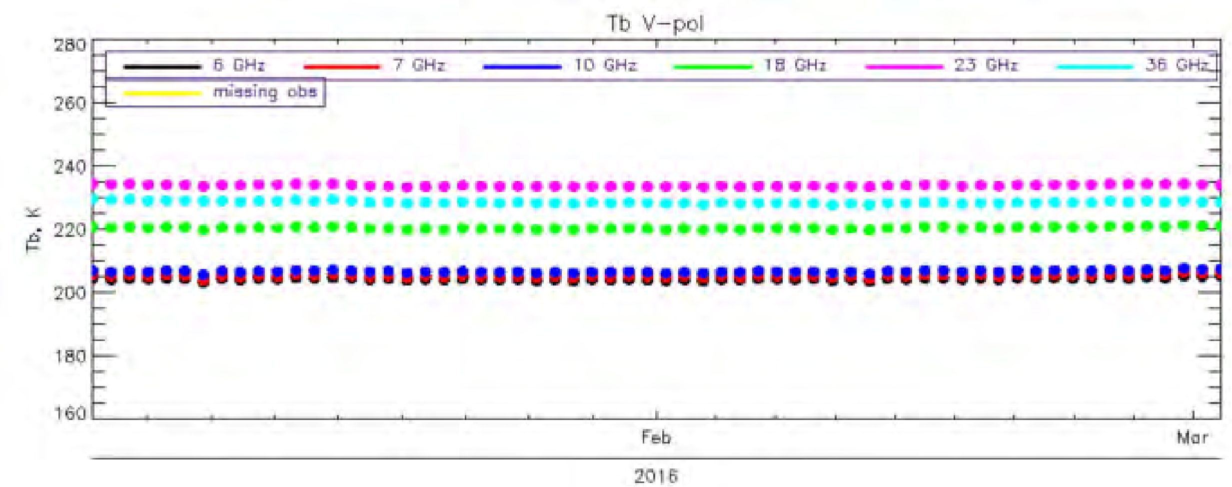


Fig. 2 – Example of TB monitoring from the NOAA/STAR AMSR2 website. Significant departures from the mean would indicate problems with the sensor or processing system.

Publications

Meyers, P. C. and R. R. Ferraro: Precipitation from the Advanced Microwave Scanning Radiometer 2. *J. of Sel. Top. Earth Obs. Remote Sens.*, **99**, 1-8, doi: 10.1109/JSTARS.2015.2513666.

Meyers, P. C., and R. R. Ferraro, 2015: Accounting for surface ice and snow in the Goddard Profiling algorithm rain rate retrievals. *Proc. IEEE Int.l Geoscience and Remote Sensing Symp. 2015*, Milan, IT,. Institute of Electrical and Electronics Engineers, 2619-2621, doi: 10.1109/IGARSS.2015.7326349.

Maggioni, V., P. C. Meyers, and M. Robinson: A review of merged high resolution satellite precipitation product accuracy during the Tropical Rainfall Measuring Mission (TRMM) - era. *J. Hydrometeor.: IPWG Special Collection.*, in press, doi: 10.1175/JHM-D-15-0190.1.

Rudlosky, S. D., M. A. Nichols, P. C. Meyers, and D. F. Wheeler: Seasonal and annual validation of operational satellite precipitation estimates. *J. Operational Meteor.*, **4** (5), 58-74, doi: 10.15191/nwajom.2016.0405.

Products

EDRs for rain rate, wind speed, sea surface temperature, cloud liquid water, and total precipitable water are produced by OSPO.

Presentations

Park, J. et al.: Inter-satellite calibration of GCOM-W1 AMSR-2 Brightness Temperature, CoRP Annual Science Symposium, September 2015, College Park, MD.

Meyers, P. et al.: GPROF2010 Updates for AMSR2 Precipitation Retrievals, CoRP Annual Science Symposium, September 2015, College Park, MD.

Meyers, P. et al.: Accounting for surface ice and snow in the Goddard profiling algorithm rain rate retrievals, IGARSS 2015, July 2015, Milan, Italy, WE3.G3.5.

Meyers, P. and R. R. Ferraro: Surface characterization for AMSR2 precipitation EDR, Precipitation Measurement Missions Science Team Meeting, July 2015, Baltimore, MD, P200.

Other

A University of Maryland graduate student and undergraduate were mentored on the topic of satellite precipitation measurements. Both of the students coauthored peer-reviewed publications about Level-3 precipitation products. Further, an overview of remote sensing was presented to the Univ. of Maryland chapter of the American Meteorological Society, introducing students to geostationary and polar orbiting satellites.

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	**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	**1**

AMSR2 EDRs for rain rate, wind speed, sea surface temperature, cloud liquid water, and total precipitable water are produced operationally by OSPO. Conference proceedings and a peer-reviewed manuscript on the AMSR2 precipitation product wer published, plus two coauthored papers related to blended precipitation products.

Near Real-Time Precipitation Using Lightning

Task Leader Patrick Meyers
Task Code EBPM_LTNG_15
NOAA Sponsor Michael Kalb
NOAA Office NESDIS/STAR
Contribution to CICS Research 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: 80%; Goal 2: 20%; Goal 3: 0%
Highlight Applications of lightning data for precipitation remote sensing are being expanded at the CICS-MD Proving Ground and Training Center.

Background

Low earth orbit (LEO) satellites provide critical precipitation information for weather forecasting and monitoring. LEO observations supplement ground-based networks (i.e. radar) in data-poor regions, such as over mountainous terrain and large water bodies, however low temporal sampling and relatively high data latency leaves much to be desired by forecasters. Supplemental information could be used to advance recent LEO precipitation observations to the present, offering forecasters an estimate of the current precipitation field.

Lightning is emerging as valuable parameter for satellite precipitation estimation. Presence of lightning identifies convective regions and can constrain in precipitation retrievals from infrared. Raw ground-based lightning data from regional lightning mapping arrays (LMAs) and Vaisala's Global Lightning Dataset (GLD360) are aggregated in time and space to produce lightning density values. The time-evolution of the lightning density field reveals storm motion, which can be used to propagate LEO precipitation estimates to near real-time.

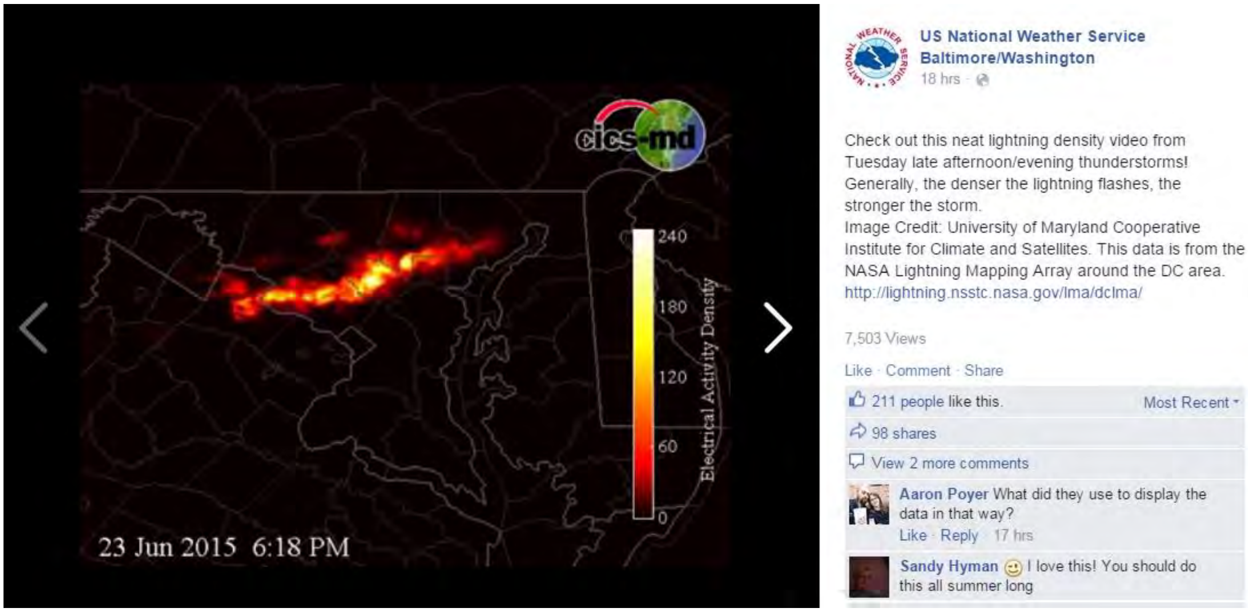
This project was funded out of end-of-year funds from NOAA/STAR. Baseline research is underway, and most of the work will be done in 2016. Testing and development of the algorithm is conducted at the CICS-MD Proving Ground and Training Center using systems that replicate National Weather Service forecast workstations. A core component of the project will be formatting the resultant precipitation fields for ingest in the AWIPS-II software.

Accomplishments

Most of the effort to date has been spent laying the groundwork of the project. A year of data from GLD360 was processed to track the lifespan of persistent electrical storms. This dataset will be used to match with geostationary IR imagery and precipitation from passive microwave polar orbiters.

Some of the lightning work using the Washington DC LMA has received local media attention. The Capital Weather Gang used two animations of regional lightning events on their social media feed, and the Sterling NWS forecasting office also publicized the animation.

We have collaborated with many agencies to garner information about operational and direct broadcast functionalities. Attending a Community Satellite Processing Package Users Meeting shed light on the direct broadcast capabilities of NOAA forecasting offices. Meetings with NOAA regional science officers informed us of the types of value-added products that can successfully be transitioned to operations. Collaboration with colleagues at CIMSS will give us the framework to build offshore monitoring capabilities. The lessons learned will be used to support future projects aimed at producing valuable forecasting tools for NWS entities.



Facebook post from the Baltimore/Washington NWS Weather Forecasting Office of regional lightning.

Planned work

- A team member will be involved in the NASA/SPoRT Experimental Product Development Team meetings. This workshop was intended to occur this past year, but travel plans were canceled due to inclement weather. This was funded through the GOES-R Visiting Scientist Program, CICS Task: EBPM_FCCM_15.
- Create a basic precipitation field modified by lightning that can be visualized in AWIPS-II in the CICS-MD Proving Ground and Training Center.
- Use CIMSS's ProbSevere models as the basis for a similar product outside of CONUS, while leveraging other ongoing/proposed projects
- Interview forecasters at the Ocean Prediction Center and Weather Forecast Offices responsible for off-shore forecasting and weather monitoring.

Products

None developed at this time. Eventually, a radar-like loop of precipitation from LEO satellites will be created for use in AWIPS-II.

Presentations

Meyers, P. et al.: Propagation of JPSS precipitation retrievals using near real-time lightning data, AMS Annual Meeting, January 2016, New Orleans, LA, P744.

Meyers, P. et al.: Lightning Enhancement of Satellite Precipitation Estimates, CICS-MD Science Meeting, October 2015, College Park, MD.

Meyers, P. et al.: Direct Broadcast activities at CICS-MD, Community Satellite Processing Package Users' Group Meeting, April 2015, Darmstadt, Germany, P10.

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**

Only preliminary proof-of-concept work has been performed, hence the lack of trackable performance metrics.

GOES-R Surface Albedo Project

Task Leader Shunlin Liang, Tao He
Task Code SLTH_GOESR_15
NOAA Sponsor Yunyue Yu
NOAA Office STAR/AIT
Contribution to CICS Research Themes (%) Theme 1: 40%; Theme 2: 40%; Theme 3: 20%.
Main CICS Research Topic Data Fusion and Algorithm Development
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%
Highlight
Link to a research web page

Background

Surface albedo is a key variable for driving climate, mesoscale, atmospheric, hydrological, and land surface models. The accuracy of surface albedo also affects the reliability of weather prediction. Spectral directional reflectance from satellite observations is a fundamental remote sensing variable that has been used for generating various high level products. The frequent temporal resolution and multispectral information from GOES-R/ABI make it a unique data source for characterizing surface anisotropy and thus mapping surface albedo and directional reflectance.

The goal of this task is to develop algorithms to generate GOES-R land surface albedo (LSA) and spectral directional reflectance product. Previously, we have conducted some preliminary work on developing the prototype algorithms: 1) we developed a framework to simultaneously retrieve instantaneous surface albedo/reflectance and aerosol optical depth; 2) we applied the algorithm using MODerate resolution Imaging Spectroradiometer (MODIS) observations as proxy data and made extensive validations on surface albedo and reflectance retrievals; 3) we also applied the algorithm to the Spinning Enhanced Visible and Infrared Imager (SEVIRI) onboard Meteosat and demonstrated the effectiveness of our algorithm in albedo estimation using geostationary data; 4) we provided some preliminary science codes to the algorithm integration team (AIT) for software implementation and process demonstration.
With the successful applications of our algorithm to both polar-orbiting and geostationary data, we plan to demonstrate that our algorithm will also work for GOES-R/ABI. Data from the Japanese Himawari AHI, with a design of spectral bands and spatial resolution similar to ABI data, are used in this task to evaluate and improve our algorithm. We will evaluate surface albedo and reflectance generated from the LSA algorithm over different surfaces, utilizing ground measurement and other satellite-derived products. This report summarizes our main accomplishments in algorithm and software development and products validation during the past year.

Accomplishments

During the past year, our major task is to continue preparing for the software package using Himawari AHI data as the proxy of GOES-R ABI. Our efforts to accomplish this goal include the following specific tasks:

1) Software package transfer from using MSG/SEVIRI to using AHI as proxy
Due to the difference in data structure, band design and spatial/temporal coverages between SEVIRI and AHI, all the ancillary data used in the software package need to be updated, which include atmospheric lookup-table, narrow-to-broadband conversion, and shortwave albedo climatologies. We have finished

preparing for these ancillary data and will be using them for both the pixel/point-based algorithm development and image-based software package preparation. In February 2016, we delivered our Version 6 software codes to AIT for them to test our algorithms.

2) AHI data preparation and extraction
The current AHI data archived at NOAA STAR servers are in two data formats. One was designed for the experimental period of Himawari-8, mostly in the first half of 2015. Only in this period, the ground measurements are currently available for the verification of our algorithm retrieval. However, there are no cloud mask data available from NOAA. The other is the data format for the operational period of Himawari-8, covering the second half of 2015. For this dataset, we can obtain both the satellite radiance data and cloud mask data from NOAA. However, there are no ground measurements for validation.
Due to the data format and huge data volume, we extracted the top-of-atmosphere radiance for the shortwave bands from the raw data and reorganized the data structure for our purposes in order to test our algorithm and software package at a later stage.

3) Ground measurements collection
Ground measurements of surface albedo are crucial for the validity test of the surface albedo/reflectance algorithm. In addition to the data we collected at one site in China, we were able to find additional ground measurements for the first quarter of 2015 at more than ten sites in Australia. The data were provided by the OzFlux, which is a network of micrometeorological flux stations. The sites cover different regions of Australia and a variety of land cover types.

4) Fine resolution satellite data collection
Because the ground measurements are primarily obtained in Australia, fine resolution satellite data are needed to help further examine the surface albedo retrievals at other regions with an emphasis on their spatial consistency. We were acquiring data from Landsat 8 OLI in Australia and China. Before we use them to validate results from AHI data, the surface albedo estimates from Landsat data will be validated against the ground measurements.

5) MODIS albedo/BRDF data collection
Diurnal variation is one important signature of surface albedo, which can be monitored from the geostationary data. Due to the fact that there are no ground measurements currently available for the operational period of Himawari-8, we collected the MODIS albedo/BRDF data to investigate the surface albedo diurnal variation. The diurnal albedo can be calculated directly using MODIS BRDF information. Based on the MODIS data, we will be able to assess the uncertainties of the AHI albedo estimation at large solar zenith angles.

6) Algorithm development and validation with AHI data
With all the ancillary data needed for estimating surface albedo from AHI data, we had successfully transferred the point-based version of our albedo algorithm software from using SEVIRI data to AHI data. Validation has been made against ground measurements from OzFlux sites. An example is shown in Fig. 2, which indicates that our retrieving algorithm works well to capture the intra-day and diurnal surface albedo variations. However, cloud mask data is missing from the AHI datasets during the first half of 2015, which is critical in retrieving surface albedo at a broader temporal and spatial domain.

Planned work

- Task 1 - Algorithm Development
  - Cloud masking will be improved to reduce the subpixel clouds' impact on LSA estimation.
  - Efforts will be made to derive aerosol type climatology from existing satellite products. An aerosol-specific LUT will be used based on the aerosol type climatology.
  - Task 2 – Product validation against ground measurements
  - Ground measurements of LSA will be continually collected at sites in China, Japan, and Australia. GOES-R albedo retrievals will be validated against those ground measurements.

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

- Task 4 - Software/Algorithm Integration and Testing
  - With an extensive evaluation of the AHI-based and ABI-based algorithm, we will update our software package and ATBD documentation accordingly and deliver them to AIT for testing. In addition, we will collect some sample test data and evaluate the stability and accuracy of the algorithm software under different scenario.

- Task 5 - Algorithm Maintenance
  - Based on the algorithm refinement progress and feedbacks from AIT on the test version software package, our efforts will be made to maintain the software algorithm by updating the parameters and ancillary data.

- Task 6 – Enterprise algorithm development
  - Efforts will be made on the enterprise algorithm development to ensure that the same science algorithm from GOES-R ABI and JPSS VIIRS can generate consistent and accurate surface albedo estimation and data quality information.

Publications (Peer-reviewed)

[1] Zhou, Y., D. Wang, S. Liang, Y. Yu, and T. He, (2016). Assessment of the Suomi NPP VIIRS land surface albedo data using station measurements and high-resolution albedo maps. Remote Sensing, 8(2), 137, doi: 10.3390/rs8020137

[2] He, T., S. Liang, D. Wang, Y. Cao, F. Gao, and Y. Yu, (under review). Deriving a global land surface albedo product from Landsat MSS, TM, ETM+, and OLI data based on the unified direct estimation approach. Remote Sensing of

Products

GOES-R surface albedo and reflectance products will be generated from this project.
Liang, S., D. Wang, T. He, and Y. Yu, (2011). GOES-R Advanced Baseline Imager (ABI) algorithm theoretical basis document for surface albedo. NOAA/NESDIS, Version 2.0

Other

Graduate Students, Yi Zhang, Yuhan Rao, and Yunfeng Cao, are currently supported and advised under this project

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	0
# of invited presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	3
# of undergraduate students mentored during the year	0

JPSS Microwave Integrated Retrieval System (MiRS) Calibration and Validation

Task Leader: Christopher Grassotti
Task Code: EBCG_JMIR_15
NOAA Sponsor: Quanhua (Mark) Liu
NOAA Office: NESDIS/STAR/SMCD/SCDAB
Contribution to CICS Research Themes (%): Theme 1: 20%, Theme 2: 80%.
Main CICS Research Topic: (1) Data Fusion and Algorithm Development
Contribution to NOAA goals (%): Goal 1: 0%, Goal 2: 100%, Goal 3: 0%
Highlight: Delivery of updated MiRS Version 11.1 to NOAA operations for all NOAA operational microwave satellites/sensors. V11.1 includes numerous changes leading to significantly improved retrievals of atmospheric temperature, water vapor, land surface temperature, and hydrometeors.
Link to a research web page: http://www.mirs.nesdis.noaa.gov

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

Task Leader: Christopher Grassotti
Task Code: EBCG_PMIR_15
NOAA Sponsor: Quanhua (Mark) Liu
NOAA Office: NESDIS/STAR/SMCD/SCDAB
Contribution to CICS Research Themes (%): Theme 1: 20%, Theme 2: 80%.
Main CICS Research Topic: (1) Data Fusion and Algorithm Development
Contribution to NOAA goals (%): Goal 1: 0%, Goal 2: 100%, Goal 3: 0%
Highlight: Addition of snow grain size as preliminary operational product. Addition of sea ice age (first year and multiyear ice) as operational product. Validation of both snow water equivalent and snow grain size performed by comparison with several reference data sets for a 6-month period in winter 2012-2013 season. All operational products generated at high-resolution.
Link to a research web page: http://www.mirs.nesdis.noaa.gov

Background

This report summarizes work performed on the Microwave Integrated Retrieval System (MiRS) for the period April 1, 2015 through March 31, 2016. The Microwave Integrated Retrieval System (MiRS) has been the NOAA official operational microwave retrieval algorithm since 2007 and is currently run operationally on microwave data from NOAA, Metop, DMSP and Suomi-NPP polar orbiting satellites, and on data from Megha-Tropics/SAPHIR. It has also been run experimentally on data from TRMM/TMI, Aqua/AMSR-E, GCOM-W1/AMSR2, and GPM/GMI. The inversion within MiRS follows a 1D-variational methodology, in which the fundamental physical attributes affecting the microwave observations are retrieved physically, including the profile of atmospheric temperature, water vapor, hydrometeors, as well as surface emissivity and temperature. The community radiative transfer model (CRTM) is used as the forward and Jacobian operator to simulate the radiances at each iteration prior to fitting the measurements to within the noise level. The retrieved surface properties are then used to determine surface physical characteristics, including, when appropriate, cryospheric parameters such as sea ice concentration, ice age, and snow water amount, and snow grain size, using pre-determined relationships that link emissivity and effective skin temperature to these parameters.

These links are based, in part, on physical modeling of snow and ice radiative properties. MiRS is has also been integrated into the Community Satellite Processing Package (CSPP), developed at the University of Wisconsin/Space Science and Engineering Center.

Accomplishments

Note: all efforts funded at 50% by PSDI and 50% by JPSS ADP

4-15-15 **Presentation at the CSPP/IMAPP Users' Group Meeting** Chris Grassotti

Presented MiRS Community Satellite Processing Package (CSPP) results at the Users' Meeting held at EUMETSAT, Darmstadt, Germany. This allowed users to see the improvements that would be contained in the upcoming release of CSPP_MiRS_2.0, which was officially released in October 2015 (see below).

6-25-15 **MiRS Algorithm Readiness Review** Chris Grassotti

Planned and led an important Algorithm Readiness Review (ARR) presentation to NOAA management and stakeholders. This was a significant milestone, in which a new version of MiRS was presented (v11.1) in preparation for delivery to operational use. Significant changes to MiRS in this version of MIRS included substantial improvements to the temperature and water vapor sounding, integration of a snowfall rate (SFR) algorithm, and extension to DMSP F18/SSMIS data processing, and updating of the snow water and snow grain size retrieval procedure (see figures 1 and 2 below). Several new variables, snow grain size and sea ice age were added to the list of MiRS official retrieval products. Additionally, the integration of snowfall rate into the MiRS processing package will allow NESDIS operations (OSPO) to turn off their stand-alone SFR processing algorithm.

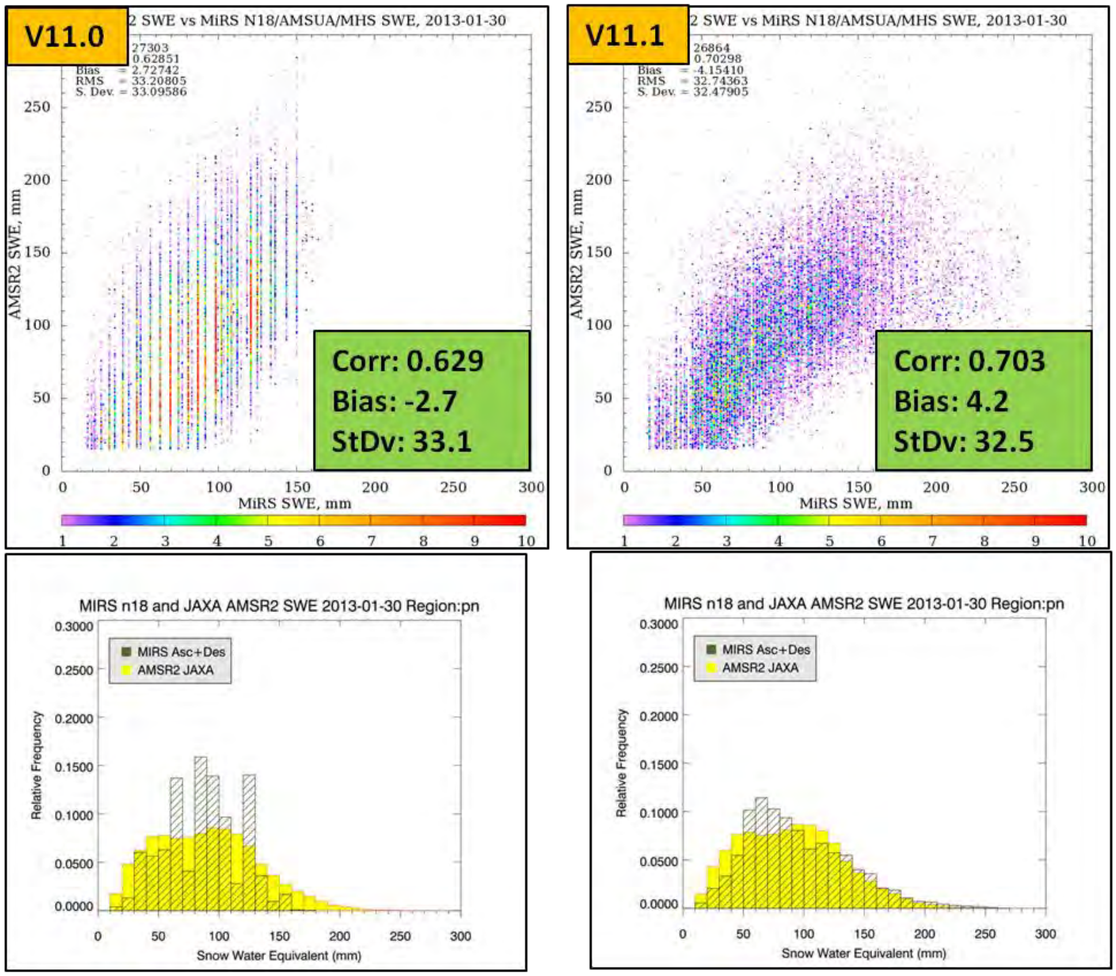


Figure 1: Comparison of MiRS Snow Water Equivalent (mm) from NOAA-18 AMSU/MHS with the JAXA AMSR2 official product. Right hand panels show the improvement made in the latest version of MiRS (v11.1) compared to the previous version.

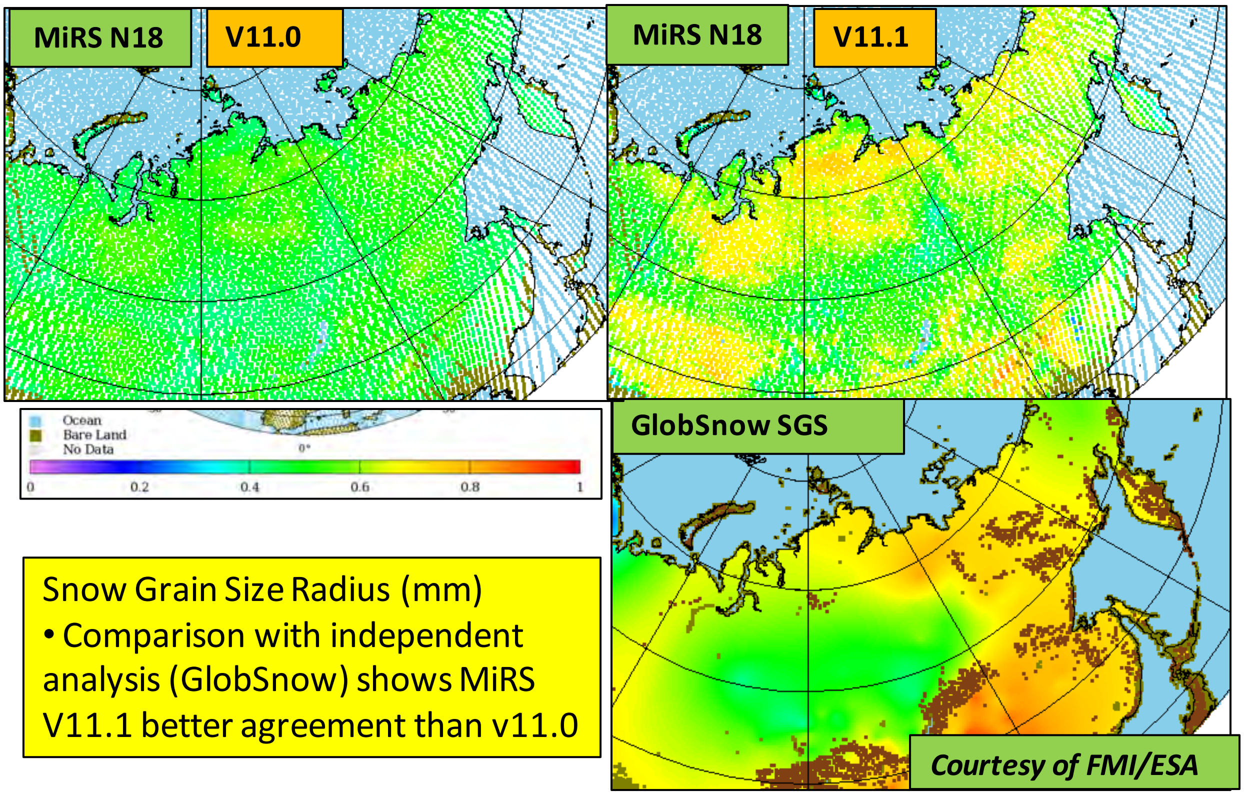


Figure 2: Comparison of MiRS Snow Grain Size (mm) from NOAA-18 AMSU/MHS with the GlobSnow product. Upper right hand panel shows the improvement made in the latest version of MiRS (v11.1) compared to the previous version (upper left).

08-06-15 **MiRS Official Delivery to Operations for non-ATMS Processing** Chris Grassotti
Supervised delivery of MiRS to NOAA/NESDIS/OSPO in August 2015.This supported processing of all non-Suomi/NPP operational microwave satellites.

09-15-15 **MiRS Official Delivery to Operations for SNPP/ATMS Processing** Chris Grassotti
Supervised delivery of MIRS to operations for Suomi-NPP/ATMS processing at NPOESS Data Exploitation Project System in September 2015. Subsequently, products based on the updated MiRS version have been archived in the NOAA CLASS archive since November 2015.

8-28-15 **SCSB/CICS-MD Presenters at the JPSS Science Meeting** Chris Grassotti
The STAR JPSS 2015 Annual Science Team Meeting was held this week, August 24-28 August 2015 at NCWCP in College Park, MD. Chris Grassotti, gave a talk entitled “MiRS ATMS Retrievals: Algorithm Updates, Product Assessment, and Preparations for JPSS-1.”

10-16-15 **MiRS Observes Typhoon Soudelor’s 3D Hydrometeor Structure** Chris Grassotti
Typhoon Soudelor recently struck both Taiwan and the mainland of China causing significant damage and loss of life due to high winds, heavy rainfall and flooding (see figure 3).

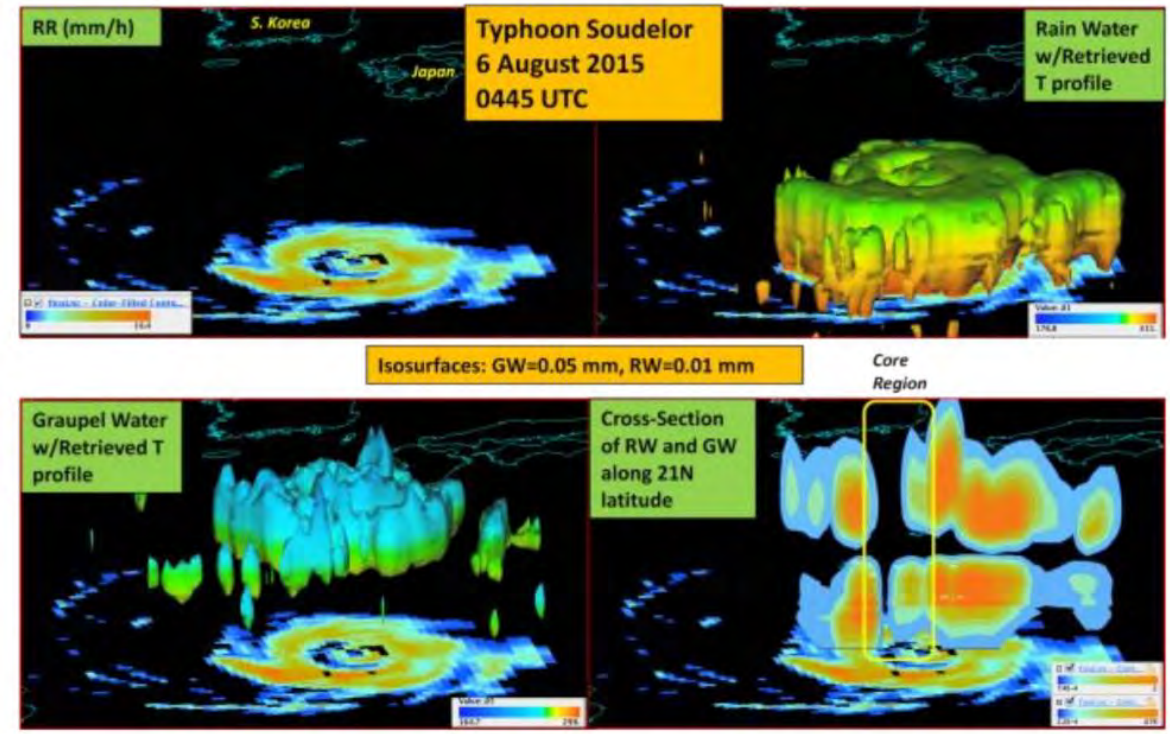


Figure 3: MiRS retrievals of hydrometeor and temperature structure around Typhoon Soudelor from Suomi-NPP/ATMS microwave observations at 0445 UTC on 6 August 2015. Panels show surface rain rate (top left), rain water 0.01 mm isosurface with temperature profile superimposed (top right), graupel water 0.05 mm isosurface with temperature profile superimposed (bottom left), and a vertical cross-section along 21 degrees north latitude of both rain and graupel water (bottom right).

CICS-MD Scientist Chris Grassotti and his colleagues at STAR/SMCD applied the MiRS retrieval algorithm to Suomi-NPP/ATMS microwave data obtained on 6 August, approximately 24 hours prior to landfall. The MiRS algorithm simultaneously retrieves not only the atmospheric profiles of temperature and water vapor, but also atmospheric rain water, graupel and cloud, making it possible to reconstruct the 3-dimensional structure of the storm. The results show that the 3-dimensional structure of atmospheric rain and ice, as well as the surface rain rate are realistically retrieved, with maximum surface rain rates of 16 mm/h, and the storm core structure present in both rain and graupel fields. *Importance*: Accurate near real time estimates of tropical cyclone intensity and structure are a key component of generating reliable warnings to the public of related weather hazards. The retrieval of storm structure also provides an opportunity for researchers to test physical assumptions of weather forecast and radiative transfer models. *POC*: C. Grassotti and X. Zhan

10-23-15 **AMSR-2 and ATMS Imagery Related to Joaquin and S.C. Floods** Chris Grassotti
Through a collaborative effort that pulled together an assortment of water vapor and precipitation products that are part of NOAA's JPSS program (e.g., GCOM AMSR-2 and S-NPP ATMS) in which SCSB (R. Ferraro, S. Rudlosky) and CICS-MD (J. Park, P. Meyers, C. Grassotti) scientists are heavily involved with, a compilation of the products was sent to JPSS Project Scientist (M. Goldberg) and his staff for their future use. The water vapor products depicted a strong connection between Joaquin's moist environment and the strong mid-latitude disturbance that eventually dumped the excessive rain over South Carolina (see figure

4 for image from ATMS below). Additionally, the rate rate products performed relatively well during the event.

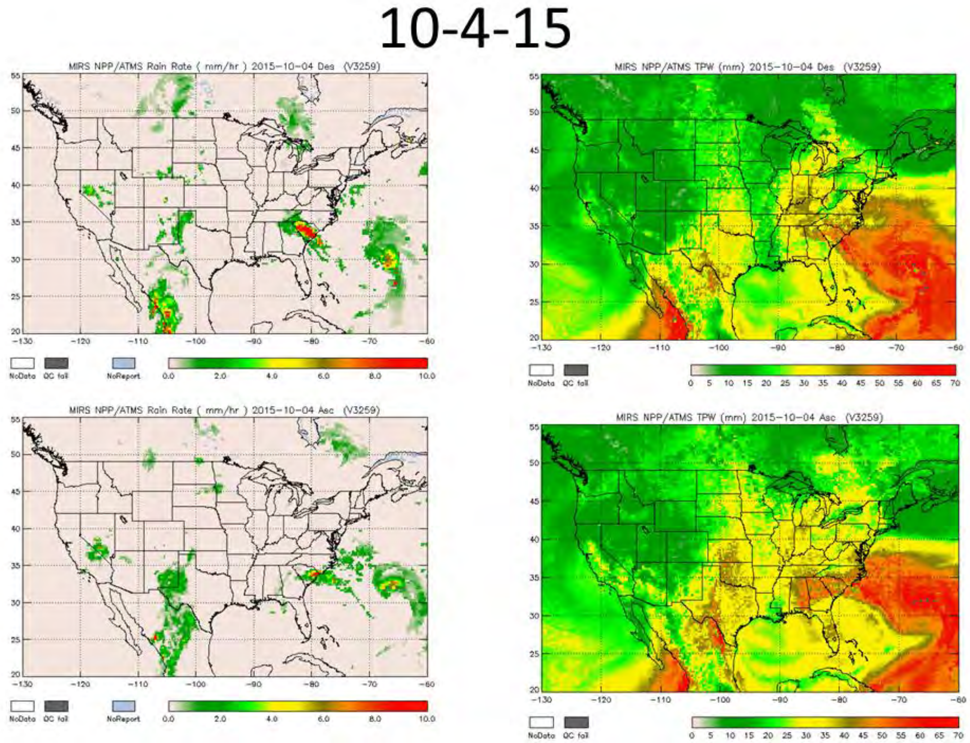


Figure 4: MiRS retrievals of rain rate and total precipitable water structure associated with the extreme rainfall and flooding event in the southeast US from Suomi-NPP/ATMS microwave observations on 4 October 2015.

Importance: NOAA's JPSS satellite program provides valuable information to support NOAA's Weather Ready Nation mission goal. *POC*: R. Ferraro, S. Rudlosky, J. Park, P. Meyers, C. Grassotti

10-23-15 **MiRS Version 11.1 Operational at NDE and within the CSPP package** Chris Grassotti

As of 15 October, MiRS version 11.1 is now officially operational within the Suomi-NPP Data Exploitation (NDE) system, providing updated versions of all operational products from ATMS data to users. In addition, MiRS version 11.1 has also been integrated into the Community Satellite Processing Package (CSPP) developed at the University of Wisconsin/Space Science and Engineering Center for use with direct broadcast data from S-NPP/ATMS, as well as from AMSU-MHS data from MetopA, MetopB, NOAA-18, and NOAA-19. *Importance*: The significance of this update is it replaces the previous operational version of MiRS (v9.2) and includes a number of important science and algorithm enhancements that yield improved temperature and water vapor retrievals, precipitation estimates, cryospheric products, as well as a transition to high resolution for all AMSU-MHS retrievals. *POC*: C. Grassotti

1-8-16 **C. Grassotti Presents MiRS Poster at AGU** Chris Grassotti

CICS-MD Scientist Christopher Grassotti presented a poster on recent scientific improvements to the Microwave Integrated Retrieval System (MiRS). MiRS is a One-Dimensional Variational inversion scheme (1D-Var) that employs the Community Radiative Transfer Model (CRTM) as the forward and adjoint operators. It simultaneously solves for surface (Tskin, emissivity), and atmospheric parameters (temperature, water vapor, non-precipitating cloud and hydrometeor profiles). Mir is currently being run operationally at NOAA for Suomi-NPP/ATMS, POES N18/N19, Metop-A, Metop-B, DMSP-F17/F18, and Megha-Tropiques/SAPHIR.

Description	Benefit
Extension to high (MHS) resolution for AMSUA-MHS (LR=30 FOVs/scan, HR=90FOVs/scan)	Improved depiction of small-scale features: CLW, RR, WV, ice edge
Extension to high (ENV) resolution for SSMIS (LR=30 FOVs/scan, HR=90FOVs/scan)	Better depiction of small-scale features: CLW, RR, WV, ice edge
Integration of CRTM 2.1.1	Better sync with CRTM development cycle; more realistic ice water retrievals (Jacobians)
New radiometric bias corrections for all sensors	Needed for consistency with CRTM 2.1.1
Integration of new dynamic (varies spatially, temporally) a priori atmospheric background	Large improvement in T, WV sounding; reduction in average number of iterations; increase in convergence rate
Updated hydrometeor/rain rate relationships	Improved RR over land and ocean
Updated hydrometeor a priori background profiles	Improved RR over land and ocean; improved sounding products in rainy conditions
Updated surface type preclassifier	Improved snow detection for conical scan instruments
New parameter: Snowfall Rate (SFR)	New product, supplements rain rate. At NOAA, separate OSPO/MSPPS processing can be turned off; potential for leveraging real-time MiRS retrieval products rather than GFS forecasts
Snow Water Equivalent (SWE) spatially-temporally variable climatology background	Better spatial and temporal constraint on SWE; also improved SGS retrieval
Snow Grain Size (SGS) and Sea Ice Age (SIA)	New product, satisfies operational user request
Updated all Snow Emissivity Catalogs: finer SGS discretization and larger physical ranges	Smoother distributions for SGS, SWE, larger dynamic range for SGS.
Miscellaneous changes to improve code efficiency, bug fixes	Matrix preparation time reduced from 40% to 5% of 1dvar

The table above from the poster lists the improvements and benefits of the newly-released version 11.1 of MiRS. *Importance*: Retrieval systems like MiRS are critical to ensuring the precision and accuracy of NOAA's satellite-based products. *POC*: C. Grassotti

1-12-16 **Contribution to STAR JPSS Big Screen Demo at AMS Meeting** Chris Grassotti

The MiRS project provided several animation visualizations for the STAR JPSS demo that took place on 12 January 2016. These visualizations were animations of MiRS retrieval products that highlighted the important capabilities of the algorithm for observing significant weather events occurring at a global scale. For example, one visualization contained a week-long sequence of MiRS 850 hPa temperature retrievals in late December 2016 that captured the anomalous warm event over the Arctic region.

1-28-16 **Declaration of MiRS Land Temperature Profile Operational Quality** Chris Grassotti

Based on extensive comparisons with reference data such as radiosondes and global analyses from GDAS and ECMWF, the project developed the supporting material and sent an official announcement to stakeholders of the operational quality of temperature profiles over land surfaces. Prior to this announcement, only over-ocean temperature profiles were considered to be of sufficient accuracy to be declared operational quality. One of the major improvements in the v11.1 of MiRS is the significantly improved temperature profile retrievals over land.

Planned work

- Extend MiRS to process data from the Global Precipitation Mission Microwave Imager GPM/GMI). Validate products.
- Extend MiRS to process data from the DMSP F19/SSMIS instrument. Validate products.
- Conduct Algorithm Readiness Reviews for GPM/GMI and F19/SSMIS, and deliver updated MiRS package to NESDIS operations (OSPO).
- Extend MiRS to process ATMS data from the upcoming JPSS-1 mission. Test with proxy data prior to launch (~March 2017). Post-launch, conduct tuning and calibration/validation of MiRS JPSS-1/ATMS products. Deliver preliminary operational MiRS package to operations at NDE.
- Integrate snowfall rate (SFR) algorithm for ATMS (provided by H. Meng) in to the MiRS package.
- Continue calibration/validation activities for all ATMS products.

Products

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

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

Presentations

Grassotti, Christopher
Review of MiRS Improvements and Integration within CSPP
CSPP/IMAPP Users' Group Meeting
EUMETSAT, Darmstadt Germany
4/14/2015 to 4/16/2015

Grassotti, Christopher

MiRS ATMS Retrievals: Algorithm Up-dates, Product Assessment, and Preparations for JPSS-1
STAR JPSS Annual Science Team Meeting
College Park, MD
8/24/2015 to 8/28/2015

Grassotti , Christopher
CICS-MD Science Meeting
College Park, MD
11/23/2015 to 11/24/2015

Grassotti , Christopher
Microwave Integrated Retrieval System: Recent Science Improvements
AGU Fall Meeting
San Francisco, California
12/14/2015 to 12/18/2015

Grassotti, Christopher, Xiwu Zhan, Sid Boukabara, Mohar Chattopadhyay, Craig Smith, Tanvir Islam, and James Davies
The NOAA Microwave Integrated Retrieval System (MiRS): Recent Science Improvements and Validation Results
AGU Fall Meeting
San Francisco, CA
12/14/2015 to 12/18/2015

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	
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	**1**
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

New or Improved Products Developed – All are produced in operations

- Temperature Profiles over both Land and Ocean (Improved)
- Water Vapor Profiles over both Land and Ocean (Improved)
- Integrated Water Vapor, TPW (Improved)
- Land Surface Temperature (Improved)
- Rain Rate (Improved)
- Graupel Water Path (Improved)
- Snow Water Equivalent (Improved)

- Snow Grain Size (New)
- Sea Ice Age (New)
- Snowfall Rate (New, integrated existing external algorithm developed by H. Meng)

Validation of Operational AMSR2 SSTs

Task Leader	Andy Harris
Task Code	AHAH_AMSRE_15
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: 50%; Goal 3: 50%;

Highlight: A third version of the GAASP AMSR-2 SST product, utilizing a different algorithm, has been evaluated and significant algorithm artifacts were identified. Further advice was passed back to the GAASP development team to inform their enhancements to the Day-1 SST algorithm. Validation has been redone for a 4th version of the product and results are now much improved.

Background

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

Accomplishments

The 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 replicated in the revised GAASP SST product. The previous version of the GAASP product showed essentially no warming, so this might be considered something of an improvement. However, the exclusion of data at the very lowest windspeeds is indicative of the revised algorithmic approach taken by the GAASP development team in response to the feedback we gave last year. In this version, they decided to adopt a Bayesian probability approach with a profile library search. The library appears to have had essentially no data close to zero wind-speed. However, the resultant quantization in SST causes greater problems.

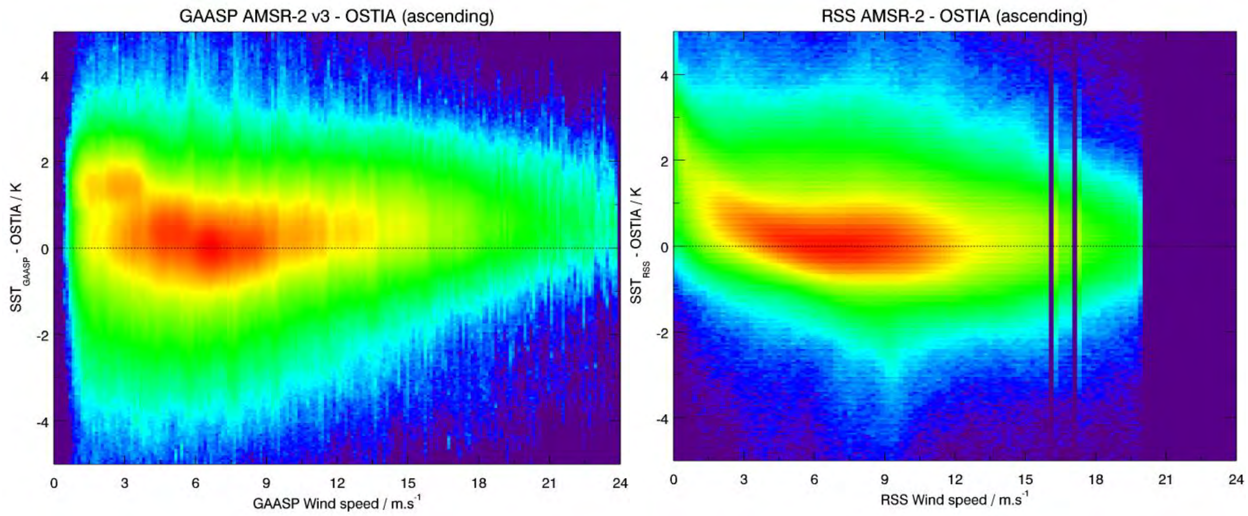
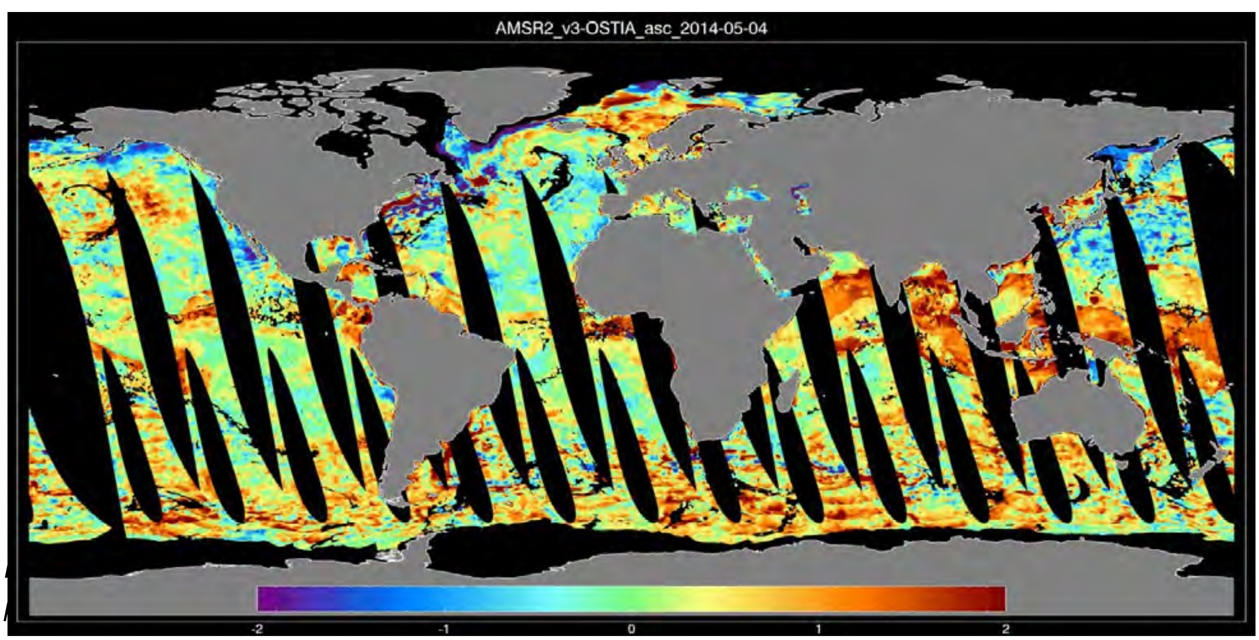


Figure 1. Bias in SST retrieved from AMSR-2 with respect to OSTIA SST Analysis. Left panel shows bias for revised daytime GAASP data while right panel shows the same plot for RSS data. The lines in the R.H. plot are due to digitization of the wind values in the GHRSST L2P format.

Figure 2 shows the difference between the revised 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 quantized areas of SST bias, and stepping artifacts due to attempts to speed up the excessively slow library search. The latter are particularly evident at high Southern latitudes.



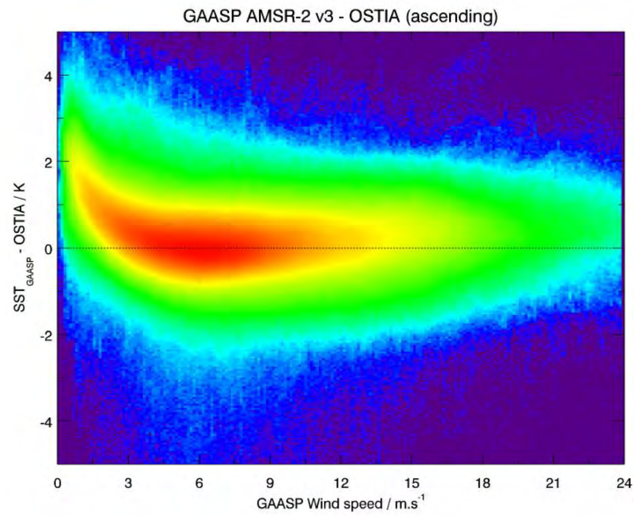


Figure 3. Dependence on windspeed for latest version of GAASP SST algorithm. Note the improved density at low wind-speed and overall reduction in scatter cf. left-hand panel of Figure 1.

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.

In response to our extensive feedback and suggestions, the GAASP algorithm team developed a 4th version of the product, which has recently been validated and is a substantial improvement (0.62 K rms), with error characteristics that are broadly similar to those observed in other SST products. Some residual bias dependencies remain and these findings have been passed back to the team. Figure 3 shows the equivalent plot to Figure 1, but for the latest version of the algorithm.

Planned Work

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

- Develop a GHRSST Level-2P Sensor Specific Error Statistics algorithm to account for residual errors in the GAASP AMSR-2 SST product
- Develop a template for GHRSST L2P format
- Continue to provide feedback on further revisions to the GAASP AMSR-2 SST product development team

Products

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

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**

Performance Metrics Explanation

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

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

Task Leader	Andy Harris
Task Code	AHAH_H8SST_15
NOAA Sponsor	Tom Schott
NOAA Office	NESDIS/OSGS
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 50%; Goal 3: 50%

Highlight: The experimental version of the ACSPO Himawari-8 SST product has been successfully incorporated into the Geo-Polar Blended SST analysis. The Himawari-8 data are higher resolution and less noisy than those from the previous generation MTSAT-2 Imager. The results are encouraging for the prospect of including data from the upcoming GOES-R and, in the future, Meteosat Third Generation.

Background

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

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

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

Accomplishments

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

d) Adapt blended SST ingestion software and incorporate experimental version of ACSPO Himawari-8 SST product into operational Geo-Polar Blended SST analysis. This is essential to maintain product accuracy in the W Pacific;

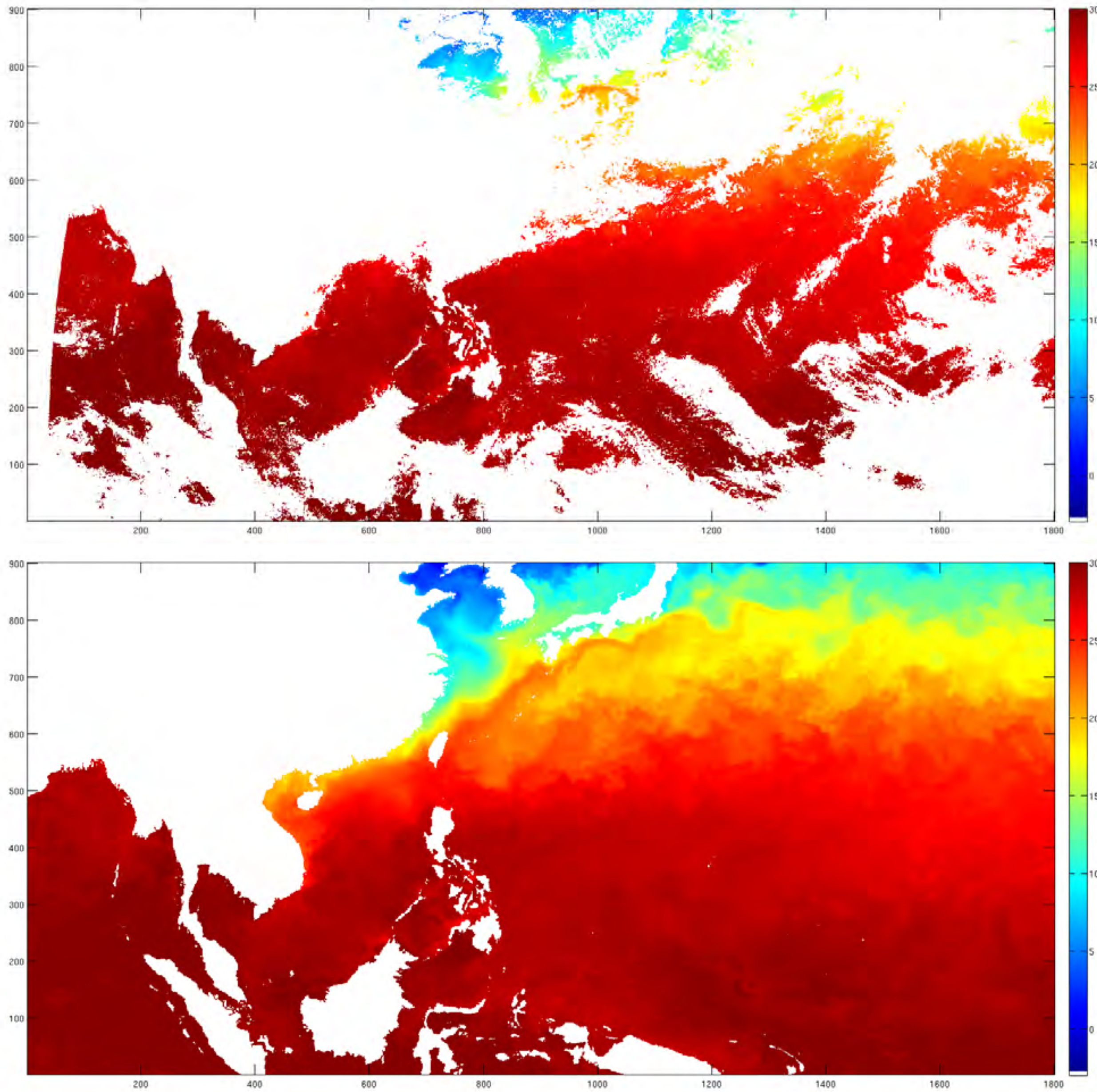


Figure 1. Top panel shows resultant field of nighttime Himawari-8 SST data ingested onto 5-km analysis grid for March 24, 2016. The concomitant Geo-Polar Blended SST analysis for the same day is shown in the bottom panel.

e) Ingest the BoM operational Himawari-8 SST in a parallel trial of the Geo-Polar Blended SST analysis;Compare the accuracies of the Blended SST analyses using ACSPO and BoM Himawari-8 data, and switch to BoM data if product accuracy is not degraded;

f) Make refinements to analysis software to include operational version of ACSPO Himawari-8 SST data when those become available

Stage 1 has been successfully completed in order to provide continuity of coverage for the W Pacific. Figure 1 (top panel) shows a detail of the nighttime Himawari-8 SST data ingested onto the 5-km analysis grid for a single day. There is no discernable evidence of detector striping that was becoming an issue with the MTSAT-2 Imager, and features are well-resolved (*e.g.* in the Sulu Sea, between the Phillipines and Borneo). The resultant Geo-Polar Blended SST analysis for the same day can be seen in the bottom panel of Figure 1. The benefits of utilizing the data-weighted correlation length scales can be discerned by the way that features in the ingested Himawari-8 SST field are largely preserved in the resultant analysis.

Planned Work

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

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

Products

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

Performance Metrics	
# of new or improved products developed (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**

Performance Metrics Explanation

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

Development of Global Soil Moisture Product System (SMOPS)

Task Leader :	Christopher Hain
Task Code:	CHCH_SMOPS_15
NOAA Sponsor	Xiwu Zhan
NOAA Office	STAR
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%
Main CICS Research Topic	Data Fusion and Algorthimn Development
Contribution to NOAA goals (%)	Goal 1: 40%; Goal 2: 25%; Goal 3: 35%

Highlight: We have finished ingesting ASCAT soil moisture data from MetOp-B into SMOPS and the new SMOPS version (V1.20) has been operationally running since July, 2015 at OSPO. We have finished upgrading SMOPS to Version 2.0 that includes GCOM-W1 AMSR2 L2 orbital soil moisture retrievals and SMOS NRT soil moisture retrievals. The code has been delivered to OSPO and the operational system is expected to be updated in Apriial, 2016.

Link to a research web page http://www.ospo.noaa.gov/Products/land/smops/index.html

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 out- put a global gridded soil moisture map for each sensor at a quarter degree resolution every 6 hours. In addition to the gridded soil moisture layers, SMOPS also generates a blended soil mois-ture layer that merges all the available soil moisture values using a cumulative distribution func- tion (CDF) approach. As soil moisture data became available from MetOp-B ASCAT, MetOp-B ASCAT soil moisture has been added 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 is now being generated at NOAA. This product has also been ingested in SMOPS. To improve the data latency of SMOS soil moisture generation, we are also developed 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 (V1.2) to include soil moisture data from MetOp-B ASCAT.
SMOPS Version 2.0 code has been completed and delivered to OSPO. This version of SMOPS added GCOME-W2 soil moisture and SMOS NRT soil moisture retrieved by SMOPS algorithm. It is now under testing on the operational system and will go operational in coming months. Because of the data quality and life cycle issues, WindSat soil moisture layer is eliminated from SMOPS Version 2.0 and will not be produced operationally once this new version goes opera- tional. Table 1 shows the data layers for the SMOPS version (V1.2) and the future version of SMOPS (V2.0).

Table 1. Soil Moisture data layers of SMOPS current version (V1.2) and future version (V2.0).

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

Data link for the Global Precipitation measurement (GPM) Microwave Imager (GMI) brightness temperature has been established. Codes for reading and gridding this data set has been complet - ed. Figure 1 shows an example of brightness temperature map gridded using the reader.

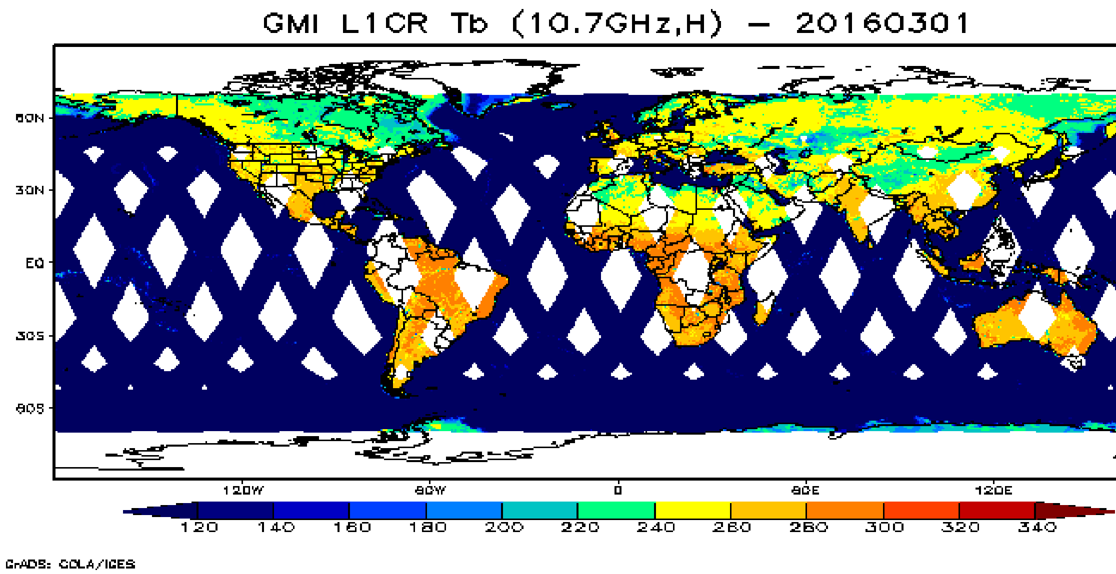


Figure 1. GMI L1CR brightness temperature (Channel 10.7 GHz, H).

Data link for SMAP Near Real Time (NRT) brightness temperature data has been established and the codes for reading and processing this data set has been completed. Figure 2 shows an ex - ample of the gridded SMAP NRT brightness temperature.

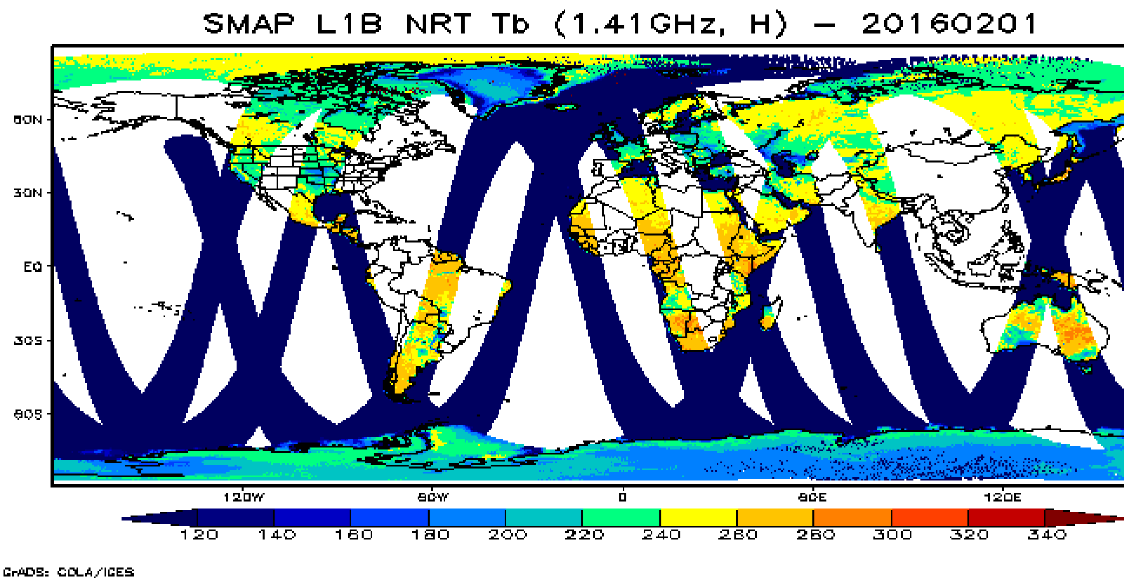


Figure 2. SMAP NRT L1B brightness temperature (H-Pol).

Planned work

- Work with OSPO to test the updated SMOPS V2.0 code and make it operational.
- Continue working on ingesting GPM/GMI soil moisture and SMAP soil moisture.

Products

- SMOPS V2.0 code.
- GMI brightness temperature data processing code.
- NRT SMAP brightness temperature data processing code.
- Testing algorithms for GMI and SMAP soil moisture retrieval.

Presentations

Comparison of different methods to Merge Satellite Soil Moisture Products from Different Sensors", Jicheng Liu et al., *CICS-MD Science Meeting*, November, 2015.

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

Performance Metrics Explanation

The new version of SMOPS delivered to OSPO will have both AMSR2 and NRT SMOS 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	Cezar Kongoli
Task Code	CKCK_BICA_14 & CKCK_IMS3_15
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 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

Non-peer reviewed papers

Kongoli, C. and S. Helfrich, 2015. A multi-source interactive analysis approach for Northern hemispheric snow depth estimation, Proceedings of the Geoscience and Remote Sensing Symposium (IGARSS), IEEE International, Milan, Italy, DOI: 10.1109/IGARSS.2015.7325878

Kongoli C, S. Healfrich and R. Kuligowski, 2015. Satellite-based estimation of hydrologic components, Proceedings of the 5th International Conference on Ecosystems, ICE 2015, Tirana, Albania, ISBN: 978-9928-4248-4-6.

Peer-reviewed papers

Kongoli C, S. Helfrich and R. Kuligowski, 2015. Satellite-based estimation of hydrologic components – Application to Snow and Precipitation, International Journal of Ecosystems and Ecology Science (IJEES), 5(2), 261-268

Kongoli, C., 2015. Optimal interpolation of in-situ and satellite passive microwave data for global snow depth estimation, International journal of ecosystems and ecology science (IJEES), 5(4), 637-642.

Planned Work

- Improve blending snow depth algorithm
- Test improvements and transition to operations

Performance Metrics	
# of new or improved products developed	1
# of products or techniques transitioned from research to ops	0
# of peer reviewed papers	1
# of non-peered reviewed papers	1
# of invited presentations	1
# of graduate students supported by a CICS task	N/A
# of undergraduate students supported by a CICS task	0

Performance Metrics Explanation

This year, we improved an operational sow depth product (1). One journal paper (1) and one non-peer reviewed conference proceedings paper (1) has been published, as well as one presentation (1).

Precipitation Research and Applications	
Task Leader	Yalei You
Task Code	EBWY_PRA_15
NOAA Sponsor	Mike Kalb
NOAA Office	STAR
Contribution to CICS Research Themes:	Theme 1 (100%); Theme 2 (0%); Theme 3 (0%);
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals:	Goal 1 (100%); Goal 2 (0%); Goal 3 (0%)
Highlight Precipitation retrieval algorithm development and validation	
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 polar orbiting satellites, in particular, microwave sensors, offer perhaps the most viable means to develop global precipitation retrievals.

Accomplishments

12/19/2015 **Emissivity evaluation study published** Yalei You

ESSIC scientist Yudong Tian along with CICS scientist Yalei have a new paper published on *J. Geophys. Res*. In this study, three types of approaches (physical modeling, statistical modeling, and a hybrid of physical and statistical modeling), which are used to estimate the land surface emissivity is evaluated in details. Every approach is subject to evaluation against retrieved emissivity over a large area in the Southern Great Plains for a period of 2 years. Physical modeling, based on two radiative transfer models coupled to a land surface modeling framework, produced reasonable estimates, with channel- and polarization-dependent errors. Calibration of these models with historical data substantially improved their performance at lower frequencies. The statistical method was tested with five different regression models, and each of them consistently outperformed physical models by about 50%. The best statistical model had an average error of 0.9–2.1%. These statistical models were slightly improved when empirical orthogonal function analysis was incorporated in the emissivity data. The hybrid approach produced errors between the uncalibrated and calibrated physical model errors

01/11/2016 **Snowfall inter-comparison work presented at AMS** Yalei You

CICS summer intern Ryan Smith along with CICS scientist Yalei You have presented their snowfall inter-comparison work at American Meteorological Society (AMS) annual meeting. In this work, we compared the snowfall measurement from gauge, ground radar, spaceborne radar and radiometer over the Continental United States (CONUS).

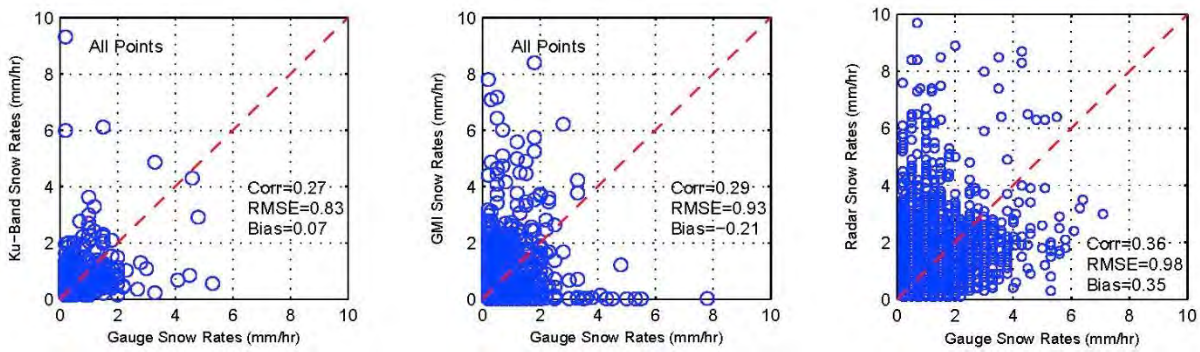


Figure 1: (from right to left) snowfall scatter plots between Ku PR and gauge, GMI and gauge, MRMS and guage.

02/20/2016 **ATMS Precipitation Algorithm Article Accepted** Yalei You

CICS Scientist Yalei You along with CoRP Scientist Nai-Yu Wang have a new article accepted by the Journal of Hydrometeorology on February 15. It describes a prototype precipitation retrieval algorithm over land that uses a three-year National Mosaic and Multi-Sensor Quantitative Precipitation Estimation (NMQ) and Advanced Technology Microwave Sounder (ATMS) coincident datasets. One of the unique features of this algorithm is using ancillary parameters, such as surface type, surface temperature, land elevation and ice layer thickness, to stratify the single database into many smaller but more homogeneous databases, in which both the surface condition and precipitation vertical structure are similar. In addition. It is showed that the representative nature of rainfall over CONUS permitted the application of this algorithm to 60◦S-60◦N for rainfall retrieval, evidenced by the progress and retreat of the major rain bands. However, artificially large snowfall rate is observed in several regions (e.g., Tibetan Plateau and Siberia), due to frequent false detection and overestimation caused by much colder brightness temperatures.

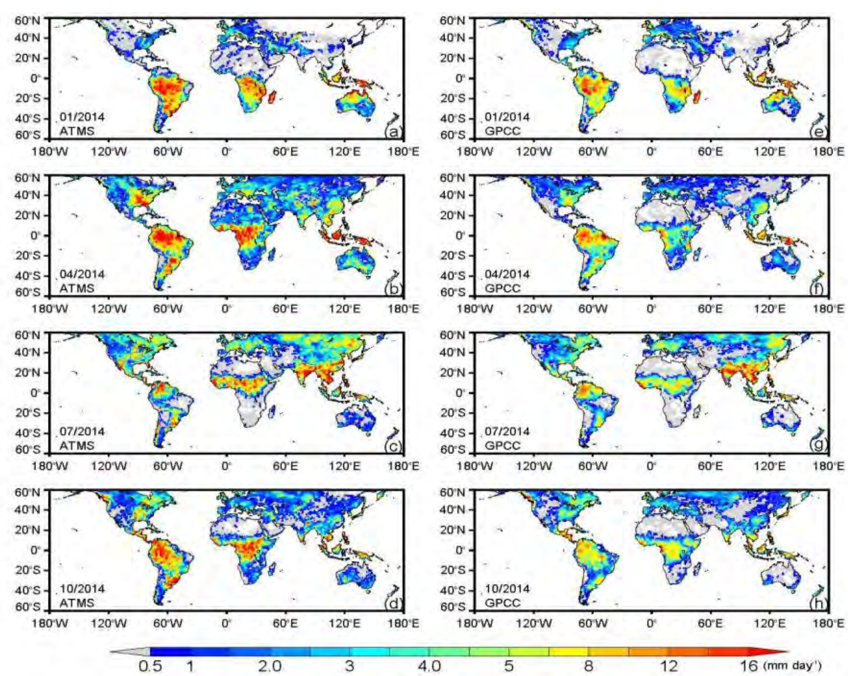


Figure 2: (a)-(d) Geospatial distribution of the ATMS retrieved rain rate over the 60◦S-60◦N in January, April, July and October of 2014. (e)-(h) Geospatial distribution of the gauge-analysis (GPCC) rain rate over the 60◦S-60◦N in January, April July and October of 2014.

Citation: You, Yalei, Nai-Yu Wang and Ralph Ferraro, 2015: A Prototype Precipitation Retrieval Algorithm for ATMS, *J. Hydrol* (in press) (Yalei You, CICS, yyou@umd.edu, 301-405-0068).

Planned work

- Provide 2-yr ATMS retrieval results for evaluation
- Compare the level-2 precipitation product from NASA and JAXA.

Publications

- You, Y., N.-Y. Wang, and R. Ferraro (2016), A prototype precipitation retrieval algorithm for ATMS. *J. Hydrometeor* (accepted).
- Tian, Y., et al. *(*2015*),* An examination of methods for estimating land surface microwave emissivity*,* J. Geophys. Res. Atmos.*,* 120*,* 11,114–11,128*, doi:*10.1002/2015JD023582.

Presentations

Ryan Smith, Yalei You, Nai-Yu Wang and Ralph Ferraro
Comparison of Snowfall Rate from Gauge, Ground Radar, Space Radar, and Space Radiometer over the Contiguous United States

AMS annual meeting
New Orleans, LA
1/10/2016-1/14/2016

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	**2**
# of non-peered reviewed papers	
# of invited presentations	**1**
# of graduate students supported by a CICS task	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	

GCOM-W1 Soil Moisture Product Development and Validation

Task Leader	Dr. Jicheng Liu
Task Code	JLJL_GCOM_15
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: 35%

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

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. AMSR2 Soil Moisture EDR is designed as one of the Day 2 products that need to take some of the Day 1 product as input. Test mode of day 2 products has been running since the summer of 2015 and will go fully operationally in 2016.

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.

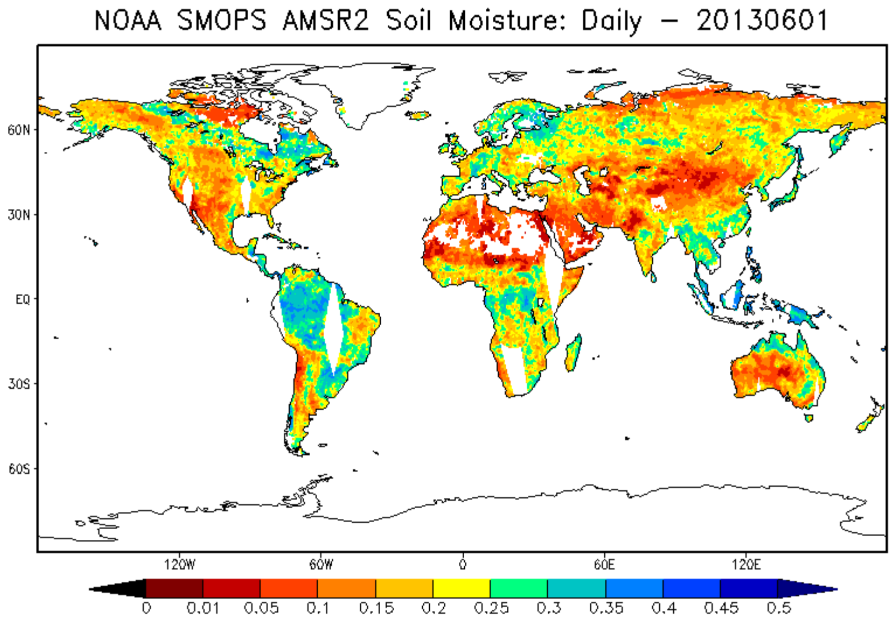


Figure 1. Daily gridded AMSR2 soil moisture product.

This product has also successfully ingested into NOAA Soil Moisture Operational Product System (SMOPS) Version 2.0. It will make major contribution to the blended soil moisture product of SMOPS. This version of SMOPS is now under testing at NOAA/STAR/OSPO and will go operational in the summer of 2016.

Planned work

- Work with NOAA/NESDIS/STAR for soil moisture EDR operational running.
- Develop monitoring tools for the product quality.
- 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 operational code.
- Documents related GAASP SM EDR code.
- Collection of processors for in-situ soil moisture observations.
- Validation code for the SM EDR product using field measurements.

Presentations

- Comparison of different methods to Merge Satellite Soil Moisture Products from Different Sensors", Jicheng Liu et al., *2015 CICS-MD Science Meeting*, November, 2015.

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**

PERFORMANCE METRICS EXPLANATION

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

2 Calibration and Validation

Scientific Exchange Between DLR/Berlin and NESDIS/STAR Fire Scientists Using the German FireBird Small Satellite Constellation in Support of GOES-R/ABI and Suomi NPP/VIIRS Fire Product Validation

Task Leader	Wilfrid Schroeder
Task Code	WSWS_DLR_14
NOAA Sponsor	Jaime Daniels
NOAA Office	NESDIS/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: Through this collaborative work, the satellite retrieval of gas flares can be improved. This work is necessary for next generation NESDIS satellite architecture, pointing to the need for a constellation of "smallsats" to get the same VIIRS coverage in the future.

Mr. Gernot Rucker (ZEBRIS Consulting/Germany) visited the Department of Geographical Sciences at the University of Maryland (GEOG/UMD) during 27 May – 05 June 2015 to collaborate with Dr. Wilfrid Schroeder (GEOG/UMD) and Dr. Ivan Csiszar (NESDIS/STAR). In preparation for Mr. Rucker's visit, targeted acquisitions were planned and successfully implemented for the German Aerospace Center (DLR) Technology Experiment Carrier (TET-1) satellite over select areas containing active gas flares, including North Dakota/US, Kuwait and Russia. Fire detection and characterization data derived from TET-1 were analyzed and used to verify near-coincident Suomi NPP VIIRS data (Figure 1).

Preliminary results showed good agreement between TET-1 and VIIRS fire radiative power retrievals characterizing gas flare intensity. Data processing findings and recommendations were submitted to the TET-1 science team at DLR/Berlin in order further promote the use of those data in support of Suomi NPP VIIRS and future GOES-R ABI fire product assessment. The NOAA GOES-R Risk Reduction and JPSS Proving Ground and Risk Reduction Visiting Scientist program sponsored this scientific exchange.

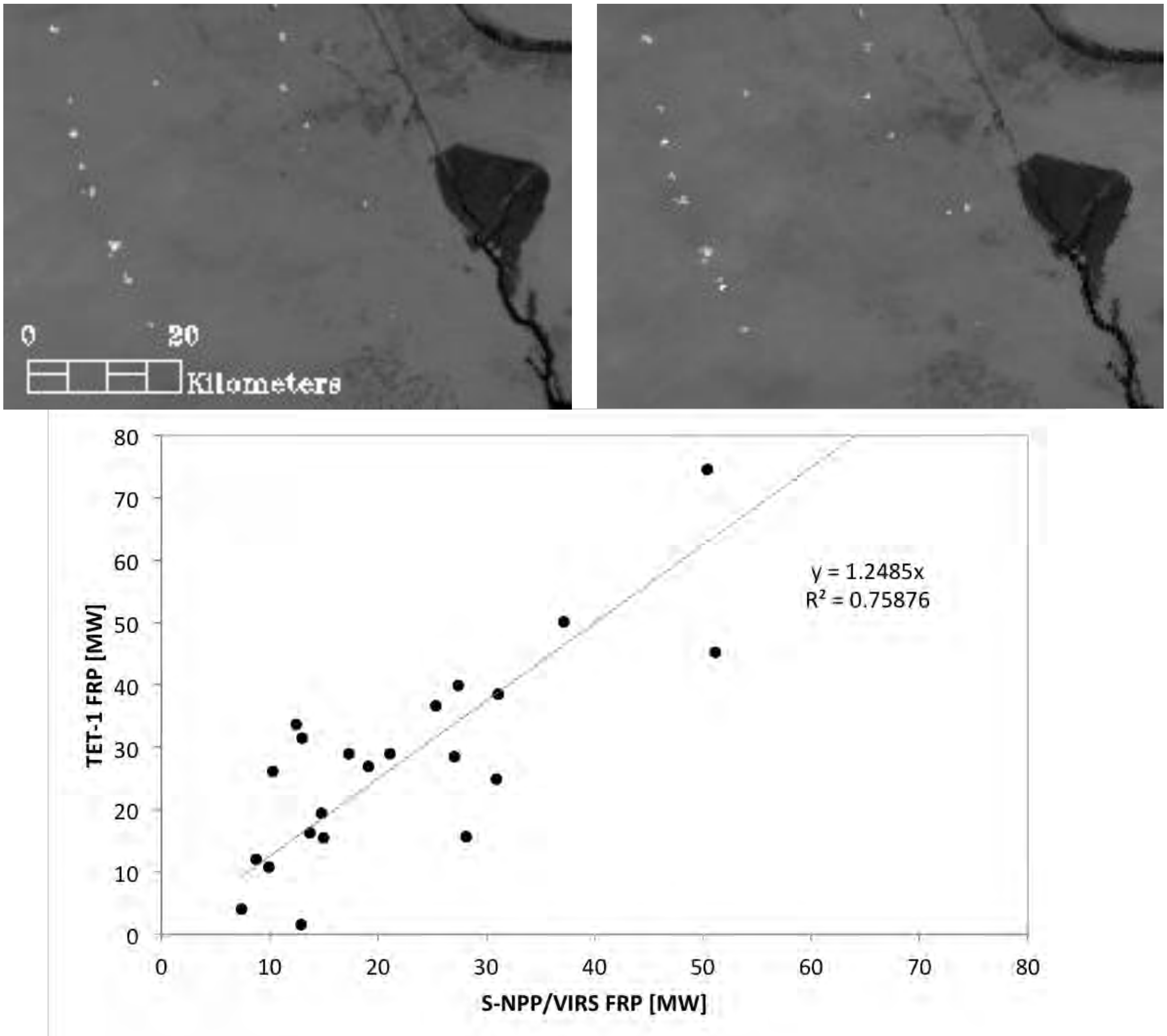


Figure 1*: Sampling of gas flares (bright pixels) in Kuwait using DLR's TET-1 160 m (top left) and Suomi NPP VIIRS 375 m (top right) mid-infrared data. The lower panel shows a comparison between fire radiative power (FRP) retrievals derived from near-coincident TET-1 and Suomi NPP VIIRS data for numerous gas flares in the Middle East.*

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

Task Leader: Yong Chen
Task Code: YCYC_CRIS_15 & YCYC_JPSS_15 (Part 1 of 4)
NOAA Sponsor: Fuzhong Weng
NOAA Office: NESDIS/STAR
Contribution to CICS Research Themes (%): 60% Theme 1 and 40% Theme 2
Main CICS Research Topic:. Calibration and Validation
Contribution to NOAA goals (%): Goal 1: 30%; Goal 2: 70%
Highlight: CICS Scientist Yong Chen continue work to improve the calibration algorithms, including optimization of the calibration equation, implement ringing artifact reduction algorithm updates into FSR-ADL software, further assess the spectral and radiometric accuracies of the SDR product from the FSR processing system, and analyze JPSS-1 pre-launch test data and derive parameters for CrIS spectral and radiometric calibration.

Background

This report summarizes the second 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. CrIS on S-NPP is a Fourier transform spectrometer. It provides a total of 1305 channels in the normal mode for sounding the atmosphere. CrIS can also be operated in the full spectral resolution (FSR) mode with spectral resolution of 0.625 cm^{-1} for all three bands (total 2211 channels). NOAA operated CrIS in FSR mode from normal mode on December 4, 2014 for S-NPP, and will operate CrIS in FSR mode for the Joint Polar Satellite System (JPSS). Based on CrIS Algorithm Development Library (ADL), CrIS full resolution Processing System (CRPS) has been developed to generate the FSR Sensor Data Record (SDR). This code can also be run for normal mode and truncation mode SDRs. Since CrIS is a Fourier transform spectrometer, the CrIS SDR need to be radiometrically and spectrally calibrated. The current calibration approach does the radiometric calibration first, and then applies the correction matrix operator (CMO) to the spectral calibration. The ringing artifacts are observed in CrIS normal mode SDR un-apodized spectra for this operational calibration approach. The ringing artifacts are also depending on Optical Path Delay (OPD) sweep direction. In order to study and understand the ringing effect and to support to select the best calibration algorithm for JPSS-1, different calibration approaches are implemented in the ADL code. Great efforts had been taken to evaluate different calibration approaches and to understand the causes of the ringing artifacts. Major sources of these ringing artifacts are due to non-circular onboard Finite Impulse Response (FIR) digital filter, suboptimal calibration equation, and missing the instrument responsivity function for simulating CrIS spectra using radiative transfer models. Below are the accomplishments of this year, followed by future plans.

Accomplishments

4-15-15 **Evaluation of CrIS SDR Algorithms Using FSR CrIS Data and LBLRTM** Yong Chen
Four different calibration algorithms are implemented into ADL software and evaluated by compared to LBLRTM simulations. Results show that Algorithms 3 and 4 (first apply spectral calibration and then radiometric calibration) are the best choice in term of absolute bias, sweep direction difference (ringing artifact) reduction, and FOV-2-FOV consistence.

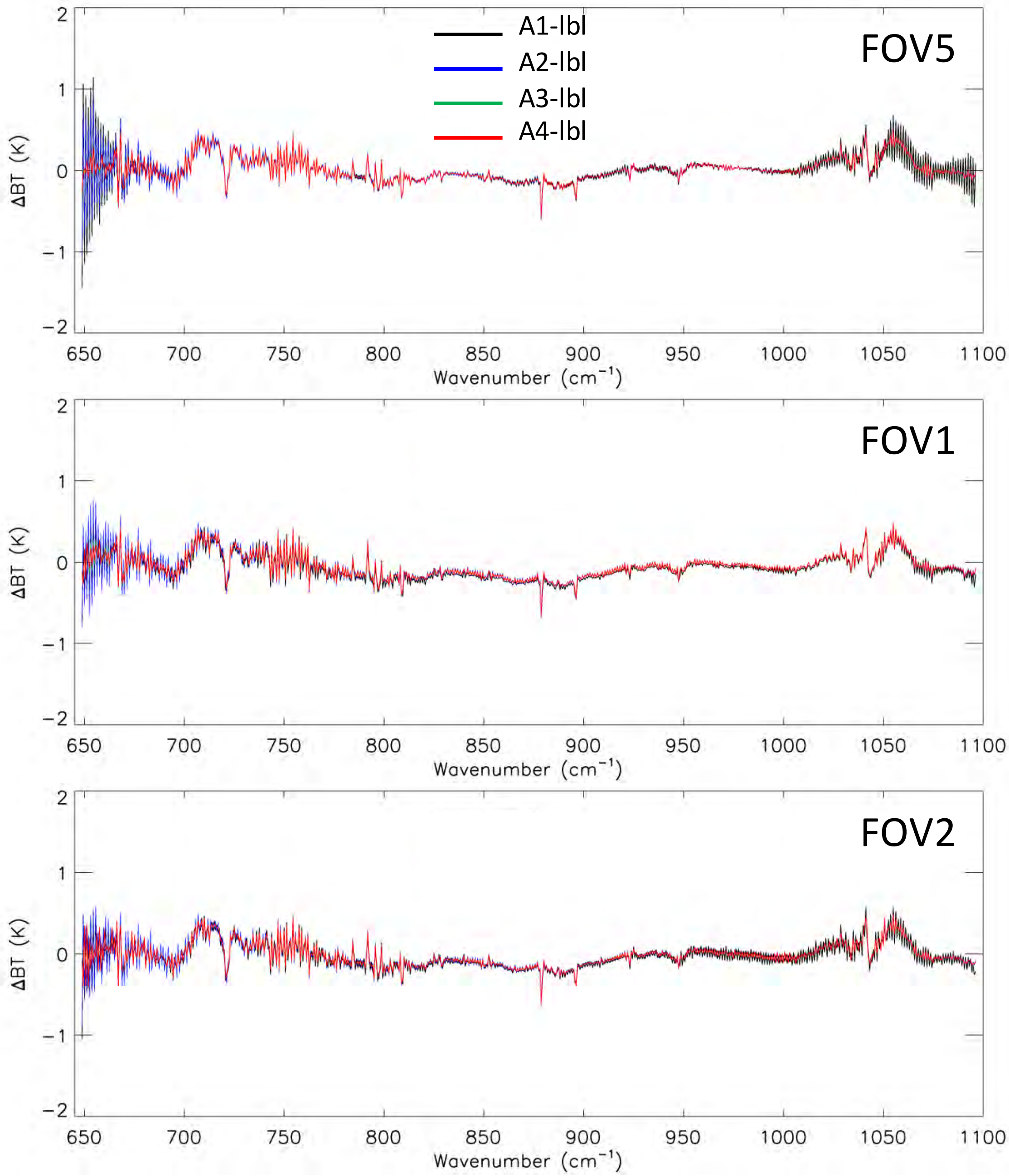


Figure 1. Mean brightness temperature difference between different algorithms and LBLRTM simulations. Algorithm 4 (A4) shows the smallest ringing artifact at both band 1 edges.

7-28-15 **Poster Presentation and Proceeding paper at 2015 IGARSS Conference** Yong Chen
CICS-MD Scientist Yong Chen presented a poster titled "Evaluation of different calibration approaches for S-NPP CrIS full spectral resolution SDR processing" at 2015 IGARSS Conference. In this study, four different calibration approaches are implemented in the FSR ADL code to study and understand the ringing artifacts and to support to select the best calibration algorithm for CrIS on JPSS-1. The full proceeding paper can be cited: Yong Chen, and Yong Han, Evaluation of different calibration approaches for S-NPP CrIS full spectral resolution SDR processing, IEEE Geoscience and Remote Sensing Symposium, Milan, Italy, 2015, 2127-2130, doi:10.1109/IGARSS.2015.7326223

8-5-15 **Lunar Intrusion Issues in CrIS SDR Processing** Yong Chen

There are two lunar Intrusion detection issues in CrIS SDR processing. One is the averaged uncalibrated deep space spectrum and the other is the threshold. When the first DS spectrum is contaminated by the moon, the new normal DS views will be rejected and the Earth views will be invalid due to the valid DS window size is less than 15. This could happen more frequently for parallel run than serial run. The detection threshold 10% is not a reasonable value, which will allow contaminated DS spectra into the valid sliding window and cause large radiometric error for Earth radiance. We make improvement for both issues. The purposed changes to get the DS referenceSpectra and thresholds (0.3% for LW, 0.4% for MW, and 0.6% for SW) need more tests.

8-28-15 **SCSB/CICS-MD Presenters at the JPSS Science Meeting** Yong Chen

The STAR JPSS 2015 Annual Science Team Meeting was held this week, August 24-28 August 2015 at NCWCP in College Park, MD. Yong Chen gave a talk on "J1 CrIS SDR Algorithm and Software."

9-4-15 **New Algorithm More Accurately Characterizes Instrument "Noise"** Yong Chen

CICS-MD Scientist Yong Chen has published an article in the September 10th issue of Applied Optics outlining a new solution to representing the amount of random noise in satellite interferometer data. The Cross-track Infrared Sounder (CrIS) on the Suomi National Polar-orbiting Partnership Satellite (S-NPP) is a Fourier transform spectrometer and provides the sensor data record (SDR) that can be used to retrieve atmospheric temperature and water vapor profiles and can also be directly assimilated in numerical weather prediction models. The noise equivalent differential radiance (NEdN) is part of CrIS SDR products and represents the amount of random noise in the interferometer data. It is a crucial parameter that affects the accuracy of retrieval and satellite radiance assimilation. In this study, they used the international system of units (SI) traceable method Allan deviation to estimate the CrIS NEdN because the internal calibration target (ICT) radiance was slowly varying with time. Compared to the current standard deviation method, this study shows that the NEdN calculated from Allan deviation is converged to a stable value when a number of samples or the average window size is set to 510. Thus, Allan deviation can result in CrIS NEdN SI traceable noise. An optimal averaging window size is 30 if the NEdN is calculated from the standard deviation. Citation: Chen, Yong, Fuzhong Weng, and Yong Han: SI traceable algorithm for characterizing hyperspectral infrared sounder CrIS noise, Appl. Opt. 54, 7889-7894, doi: 10.1364/AO.54.007889. *Importance*: This is the first application of the Allan deivation algorithm to NOAA infrared sensor CrIS and it has been shown to provide highly accurate characterizations of instrument noise. *POC*: Yong Chen

11-6-15 **Yong Chen Wins Best Paper Award** Yong Chen

Dr. Yong Chen –a CICS Research Scientist supporting activities at SMCD– was rewarded the best proceeding paper award for his paper titled as "CrIS Full Resolution Processing and Validation System for JPSS" authored by **Yong Chen**, Yong Han, Denis Tremblay, Likun Wang, Xin Jin, and Fuzhong Weng during the 20th International TOVS Study Conferences, which was held at Lake Geneva, Wisconsin from 28 October to 3 November 2015. The International TOVS Study Conferences (ITSCs), which have met every 18-24 months since 1983, is a forum for operational and research users of TIROS Operational Vertical Sounder (TOVS) data from the NOAA series of polar orbiting satellites and other atmospheric sounding data. The purpose of the conference is to exchange information on methods for extracting information from these data on atmospheric temperature and moisture fields and on the impact of these data in numerical weather prediction and in climate studies. Dr. Chen's paper is focused on the Cross-track Infrared Sounder (CrIS)– a key instrument onboard on Suomi NPP and future JPSS satellites that provides atmospheric sounding information for numerical weather prediction models. Dr. Chen has made significant contribution to develop the NOAA's first-ever full spectral resolution CrIS data processing system. The high-quality shown in his paper, and, perhaps most importantly, the innovativeness and accomplishments from his paper fully convinced the conference committee how important his work is to promote the use of NOAA data. *Importance*: International recognition for NOAA scientists continues to support a mission goal of a world class workforce. *POC*: Y. Chen & L. Wang

1-13-16 **Poster Presentation on CrIS Spectral Accuracy at AMS** Yong Chen
CICS-MD Scientist Yong Chen presented a poster titled "On Hyper-spectral Infrared Sensor CrIS spectral accuracy" at the AMS Annual Meeting held in New Orleans. His talk focused on using Line-by-Line Radiative Transfer Model (LBLRTM) and European Centre for Medium-Range Weather Forecasts (ECMWF) forecast fields to systematically evaluate the spectral accuracy of CrIS full resolution SDR, processed at NOAA/STAR since December 2014, at different spectral ranges for all three bands. Based on these results, the best spectral ranges can be chosen to evaluate the spectral accuracy and stability for CrIS, IASI and future FTS infrared instruments. Long-term CrIS spectral accuracy and spectral stability from the operational SDRs will be further studied based on the selected best spectral ranges.

Planned work

- Implement all the updates, including optimization of the calibration equation, new fringe count error (FCE) module, new lunar intrusion detection module, to the ADL block 2 version 5.3.1 which is the official release of JPSS-1 baseline code.
- Transit algorithm to operations for JPSS-1.
- Further assess the spectral and radiometric accuracies of the SDR product from the FSR processing system
- Prepare and work on reprocessing the CrIS life-cycle SDR data
- Analyze JPSS-1 pre-launch test data and derive parameters for CrIS spectral and radiometric calibration

Publications

Peer-Reviewed

Yong Han, Lewence Suwinski, David Tobin, and Yong Chen, Effect of self-apodization correction on Cross-track Infrared Sounder radiance noise, Appl. Opt., 54, 10114-10122. doi: 10.1364/AO.54.010114 (2015).

Yong Chen, Fuzhong Weng, and Yong Han, SI traceable algorithm for characterizing hyperspectral infrared sounder CrIS noise, Appl. Opt., 54, 7889–7894. doi: 10.1364/AO.54.007889 (2015).

Likun Wang, Yong Han, Xin Jin, Yong Chen, and Denis Tremblay, Radiometric consistency assessment of hyperspectral infrared sounders, Atmos. Meas. Tech., 8, 4831-4844, doi:10.5194/amt-8-4831-2015 (2015).

Non-peer reviewed

Yong Chen, and Yong Han, Evaluation of different calibration approaches for S-NPP CrIS full spectral resolution SDR processing, IEEE Geoscience and Remote Sensing Symposium, Milan, Italy, 2015, 2127-2130, doi:10.1109/IGARSS.2015.7326223

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

Yong Chen, Yong Han and Fuzhong Weng, On Hyper-spectral Infrared Sensor CrIS Spectral Accuracy, the 96th American Meteorological Society Annual Meeting, 10-14 January, 2016, New Orleans, Louisiana, poster 728, 2016.

Likun Wang, Bin Zhang, Yong Han, Xin Jin, Yong Chen, and Denis Tremblay, Geolocation Assessment Tool and Correction Model for JPSS CrIS, the 96th American Meteorological Society Annual Meeting, 10-14 January, 2016, New Orleans, Louisiana, poster 730, 2016.

Denis Tremblay, Yong Han, Likun Wang, Yong Chen, Xin Jin, and Xiaozhen Xiong, JPSS-1 CrIS Measurement Noise Covariance Characterization at Full Spectral Resolution, the 96th American Meteorological Society Annual Meeting, 10-14 January, 2016, New Orleans, Louisiana, poster 346, 2016.

Xiaozhen Xiong, Yong Han, Yong Chen, Likun Wang, Denis Tremblay, Xin Jin, and Lihang Zhou, Near-Real Time Processing of S-NPP CrIS Full Spectral Resolution SDR Data at NOAA/STAR, the 96th American Meteorological Society Annual Meeting, 10-14 January, 2016, New Orleans, Louisiana, poster 350, 2016.

Xiaozhen Xiong, Jeff Peischl, Thomas B Ryerson, Motoki Sasakawa, Yong Han, Yong Chen, Likun Wang, Denis Tremblay, Xin Jin, Lihang Zhou, Quanhua Liu, Fuzhong Weng and Toshinobu Machida, Full Spectral Resolution Data Generation from the Cross-track Infrared Sounder on S-NPP at NOAA and its Use to Investigate Uncertainty in Methane Absorption Band Near 7.66 μm, 2015 AGU Fall Meeting, San Francisco, California, 2015 Dec

Denis Tremblay, Yong Chen, Yong Han, Likun Wang, Xin Jin, Xiaozhen Xiong, and Lihang Zhou, Correlated and uncorrelated noise of the JPSS-1 Crosstrack Infrared Sensor (CrIS), the 20th International TOVS Study Conference (ITSC-20), Lake Geneva, Wisconsin, 2015 Nov

Yong Chen, and Yong Han, Evaluation of different calibration approaches for JPSS CrIS, 2015 CICS Science Meeting, College Park, Maryland, 2015 Nov http://cicsmd.umd.edu/assets/1/7/2-4_Yong_Chen.pdf

Yong Chen, Fuzhong Weng, and Yong Han, SI Traceable Algorithm for Characterizing Hyperspectral Infrared Sounder CrIS Noise, 2015 CICS Science Meeting, College Park, Maryland, 2015 Nov http://cicsmd.umd.edu/assets/1/7/2_Yong_Chen.pdf

Yong Chen, and Yong Han, Evaluation of Different Calibration Approaches for JPSS CrIS, the 20th International TOVS Study Conference (ITSC-20), Lake Geneva, Wisconsin, 2015 Oct https://cimss.ssec.wisc.edu/itwg/itsc/itsc20/program/PDFs/28Oct/session1d/1p_11_chen.pdf

Yong Chen, Fuzhong Weng, and Yong Han, SI Traceable Algorithm for Characterizing Hyperspectral Infrared Sounder CrIS Noise, the 20th International TOVS Study Conference (ITSC-20), Lake Geneva, Wisconsin, 2015 Oct https://cimss.ssec.wisc.edu/itwg/itsc/itsc20/program/PDFs/28Oct/session1d/1p_12_chen.pdf

Xiaozhen Xiong, Yong Han, Yong Chen, Likun Wang, Denis Tremblay, Xin Jin, and Lihong Zhou, Update on S-NPP CrIS full spectral resolution SDR processing at NOAA/STAR, the 20th International TOVS Study Conference (ITSC-20), Lake Geneva, Wisconsin, 2015 Oct

Xin Jin, Ninghai Sun, Yong Han, Fuzhong Weng, Yong Chen, Likun Wang, and Denis Tremblay, A comprehensive review of SNPP CrIS instrument performance and data quality, the 20th International TOVS Study Conference (ITSC-20), Lake Geneva, Wisconsin, 2015 Oct

Yong Han, and Yong Chen, J1 CrIS SDR Algorithm and Software, 2015 STAR JPSS Annual Science Team Meeting, College Park, Maryland, 2015 Aug http://www.orbit.nesdis.noaa.gov/star/documents/meetings/2015JPSSAnnual/dayThree/06_Session6c_Han_J1-CrIS-SDR-Algorithm-Software.pdf

Fuzhong Weng, Mitch Goldberg, Xiaolei Zou, Yong Chen, Lin Lin, Banglin Zhang, and Vijay Tallapragada, Improve assimilation of CrIS radiances in HWRF for better hurricane and typhoon forecasts, IEEE Geoscience and Remote Sensing Symposium, Milan, Italy, 2015 Jul

Xiaozhen Xiong, Yong Han, Yong Chen, Lihang Zhou, and Fuzhong Weng, Investigation of the uncertainty in methane absorption band using full spectrum data of CrIS on S-NPP and radiative transfer models, IEEE Geoscience and Remote Sensing Symposium, Milan, Italy, 2015 Jul

Yong Chen, and Yong Han, Evaluation of different calibration approaches for S-NPP CrIS full spectral resolution SDR processing, IEEE Geoscience and Remote Sensing Symposium, Milan, Italy, 2015 Jul

Other

November 2015, best proceedings paper award from International TOVS Study Conference (ITSC) for CrIS full resolution processing and validation system for JPSS

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	**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**

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

Task Leader: **Yong Chen (Chunhui Pan's Report)**
Task Code: **YCYC_JPSS_14 (Part 2 of 4)**
NOAA Sponsor: **Fuzhong Weng**
NOAA Office: **NESDIS/STAR**
Contribution to CICS Research Themes (%): **60% Theme 1 and 40% Theme 2**
Main CICS Research Topic: **Calibration and Validation**
Contribution to NOAA goals (%) **Goal 1: 70%; Goal 2: 20%; Goal 5: 10%**
Highlight: I have developed new comprehensive data analysis algorithms and models to evaluate and characterize sensor orbital stray light contamination, wavelength calibration and optical system stability. Numbers of milestone deliveries have been made to STAR, including sensor performance as-sessment, software tools, and weekly delivery of dark calibration tables. Four journal papers have been published in 2014.
Link to a research web page http://cicsmd.umd.edu/performance-evaluation-of-omps/?pg=5

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 fourth year of the project, followed by future plans for fourth year.

Accomplishments

2-20-15 **New Stray Light Algorithm** Chunhui Pan

CICS-MD Scientist Chunhui Pan, working on the Ozone Mapping and Profiler Suite (OMPS), developed a new algorithm last week for a Nadir Profiler (NP) Stray Light Calibration Table. This new algorithm extends spectral channels from 147 to 157 and includes extension of the NP wavelength coverage and radiometric coefficients. This new table is for Field of View (FOV) resolution of 50 km x 50 km data.

3-6-15 **OMPS Corrections and Calibrations** Chunhui Pan

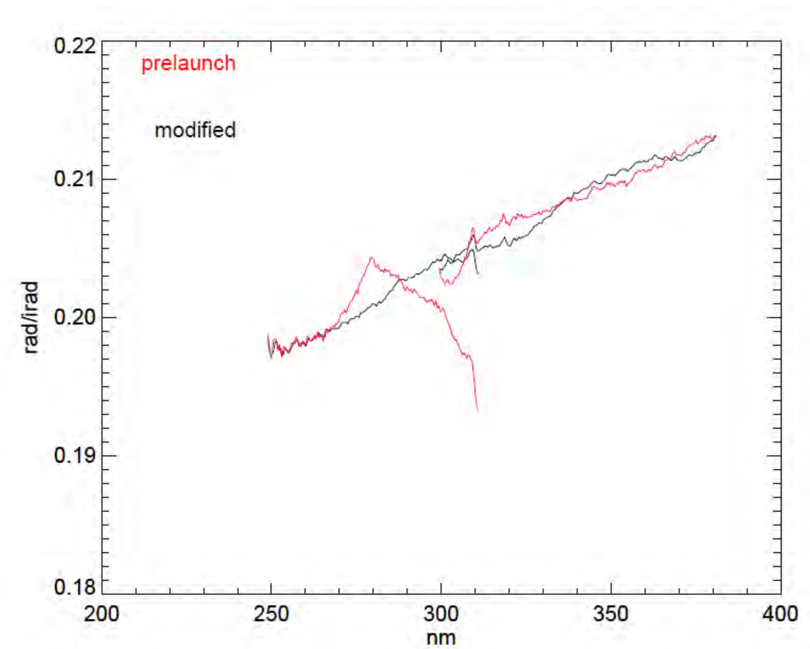
CICS-MD Scientist Chunhui Pan has improved the Raw Data Records (RDRs) and Sensor Data Records (SDRs) for the Nadir Profiler (NP) of the Ozone Mapping and Profiler Suite (OMPS). She developed a mathematical model to compute orbital NP stray light contamination and evaluate a stray light table by computing correction residuals with the real RDRs. She is now working on significant discrepancies in the 300-310 nm band between the NP and Nadir Mapper (NM). Both the radiance and irradiance coefficients need to be re-calibrated.

3-13-15 **TOMRAD Model for OMPS Verification** Chunhui Pan

CICS-MD Scientist Chunhui Pan is currently using the radiative transfer forward model TOMRAD (TOMS RA-Diative transfer model) to verify Ozone Mapping and Profiler Suite (OMPS) radiance retrieval. TOMRAD is used in creating look-up tables and conducting sensitivity tests. It is based on successive iteration of the auxiliary equation in the theory of radiative transfer, an elegant solution that accounts for all orders of scattering, as well as the effects of polarization. Though the solution is limited to Rayleigh scattering an d can only handle reflection by Lambertian surfaces, the original TOMRAD code, written in 1964, is still one of the fastest radiative transfer codes that is currently available to solve such problems.

4-3-15 **Albedo Calibration Problem Corrected** Chunhui Pan

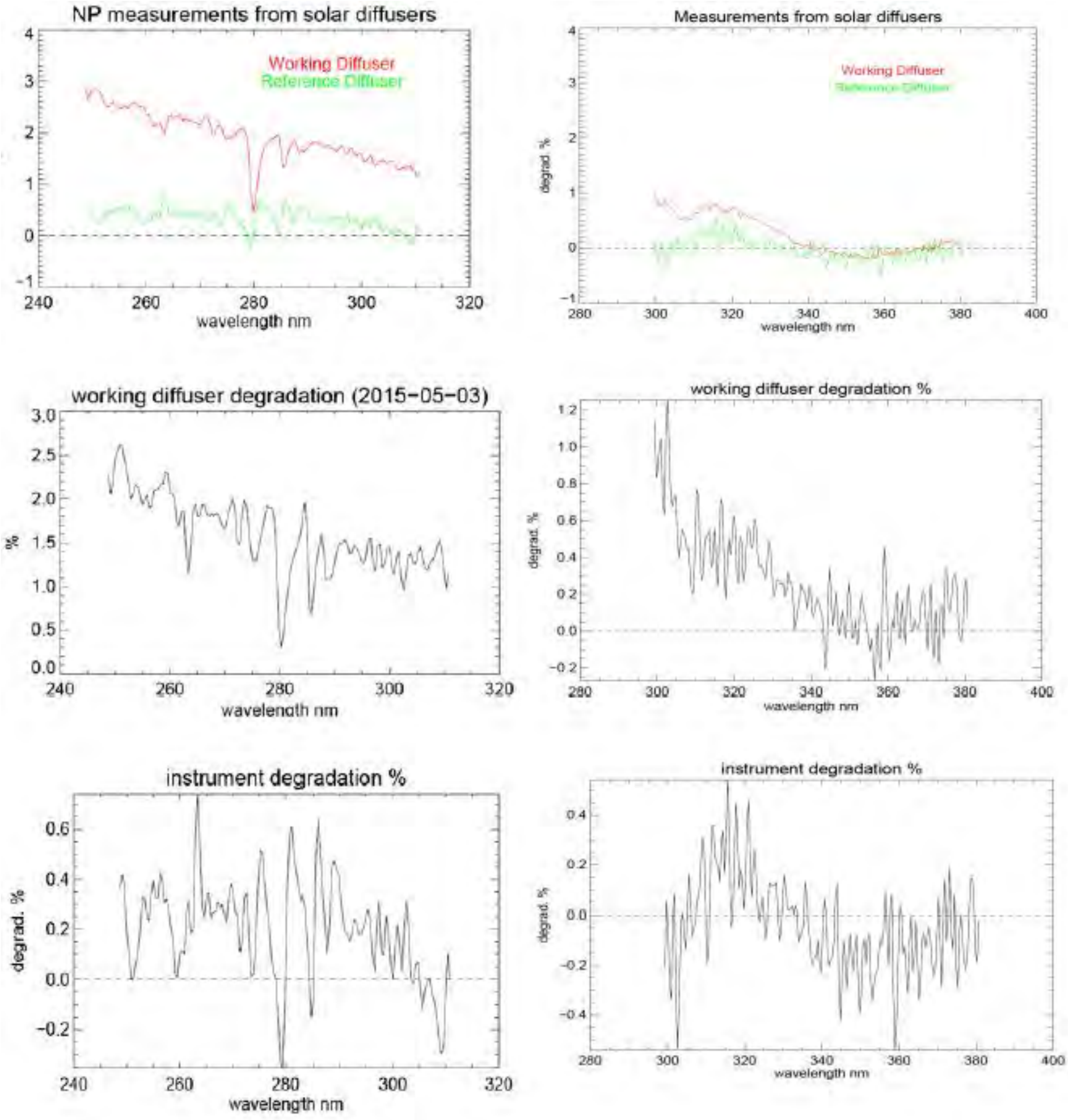
Prelaunch data for OMPS Nadir Profiler (NP) showed significant discrepancies in the overlap spectral region (red). CICS Scientist Chunhui Pan collaborated with NASA on this problem. They found that the radiance and irradiance calibration coefficients are not consistent in the spectral overlap region. Modifications have been for these two sets of the calibration coefficients by accounting for the dichroic wavelength shift and straylight contamination. Pan worked on the straylight correction.



The figure above is a comparison of irradiance calibration before and after the modification of calibration coefficients–a ratio of the prelaunch divided by the modified data. The irradiance was derived from seven diffuser positions and stitched to form a Field of Vision (FOV) of 110 deg. Red is the result without stray-light correction and the black is the result with the straylight correction.

5-8-15 **OMPS Wavelength-Dependent Degradation Study** Chunhui Pan

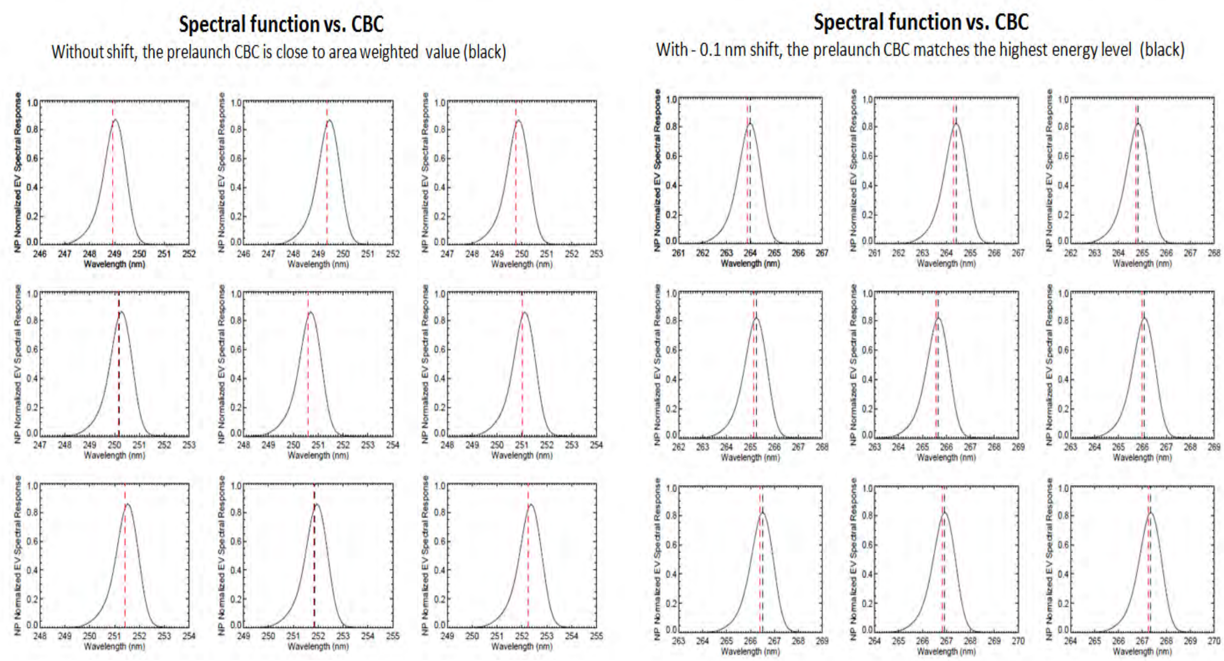
CICS-MD Scientist Chunhui Pan is studying the most recent instrument optical degradation and solar diffusers degradation for both Nadir Profiler and Nadir Mapper of the Ozone Mapping and Profiler Suite (OMPS). The study have collected all the available solar measurement data, assessed optical degradations for all channels in sensors Nadir Profiler and Nadir Mapper; computed solar diffuser degradation for each wavelength channel from 250-380 nm caused by exposure time. Data from NM sensor comes from seven different solar diffuser positions.



Based on this study, results have delivered to STAR in four independent files that contain wavelength dependent degradation for diffusers and optical systems, as well as time dependent solar flux (see figures above). As a result, OMPS sensor optics degradation is less than 0.5% and on average of <0.2% - a high level stability.

5-15-15 **Band-Pass Calibration for OMPS** Chunhui Pan

This week, CICS-MD Scientist Chunhui Pan worked on the Nadir Profiler (NP) band-pass (BPS) on the Ozone Mapping and Profiler Suite (OMPS). She verified SNPP prelaunch BPS and band center (CBC) from Ball Aerospace & Technologies Corp. The calibrated CBC matches spectral function at the highest energy level if a -0.1 nm shift is applied. Otherwise, the area weighted CBC is used.



Red : Newly calculate area weighted CBC

Black: Prelaunch CBC with (right) and without (left) shift.

The figure above compares the band center and band pass spectral response function. The on-orbital calibration suggests the appropriate band center should be at the peak response location. She also computed and delivered a new NP band-pass to the STAR EDR team.

8-28-15 **SCSB/CICS-MD Presenters at the JPSS Science Meeting** Chunhui Pan

The STAR JPSS 2015 Annual Science Team Meeting was held this week, August 24-28 August 2015 at NCWCP in College Park, MD. CICS-MD Scientist Chunhui Pan chaired the session on the Ozone Mapping and Profiler Suite (OMPS). She started the session with "An Overview of OMPS."

1-15-16 **Pan Presents on OMPS Improvements at AMS** Chunhui Pan

CICS-MD Scientist Chunhui Pan (NESDIS/OSGS) gave a presentation on the OMPS Nadir Sensors at the AMS Annual Meeting held this week in New Orleans. Her talk focused on recent improvements from version 8 of the Environmental Data Record (EDR) algorithm, which include reductions in normalized radiance error, improved radiance consistency, and corrected for seasonal wavelength variation. The figures above from the presentation shows the reduced cross-track errors in the sulfur dioxide (SO_2) index from the OMPS Nadir Mapper, which resulted from the revised algorithm (EDR V8, bottom) that corrected for the exaggerated impact of wavelength variation (top). Pan, C., F. Weng, T. Beck and S. Ding, 2015: Recent Improvements to S-NPP Ozone Mapping Profiler Suite Nadir Sensor Data Record, AMS Annual Meeting, New Orleans, LA (Jan. 10–14). *Importance*: Algorithm improvements increase the accuracy and reliability of NOAA's satellite-based products. *POC*: C. Pan.

Planned work

- Continue work on calibration and monitoring of SNPP-OMPS sensor orbital performance.
- Support Calibration SDR transition from NASA to GRAVITE.
- Conducted end-to-end data analysis for J1 OMPS prelaunch calibration data and derive and deliver calibration tables and Look-up-Tables.
- Conduct end-to-end system test for J1 OMPS ground system with the newly established algorithm as well as the corresponding calibration tables and operational tables.

Publications

Peer-Reviewed

Pan, Chunhui, and Larry Flynn
2015
Solar observation of Ozone Mapping and Profiler Suite nadir system during the first three years of on-orbit operation
J. Appl. Remote Sens. 9 (1), 094095
http://dx.doi.org/10.1117/1.JRS.9.094095

Presentations

Pan, Chunhui
An Overview of OMPS (invited)
STAR JPSS Annual Science Team Meeting
College Park, MD
8/24/2015 to 8/28/2015

Pan, Chunhui
Evaluation of Different Calibration Approaches for JPSS CrIS
CICS-MD Science Meeting
College Park, MD
11/23/2015 to 11/24/2015

Pan, C., F. Weng, T. Beck and S. Ding
Recent Improvements to S-NPP Ozone Mapping Profiler Suite Nadir Sensor Data Record
AMS Annual Meeting
New Orleans, LA
1/10/2016 to 1/14/2016

Pan, Chunhui , F. Weng, T. Beck, L. Flynn, A. C. Tolea, D. Liang, and D. Liang
Recent Improvements to S-NPP OMPS SDR
AMS Annual Meeting
New Orleans, LA
1/10/2016 to 1/14/2016

Tolea, Alin Catalin, C. Pan, T. Beck, and L. Flynn
Wavelength Registration Correction for the S-NPP OMPS Nadir Instruments
AMS Annual Meeting
New Orleans, LA
1/10/2016 to 1/14/2016

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	1
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0
# of professional data analysts formally advised	4

Scientific Support for Joint Polar Satellite System JPSS CrIS and VIIRS Calibration

Task Leader	Yong Chen (Likun Wang's Report)
Task Code	YCYC_JPSS_14 (Part 3 of 4)
NOAA Sponsor	Lihang Zhou
NOAA Office	NOAA/NESDIS/STAR/SMCD
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 0%; Goal 2: 50%; Goal 3: 50%;

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

Link to a research web page:

Background

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

Accomplishments

A state-of-the-art high-spatial-resolution imager and a high-spectral-resolution infrared sounder, the Visible Infrared Imaging Radiometer Suite (VIIRS) and Cross-track Infrared Sounder (CrIS), respectively, are both onboard current Suomi National Polar-orbiting Partnership (SNPP) and future Joint Polar Satellite System (JPSS) satellites. Specifically, VIIRS is a whiskbroom scanning imaging radiometer, collecting visible and infrared imagery of the Earth through 22 spectral bands between 0.412 µm and 12.01 µm; VIIRS also has various (21) operational environmental products including cloud, surface, aerosols, and vegetation parameters. In contrast to VIIRS, the sounder instrument – CrIS provides information on the vertical profiles of temperature, water vapor, and critical trace gases of the atmosphere, albeit with coarse spatial resolution (14.0 km at nadir). The combination of high spatial resolution measurements from an imager and high spectral resolution measurements from an infrared (IR) sounder can take advantage of both spectral and spatial capabilities; hence it can further advance atmospheric and surface geophysical parameter retrievals and extend data utilization for numerical weather prediction models.

The first achievement of this year is to develop an accurate and fast collocation method to collocate VIIRS measurements within CrIS instantaneous field of view (IFOV) directly based on line-of-sight (LOS) pointing vectors is developed. This method is not only accurate and precise in mathematic essence and but also is straightforward to implement in any programming language (such as IDL, Python, and C++). More importantly, with optimization, this method is very fast and efficient and thus can meet operational requirements. Finally, this collocation method can be extended to a wide variety of sensors on different satellite platforms. Shown in Figure 1 is an example of collocating CrIS with VIIRS I5 band pixels.

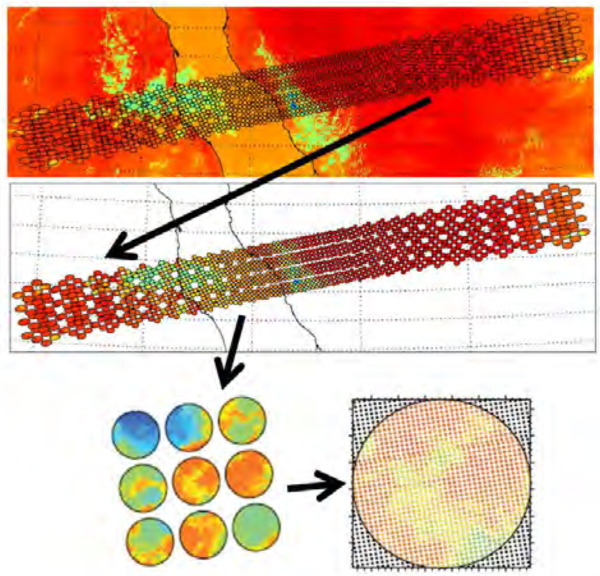


Figure 1 Example of collocating VIIRS with CrIS, including (a) projected CrIS FOV footprints (top), (b) CrIS FOV images (middle), and (c) enlarged CrIS FOVs at nadir (left, bottom), and (d) the enlarged plot for the center FOV (FOV 5) (right, bottom), where the colorful points indicate VIIRS pixels falling within the CrIS FOV and the black ones represent those outside CrIS FOVs.

As the second achievement, spatially collocated measurements from VIIRS is used to evaluate the geolocation performance of the CrIS with coarse spatial resolution by taking advantage of high spatial resolution (375m at nadir) and accurate geolocation of VIIRS. More importantly, based on the evaluation results, CrIS geometric parameters can be further adjusted to make CrIS perfectly align with VIIRS. Based on this implementation, several applications have been carried out to demonstrate the benefits of combination of VIIRS with CrIS. For example, combining VIIRS and CrIS can characterize CrIS scene features by taking advantage of various VIIRS products, which potentially extends CrIS data utilization for numerical weather prediction data assimilation. In particular, collocated VIIRS cloud products (e.g, cloud mask and cloud top) within CrIS can provide independent cloud information when assimilating CrIS into numerical weather prediction models. We also compare the imager-collocated cloud-detection scheme with the widely-used observation minus background (O-B) method. Finally, we also study the benefits of how CrIS footprint size effects on clear sky observation for future CrIS sensors.

Planned Work

* Develop a system to long-term monitoring CrIS SDR stability through inter-sensor calibration.
* Process pre-launch test data for JPSS-1/CrIS satellite.
* Draft a paper on CrIS geolocation assessment and spatial resolution on clear sky detection

Publications

1. **Wang, L.**, D. A. Tremblay, B. Zhang, and Y. Han, 2016: Fast and Accurate Collocation of the Visible Infrared Imaging Radiometer Suite Measurements and Cross-track Infrared Sounder Measurements. *Remote Sensing*, *8*, 76; doi:10.3390/rs8010076.
2. **Wang, L.**, Y. Han, X. Jin, Y. Chen, and D. A. Tremblay, 2015: Radiometric consistency assessment of hyperspectral infrared sounders, *Atmos. Meas. Tech.*, **8**, 4831-4844, doi:10.5194/amt-8-4831-2015.
3. **Wang L.**, Y. Han, Y. Chen, X. Jin, X. Xiaong, and D. Tremblay, 2015: Inter-comparison of CrIS full resolution radiances with IASI. GSICS GSICS Quarterly, Vol. 8, No.4, doi: 10.7289/V5KW5CZB.

Products

- JPSS-1 CrIS geolocation Cal/Val plan;
- Collocation Software of combining VIIRS radiances and products into CrIS footprint;
- All-scan, angle-based geolocation evaluation tool for CrIS.

Presentations

1. **Wang, L.,** B. Zhang, D. Tremblay, and Y. Han, 2016: Fast and accurate collocation of CrIS and VIIRS. *2016 GSICS Annual Meeting*, Tsukuba Japan, February 29-March 4, 2016.
2. **Wang, L.,** and T. Hewison, 2016: Hyperspectral infrared sounder traceability and uncertainty. *2016 GSICS Annual Meeting*, Tsukuba Japan, February 29-March 4, 2016.
3. **Wang, L.,** B. Zhang, Y. Han, X. Jin, Y. Chen, and D. Tremblay, 2016: Geolocation Assessment Tool and Correction Model for JPSS CrIS. *96th AMS Annual Meeting*, New Orleans, LA, USA, January 10-14 2016.
4. **Wang L.**, Y. Han, H. Huang, and M. Goldberg, 2015: Scientific Benefits of Spatial Resolution for Next Generation Infrared Hyperspectral Sounder Instruments. *2015 Annual CICS-MD Science Meeting***,** College Park, MD, November 23-34 2015.
5. **Wang, L.,** B. Zhang, D. Tremblay, Y. Han, 2015: Accurate Collocation of VIIRS measurements with CrIS. The 20th International TOVS Study Conference (ITSC-20), Lake Geneva, Wisconsin, USA, October 27-November 3 2015.
6. **Wang L.**, Yong Han; Yong Chen; Xin Jin; Denis A. Tremblay, 2015: Soumi NPP CrIS Radiometric Calibration Stability Assessment: A Perspective from Two Years' Inter Comparison with AIRS and IASI. *2015 EUMETSAT Metrological Satellite Conference*. Toulouse, France, September 21-25 2015.
7. **Wang, L.,** B. Zhang, D. Tremblay, Y. Han, M. Esplin, J. Predina, L. Suwinski, Y. Chen, and X. Jin, 2015: Geolocation Assessment Tool and Correction Model for JPSS CrIS. *2015 STAR JPSS Annual Science Team Meeting,* College Park, MD*,* August 24-28 2015
8. **Wang L.**, Yong Han; Yong Chen; Xin Jin; Denis A. Tremblay, 2015: Soumi NPP CrIS Radiometric Calibration Stability Assessment: A Perspective from Two Years' Inter Comparison with AIRS and IASI. *2015 Conference on Characterization and Radiometric Calibration for Remote Sensing*, Logan, Utah, August 22-25 2015.
9. **Wang L.**, Yong Han; Yong Chen; Xin Jin; Denis A. Tremblay, 2015: Soumi NPP CrIS Radiometric Calibration Stability Assessment: A Perspective from Two Years' Inter-Comparison with AIRS and IASI. *2015 NOAA Satellite Conference*. April 27-May1 2015, College Park, MD.

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	**2**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**1**
# of invited presentations	**10**
# 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.

Scientific Support for Joint Polar Satellite System JPSS VIIRS Calibration

Task Leader Yong Chen (Slawomir Blonski's Report)
Task Code YCYC_JPSS_15 (Part 4 of 4)
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
Results of the VIIRS reflective solar bands radiometric calibration reprocessing were presented at a major scientific conference and in a peer-reviewed publication
Link to a research web page http://ncc.nesdis.noaa.gov/VIIRS/ReprocessingLUTs.php

Background

The Joint Polar Satellite System (JPSS) is the next generation of the U.S. polar-orbiting satellites that will continue observations from 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 spacecraft. Calibration methods developed for the S-NPP VIIRS have improved the current operational data products and will also apply to the future JPSS measurements. 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. The day-night band has an unprecedented dynamic range that enables Earth imaging under both solar and lunar illumination. These novel imaging capabilities necessitate development of new techniques for on-orbit calibration and validation of the VIIRS instruments.

Accomplishments

VIIRS Calibration Reprocessing Presented at IGARSS 2015

Slawomir Blonski attended 2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) held on 26-31 July in Milan, Italy, participated in sessions "The Joint Polar Satellite System: NOAA's New Global Operational Capability to Monitor the Planet" and "Optical Sensors Calibration and Validation," and gave the presentation "VIIRS Reflective Solar Bands Calibration Reprocessing." A brief paper accompanying the presentation was published in the conference proceedings.

Importance: The uncertainty of the radiometric calibration for the RSB channels must be kept within 2% to assure quality of the VIIRS data products. *POC*: S. Blonski

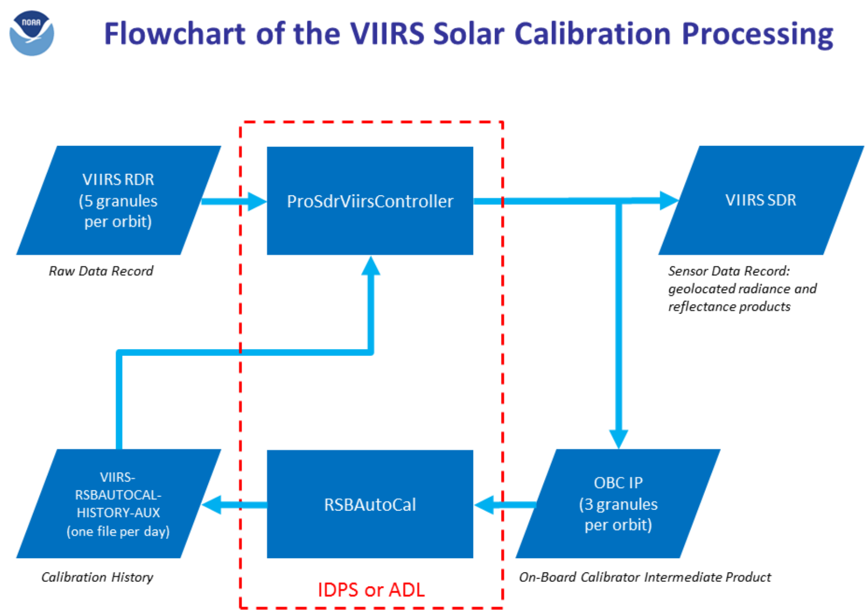
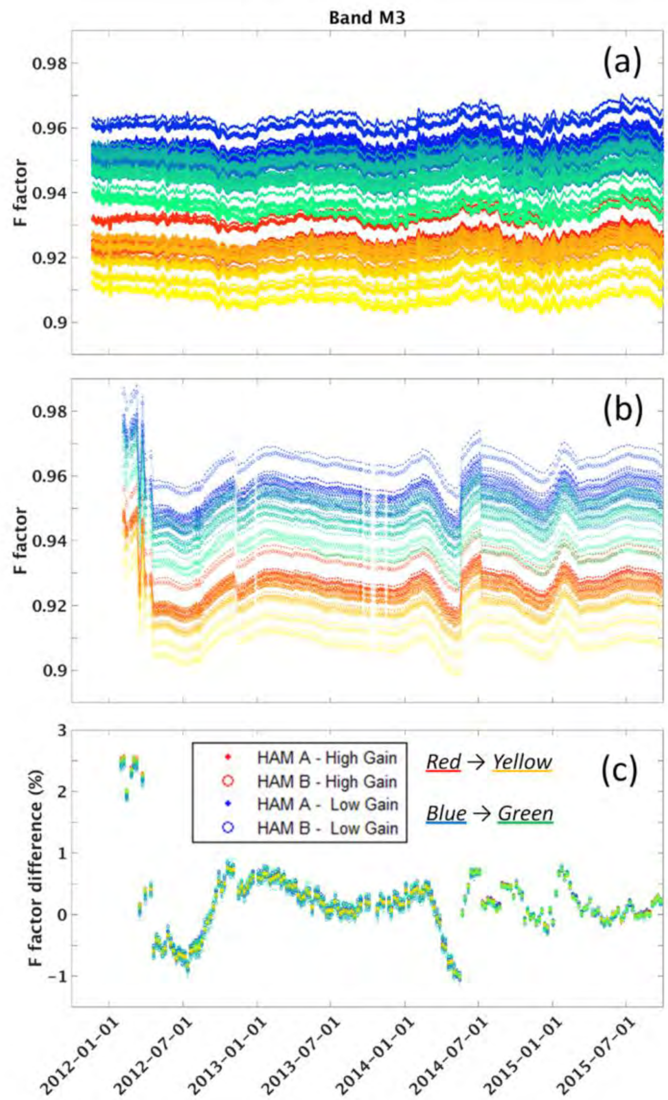


Chart from the IGARSS presentation depicting main steps of the calibration reprocessing

Publication on VIIRS Calibration Reprocessing

CICS-MD Scientist Slawomir Blonski (STAR/SMCD/SCDAB) has published an article in the December 2015 issue of the journal *Remote Sensing*. The article describes reprocessing of the radiometric calibration for the reflective solar bands of the Visible Infrared Imaging Radiometer Suite (VIIRS) deployed on the Soumi National Polar-orbiting Partnership (NPP) satellite. The reprocessing has demonstrated that an automated calibration procedure can be successfully applied to all solar measurements acquired from the beginning of the mission until the full deployment of the automated procedure in the operational processing system. The reprocessed calibration coefficients can be further used to reprocess VIIRS SDR (Sensor Data Record) and other data products. The reprocessing has also demonstrated how the automated calibration procedure can be used during activation of the VIIRS instruments on the future JPSS satellites.

Importance: Accurate JPSS VIIRS calibration ensures excellent quality measurements can be used to derive environmental products that serve NOAA end users such as the National Weather Service and National Ocean Service. *POC*: S. Blonski



One of graphs from the *Remote Sensing* publication that compares original and reprocessed calibration coefficients

Planned work

- Provide analysis of the VIIRS SDR processing codes to ensure correct implementation of scientific algorithms and calibration procedures
- Provide validation of the look-up tables with processing parameters needed for the JPSS-1 VIIRS SDR algorithms

Publications

Peer reviewed

Blonski, S., and C. Cao, 2015: Suomi NPP VIIRS Reflective Solar Bands Operational Calibration Reprocessing, *Remote Sens.*, **7**, 16131-16149, doi: 10.3390/rs71215823

Non-peer reviewed

Blonski, S., and C. Cao, 2015: VIIRS reflective solar bands calibration reprocessing, *IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, 2015, 3906–3909, doi: 10.1109/IGARSS.2015.7326678

Presentations

Blonski, S., and C. Cao: Use of VIIRS RSBAutoCal in Calibration Monitoring and Direct Readout Support, *NOAA Satellite Conference*, Greenbelt, Maryland (27 April – 1 May 2015)

Blonski, S., and C. Cao: VIIRS reflective solar bands calibration reprocessing, *IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Milan, Italy (26-31 July 2015)

Blonski, S., and C. Cao: On-orbit Characterization of the Dependence of VIIRS Thermal Bands Noise on Cold FPA Temperature, *Meeting on Characterization and Radiometric Calibration for Remote Sensing (CALCON)*, Logan, Utah (24-26 August 2015)

Blonski, S.: VIIRS SDR Cal/Val: S-NPP Update and JPSS-1 Preparations, *CICS-MD Science Meeting*, College Park, Maryland (23-24 November 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	**1**
# 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	

CUNY Science and Management Support for NPP VIIRS Snow EDR

Task Leader Peter Romanov
Task Code PRPR_VIIRS_15
NOAA Sponsor Jeff Key
NOAA Office NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%) Theme 2: 100%
Main CICS Research Topic Calibration and Validation
Contribution to NOAA goals (%) Goal 2: 100%
Highlight We have maintained the S-NPP VIIRS Operational Binary and Fractional Snow Cover Algorithm at the NOAA IDPS. Intensive calibration and validation of both snow products has been conducted. It has been determined that the accuracy of the binary snow products satisfies the mission requirements.

Both products are available to the users through NOAA CLASS. Two new snow fraction algorithms have been developed and tested in a quasi-operational mode. Both new snow fraction algorithms have been prepared for implementation within NOAA NDE system.
Link to a research web page http://www.star.nesdis.noaa.gov/smcd/emb/snow/viirs/viirs-snow-fraction.html

Background
Providing information on the state of the Earth's cryosphere presents one of the primary missions of the VIIRS instrument onboard S-NPP satellite. The scope of cryosphere products includes two parameters characterizing he snow cover: the binary snow cover extant and the fractional snow cover. The objectives of this project consists in providing routine monitoring of the accuracy and quality of the snow cover products and in the development of improved version of the retrieval algorithm for use with SNPP and future JPSS data.

Accomplishments
Performance of the JPSS VIIRS operational snow cover algorithm and the snow cover product during the fourth year of the instrument operation has been examined. The product accuracy assessment was performed through its comparison with surface observations of snow cover and snow cover charts generated interactively by NOAA analysts within NOAA IMS system. The quality of the product remained good through the year. The accuracy of snow cover maps in cloud-clear portions of VIIRS imagery generally exceeded 90%. Better correspondence has been achieved to NOAA interactive snow cover maps than to ground-based observations. High accuracy of VIIRS snow cover maps should be partially attributed to a very conservative cloud mask. The VIIRS cloud mask algorithm frequently (and erroneously) interprets as cloudy clear sky pixels along the snow cover boundary where most errors in snow cover identification typically occur.

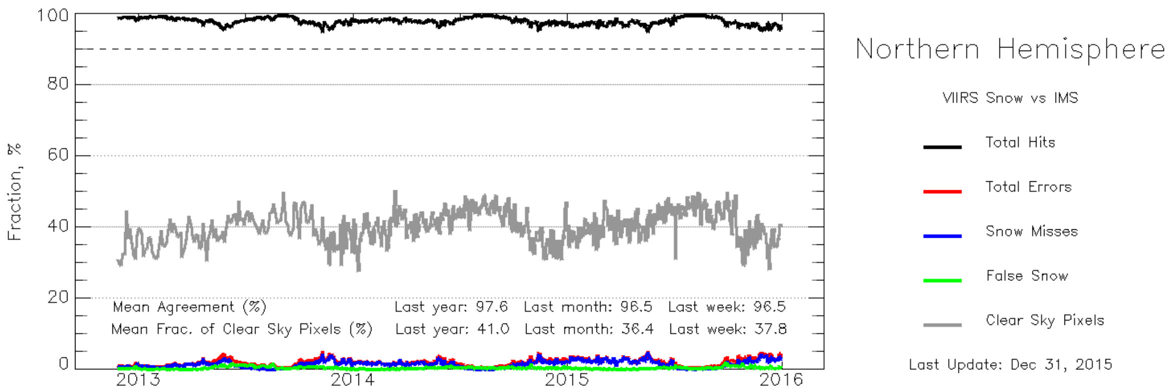


Figure 1. Daily estimates of the accuracy of VIIRS snow cover maps over Northern Hemisphere. The accuracy is estimated as the percent of exact agreement (labeled as "Total Hits" in the graph) of the snow cover mapped in the VIIRS binary snow cover product with the NOAA IMS snow cover map in the clear sky portion of the VIIRS imagery.

Planned work

It is planned to continue the snow product validation activity using both IMS and in situ data. New algorithms for snow fraction retrieval will be evaluated and tested.

Presentations

P. Romanov, NESDIS Global Automated Satellite Snow Product: current status and planned upgrades. 2nd International Satellite Snow Product Intercomparison Workshop, Boulder, CO, 14-16 September, 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	**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**

Two algorithms to derive snow fraction from SNPP VIIRS have been submitted to NOAA for incorporation in the NOAA NDE operational VIIRS data processing system.

NPP/VIIRS Land Surface Albedo Validation Research and Algorithm Refinement

Task Leader Dongdong Wang, Shunlin Liang
Task Code SLDW_VIIRS_15
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 have completed a round of comprehensive evaluation of VIIRS albedo using both field measurements and high resolution albedo reference maps. We have updated the LUT to account for desert aerosol. We are developing a new daily gridded product of VIIRS albedo.

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. Comprehensively evaluating VIIRS LSA

Ground measured albedo was collected over 23 sites for the whole years 2012 and 2013. To investigate the influence of land heterogeneity and mixed pixel effect on the VIIRS albedo validation results, we also collected Landsat data (Landsat 7 ETM+ and Landsat 8 OLI, up to 3TB in total) over those 23 sites of the same period. With a high spatial resolution (30 m), Landsat-retrieved albedo is expected to function as a bridge between VIIRS LSA and the ground measurement, thereby helping in further understanding the main factor that leads to the biases of VIIRS LSA retrievals.

Results indicate that: 1) LSA retrieval on snow-covered surfaces is more accurate if the newly developed snow-specific LUT (RMSE = 0.082) replaces the generic LUT (RMSE = 0.093) that is employed in the current operational LSA EDR production. 2) VIIRS LSA is also comparable to high-resolution Landsat albedo retrieval (RMSE < 0.04), although Landsat albedo has a slightly higher accuracy, probably owing to higher spatial resolution with less impacts of mixed pixel. 3) VIIRS LSA retrievals agree well with the MODIS albedo product over various land surface types, with overall RMSE of lower than 0.05 and the overall bias as low as 0.025, demonstrating the comparable data quality between VIIRS and the MODIS LSA product.

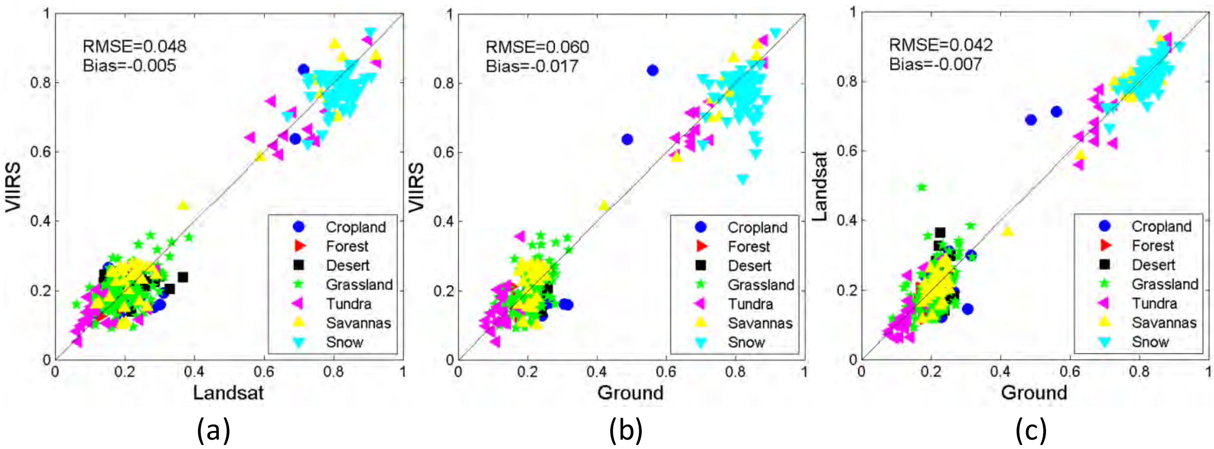


Figure 1. Inter-comparison results between VIIRS LSA and Landsat retrieved albedo over all sites listed in Table 1. a) VIIRS validated against Landsat; b) VIIRS validated against ground truth; c) Landsat validated against ground truth.

2. Updating LUT

For a desert surface, the current operational VIIRS LSA EDR is calculated by desert-specific LUT, which mainly uses the BRDF of bare soil in the simulation of atmospheric radiative transfer. Validation against the field measurement over a desert site called Rock Desert from the SURFRAD network for the whole year 2013 shows that the current LSA EDR achieves an RMSE of 0.036 and a positive bias of 0.030, both of which are much higher than those of MODIS albedo validation results. To address the issue of overestimation, we revisited the radiative transfer simulation process and employed a stricter standard to select the training data that is specific for desert aerosol type. Comparison clearly demonstrate the improvement made in the retrieval accuracy over this site by using the updated desert LUT, with RMSE and bias reduced to 0.023 and 0.006, respectively, suggesting the potential of the updated desert LUT to improve the VIIRS albedo retrieval over desert site. Further validation will be performed using extensive desert sites in future works to comprehensively demonstrate the effectiveness of such improved desert LUT.

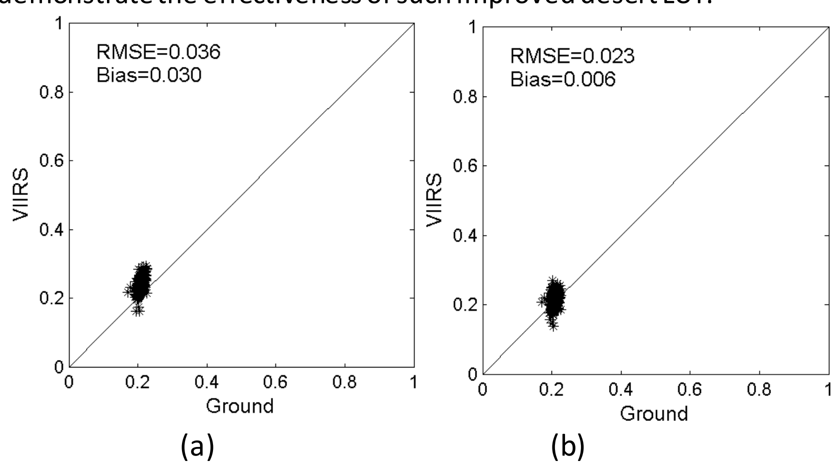


Figure 2. Validation results over a desert site (Rock Desert) for the year 2013. Comparison results between ground truth and VIIRS-retrieved albedo using a) previous and b) updated LUT, respectively.

3. Developing daily gridded albedo product

Compared to the current granule data, the gridded product of LSA is much easier for the modeling team and other end users to use. We are developing a new gridded product of the gap-free LSA data with improved accuracy. The processing chain consists of three major components: data retrieval, gridding and temporal filtering.

We have been working on a novel approach to directly retrieve daily mean albedo from VIIRS data. Results for retrievals from snow-free and snow-covered surfaces were combined to evaluate the overall quality of daily mean albedo (Figure 3). The results indicate that daily mean albedo can be retrieved with very high accuracy given ideal view geometry. The retrieved values are strongly correlated with measured albedo (R2 = 0.996). The snow-free albedo is slightly underestimated and the snow albedo has a small positive bias. The overall bias is 0.004, with an RMSE as small as 0.024.

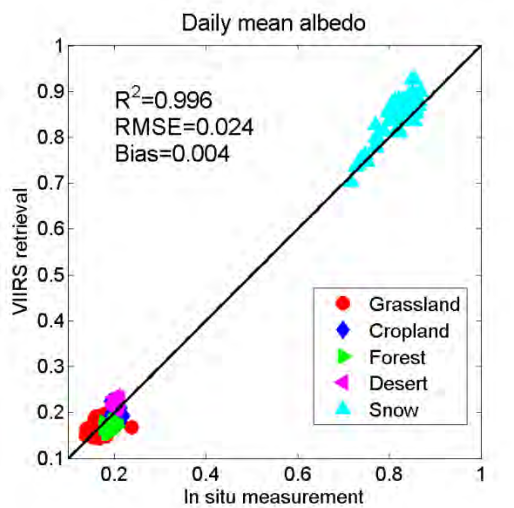


Figure 3. Validation results of 16-day averaged mean of daily albedo.

Regarding temporal filter, an algorithm based on temporal autocorrelation and climatology is being developed, which can incorporate multisource of information, including: VIIRS retrieval and its QF, climatology (mean and variance) and temporal correlation (historical observation). Figure 4 illustrates a annual time series of albedo after temporal filtering.

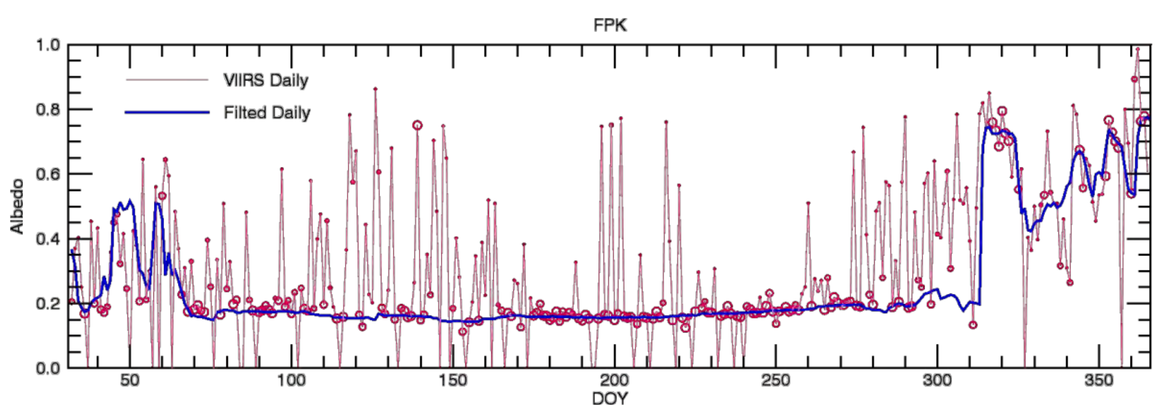


Figure 4. An example of VIIRS LSA original and filtered time series. The sizes of the data circles represent the quality of the retrievals from QF.

Performance Metrics	**FY15**
# of new or improved products developed	1
# of products or techniques transitioned from research to ops	0
# of peer reviewed papers	3
# of non-peered reviewed papers	0
# of presentations	0
# of graduate students supported by a CICS task	2
# of undergraduate students supported by a CICS task	0

Planned Work

* Continuing to assess albedo algorithms and products;
* Generating gridded VIIRS albedo product;
* Developing NOAA enterprise albedo product;
* Updating LUT for sea ice surface albedo.

Publication

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

Wang, D., Liang, S., He, T., Yu, Y., Schaaf, C., & Wang, Z. (2015). Estimating daily mean land surface albedo from MODIS data. Journal of Geophysical Research-Atmospheres, 120(10), 4825-4841, doi:10.1002/2015JD023178.

Wang, D., Liang, S., Zhou, Y., &Yu, Y. A new method to retrieve daily albedo from VIIRS data, Submitted to IEEE Transactions on Geoscience and Remote Sensing.

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

Task Leader Chengquan Huang
Task Code CHCH_VIIRS_15
NOAA Sponsor Xiwu Zhan
NOAA Office NESDIS/STAR
Contribution to CICS Research Themes (%) Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic Calibration and Validation
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%; Goal 3: 0%
Highlight Developed a new global surface type classification map based on 2014 VIIRS data
Link to a research web page http://vct.geog.umd.edu/st/

Background

This report summarizes the work of an ongoing NOAA project entitled "NPP/VIIRS Land Product Validation Research and Algorithm Refinement: Science and Management Support for NPP VIIRS Surface Type EDR" for the period of Apr 2015 through Mar 2016. The purpose of this project is to develop the surface type environmental data record (EDR) product using the VIIRS sensor onboard the JPSS/NPP satellite. This product includes an Annual Global Gridded Surface Type (GST) ancillary data product (ADP) with daily update of snow cover and fire activities. This product is a major input for producing the VIIRS Land Surface Temperature and Albedo EDRs, and is required for many climate and earth system modeling studies as well as ecological applications. The GST ADP is a successor of global land cover products derived based on the POES/AVHRR, EOS/MODIS, and other global monitoring systems. Such products typically requires at least one year's of observations to capture the phenological dynamics of different surface types in a full year. The GST ADP needs to be generated and delivered to the IDPS and NOAA's planned NDE system on an annual basis.

Accomplishments

Major accomplishments in the last project year include development of the GST ADP using 2014 VIIRS data, a refined product for use by NOAA NCEP modelers, and a monitoring system for the Surface Type EDR product.

The GST ADP is a global surface type map developed using the 17-class IGBP classification system. The 2014 product was created using a series of annual metrics extracted from 2014 VIIRS surface reflectance data (Figure 1). Compared to the surface type map delivered in 2013, a major improvement is that a more robust and powerful algorithm, i.e., the support vector machines (SVMs), was implemented to replace the previously used C5.0 decision tree algorithm. Associated processing steps, including training, parameters tuning, and classification, were also refined considerably. Additional training samples were collected to improve the representativeness and to address the issues such as overestimation of snow/ice and underestimation of croplands. To reduce the computational load of the training and classification of SVMs caused by the use of a large training sample set and a complicated classification model, parallel implementations were employed in the map production. Meanwhile, post-classification was redesigned to address issues noticed in the new classification results.

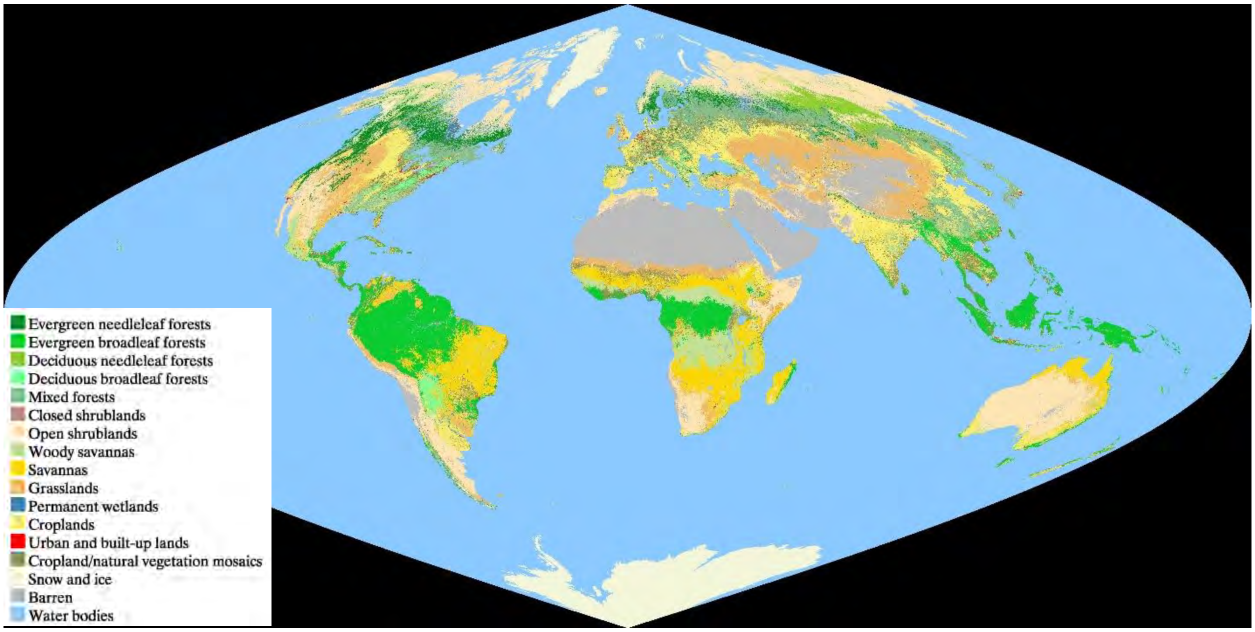


Figure 1. The 2014 global surface type classification map in the 17-class IGBP legend using the SVMs classification algorithm.

Validation results suggested that the newly created GST ADP not only met the accuracy requirement, but also outperformed the previously delivered map in terms of overall accuracy. Snow/ice and croplands classes, which were intended to improve in this version, were indeed found superior to the 2013 classification map.

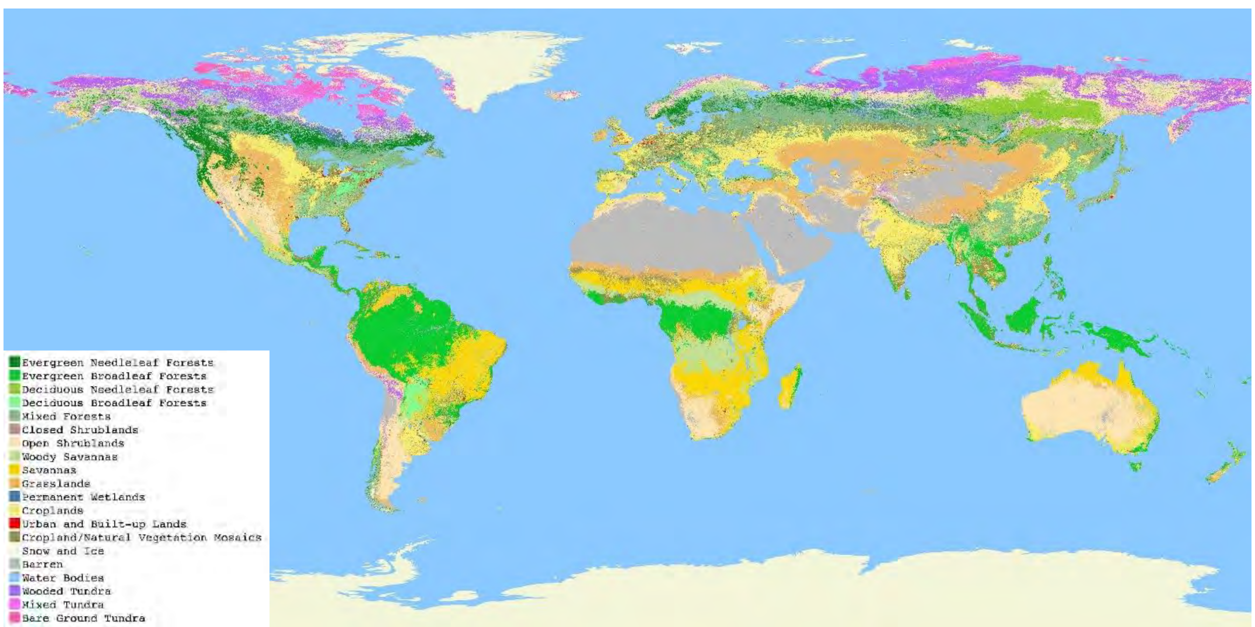


Figure 2. The 20-class 2014 global surface type classification map for NCEP.

Building on the 17-class GST ADP, we also developed a 20-class global surface type map. This map provide 3 additional classes over the tundra region (Figure 2). This product was developed specifically for use by NCEP modelers.

Further, we developed a fully automated tool for daily monitoring of all four components of the surface type EDR, including surface type, snow cover, fire, and vegetation fraction. This tool has been integrated into NOAA's web-based monitoring system for its JPSS based EDR products (http://www.star.nesdis.noaa.gov/jpss/EDRs/products_surfacetype.php).

Our work led to several oral and poster presentations in nationwide workshops and conferences, and a paper introducing the entire framework of the development and validation of surface type products has been published in a peer-reviewed journal.

Planned Work

- Continue working on algorithm refinement for the surface type classification, including collecting more representative training samples and assessing the importance of individual annual metrics in classification.
- Continue working on generating 2015 surface type classification map using the SVMs.
- Improve daily and monthly surface reflectance compositing method.
- Develop a suite of continuous field maps of various land cover components, e.g. surface water, impervious surface, tree cover, to improve surface type characterization.
- Improve existing cloud/shadow algorithms to achieve virtual clear view on a weekly or even near daily basis.
- Prepare the transition of the surface type input data to the NDE environment.

Publications

Rui Zhang, Chengquan Huang, Xiwu Zhan, Qin Dai, Kuan Song. (2016). Development and Validation of the Global Surface Type Data Product from S- NPP VIIRS. *Remote Sensing Letters*, 7(1): 51-60.

Xi Li, Rui Zhang, Chengquan Huang, Deren Li. (2015) Detecting 2014 Northern Iraq Insurgency using night-time light imagery. *International Journal of Remote Sensing*, 36(13): 3446-3458.

Ran Meng, Feng R. Zhao, Kang Sun, Rui Zhang, Chengquan Huang, Jianying Yang. (2015). Analysis of the, APEC Blue, in Beijing Using More than One Decade of Satellite Observations: Lessons Learned from Radical Emission Control Measures. *Remote Sensing*, 7(11): 15224-15243.

Products

The 2014 global surface type classification maps in the 17-class IGBP legend and the 20-class NCEP legend.

Presentations

Rui Zhang, Chengquan Huang, Kuan Song, Mark Friedl, Damien Sulla-Menashe, Xiwu Zhan, Development of S-NPP VIIRS surface type products, 2015 NASA Carbon Cycle & Ecosystems Joint workshop, College Park, Maryland, USA, 2015.

Rui Zhang, Chengquan Huang, Xiwu Zhan, Validation of JPSS S-NPP VIIRS Surface Type Environmental Data Record, 2015 NOAA Satellite Conference, Greenbelt, Maryland, USA, 2015.

Rui Zhang, Chengquan Huang, Xiwu Zhan, SVM based VIIRS global surface type classification map and preliminary validation, 2015 STAR JPSS Science Team Meeting, College Park, Maryland, USA, 2015.

Rui Zhang, Chengquan Huang, Xiwu Zhan, Suomi NPP surface type environmental data record – a continuity of EOS MODIS land cover product, 2015 AGU Fall Meeting, San Francisco, California, USA, 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	**3**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Table explanation:

- The two products listed in the first two rows include a newly developed GST ADP with the IGBP legend and a new 20-class surface type map for use by NCEP modelers. These products have been delivered to NOAA for consideration in the operational use.
- See the Publications section for details on the three peer-reviewed journal articles.

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

Task Leader: E. Hugo Berbery
Task Code: EBEB_SCAV_15
NOAA Sponsor: Mike Kalb
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: Daily and seasonal validation of satellite precipitation estimates continued, and a manuscript titled "Seasonal and Regional Validation of Operational Satellite Precipitation Estimates" was published in the Journal of Operational Meteorology.
Link to a research web page: http://cics.umd.edu/ipwg/index.html

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. Successful use of satellite-derived precipitation estimates requires verification at various spatial and temporal scales. The Cooperative Institute for Climate and Satellites at the University of Maryland (CICS-MD) produces daily and seasonal validation statistics over the contiguous United States (CONUS) for many precipitation products using a common International Precipitation Working Group (IPWG) framework. This routine monitoring focuses on products produced by the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA). A website is updated daily to provide monitoring and validation tools to operational users and algorithm developers.

Accomplishments

Validation of STAR rainfall products over the contiguous United States 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). 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. These activities seek 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 2015-2016 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. The 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.

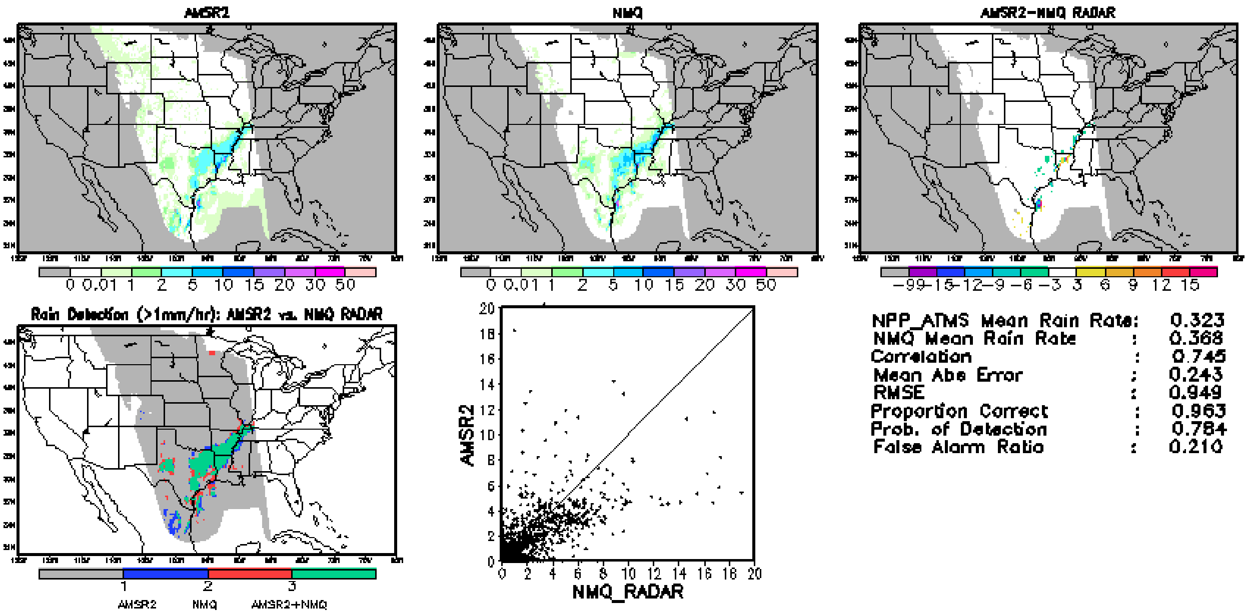


Fig. 1. Comparison of satellite rainfall from AMSR-2 with ground-based observations integrated by the multi-radar multi-sensor system (MRMS) on March 9, 2016. Green areas in the lower-left panel indicate that the satellite and radar products agree on the occurrence of rainfall.

Website modifications continued to help ease access and better serve the community. The main page now directly links our various validation activities. Navigation buttons accompany the daily validation images, allowing for easier analysis of consecutive days. Archives now provide access to daily imagery over 60 days old. The validation procedures were modified to incorporate precipitation estimates from the ATMS and AMSR2 instruments. In addition, considerable effort has been expended to streamline and document these procedures.

A manuscript was recently published in the Journal of Operational Meteorology (Rudlosky et al. 2016). The daily validation statistics were composited into annual and seasonal composites to investigate the factors contributing to seasonal and regional biases in the precipitation estimation products. This manuscript analyzed the performance of five satellite-derived precipitation products relative to ground-based gauge observations. Differences in passive microwave (PMW) and/or infrared (IR) observations observations lead to seasonal and regional biases that influence the operational utility of the satellite precipitation estimates. In turn, these products require informed interpretation by forecasters. Five years of daily satellite precipitation estimates (2010–14) were composited into two types of seasonal and annual maps to characterize performance. The seasonal composites revealed positive biases during summer and greater variability among satellite products during winter. Each satellite product overestimated the maximum daily precipitation relative to gauge throughout much of the central and eastern United States. In this region, the 95th percentile of gauge-reported daily precipitation values generally ranged between 20–40 mm day^{-1}, whereas the satellite-reported values generally exceeded 40 mm day^{-1}. Winter exhibited greater variability among satellite products and a mix of both positive and negative biases. The bias magnitudes were greater and the spatial correlations were lower (i.e., the composite maps are less similar) during winter than during summer. The IR-based products generally overestimated winter precipitation north of 36° N, and the

PMW-based products performed poorly in mountainous regions along the west coast. These results characterized biases in satellite precipitation estimates to better inform the user community and help researchers improve future versions of their operational products.

Planned Work

- Routine daily and seasonal validation activities will continue, and the procedures will continue to be streamlined to ease user access.
- Plans are in place to incorporate lightning data to obtain estimates of product performance in convective and non-convective regions.
- 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.

Publications

Rudlosky, S. D., M. A. Nichols, P. C. Meyers, and D. F. Wheeler, 2016: Seasonal and annual validation of operational satellite precipitation estimates. *J. Operational Meteor.,* **4** (5), 58-74, doi: http://dx.doi.org/10.15191/nwajom.2016.0405.

PERFORMANCE METRICS	FY15
# 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	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

Science and Managerial Support to Global Space-Based Inter-Calibration System (GSICS)

Task Leader **Manik Bali**
Task Code **EBMB_GSIC_15**
NOAA Sponsor **Fuzhong Weng/Lawrence E. Flynn**
NOAA Office **SMCD**
Contribution to CICS Research Themes (%) **Theme 1 (100%)**
Main CICS Research Topic **Calibration and Validation**
Contribution to NOAA goals (%) **Goal 1 (100%)**
Highlight
Link to a research web page

Background

The GSICS (gsics.wmo.int) Coordination Center (GCC) hosted by NOAA Star is lead by NOAA lead Lawrence E. Flynn who serves as Director of GCC. Manik Bali, the Task Leader of this task supports the NOAA lead as Deputy Director of GCC, Editor of GSICS Newsletter and Member of GSICS Data Working Grou p.

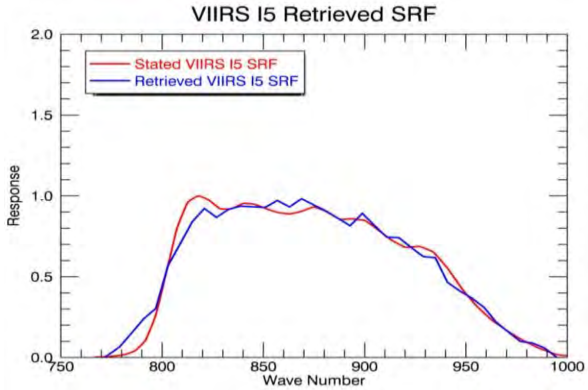
The main aim of GCC is to facilitate the sharing of inter-calibration activities across 15 satellite agencies (members of GSICS) and to lead the scientific discourse on application of inter-calibration data and algorithms for monitoring and maintaining in-orbit satellite accuracy and stability. A major GCC also helps members decide on choosing in-orbit references and making them aware of expectations from user community. GCC also publishes quarterly newsletters that are vetted by WMO and member agencie s.

As member of GSICS Data Working group, Manik Bali supports identification of Meta data standards for GSICS products, Mirroring of GSICS Products and routine activities of GSICS Product generation such as supporting threads migration.

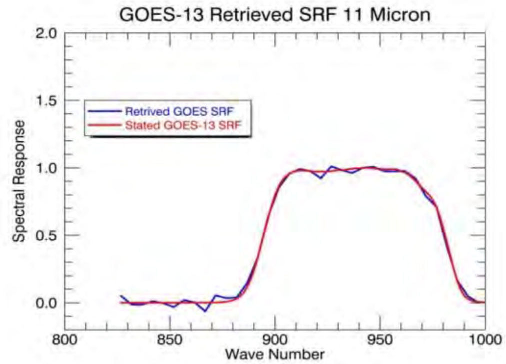
Accomplishments

Past year has seen several accomplishments. These accomplishments have been presented in international conferences.

1. GCC enhanced the capabilities of GSICS Procedure for Product Acceptance and for the first time a GSICS product was assigned the highest maturity level i.e Operational.
2. GCC lead acquiring the user requirements from the scientific community. The collected user requirements would help GSICS to set concrete goals for the coming years.
3. GCC Published four newsletters in the past year
4. GCC was invited to review the GSICS Product User Guide by EUMETSAT



VIIRS I5 SRF retrieved from collocations with



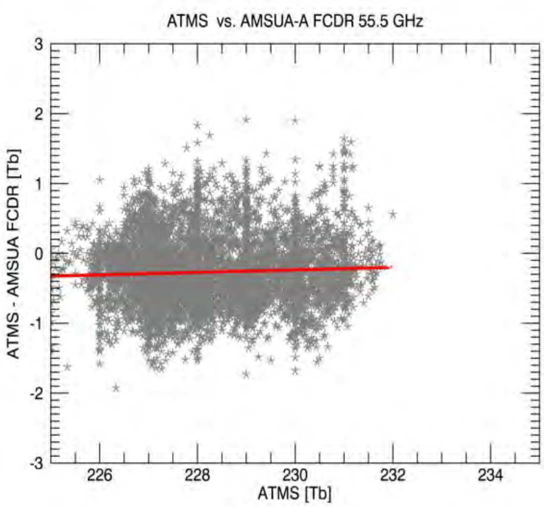
GOES-13 SRF retrieved from collocations with IASI

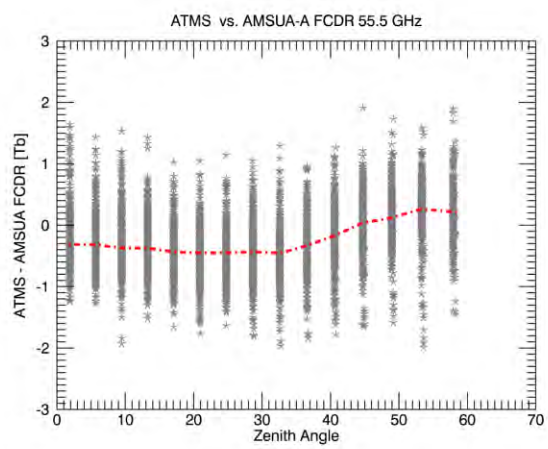
GCC developed algorithms to produce Spectral Response Function by inter-comparison with Hyper Spectral Instrument

The spectral response function is retrieved by using de-convolution. This technique gives a deterministic solution to the system linear equations that are used to fit the representative radiances.
GSICS wishes to include this as a product.

GCC investigated the use of a fundamental climate data record as an in-orbit reference.

A common problem with finding a suitable in-orbit reference in Microwave is the temporal degradation of instruments, the scan angle dependence of detectors and other biases that crop up during the instruments life in orbit.
Using a set of collocations between SATMS and MSU-AMSU-A FCDR developed by Cheng Zhi Zou , GCC showed that this FCDR can be a





Zenith angle dependence of ATMS is captured within the limits predicted by Faultwetter

The bias between ATMS and AMSU-A FCDR is of the prelaunch level.

NOAA- GSICS Data Working Group duties

- Established the GSICS Microwave metadata standards. These have been accepted by the micro-wave subgroup.
- Established a mirror site for GSICS product . The mirror of the products can be visited here .
- Developed a SNO testing suite. This suite uses AATSR pixels as a reference in a SNO algorithm. The idea is to detect if the SNO is able to identify collocations that are previously known. This work was presented in the GSICS Annual Meeting (See here).

SCSB/CICS-MD Presenters at the JPSS Science Meeting Manik Bali

The STAR JPSS 2015 Annual Science Team Meeting was held this week, August 24-28 August 2015 at NCWCP in College Park, MD... There were also CICS-MD Posters, including Manik Bali poster entitled "JPSS Instrument lead GSICS cross calibration activities." *Importance*: JPSS is NOAA's primary polar observing sys-tem and its measurements contribute to NOAA mission goals. *POC*: R. Ferraro & C. Pan

Planned Work

1) Perform duties as the Editor of the GSICS Quarterly Newsletter， co-ordinate and Manage web meet-ing of various GSICS subgroups， help to co-ordinate and organize international workshops on GSICS topics

2) Prepare reports and track action items for GCC and subsidiary working groups , assist the GCC Director in establishing the GRWG sub-working research groups, assist the GSICS director in identification of new Satellite products to promote.

3) Design and maintain the GSICS data working group website and wiki pages, design and develop a GSICS product acceptance plan as well as product taxonomy, file naming conventions and meta data conventions for all the subgroups of GSICS (IR MW VIS UV).

4) Establish trust-worthiness of GSICS community reference instruments such as CrIS/IASI/AIRS and use them for re-constructing post launch status of Spectral Response Functions of GEO instruments such as GOES.

5) Perform bias monitoring of GOES series of instrument by comparing with CrIS.

6) Confirmation of requirements and development of acceptance procedures for GSICS measurements, prepare reports and track action items for GCC and subsidiary working groups, publish work in inter-national journals of repute.

7) Conduct original research on calibration for space-based measurement systems operating in the visible and ultraviolet, including on-orbit refinement of spectral response functions and development of vicarious calibration methods.

8) Support GSICS/WMO to develop a Document Management System.

Publications

Paper submitted to Atmospheric Measurement Techniques is accepted and under review : See here .

Presentations

Bali, Manik
JPSS Instrument lead GSICS cross calibration activities
STAR JPSS Annual Science Team Meeting
College Park, MD
8/24/2015 to 8/28/2015

Bali, Manik
GSICS Products and Deliverables
CICS-MD Science Meeting
College Park, MD
11/23/2015 to 11/24/2015

Bali, Manik, and Lawrence Flynn
GSICS Satellite Intercalibration Products
AGU Fall Meeting
San Francisco, CA
12/14/2015 to 12/18/2015

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	**2**
# 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**

# of peer reviewed papers -> One paper under review at AMT.
# of non-peered reviewed papers -> Contributed to GSICS Newsletter
# of invited presentations -> GSICS Executive Panel Meeting 2016

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

Task Leader	Evan Ellicott
Task Code	EEEE_SNPP_15
NOAA Sponsor	Arron L. Layns
NOAA Office	Joint Polar Satellite System
Contribution to CICS Research Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%.
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%

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

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

Background

When the Suomi National Polar-orbiting Partnership (SNPP) launched in 2011 it was expected that the VIIRS Active Fire (AF) product would play an important role in wildland fire management and research. Over the past 4 years, the AF data has been used to improve situational awareness such as hot-spot detection and characterization, air quality monitoring, and fire weather-related applications while also supporting fundamental and applied research. 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. It is this need for timely and accurate data which is demanded by end-users in both research and operational fields, whether this is to develop improved fire spread models or providing near-real time situational awareness. Thus, the VIIRS AF Proving Ground and Risk Reduction (PGRR) project was established by NOAA to ensure maximum benefit for downstream users through outreach and education and product evaluation and improvement. The goal of this project is to leverage the VIIRS AF products for active and post-fire management and NOAA operations to improve research and decision making.

Accomplishments

Communication with end-users is critical and thus we have maintained on-going and frequent discussions with our partners in the USFS, NOAA, and Direct Readout/Broadcast community. Our monthly telecons as part of the Fire & Smoke initiative provides a forum to discuss strategies and approaches to best engage our stakeholders while also opportunities to perform case studies. At the national-level of fire operations, communication with the Predictive Services, Intelligence, and NWS staff at the National Interagency Fire Center (NIFC) in Boise has been extremely fruitful in understanding their specific goals and hurdles and the current and potential value of VIIRS AF data for their operations. Our regular communication with Ed Delgado, National Program Manager of Predictive Services at NIFC, started in 2014 and continued though 2015 (and will likely continue for the foreseeable future). This dialogue has allowed us to to keep them informed of VIIRS updates and progress while we stay abreast of activities in the fire operations community. In addition, we monitored the transition to the AWIPS II CAVE workstations which will be supported in the NIFC and Geographical Area Coordination Centers (GACC) offices. Regular discussions with Evan Polster, the technical lead of the FxCAVE project (formerly the FX-Net project) which mostly services the fire weather community (NIFC), has provided an opportunity for both sides of this discussion to learn about the other's respective products and applications. Evan reached out to us in early September to inquire about ingesting VIIRS AF data, as well as smoke forecast products. For the latter, we included Shobha Kondragunta into the discussion. Shobha is a fellow PGRR PI from the IDEA (Infusing satellite Data into Environmental air quality Applications) project with whom we maintain communication with to facilitate interaction with, and disseminate information to, relevant fire operations personnel (e.g. IMETs and Incident Air Quality specialists).

In Alaska, several teleconferences were held throughout the year with the Geographic Information Network of Alaska (GINA) to discuss the dissemination of VIIRS AF data via their Direct Readout operations. This is of particular interest, and of critical need, to the Alaska Fire Service (AFS) and the Alaska Interagency Coordination Center (AICC). Our interactions with the Alaska fire community led to us participating in their Alaska Wildland Fire Coordinating Group Interagency Fall Fire Review meeting (remotely) in October. We have subsequently arranged to travel to Fairbanks in March, 2016 to provide hands-on support, training, and face-to-face meetings.

As a part of international outreach activities, the VIIRS AF information was communicated to the GOFC-GOLD Fire Implementation team regional networks at meetings such as the Global Forest Observations Initiative (GFOI) capacity building meeting, Sydney, Australia, 2 – 6 March 2015. Further, an online survey was disseminated to the GOFC network to capture the user needs of fire community specific to VIIRS fire datasets, including topics such as ease of access and usefulness for various applications. We've also assisted the World Resource Institute (WRI) with downloading and describing the VIIRS AF data into their Global Forest Watch – Fires web mapper. This interactive map and data dissemination portal is used to cover fire activity and related air quality issues in Southeast Asia, and Indonesia specifically.

Long-term monitoring of the IDPS product revealed that there have been no spurious detections to date in 2015. With this, our efforts to improve the quality of the IDPS product is considered to be finished and we re-directed our algorithm development focus to the new Active Fire product to be implemented in NDE. The new product includes fire radiative power and the code accommodates the sensor scanning geometry. Along these lines we continued our cal/val efforts both in the laboratory here at UMD and in the field, working with our partners in the USFS and Maryland Department of Natural Resources (DNR), among others (Figure 1).

Figure 1: Photo examples of VIIRS AF evaluation and validation efforts; a) Laboratory experiments being performed at the University of Maryland to validate our radiometers; b) Overhead array of instruments including dual-band radiometers and FLIR T-640; c) Prescribed fire (Rx) in George Washington National Forest (GWNF), Virginia, with *in situ,* tower-based radiometers and d) Post-fire residual smoke from GWNF fires.

Planned work

Support role-out of AWIPS II with VIIRS AF products. This has not been of critical importance, but as the role-out stabilizes we will push hard to ensure the VIIRS fire products are available and the necessary training and meta-data is available.

We will also continue to communicate and work with Shobha Kondragunta to facilitate interaction and dissemination of fire and smoke data to operations personnel (e.g. IMETs and Incident Air Quality specialists). Our planned visit to GINA, AFS, and AICC in March 2016 in Fairbanks, Alaska, will include BOTH an active fire and smoke/aerosol component.

Our outreach efforts are fundamentally targeted at organizations, agencies, and individuals in the realm of fire operations and as such the focus for this PGRR project has been the operational end-users with a particular emphasis at dissemination information and education in a top-down approach. Thus, we will continue to engage members of the GACCs and NIFC to assist in training. We will continue to participate in monthly telecons facilitated by the National Interagency Coordination Center at NIFC. These monthly collaboration calls also double as a vehicle for showcasing new research and technology that is relevant to their work.

In addition, our experiments to validate VIIRS AF and conduct basic research using VIIRS and VIIRS-like proxy sensors are paving the way to better characterize the product and demonstrate opportunities for satellite-based fire product synergies.

We will attend a NASA LCLUC meeting in Yangon, Myanmar, in January to meet with individuals from the GOFC network to discuss the use of VIIRS AF. Currently, many users in Southeast Asia rely on NOAA-18 and are not comfortable or even familiar with using VIIRS. Krishna Vadrevu, IT Executive of GOFC, is coordinating this meeting and will be in attendance.

Publications

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

Presentations

Presentations have included, but limited to:

- Participation at the WIFIRE workshop "Towards Data-Driven Operational Wildfire Spread Modelling" in San Diego (January, 2015). This talk gave a brief overview of current Suomi NPP fire detection and characterization capabilities and developments coming down the pipeline. It also provided information on smoke products and where to find all the data and learn more about them.
- We presented (remotely) a talk at the NOAA Satellite Proving Ground/User Readiness Meeting in Kansas City on June 19, 2015, titled "Fire and Smoke:

- An overview of VIIRS products". (In January, we participated at the WIFIRE workshop "Towards Data-Driven Operational Wildfire Spread Modelling". This talk gave a brief overview of current Suomi NPP fire detection and characterization capabilities and developments coming down the pipeline. It also provided information on smoke products and where to find all the data and learn more about them.
- On May 14, 2015 we provided (again, remotely) a similar talk at the OCONUS Technical Interchange Meeting in Anchorage Alaska.
- Two posters were presented at the NOAA Satellite Conference on April 29th entitled "The VIIRS Active Fire Data for Fire Management: A review of the Proving Ground and Risk Reduction (PGRR) Project efforts". An additional poster will be presented by Ivan Csiszar entitled "Latest developments related to the improvement of the operational NOAA VIIRS active fire product"
- A poster presentation at the 2015 STAR JPSS Annual Science Team Meeting (August 24-28)
- We attended the NOAA Satellite Air Quality Proving Ground (AQPG) workshop September 9, 2015 at which Ivan Csiszar provided a presentation titled "Use of VIIRS fire products to support fire management".

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	**0**
# of non-peered reviewed papers	**0**
# of invited presentations	**8**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**1**

Performance Table Explanation

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

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

Task Leader **Jun Dong**
Task Code **JDCK_FCST_15**
NOAA Sponsor **Huan Meng**
NOAA Office **NESDIS/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: 70%; Goal 2: 30%**
Highlight: The ATMS SFR algorithm was improved based on better MRMS radar data; A new satellite and radar merged product has been produced by a real-time system.
Link to a research web page http://cics.umd.edu/sfr; http://cics.umd.edu/data

Background

An ATMS Snowfall Rate (SFR) algorithm has been developed with the support of JPSS PGRR Program and NESDIS/STAR, and partially runs real-time under framework of the operational AMSU product. The ATMS and AMSU SFR products have been proved very useful through NASA/SPoRT assessment at several WFOs. However, current algorithms still have some weakness: negative bias comparing to radar observations; the effect of the super cooled liquid water in the cloud and the inability to detect snowing low cloud. In the past year, the SFR product was recalibrated and validated using new Multi-Radar Multi-Sensor (MRMS) data. Based feedback of the assessment, we also classified some cases in which the SFRs were underestimated due to liquid water effect. We are adding liquid water to our forward model to count for this effect. Furthermore, a updated snow detection algorithm are developing to detect snow for low cloud.

Accomplishments

1. Comparison to MRMS SFR

For ATMS, five snow events were picked for calibration and other three cases for validation during two-winter season, 2013/12 - 2015/02. The ATMS data were matched with MRMS radar data using convolution method. To ensure the observation quality, only good quality radar data were picked using Radar Quality Index (RQI). Then, the histogram of ATMS SFR was adjusted toward MRMS data by least square fitting, and the statistics before and after the new calibration are shown in Table 1, as well as for the validation cases. The new calibration greatly reduces SFR bias and improves other statistics (Table 1), and makes histogram of ATMS SFR more consistent with radar observation (Figure 1 upper panel). Following the same procedure, we also recalibrated MHS sensor and got the similar result (not shown).

Table 1: The comparison of statistics before and after new calibration for ATMS

	COR	BIA	RMS
Original	0.55	-0.30	0.77
Calibration	0.56	-0.10	0.73
Validation	0.50	-0.05	0.62

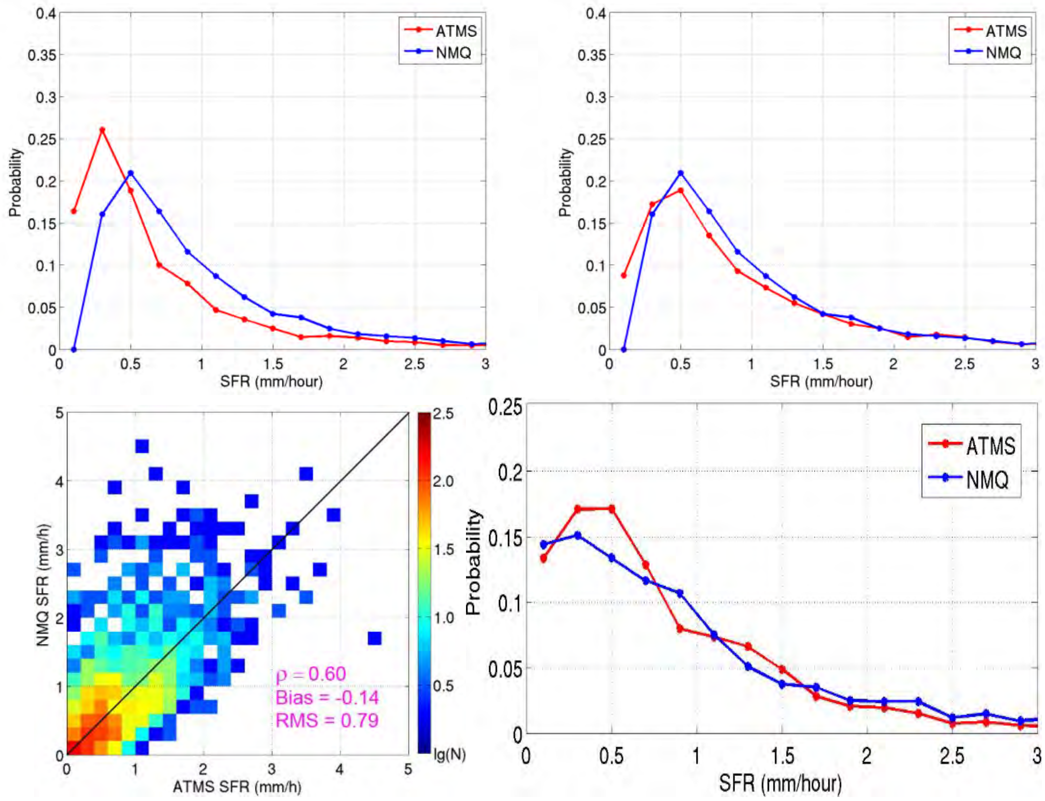


Figure 1: Histograms before (upper left) and after new calibration (upper right) for ATMS. Lower panel are scatter plot (left) and histogram (right) of Jonas snow event between ATMS and MRMS SFR.

2. Jonas snow event (January 22-24, 2016)

A historical nor'easter, Jonas, hit the Mid-Atlantic region on January 22-24, 2016 and produced record snowfall in many local areas. The NESDIS SFR product captured the evolution of Jonas with five satellites including S-NPP (ATMS), POES and Metop (AMSU and MHS) satellites. The SFR product and a SFR-based radar-satellite merged product, mSFR, were used by NWS Sterling Office (LWX) for the forecast of Jonas. Feedback from LWX indicated that the products were "Very Useful", and their impact was "Very Large" on the LWX forecast process. Figure 1 (lower panel) shows the consistency between the satellite SFR product and radar observation for this event.

3. Low Clouds snow detection

The objective was to improve the current snowfall detection algorithm for shallow to moderate cloud systems. A sample of snowfall events over Continental US and Alaska during the months of October 2014 and March 2015 was collected. For the selected events, a number of cloud and atmospheric parameters was obtained from GDAS and matched with ATMS measurements and in-situ station data. GDAS cloud parameters included cloud height, cloud top height, cloud top temperature and pressure. Matched were also retrieved snowfall from the existing algorithm – probability of snowfall detection and snowfall rate.

The training sample was classified into two cloud categories, a moderate cloud and thick cloud regime. Cloud thickness threshold to discriminate between the moderate and thick cloud regime was estimated at 3500 m as approximately the mean thickness of the snowfall sample. A new shallow-to moderate cloud snowfall algorithm was developed as follows:

- For cloud thickness less than 1500 m, the associated event was classified as no-snowfall since the (ground truth) fraction of snowfall cases in this thickness range was at 10%;
- For cloud thickness between 1500 m and 3500 m, a new algorithm based on the same scheme (principal components + logistic regression) was trained for the warm and cold regimes, respectively;
- For cloud thickness greater than 3500 m, the existing algorithm was left unchanged.

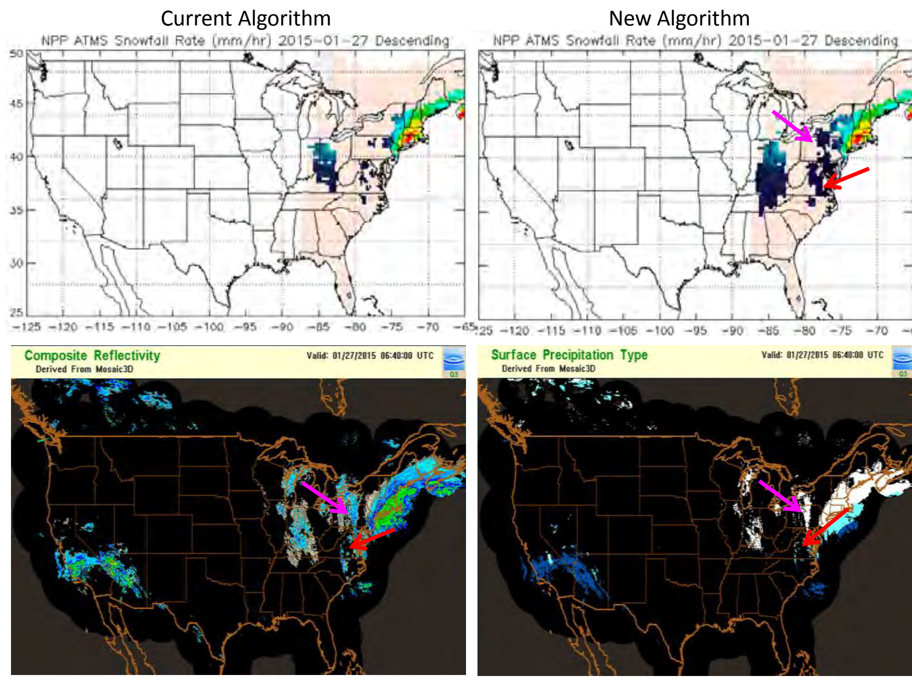


Figure 2: Comparison of the current algorithm (upper left) and the new algorithm with low cloud detection (upper right). The plots in lower panel are corresponding MRMS radar observation.

New shallow snow algorithm resulted in a 10 % and 4% gains in snowfall detected areas for the cold and warm regimes, respectively, and 1 % reduction in false alarm for both regimes. The figure below shows an inter-comparison between the current and the new ATMS snowfall detection and rate algorithm using the Multi-Radar Multi-Sensor System (MRMS) as ground truth reference. Arrow in Magenta color indicates legitimate gain in snowfall whereas the arrow in red indicates false alarm. MRMS image also shows that the snowfall event captured was associated with a shallow to moderate cloud system.

4. Modeling Super Cooled Liquid Water

In the current SFR algorithm, an assumption is the neglecting the emission impact of liquid water. Emission has a warming effect on Tb while scattering cools Tb. Consequently, significant errors can result in the RTM forward model. To count for the liquid water effect, we are adding liquid water in our one-layer RTM model. There are three steps to archive this goal:

- Generate liquid water optical parameters for liquid water to use in the forward RTM. This step has been finished;
- Add water parameters (LWP, De) in the inverse matrix. We are working on this step;
- Figure out appropriate dataset to initialize the parameters. The Atmospheric Radiation Measurement (ARM) and 0.25 degree GFS data are collecting to find best relation for the parameters.

Planned work

- Add cloud liquid water related parameters in the radiative transfer model for both ATMS and MHS;
- Establish empirical equations to initialize cloud liquid water and ice water related parameters for both ATMS and MHS;
- Calibrate the new algorithm using MRMS radar precipitation data;
- Integrate the new SFR algorithm into real-time SFR retrieval system for both ATMS and MHS;
- Refine the Low cloud snow detection algorithm in the shallow-to-moderate cloud regime by optimal utilization of GFS data;
- Develop shallow cloud snowfall detection algorithm for MHS.

Publications

Dong, J, H. Meng, Calibration and validation of Satellite Microwave Snowfall Rate Retrieval Algorithm, in preparation.

Products

- This project will provide updated SFR product considering the snow liquid water effect;
- Improved shallow snowfall detection algorithms.

Presentations

Dong, J., H. Meng, et al., Satellite Microwave Snowfall Rate Retrieval Algorithm, Cal/Val and Application, CICS-MD Science Meeting, College Park, November 2015

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	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

This is the first year of the project, and the corresponding papers and products will be produced in the following years.

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

Task Leader **Jun Dong**
Task Code **JDJD_ATMS_15**
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: 70%; Goal 2: 30%**
Highlight: The ATMS SFR algorithm was improved based on better MRMS radar data; A new satellite and radar merged product has been produced by a real-time system; SFR product assessment at NWS Weather Forecast Offices
Link to a research web page **http://cics.umd.edu/sfr**; **http://cics.umd.edu/data**

Background

This project is to develop ATMS Snowfall Rate (SFR) algorithm and produce real-time SFR product for weather forecast service. In the previous work, the ATMS Snowfall Rate (SFR) algorithm was developed and implemented in a real-time system using satellite Direct Broadcast (DB) with latency less than 30 minutes. To better serve the weather forecast, a satellite and radar merger SFR product was produced and delivered to forecaster in near real-time.

Accomplishments

1. Improvement of SFR algorithm

From satellite and radar SFR comparison, a negative bias was found in satellite retrieved SFR. So the satellite SFR was recalibrated/validated using new Multi Radar Multi Sensor (MRMS) data. The Radar Quality Index (RQI) was used to ensure only good data used. After the new adjustment, the SFR bias is greatly reduced, from -0.27 mm/h to -0.13 mm/h and the satellite and radar histogram are more consistent.

2. Development of the merge method

Generally, satellite observed snow is much high than radar observation and snow falling speed is much smaller comparing with raindrop. Therefore, if we want to merge satellite and radar SFR observation correctly, the time delays for snow falling from cloud to near ground need to be considered. To quantify this effect, the lagged correlation was calculated using collocated satellite and MRMS radar data. In Figure 1, with about 30 minutes lag, the satellite and radar have max correlation and low RMSE error. So we decided to use 30 minutes time lag to merge satellite and radar data.

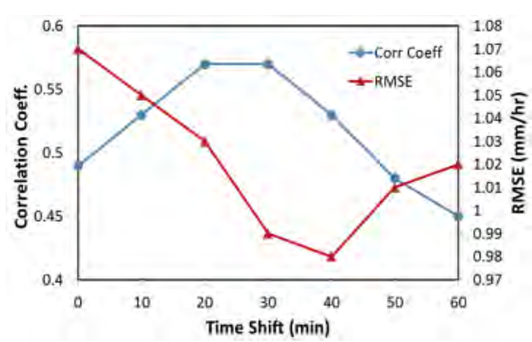


Figure 1: Lagged correlation between

The satellite SFR is merged with radar data with satellite FOV unchanged. The main criteria to merge data are that satellite SFR is added if radar does not show snow in that region; for the region radar shown no snow but RQI is not good, once satellite confirm no snow, we consider no snow in that region. One example is shown in Figure 2. It is shown in Figure 2 that the satellite SFR is especially useful for maintain region as we expected. Furthermore, the resolution difference can be seen in the zoomed area in plot (d).

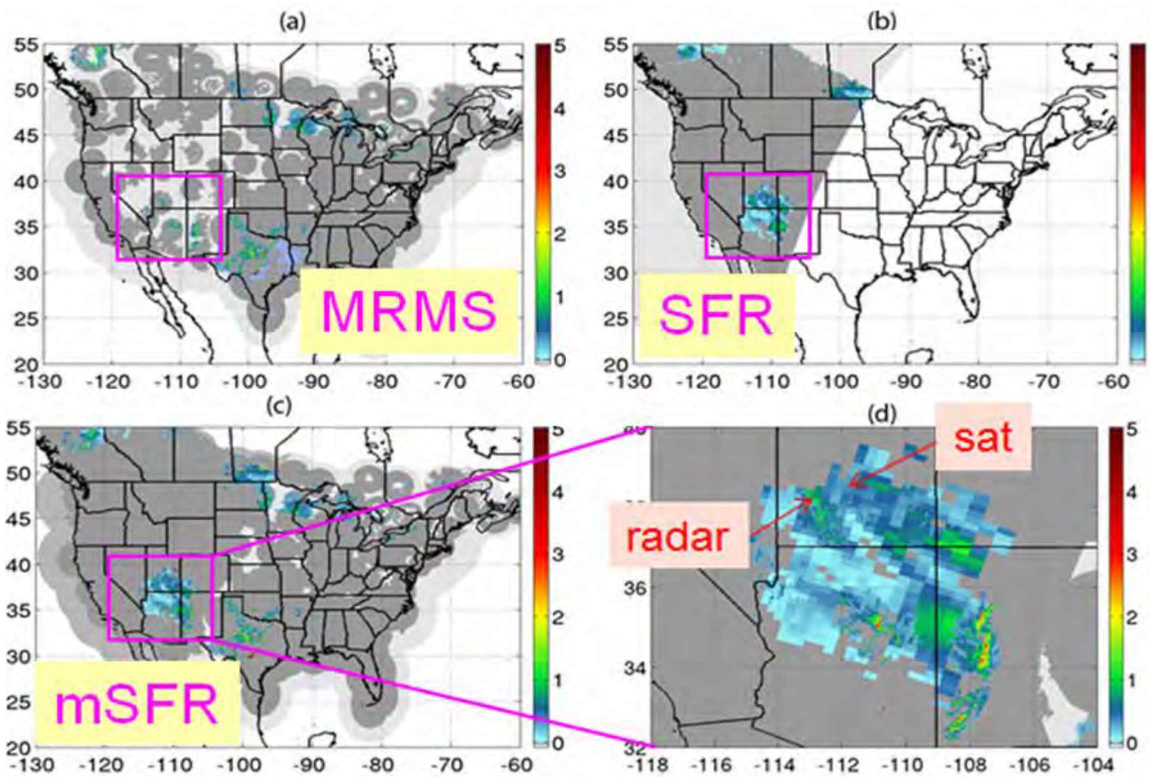


Figure 2: Example of mSFR product. (a) MRMS radar SFR only; (b) ATMS SFR only; (c) Merged SFR product; (d) Zoom in the snow region

3. Implementation of merge algorithm in real-time

The real-time merge system merges MRMS data that is every 2 minutes with ATMS and MHS SFR data that, on average, is one pass per about two-hour for CONUS at mid-latitudes. We decided to produce mSFR for every 10 minutes with the 30 minutes shift between satellite and radar. If there is satellite data available during that period, mSFR product merges both data with the algorithm above; otherwise, mSFR only contains radar data with our own flags.

4. SFR product assessment

The SFR and mSFR products were evaluated at six NWS Weather Forecast Offices (WFOs) through collaboration with NASA/SPoRT in winter 2015-2016. The products were generated at CICS-MD using direct broadcast data and provided to SPoRT at near real-time. SPoRT formatted the products into AWIPS and disseminated to WFOs to be evaluated in their operational environments. Forecasters feedback indicated that the SFR and mSFR products are useful tools for weather forecast. The result of the assessment paves the way for the ATMS SFR product to be operationalized at NOAA/NESDIS.

Products

- Merged Satellite and Radar SFR product (mSFR)
- Real-time mSFR data processing system

Presentations

Dong, J., H. Meng, et al. Satellite Microwave Snowfall Rate Retrieval Algorithm, Cal/Val and Application, CICS-MD Science Meeting, College Park, November 2015.

Meng, H., J. Dong, NESDIS SFR Trainings for six NWS Weather Forecast Offices, January 2016.

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	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

The satellite and radar merged product (mSFR) were developed, and a processing system were developed to provide mSFR at near real-time to weather forecasters.

Development of the Satellite Sea-Surface Salinity Quality Monitor System

Task Leader Li Ren
Task Code LRLR_SSS-15
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: 75%;
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 star.nesdis.noaa.gov/socd/sss/4sqm

Background

This report summarizes the work from April 2015 to December 2015 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 (http://www.star.nesdis.noaa.gov/socd/sss/4sqm/)

Accomplishments

The 4SQM system including the sea surface salinity global maps, histograms, Hovomoller diagrams are completed in updating with the newly released V4.0 Aquarius data set. Both the Aquarius ADPS and CAP V4.0 sea-surface salinity products were compared with the SMOS and Argo data sets. On a zonal mean annual mean sense, Aquarius ADPS best matches Argo *in situ* observations across all latitudes. The Aquarius data sets experience large positive differences from Argo data for latitudes poleward of 40°S/N, while SMOS data has very large negative differences poleward of about 50°N. All three satellite data sets depict an unusual abrupt large unexplained negative difference with respect to Argo data between 35°N-40°N (Figure 1).

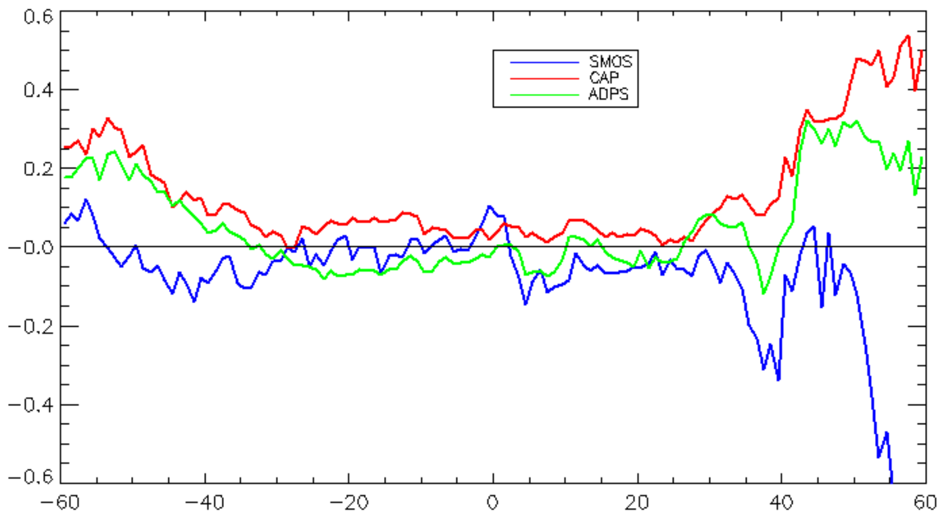


Figure 1: zonal mean annual-mean of SSS differences, ADPS minus Argo (blue), CAP minus Argo (green), and the SMOS minus Argo (red).

Products

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

Presentations

- **Ren, L.** and E. Bayler, Satellite Sea-surface salinity Retrieval Dependencies, Ocean Science Meeting, New Orland 02/2016.

- Bayler, E. and **L. Ren,** Variability and Uncertainty in satellite Sea-surface salinity observations, Ocean Science Meeting, New Orland 02/2016.

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	**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	**0**
# of undergraduate students mentored during the year	**0**

GEOG Task 10: 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_15
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%
Main CICS Research Topic Calibration and Validation
Contribution to NOAA goals (%) Goal 1: 50%, Goal 2: 50%
Highlight This task describes the GOES-R/ABI deep-dive active fire validation tool. USGS/Landsat-8 reference fire data set was published in 2015, alternative ESA/Sentinel-2 reference fire data test being developed.

Background

The future GOES-R Advanced Baseline Imager (ABI) fire detection and characterization (FDC) algorithm builds on the Wildfire Automated Biomass Burning Algorithm (WF-ABBA), which originated from GOES Visible Infrared Spin Scan Radiometer Atmospheric Sounder (VAS) data applications [Prins and Menzel, 1992]. The WF-ABBA product provides routine detection and characterization of sub-pixel active fires, serving the fire management community as well as the scientific community. 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., Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) as well as on separate platforms by limiting the time difference between acquisitions (e.g, GOES and Landsat Enhanced Thematic Mapper Plus (ETM+) [Schroeder et al., 2008a, b].

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

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

Accomplishments

During this funding cycle we completed the development of the GOES-R/ABI *deep-dive* active fire validation tool and its documentation. Primary reference fire data sets were developed using an independent fire algorithm applied to USGS/Landsat-8 Operational Land Imager (OLI) data. That algorithm built on the heritage ASTER and Landsat-7/ETM+ fire algorithms providing 30 m resolution reference fire data. The Landsat-8/OLI fire algorithm/data were published online in a peer-reviewed journal [Schroeder *et al.*, 2015].

The *deep-dive* tool was successfully tested using Data Operations Exercise (DOE) GOES-R/ABI data proxy files along with near-coincident Landsat-8/OLI reference fire data over select locations across the United States. The GOES-R/ABI proxy data contained no active fires whereas clear land/water/cloud pixels were successfully mapped to the reference data (Figure 1).

Figure 1: Demonstration of the GOES-R/ABI *deep-dive* active fire validation tool using DOE proxy data and coincident Landsat-8 imagery acquired on 19 June 2015 over part of Georgia/US. Background image shows Landsat-8/OLI RGB image (channels 7-5-2); regular grid describes the effective ABI pixel footprints (pixels are color-coded according to ABI fire product classification, black = clear land, cyan = water pixel). No ABI fire pixels were found to coincide with the reference data. The lat/lon information describes the scene's center location (marked "x").

In order to reduce risks, an alternative reference data set is being developed using ESA/Sentinel-2 Multi-spectral Imager (MSI) data. Sample reference fire data were successfully generated for select Sentinel-2a/MSI scenes acquired over the United States and Africa using a modified version of the Landsat-8/OLI fire algorithm. Near-coincident Landsat-8/OLI and Sentinel-2a imagery were selected and processed for parts of Africa covering widespread fire activity (Figure 2). Those tests served to demonstrate the consistency between the two reference fire data sets.

Planned work

Continue development of Sentinel-2a/MSI reference fire data set, apply GOES-R/ABI *deep-dive* active fire validation tool to pre-launch FDC proxy data based on Advanced Himawari Imager (AHI) inputs and post-launch GOES-R/ABI data. Generate preliminary FDC fire detection data performance metrics and use results to support FDC algorithm refinement/tuning.

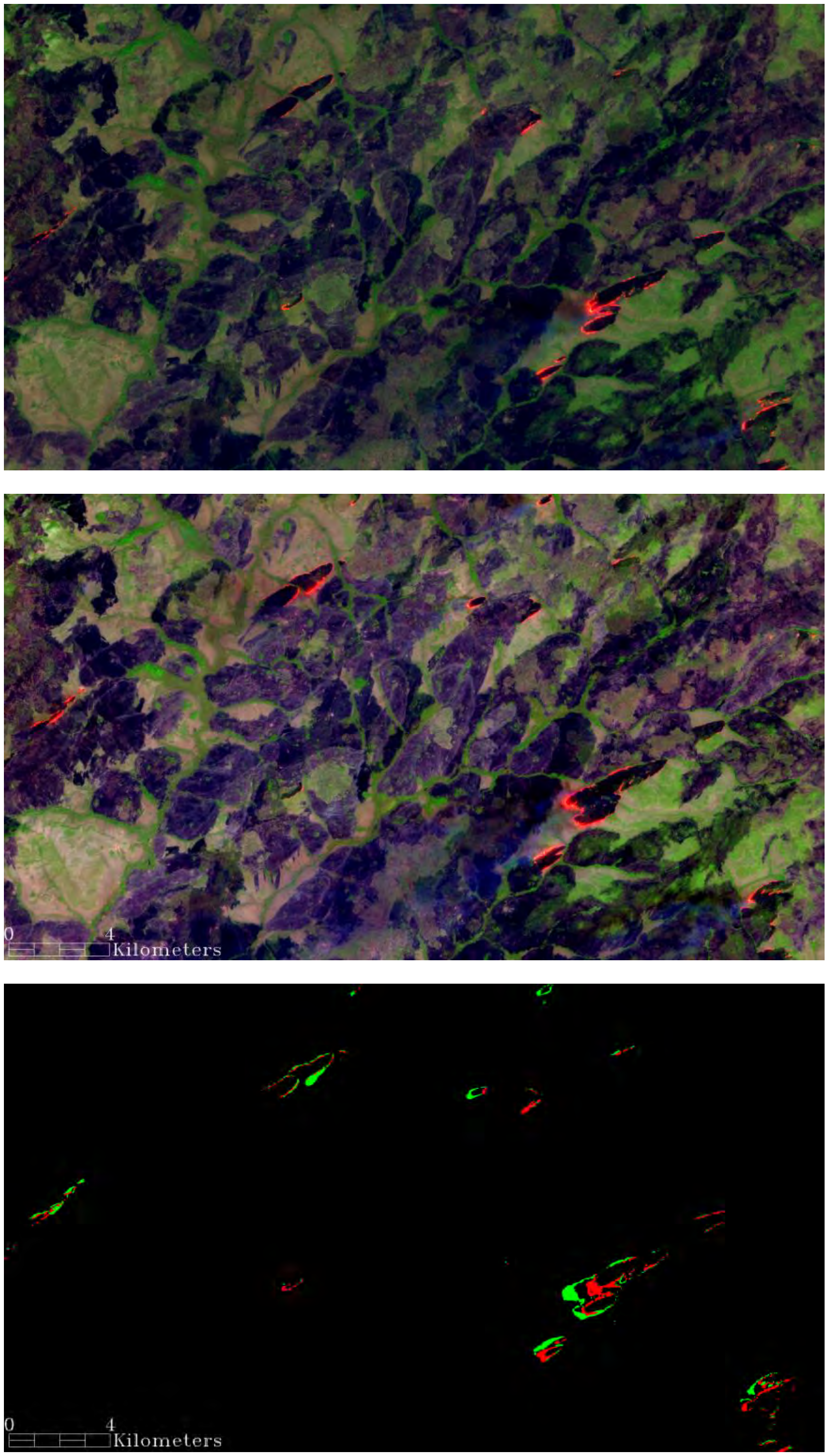


Figure 2: Near-coincident (16 min apart) observation of active fires in Africa using 30 m Landsat-8/OLI and 20 m Sentinel-2a/MSI data acquired on 27 December 2015. Top panel: Landsat-8/OLI subset, middle panel: Sentinel-2a/MSI subset, bottom panel: active fire detection masks derived from Landsat-8/OLI (red) and Sentinel-2a/MSI (green) fire algorithms applied to data subsets (center coordinate: 9°23' N 03°32' W).

Publications

Schroeder, W., Oliva, P., Giglio, L., Quayle, B., Lorenz, E., and Morelli, F. (2015). Active fire detection using Landsat-8/OLI data. *Remote Sensing of Environment*, doi: 10.1016/j.rse.2015.08.032.

Products

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

References

Csiszar, I., and Schroeder, W. (2008). Short-term observations of the temporal development of active fires from consecutive same-day ETM+ and ASTER imagery in the Amazon: Implications for active fire product validation. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 1(4), 248-253.

Prins, E., and Menzel, P. (1992). Geostationary satellite detection of biomass burning in South America. *International Journal of Remote Sensing*, 13, 2783-2799.

Schroeder, W., Prins, E., Giglio, L., et al. (2008a). Validation of GOES and MODIS active fire detection using ASTER and ETM+ data. *Remote Sensing of Environment*, 112, 2711-2726.

Schroeder, W., Ruminski, M., Csiszar, I., et al. (2008b). Validation analyses of an operational fire monitoring product: The Hazard Mapping System. *International Journal of Remote Sensing*, 29(20), 6059-6066.

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.

Accomplishments

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

1. Selenographic coordinate mapping of lunar observation by GOES imager

Radiometric stability of the lunar surface, its lack of atmosphere and smooth reflectance spectrum makes the moon an ideal target for calibrating satellite-based multi-band imagers. Lunar calibration for solar bands has been an important part of trending the radiometric performance of GOES imager. The lunar disk-equivalent irradiance has been often used to trend the on-orbit degradation of the GOES imager and its performance is largely affected by the uncertainties embedded in the lunar irradiance model in characterizi ng its dependence on lunar phase and libration. On the other hand, the lunar view by GOES imager provides opportunity to perform radiometric calibration of GOES imager using lunar radiances of selected locations on the moon. In order to do so, lunar observations by GOES need to be mapped onto selenographic coordinate, i.e. latitude and longitude in moon-centered coordinate. In our work, algorithms and procedures are developed to map lunar images observed by GOES onto selenographic coordinate. Results are published in SPIE conference proceeding.

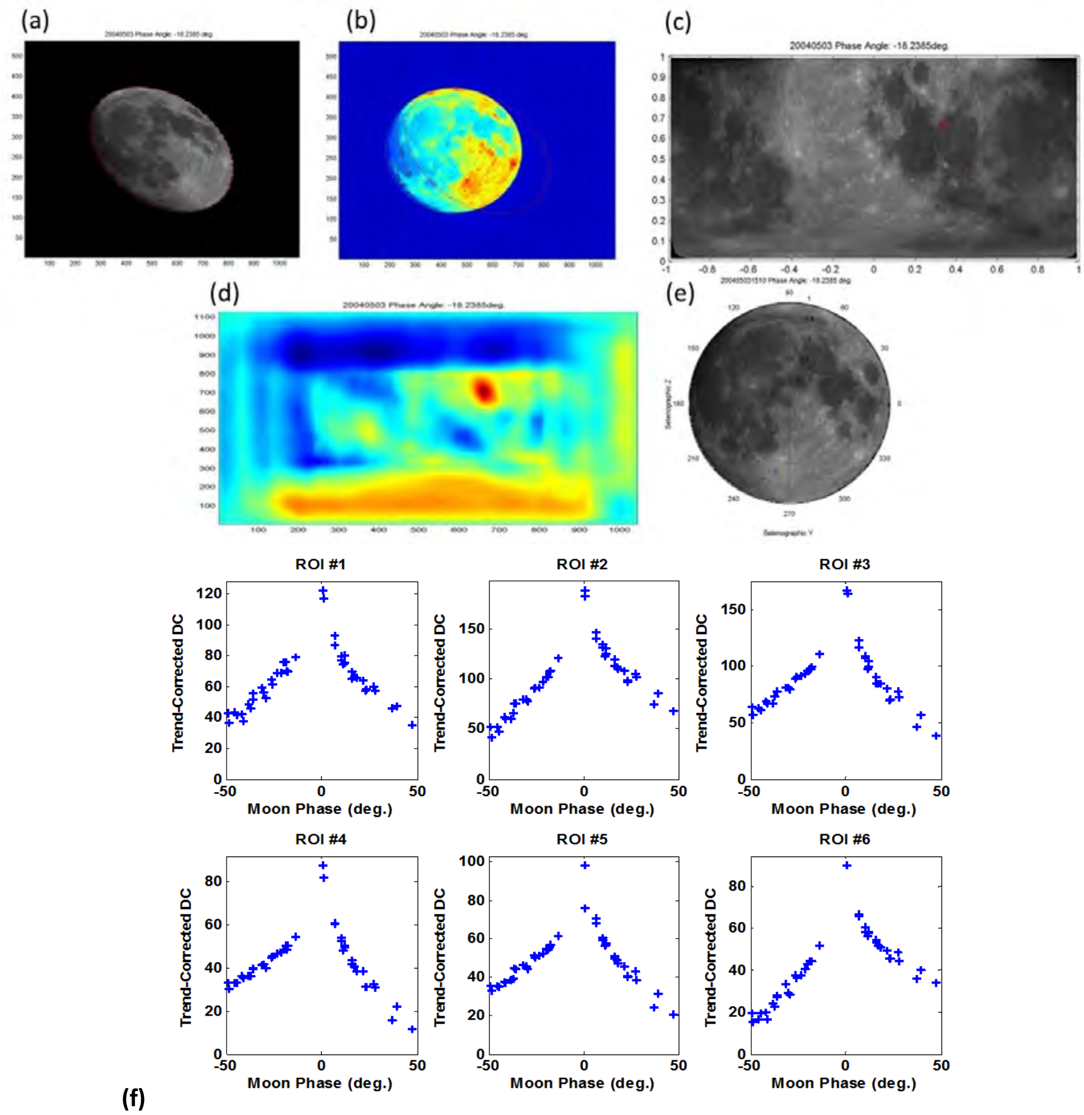


Figure 1: (a) Lunar image observed by with boundary marked with red contour line; (b) The processed lunar image after applying skewed saw-tooth boundary correction. (c) unfolded lunar image in Longitude/180-r coordinate; (d) Cross-

correlation map calculated between the template in (b) and lunar image in (c). (e) Lunar image mapped onto selenographic Y-Z coordinate. (f) Lunar measurement (trend-corrected DC) by GOES-12 Imager vs. lunar phase for 6 selected ROIs.

2. Lunar radiance model development to support lunar calibration of GOES-R ABI

Lunar observations of GOES-12 are processed to construct lunar radiance model and regions of interest (ROIs) are identified. A total of 44 lunar observations by GOES-12 Imager with |lunar phase| less than 50 degree have been processed and mapped onto selenographic coordinate. Six ROIs on moon surface were selected and characteristic trend-corrected lunar data over these ROIs were extracted. The characteristic dependence of lunar measurement over ROIs vs. lunar phase angle was investigated (Figure 1f). Our study shows strong dependence of trend-corrected lunar data on moon phase and the dependence is asymmetric between waxing and waning lunar phase. This suggests that accurate knowledge of BRDF of lunar surface is important in trending radiometric performance of GOES Imager with lunar radiance. Since lunar images observed by GOES can have different view geometry, different lunar phase, and there are uncertainties in the observation and mapping. This supports lunar calibration of GOES-R ABI.

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 performed 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 are 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. Figure 2 shows such kind of activities.

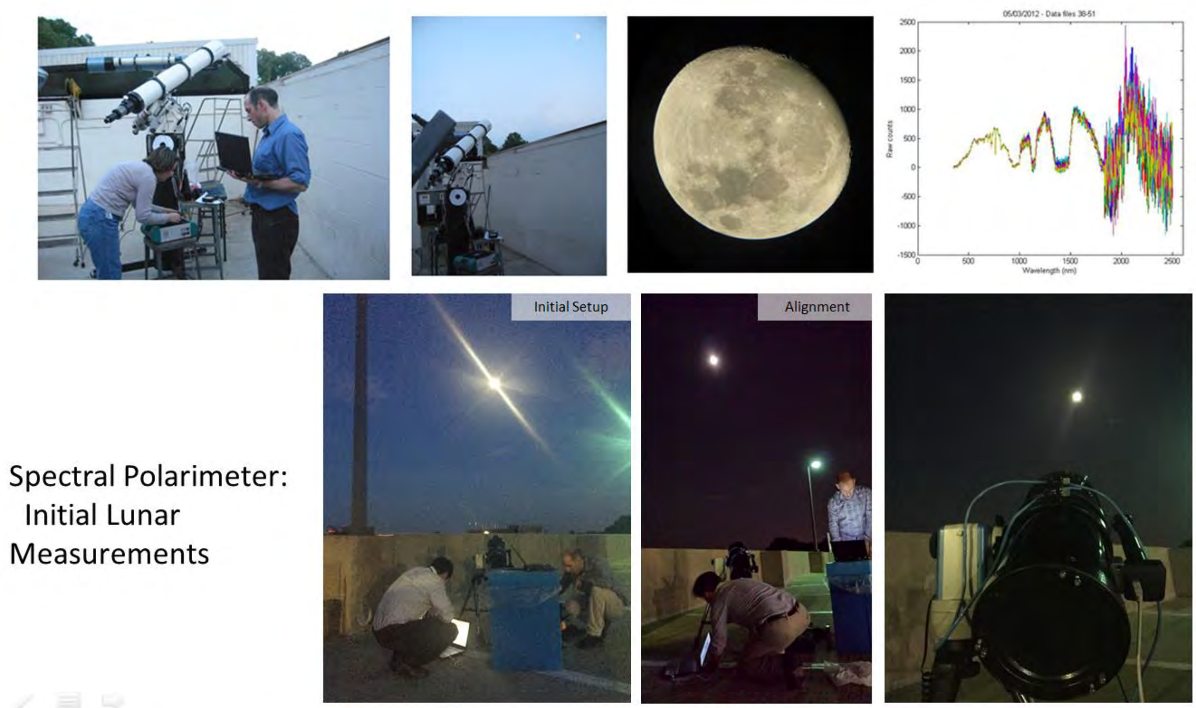


Figure 2: Lunar observation with NOAA/NESDIS/STAR scientists at UMD Astronomical Observatory.

4. **Evaluation of Himawari AHI Geospatial calibration using SNPP VIIRS SNO data**

Japan Meteorological Agency (JMA) Himawari-8 Advanced Himawari Imager (AHI) is the first in the series of next-generation geostationary (GEO) weather instruments. It has 16 spectral solar reflective and emissive bands located in three focal plane modules (FPM): one visible and near-infrared (VNIR) FPM, one midwave infrared (MWIR) FPM, and one longwave infrared (LWIR) FPM. Our study evaluated the navigation and co-registration accuracies of three AHI bands from the three FPMs using the simultaneous nadir observations (SNO) of SNPP-VIIRS I-band images. The preliminary results showed that the navigation difference between the two instruments is within 0.3 AHI pixels at 2km spatial resolution. The band-to-band co-registration (BBR) difference is within 0.5 AHI pixels, yet the BBR difference between the two thermal bands is generally less than 0.2 pixels, better than the difference between the AHI VNIR and IR bands which ranges between 0.2 to 0.7 pixels during the study period. This work supports post-launch INR validation of GOES-R ABI.

5. **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.

6. ***We acquired and maintained two 20TB data severs to support processing, archiving and backup of public data for calibration of GOES-R ABI***

Planned Work:

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

- Support lunar calibration for GOES-R ABI through
  - Analysis of Himawari-8 AHI lunar observation data
  - *Ground-based lunar observation at University of Maryland Astronomical Observatory*
  - *Development of Lunar radiance model*
- Develop tools to support radiometric calibration for GOES-R ABI through
  - *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
  - *Solar avoidance zone prediction for ABI swaths*
  - *Line of sight calculation with orbit motion compensation in fixed grid for ABI*
- Support development and maintenance of GOES-R ABI Calibration Working Group (CWG) webpage

Publications: (Non-peer reviewed)

1. Xi Shao, Xiangqian Wu, Fangfang Yu, "Selenographic coordinate mapping of lunar observations by GOES imager", in Sensors, Systems, and Next-Generation Satellites XIX, Roland Meynart; Steven P. Neeck; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9639 (SPIE, Bellingham, WA 2015), 963918.

2. Yu, F., X. Wu, and X. Shao, 2015. Photometric properties at selected lunar surface for GOES-R ABI solar reflective channels using SELENE/SP data, *EUMETSAT Met. Sat. Conf.*, Toulouse, France, 21-25 Sept. 2015.
3. Datla, R.; Shao, X.; Cao, C.; Wu, X. Comparison of the Calibration Algorithms and SI Traceability of MODIS, VIIRS, GOES, and GOES-R ABI Sensors. *Remote Sens.* **2016**, *8*, 126.

Presentations:

1. Xi Shao, Xiangqian Wu & Fangfang Yu, Selenographic Coordinate Mapping of Lunar Observations by GOES Imager, NOAA Satellite Conference, Greenbelt, MD, April 27 - May 1, 2015.
2. *Xi Shao, Yan Bai, Changyong Cao, Field Campaign Support Capabilities at University of Maryland, STAR JPSS 2015 Annual Science Meeting, College Park, MD, August 24-28,2015.*

Products:

GOES-R ABI web page: http://ncc.nesdis.noaa.gov/GOESR/index.php

Performance Metrics

Performance Metrics	
# of new or improved products **developed**	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	2
# of presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

J1-VIIRS and SNPP-VIIRS Calibration Support

Task Leader Xi Shao
Task Code XSXS_J1VI_15
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 provide prelaunch science support for JPSS-1 (J1) VIIRS instrument through support J1-VIIRS SDR look-up-tables (LUTs) preparation/testing/validation, analysis of J1-VIIRS DNB scan mode change due to DNB nonlinearity and support J1-VIIRS TEB band calibration/calibration.

Background

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

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

Accomplishments

We supported the J1 VIIRS calibration in a broad scope by

1. Support J1-VIIRS SDR look-up-tables (LUTs) preparation/testing/validation
    a. We supported characterization of pre-launch response versus scan angle (RVS) for J1 VIIRS. Characterization of pre-launch VIIRS RVS was performed using 3 sources: the Laboratory Ambient Blackbody (LABB) as a target for TEBs, a 100 cm Spherical Integrating Sources (SIS-100) for the RSBs and the OBCBB as an ambient blackbody for background subtraction purposes. We analyzed FP-10 Part 1 Data (Electronic Side A) and retrieved the VIIRS Raw Data Record (RDR) for EV and three Calibration View Data (including BB, SD, and SV) as a series of Application Identification (APIDs) with 1 APID per band. These analysis supported J1 RVS LUT development.

   b. We compared the LUTs including OBCBB Emitted Radiance, OBCBB Reflected Radiance, Radiance to Effective Blackbody Temperature (EBBT), HAM Emitted Radiance, and RTA Emitted Radiance for version 8.8 and 8.10 between J1 VIIRS and S-NPP VIIRS.
   c. We supported J1 VIIRS LUTs generation by analyzing parameters in Common Geolocation LUT and South Atlantic LUT.
   d. We supported AIT LUTs/ADL code update package delivery and tested ADL4.2 using updated J1 LUTs.
   e. We supported ADL implementation on GTM for EDR NCC products to help with the ADL code re-delivery related to interpolation rectangles.
   f. We supported comparison between ADL Block 2 (version 5.2) results and IDPS results (ADL version 4.2).

   1.

2. Performed assessment on bow-tie deletion restoration for VIIRS M bands by replacing the deleted radiance values using the radiance at the nearest pixel.

   2.

3. Supported preparation of J1 VIIRS Cal/Val plan and presented the plan in JPSS annual conference.

3.

4. Support analysis of J1-VIIRS DNB scan mode change due to DNB nonlinearity
   a. Developed software for mapping global DNB night time data with negative radiance.
   b. Tested modified ADL code with DNB aggregation mode changes and assess the performance of DNB radiometric and geolocation calibration and validation
   c. Performed assessment of scan-angle dependent radiometric bias of Suomi-NPP VIIRS day/night band from night light point source observations
   d. Performed preliminary study for improving the VIIRS DNB low light calibration accuracy with ground based active light source
   e. Performed analysis on mitigating JPSS J1 VIIRS DNB performance shortfalls with expanded Cal/Val
   f. Performed assessment of J1 VIIRS DNB waiver validation readiness

   4.

5. Performed analysis of aggregating (with and without Line Spread Function) VIIRS I3 products and comparison with M10 data. We analyzed scenarios of snow and night fire to support feasibility assessment of adding a water vapor band to VIIRS in the future. Water vapor observation at channels with central wavelength around 6.5 um is of great importance in weather forecasting and climate change detection, such as in MODIS, GOES, and GOES-R series of satellites. The VIIRS has 22 bands, however, does not have a water vapor sensing band, and the current VIIRS design cannot make space for additional band. Since the high resolution (375m) imagery band I03 and moderate resolution (750m) band M10, have very similar Spectral Response Functions centered at 1.61 um, it is possible to replace M10 observations with that from I03 to make space for a new water vapor band. However, the impact of removing M10 on different users should be assessed thoroughly. In this study, we examined the VIIRS Sensor Data Record (SDR) dataset and compared the radiance from M10 and aggregated I03 (to M10) with different earth observations. It provides an early assessment of the feasibility of aggregating i03 to m10 in order to replace the m10 with a water vapor band.

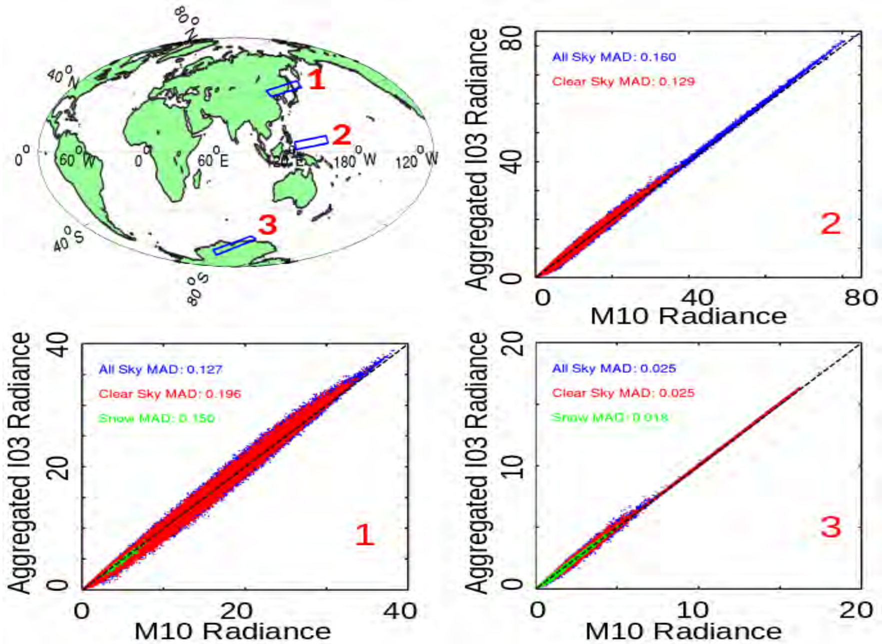


Figure 1: Scatter plots of aggregated I03 radiance and M10 radiance from three locations (land, ocean, snow/ice). Blue color represents clouds; red dots are clear sky; green dots are snow/ice. Note the scales are different. Mean absolute difference (MAD) of radiance between I03 and M10 are labeled in the figure. The unit is: W/m2/sr/um.

6. Performed TEB band calibration and validation with LBLRTM modeling. We assessed the effects of SNPP VIIRS M15/M16 detector radiometric stability and relative spectral response variation on striping using Line-by-Line Radiative Transfer Model (LBLRTM). To cover a range of environment conditions for evaluating TEB calibration and SST striping, we selected sites under various atmospheric conditions to perform simulations using LBLRTM.

7. Performed analysis of onboard blackbody (BB) PRT temperature distribution of VIIRS to find the possible root causes of striping. We have analyzed VIIRS earth view data with several striping index methods. Analysis of Variance test shows that the noise along track direction is the major reason for striping. We also found evidence of correlation between SD and BB for detector 1 in band M15. Digital Count Restoration (DCR) and detector instability are possibly related to the striping in SD and EV data, but further analysis is needed. These findings can potentially lead to further SDR processing improvements. For example, Figure 2 indicates the variations of BB–SV (*i.e.*, dBB) along track and along scan directions for detector 2 in band M15. There are 48 samples and 72 scans for three granules. The patterns are more consistent along scan. The variation along track is much larger than that along scan, which suggests that it is an important factor causing the striping pattern. Results are published in journal paper.

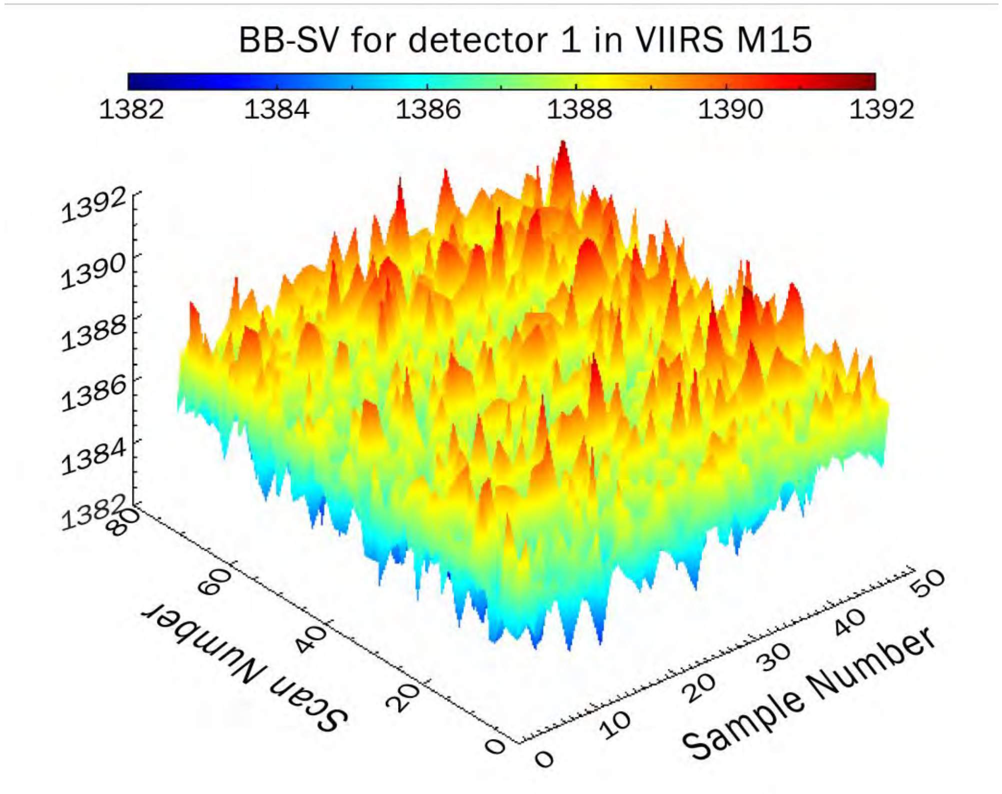


Figure 2: Variations of BB–SV (*i.e.*, dBB) along track and along scan for detector 1 in M15.

Planned Work

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

- Support J1-VIIRS SDR look-up-tables (LUTs) preparation/testing/validation
    - Validate the LUTs with updated ADL code
    - Develop tools to support updating LUTs in operation for J1-VIIRS SDR
    - Provide analysis of the VIIRS SDR processing codes in IDPS and ADL to ensure their correct implementations in operation.
- Support analysis of J1-VIIRS DNB scan mode change due to DNB nonlinearity
    - Test modified ADL code with DNB aggregation mode changes and assess the performance of DNB radiometric and geolocation calibration and validation
    - Provide analysis to ensure correct implementation of scientific algorithms and calibration procedures for DNB aggregation mode change in operation.
- Support J1-VIIRS TEB band calibration/calibration

Publications:

Peer-Reviewed:

1. Zhuo Wang and Changyong Cao. Assessing the Effects of Suomi NPP VIIRS M15/M16 Detector Radiometric Stability and Relative Spectral Response Variation on Striping. Special Issue of Remote Sensing, 2016, 8, 145, doi:10.3390/rs8020145.

Non-Peer-Reviewed:

1. Changyong Cao, Yuqing Zong, Yan Bai, Xi Shao, "Preliminary study for improving the VIIRS DNB low light calibration accuracy with ground based active light source", in Earth Observing Systems XX, James J. Butler; Xiaoxiong (Jack) Xiong; Xingfa Gu, Editors, Proceedings of SPIE Vol. 9607 (SPIE, Bellingham, WA 2015), 96070D.

Presentations:

1. Cao C, Wang W, Lee S, Shao X and Bai Y, *Mitigating JPSS J1 VIIRS DNB Performance Shortfalls with Expanded Cal/Val*, 2015 AGU Fall Meeting, San Francisco, CA (2015).
2. Xi Shao, Yan Bai, and Changyong Cao, J1 VIIRS DNB Waiver Validation Readiness, *STAR JPSS 2015 Annual Science Meeting, College Park, MD, August 24-28, 2015.*
3. Xi Shao, Changyong Cao, Mitch Schull, and Wenhui Wang, Cal/Val Plan and Field Campaign Preparation， *STAR JPSS 2015 Annual Science Meeting, College Park, MD, August 24-28, 2015.*
4. Zhuo Wang and Changyong Cao, Suomi NPP VIIRS Striping Analysis using Radiative Transfer Model Calculations and Satellite Data Analyses. American Geophysical Union (AGU) Fall Meeting, San Francisco, CA. 14-18 December, 2015.

Others:

Award: Yan Bai, Bin Zhang and Xi Shao received 2015 NOAA NESDIS Award for achieving significant advances in critical areas of Visible Infrared Imaging Radiometer Suite Day/Night Band development, including JPSS-1 waiver mitigation, operational straylight correction, and geolocation capability development and validation.

Performance Metrics	
# of new or improved products developed	0
# 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 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

Support of SNPP VIIRS SDR Calibration and Team Management/Coordination
Task Leader Xi Shao
Task Code XSXS_SNPP_15
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 Suomi-NPP VIIRS instrument through support radiometric calibration of VIIRS reflective solar bands by trending with lunar band ratio, vicarious methods and developing physics-based model of spectral dependent degradation of VIIRS solar diffuser; perform DNB stray light correction assessment with DNB observation under moon-light; support DNB radiometric and geolocation validation with nightlight sources and support VIIRS SDR team management and coordination.

Background

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

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

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

Accomplishments

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

1. **Performed comparison of the calibration algorithms and SI Traceability of MODIS, VIIRS, GOES, and GOES-R ABI sensors**. The radiometric calibration equations for the thermal emissive bands (TEB) and the reflective solar bands (RSB) measurements of the earth scenes by the polar satellite sensors, (Terra and Aqua) MODIS and Suomi NPP (SNPP VIIRS), and geostationary sensors, GOES Imager and the GOES-R Advanced Baseline Imager (ABI) are analyzed towards calibration algorithm harmonization on the basis

of SI traceability. The calibration methodologies of these satellite optical sensors are reviewed in light of the recommended practice for radiometric calibration at the National Institute of Standards and Technology (NIST). The operational and calibration features of the sensors for on-orbit observation of radiance are also compared in tabular form. Results are published in a journal paper.

2. **Performed radiometric stability monitoring of the Suomi-NPP VIIRS RSBs using the moon**. The lunar calibration coefficients and lunar F-factor are calculated by taking the ratio of the lunar observed radiance to the simulated radiance from the Miller and Turner (MT) lunar model for scheduled lunar observations by VIIRS. The lunar F-factor is also validated against that derived from the VIIRS Solar Diffuser (SD). The MT model-based lunar F-factors in general agree with SD F-factors. The Lunar Band Ratio (LBR) is also derived from two channel lunar radiances and is implemented in the NOAA Integrated Calibration and Validation System (ICVS) to monitor the VIIRS long-term radiometric performance. LBRs agree with the SD based F-factor ratios within one percent (Figure 1). Based on analysis with these two independent lunar calibration methods, SD-based and LBR-based calibrations show a lifetime consistency. Thus, it is recommended that LBR be used for both VIIRS radiometric calibration and lifetime stability monitoring.

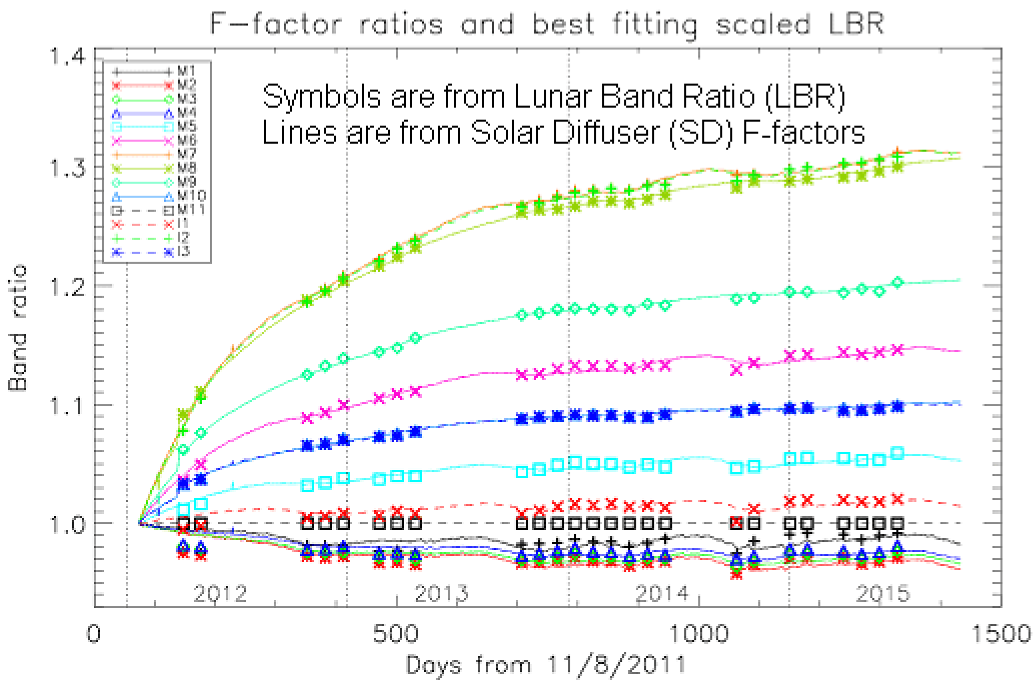


Figure 1: Evolution of VIIRS solar diffuser and lunar F-factors for all of VIIRS reflective solar bands.

3. **Developed physics-based model to trend spectral dependent degradation of the solar diffuser on Suomi-NPP VIIRS due to surface roughness-induced Rayleigh scattering**. The VIIRS onboard SNPP uses a solar diffuser (SD) as its radiometric calibrator for the reflective solar band calibration. On-orbit changes in VIIRS SD reflectance as monitored by the Solar Diffuser Stability Monitor showed faster degradation of SD reflectance for 0.4 to 0.6 µm channels than the longer wavelength channels. Analysis of VIIRS SD reflectance data show that the spectral dependent degradation of SD reflectance in short wavelength can be explained with a SD Surface Roughness (length scale << wavelength) based Rayleigh Scattering (SRRS) model due to exposure to solar UV radiation and energetic particles. The characteristic length parameter of the SD surface roughness is derived from the long term reflectance data of the VIIRS SD

and it changes at ~tens nanometer level over the operational period of VIIRS (Figure 2). This estimated roughness length scale is consistent with the experimental result. This novel approach allows us to better understand the physical processes of the SD degradation.

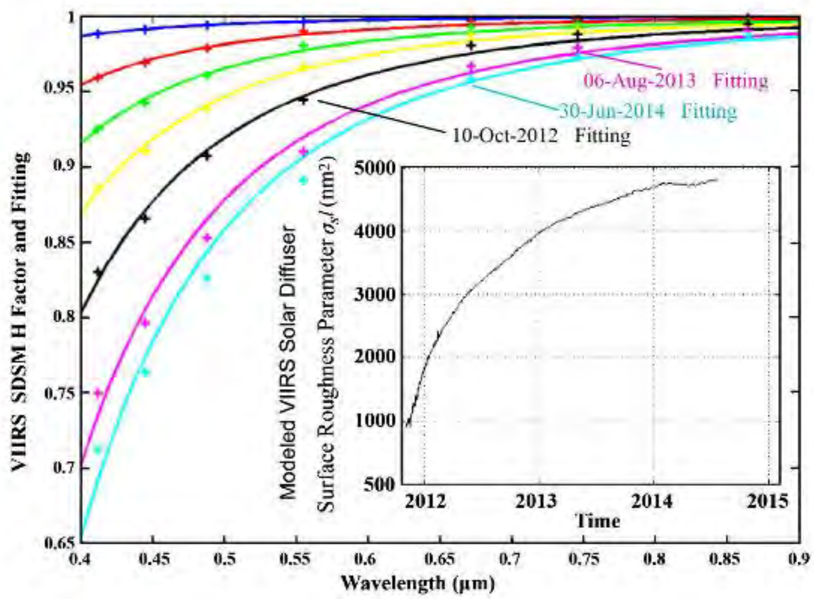


Figure 2: Modeling of Suomi-NPP VIIRS solar diffuser spectral reflectance with the Surface Roughness-induced Rayleigh Scattering (SRRS) reflectance correction model at several instants during the operation of VIIRS. Inset: Trending of characteristic parameter growth of VIIRS solar diffuser surface roughness.

4. **Performed assessment of straylight correction performance for VIIRS day/night band using Dome-C and Greenland under lunar illumination**. The straylight effect was observed in the DNB band which appeared as gray haze in radiance images. Straylight correction techniques have been implemented to remove this effect. This study presented an effective method to assess performance of straylight correction for VIIRS DNB band using DNB observations over Dome C in the Antarctic and Greenland in the Arctic under lunar illumination. Through cross-comparison between lunar-phase dependence of DNB observations of events with straylight correction and those without straylight, the quality of straylight correction has been assessed. Using this method, DNB radiance data from two different sources, i.e. the NOAA IDPS and the NASA Land PEATE, are compared for their performance in straylight correction.
5. Performed comparison of Suomi-NPP VIIRS and Himarwari-8 AHI MWIR observations for hot spot and heat island studies.

6. Performed assessment of scan-angle dependent radiometric bias of Suomi-NPP VIIRS day/night band from night light point source observations.

7. Support VIIRS SDR team management and coordination
   a. *Organize and archive weekly and monthly status reports.*
   b. *Update VIIRS event database and knowledge-base.*
   c. *Document the VIIRS sensor status, calibration and validation progress, and the recommendation on the VIIRS sensor operation, software change, and look-up table update to NPP/JPSS management.*
   d. *Maintain computer server at UMD for VIIRS data processing for the VIIRS SDR team*

Publications:

Peer-Reviewed:

1. Choi, T.; Shao, X.; Cao, C.; Weng, F. Radiometric Stability Monitoring of the Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS) Reflective Solar Bands Using the Moon. *Remote Sens.* 2016, *8*, 15.
2. Datla, R.; Shao, X.; Cao, C.; Wu, X. Comparison of the Calibration Algorithms and SI Traceability of MODIS, VIIRS, GOES, and GOES-R ABI Sensors. *Remote Sens.* 2016, *8*, 126.
3. Meng Fei, Xin Jinyuan, Cao Changyong, Shao Xi. Seasonal variations of aerosol optical thickness over eastern China determined from VIIRS and ground measurements, International Journal of Remote Sensing., Accepted, 2016.
4. Shao, X.; Cao, C.; Liu, T.-C. Spectral Dependent Degradation of the Solar Diffuser on Suomi-NPP VIIRS Due to Surface Roughness-Induced Rayleigh Scattering. *Remote Sens.* 2016, *8*, 254.
5. Wang, Likun, Denis Tremblay, B. Zhang, Yong Han, 2016. Fast and Accurate Collocation of the Visible Infrared Imaging Radiometer Suite Measurements with Cross-track Infrared Sounder. Remote Sensing, *8*(1), 76, doi: 10.3390/rs8010076.

Non-Peer-Reviewed:

1. Shi Qiu, Xi Shao, Changyong Cao, Wenhui Wang, Vicarious validation of straylight correction for VIIRS day/night band using Dome-C. Proc. SPIE 9607, Earth Observing Systems XX, 96072H (September 8, 2015);

Presentations:

1. Shi Qiu, Xi Shao, Changyong Cao & Wenhui Wang, Vicarious validation of straylight correction for VIIRS Day/Night Band using Dome-C, NOAA Satellite Conference, Greenbelt, MD, April 27 - May 1, 2015.
2. Yan Bai, Changyong Cao, Xi Shao, Assessment of scan-angle dependent radiometric bias of Suomi-NPP VIIRS day/night band from night light point source observations, STAR JPSS 2015 Annual Science Meeting, College Park, *MD, August 24-28, 2015.*
3. Shao X, Cao C, Liu T-C, Zhang B, Fung S and Sharma S, Radiometric Quantification of Aurora Activities during Severe Geomagnetic Storms from SNPP VIIRS Day-Night Band Observations, 2015 AGU Fall Meeting, San Francisco, CA (2015).

Others:

Award: Yan Bai, Bin Zhang and Xi Shao received 2015 NOAA NESDIS Award for achieving significant advances in critical areas of Visible Infrared Imaging Radiometer Suite Day/Night Band development, including JPSS-1 waiver mitigation, operational straylight correction, and geolocation capability development and validation.

PERFORMANCE METRICS

Performance Metrics	
# of new or improved products developed	0

# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	5
# of non-peered reviewed papers	1
# of presentations	3
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

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

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

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

Link to a research web page

Background

The Geostationary Operational Environmental Satellites – R Series (GOES-R) is the next generation of geostationary Earth-observing systems. The advanced spacecraft and instrument technology employed by the GOES-R series will provide significant improvements in the detection and observations of environmental phenomena that directly affect public safety, protection of property and our nation's economic health and prosperity. The first satellite in the GOES-R series is scheduled for launch in 2016. Instrument calibration, characterization, and validation are essential to GOES-R mission success and the production of high-quality data products. The Advanced Baseline Imager (ABI) is a critical instrument onboard GOES-R and was designed to provide high quality data with radiometric uncertainties within 5% for the Reflective Solar Bands (RSB), and within 1 K for the Thermal Emissive Bands (TEB). Unlike the heritage GOES imagers the SI traceability of ABI was established during pre-launch testing.

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

Accomplishments

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

1. System design and procurement
   The system includes an UAS, a UAS flight controller (Pixhawk) to control the path and record geology related metadata, a Raspberry Pi to handle the data acquisition process and various sensors and parts. The design integrates various sensors on the UAS including visible-and-near-infrared (VNIR) spectrometer, shortwave-infrared (SWIR) spectrometer, temperature and humidity sensor, barometer, etc. So far we arranged procurement of VNIR spectrometer (Ocean Optics, model Flame-S-VIS-NIR-ES), SWIR spectrometer (ArcOptics, model Rocket 0.9-2.6 w/ DSP), thermopile sensor (Apogee, model SI-411), several lab equipment and accessories from Thorlabs, TE Technology, BBN, InterMet, etc.
2. Sensor integration
   As a major part of our tasks, sensor integration could be separated into different subtasks and are further described below
   a. Sensor module integration design
      We have designed the system of integrating micro-computer with spectrometer for the payload on UAS.
   b. 3D printed sensor cases for UAS payload integration design
      We utilized the 3D printer in our lab to print cases of the sensors according to their individual sizes, which is helps designing the arrangement of the sensors on the UAS.
   c. Sensor integration with Raspberry Pi
      We developed system capable of measuring and recording data with Raspberry Pi. The system consists of data acquisition from connected sensors (including spectrometers, GPS sensor, temperature/humidity sensor and barometer), onboard data recording with SD card and wifi linkage and communication.
   d. Data exporting and reading
      First we used Windows-based OceanView Software and successfully exported data to file and control integration time. However, this software could not be executed on Raspberry Pi. As an alternative, we customized the Linux-based software SeaBreeze, and successfully integrated the spectrometer into our system. We then executed it on Raspberry Pi and recorded the data on SD card.
   e. Remote control and data transfer wirelessly
      When Raspberry Pi is connected to the internet via wifi dongle, controlling the data collecting process and sending data back could be done remotely on local computer. We have successfully acquired internet connection via the wifi dongle and used the acquisition code to record the spectrum evolution data.

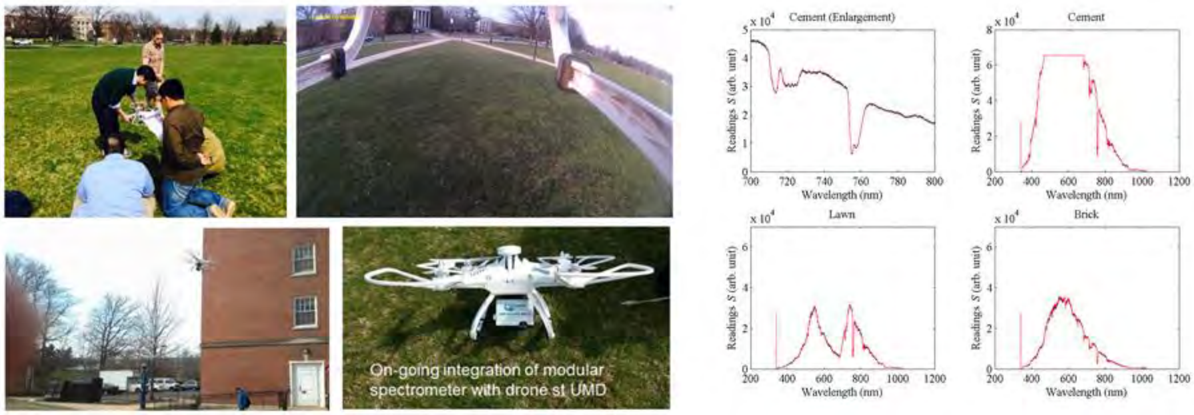


Figure 2: (Left) Testing flight with drone at UMD; (Right) measurement of spectra over different surface types with the integrated modular system consisting of the micro-computer Raspberry Pi and VNIR spectrometer.

f. VNIR spectrometer for UAS integration
The sensor we have for testing is Ocean Optics USB2000+VIS-NIR-ES modular spectrometer. It is a versatile, general-purpose UV-Vis-NIR spectrometers for absorption, transmission, reflectance, emission, color and other applications featuring compact size, robust optoelectronics and easy modularity. The spectral range of our module is 350 nm to 1000 nm. The data shown in Figure 1 is acquired using this module.

3. Arranged meeting and held discussion with Maryland UAS test site with UAV Solutions Inc. for system design and UAS test arrangement

4. Performed analysis of Open geospatial consortium (OGC) standards for sensor data archiving
The OGC standards can be used for Drones/Copters or any other device for reporting sensor data from the temperature sensor, pressure sensor, geolocation sensor, humidity sensor, spectrometer and other sensors. These standards for data analysis and data recording have one standard format throughout the world and can be used by even a layperson to understand and analyze the information obtained. OGC currently has three main operating zones: North America, Europe and India. We have performed analysis OGC standards for formatting our sensor data according to such a standard.

5. UAS test planning with Mission Planner
Mission Planner software has been used to plan the path for UAS testing and interfacing with port on UAS. Regarding path viewing on local computer with internet access, it also supports route planning shown on Google Maps. Furthermore, we have also conducted route simulations at typical locations including a desert, a water terrain, UMD UAS test site (the one shown on Figure 2), etc. with various parameters.

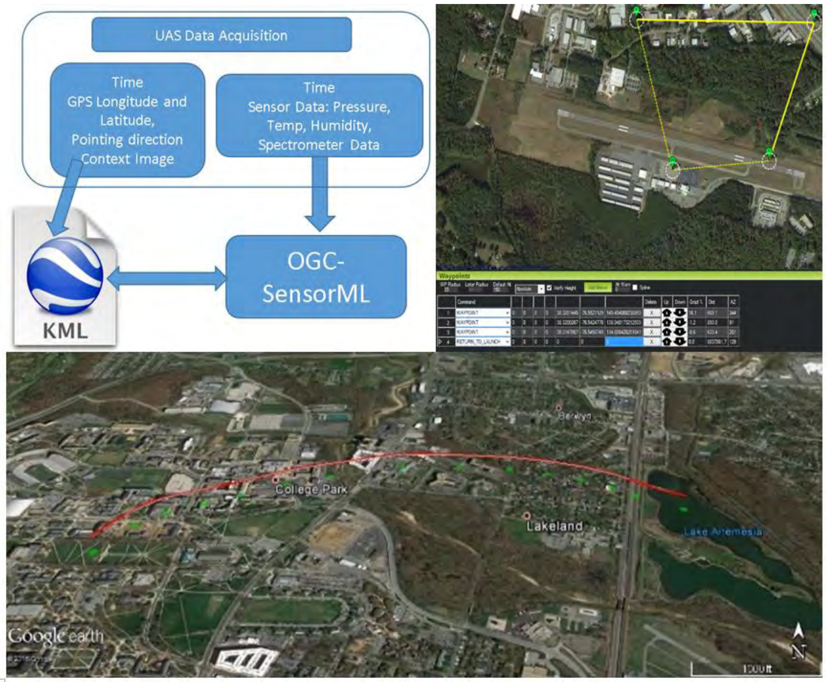


Figure 3: UAS data acquisition flow chart shown on top-left, with an exemplary path around College Park assigned in a KML file shown on bottom and one around the UMD UAS test site assigned in mission planner shown on top-right.

Planned work

We will continue to support the GOES-R near-surface Unmanned Aircraft System (UAS) feasibility demonstration study.

- Support GOES-R near-surface UAS design
- Perform hardware procurement for the prototype GOES-R UASs
- Support Development of Payload Hardware and Navigation/Pointing/ Data Acquisition Control Software for GOES-R UAS
  - Integration of spectrometer with onboard programmable firmware
  - Sensor-pointing direction determination
  - Navigation and gimbal pointing control software development
  - Onboard data collection and wireless communication
- Support the Integration and Initial Testing of GOES-R UAS
- Support GOES-R Near-Surface UAS Field Campaign Planning

Presentations

1. Xi Shao, Yan Bai, Changyong Cao, Field Campaign Support Capabilities at University of Maryland STAR JPSS 2015 Annual Science Meeting, College Park, MD, August 24-28, 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	
# of non-peered reviewed papers	
# of presentations	1
# of graduate students supported by a CICS task	1
# of graduate students formally advised	
# 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.

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 DNB radiometric and geolocation validation with nightlight sources and performed assessment of scan-angle dependent radiometric bias of Suomi-NPP VIIRS day/night band from night light point source observations. To evaluate the DNB radiometric response versus scan angle, we selected ground based night light sources. Analysis of night lights from DNB led us to focus on bridge lights and oil platforms (Figure 1). Results show that there appears to be a scan angle dependent radiometric bias, with a

low radiance at nadir while gradually increases towards edge of the scan. This pattern is found in both the San Mateo bridge and the oil platform holly samples, although it is less clear for the Arizona power plant and Bahrain cases. It is possible that this effect is due to the VIIRS DNB aggregation zones on Suomi NPP VIIRS, which would also help study the effect of J1 VIIRS DNB nonlinearity at high scan angles, which requires the use of new aggregation modes. Other effects such as atmospheric path length and light on/off schedule as well as traffic volume may also contribute to this pattern. We found that the point sources over water have the clear advantage than the ground base point sources for the radiance and geolocation validation analysis since there is little reflection from the water and this reduces the uncertainties compare with the ground point source. Results are published in SPIE paper.

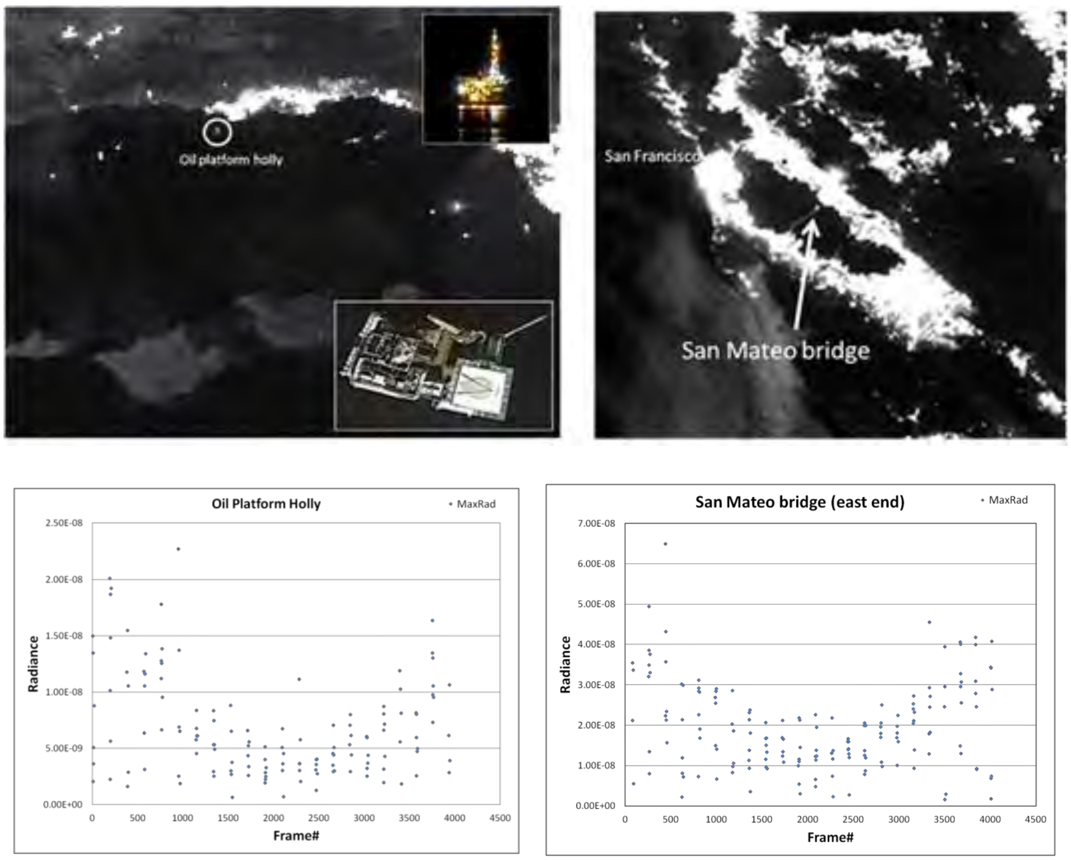


Figure 1: Top: Example of night lights from the oil platform Holly located near Los Angeles and San Mateo bridge. The lights appear to be always on at night and are relatively stable as a point source for DNB radiance and geolocation analysis. Bottom: Radiance vs. scan angle for those two sites.

2. Supported development of Suomi NPP VIIRS calibration knowledge base for SDR data quality assurance, anomaly investigation, and EDR applications.
3. Supported inter-comparison of SNPP/VIIRS longwave infrared channels using hyperspectral radiance from GOSAT FTS and MetOp-A IASI. Results are presented in Calcon meeting. The VIIRS has four longwave infrared bands (I5, M14, M15 and M16). Comparing Hyper-spectral radiance measurements from Greenhouse Gases Observing SATellite (GOSAT) and with VIIRS measurements can improve our understanding of calibration of each sensor and Infrared Atmospheric Sounding Interferometer(IASI) can reduce the gap between different datasets from different sensors by removing the calibration caused

bias in constructing climate data record. In our study, the GOSAT FTS and IASI hyper-spectra radiance have been used to simulate the three VIIRS M band radiance over Simultaneous Nadir Overlapping area and then compared with the VIIRS observations. Through inter comparison, we can estimate the bias between two sensors and further investigate the cause of this mismatch by looking into the calibration errors (Figure 1).

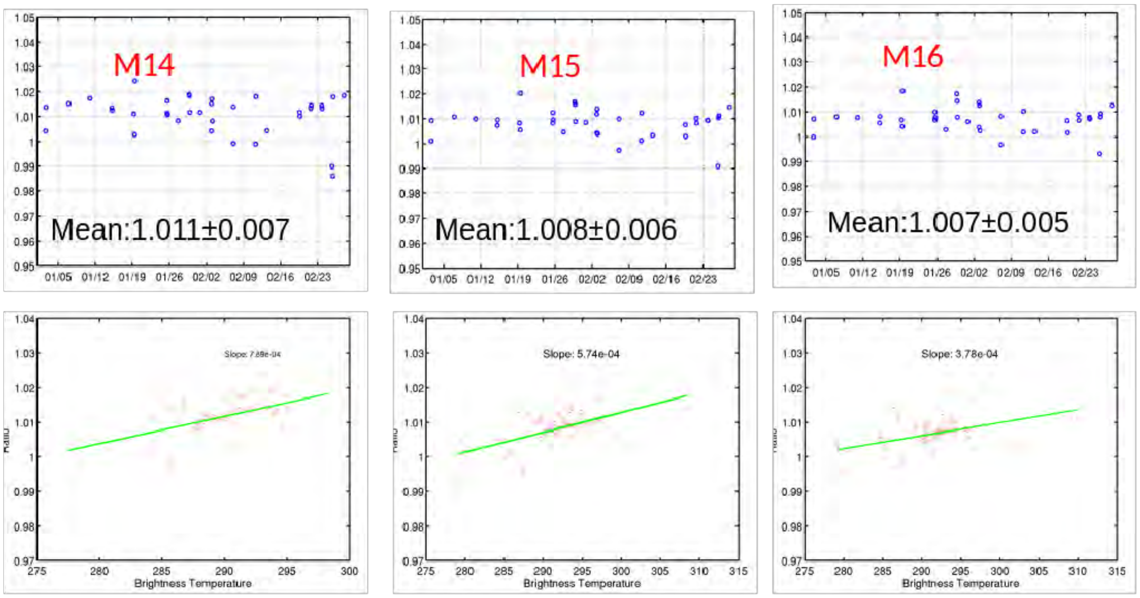


Figure 1: FTS simulated VIIRS radiance compared with VIIRS radiance over SNO locations

4. Supported analysis of ADL Common Geolocation Package and presented a talk to NOAA/NESDIS/STAR SMCD on SNPP geolocation algorithm. Investigated calculation of inclination angle of SNPP on ECEF and ECI coordinate system to illustrate the angle difference in these two different coordinate systems.
5. Supported DNB stray light correction software development through automation of IDL codes for generation and validation of DNB stray light correction LUT.
6. Supported analysis of VIIRS solar diffuser spectral dependent degradation and build models to simulate solar diffuser reflectance degradation due to surface roughness-induced Rayleigh scattering after exposure to space radiation.
7. 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.
8. Performed Vicarious validation of Suomi-NPP/VIIRS Day/Night Band using DOME-C and Greenland under moon-light and results are reported in journal paper.
9. We are maintaining a data sever to support calibration working group for processing, archiving and backup of public data for calibration of VIIRS.

Planned Work

None

Publications:

Peer-Reviewed:

1. Jing, X.; Shao, X.; Cao, C.; Fu, X.; Yan, L. Comparison between the Suomi-NPP Day-Night Band and DMSP-OLS for Correlating Socio-Economic Variables at the Provincial Level in China. *Remote Sens.* **2016**, *8*, 17.
2. Fei Meng, Changyong Cao, **Xi Shao**, Spatio-temporal variability of Suomi-NPP VIIRS-derived aerosol optical thickness over China in 2013, Remote Sensing of Environment, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2015.03.005, 2015.
3. Shi Qiu, Xi Shao, Changyong Cao, and Sirish Uprety, "Feasibility demonstration for calibrating Suomi-NPP visible infrared imaging radiometer suite day/night band using Dome C and Greenland under moon light". Journal of Applied Remote Sensing, paper No. 15219RP, 2016.

Non-Peer-Reviewed:

2. Yan Bai, Changyong Cao, Xi Shao, "Assessment of scan-angle dependent radiometric bias of Suomi-NPP VIIRS day/night band from night light point source observations", in Earth Observing Systems XX, James J. Butler; Xiaoxiong (Jack) Xiong; Xingfa Gu, Editors, Proceedings of SPIE Vol. 9607 (SPIE, Bellingham, WA 2015), 960727.
3. Xi Shao, Changyong Cao, Tung-chang Liu, Bin Zhang, Wenhui Wang, Shing F. Fung, "Auroral activities observed by SNPP VIIRS day/night band during a long period geomagnetic storm event on April 29-30, 2014", in Sensors, Systems, and Next-Generation Satellites XIX, Roland Meynart; Steven P. Neeck; Haruhisa Shimoda, Editors, Proceedings of SPIE Vol. 9639 (SPIE, Bellingham, WA 2015), 963921.

Presentations:

1. Xi Shao, and Changyong Cao, Solar Diffuser Degradation due to Surface Roughness Change, NOAA NCC / NIST Calibration Workshop, July 10, 2015,
2. Xi Shao, Yan Bai, Changyong Cao, Field Campaign Support Capabilities at University of Maryland, STAR JPSS 2015 Annual Science Meeting, College Park, MD, August 24-28, 2015.
3. Liu T-C, Shao X, Cao C, Zhang B, Fung S and Sharma S, Aurora Activities Observed by SNPP VIIRS Day-Night Band during St. Patrick's Day, 2015 G4 Level Geomagnetic Storm, 2015 AGU Fall Meeting, San Francisco, CA (2015).
4. Bin Zhang and Changyong Cao, Inter-comparison of SNPP/VIIRS Longwave Infrared Channels Using Hyperspectral Radiance from GOSAT FTS and MetOp-A IASI (poster), CALCON meeting, Logan, Utah, 08/2015.

Others:

Award: Yan Bai, Bin Zhang and Xi Shao received 2015 NOAA NESDIS Award for achieving significant advances in critical areas of Visible Infrared Imaging Radiometer Suite Day/Night Band development, including JPSS-1 waiver mitigation, operational straylight correction, and geolocation capability development and validation.

Performance Metrics	
# of new or improved products developed	0

# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	3
# of non-peered reviewed papers	2
# of 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

CUNY Creating Calibrated UTH-Related FCDRs from IR and Microwave Sensors

Task Leader:	**Zhengzhao Johnny Luo**
Task Code:	**ZLZL_FCDR_14**
NOAA Sponsor:	**NCEI CDR program**
NOAA Office:	**NESDIS**
Contribution to CICS Research Themes (%)	**Theme 1: 100%**
Main CICS Research Topic:	**Calibration and Validation**
Contribution to NOAA goals (%)	**Goal 1: 100%**
Highlight	

Link to a research web page: www.sci.ccny.cuny.edu/~luo

Background

The objective of this project is to continue working on a climate data record (CDR) project, which was funded through the NOAA CDR program from 2010-2014 (the original funding ended in April 2014). The purpose of the original CDR project is to "bring together all the upper-tropospheric humidity (UTH)-relevant radiance data from multiple satellites and process them to establish a long-term, global radiance record from which a climate data record (CDR) of UTH can be retrieved and UTH research may be conducted". Since HIRS-based IR UTH CDR has already been developed and is now operational at NCDC (Shi and Bates 2011), emphasis of this project is placed on microwave sensors, especially SSM/T2, that have not been well archived and calibrated before. Microwave-based UTH measurements have the advantage of not easily contaminable by clouds (except very thick high clouds like those associated with deep convection). To make the dataset more useful for future research, we also appendeded the ISCCP cloud properties and IR UTH radiances from geostationary satellites (GEOs).

Accomplishments

The main accomplishments of this CDR project are as follows.

- Re-archived and inter-calibrated raw SSM/T2 data
- Matched IR UTH radiances from GEOs to SSM/T2
- Appended ISCCP cloud properties (so that one can better interpret UTH radiances in future applications)

During the past year (April 1 2015 – March 31 2016), we focused on preparing for transition of our CDR product to the NCEI. Specifically, we followed the CDR requirements and wrote up a draft documentation. Also, we made changes of the data format to comply with the requirements set by the CDR program. Because our scheduled transition time is 2017 (due to a backlog at the NCEI), we were not able to feed our data to the NCEI archive yet. In August 3-7, 2015, we attended the CDR meeting at Asheville and presented our results (Luo et al. 2015).

Planned work

We will continue to work with NCEI to make sure our CDR products are transitioned to their archive (which is scheduled to 2017). Meanwhile, we are also collaborating with

Products

The MW-based UTH CDR product is still in-house. We are waiting for NCEI to schedule a transition, which is currently scheduled to 2017.

Presentations

Luo, Z. J. , J. Jeyaratnam, W. B. Rossow, 2015: Creating Calibrated UTH-Related FCDRs from IR and Microwave Sensors, NOAA Climate Data Record Program Annual Meeting, NCEI Asheville, NC, August 3 – 7, 2015

Other

A graduate student from an under-represented group (Ms. Nazia Shah) has been trained under this project. Nazia has spent 10 weeks at NESDIS and worked with Ralph Ferraro and his team to compare SSM/T2 and AMSU-B data. She is now writing up her MS thesis which is based on the CDR project.

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**

A Terrestrial Surface Climate Data Record for Global Change Studies

Task Leader Eric Vermote
Task Code CJCJ_AVHRR_15
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: 100%

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

Background

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

Accomplishments

- Release of the full 30+ record including the LAI/FAPAR TCDR (AVH15 products) algorithm (see Figure 2)
- Near Real Time algorithm transitioning for AVH09, AVH13 and AVH15 products

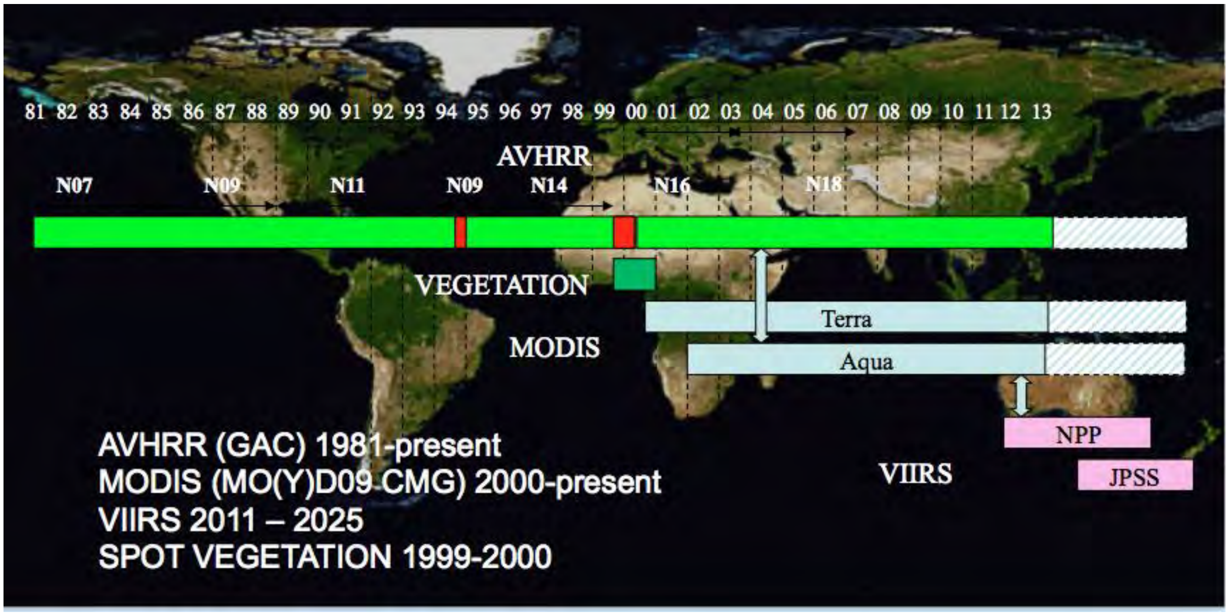


Figure 1: The generation of a Land climate data record (several decade) necessitates the use of multi instrument/multi sensor science quality data record. This record is used to quantify the trend and change in land surface parameter (e.g. Vegetation/Land Cover). A strong emphasis is put on data consistency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

Performance Metrics	**FY16**
# of new or improved products developed	3
# of products or techniques transitioned from research to ops	3
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	5
# of graduate students supported by a CICS task	N/A
# of undergraduate students supported by a CICS task	1

Planned Work

This is the final report.

Publications

Jyoteshwar R. Nagol, Eric F. Vermote, Stephen D. Prince, (2016) Assessment of Uncertainty in LTDR AVHRR NDVI data, Remote Sensing of the environment, submitted after revisions.

Claverie M., Matthews J., Vermote E., Justice C., (2016) "A 30+ year AVHRR LAI and FAPAR climate data record: algorithm description, validation", Remote Sensing (in press)

Presentations

Vermote et al., "Land Long Term Climate Data Record from AVHRR, MODIS and VIIRS", AMS 96th Annual meeting, New Orleans, LA, Jan 10-14, 2015.

Vermote et al., "Toward daily global monitoring of agriculture from space using AVHRR, MODIS, and VIIRS data" at the SED seminar Earth Sciences Division, Nov, 6, 2015.

Vermote et al., "Winter wheat production forecast in US from 1982 to present using V4.1 AVHRR LTDR", 1min talk at Town Hall Meeting, Oct, 5, 2015

Vermote et al., "Generic Methods for Cross-calibration and Validation of the Sentinel 3 Surface Reflectance: Descriptions and Applications to MODIS and VIIRS", Sentinel 3 for Science Workshop, Venice, Italy, June 2 - 5, 2015

Vermote et al.," The NOAA/NCDC Surface Reflectance Climate Data Record initiative", MODIS/VIIRS Science Team Meeting, Silver Spring, MD, May 18-21, 2015

3 Surface Observation Networks

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

Task Leader **Belay B. Demoz and Ricardo Sakai**
Task Code **BDBD_GCOS_15**
NOAA Sponsor: M. Goldberg and H. Diamond
NOAA Office : NOAA/STAR
Contribution to CICS Research Themes (%): Theme 2
Main CICS Research Topic: Surface Observation Networks
Contribution to NOAA goals (%): *To understand and predict changes in climate, weather, oceans and coasts*
Highlight
Link to a research page: http.www.gruan.org

Background

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

Accomplishments

- Continue the weekly Vaisala RS-92 and monthly CFH launches, coincident with the overpass of the Suomi National Polar-orbiting Partnership satellite (NPP). We have continued to build the archive of sonde-satellite sounding data base. Soundings were acquired and launched at Beltsville at night to minimize radiation correction and are timed with NPP overpass (figure-1). Once a month, a daytime launch is performed during a NPP overpass and concomitant with a launch coordinated with NWS Sterling. Also, on monthly basis, we have continued launching the Cryogenic Frost-point Hygrometer (CFH) at nighttime.

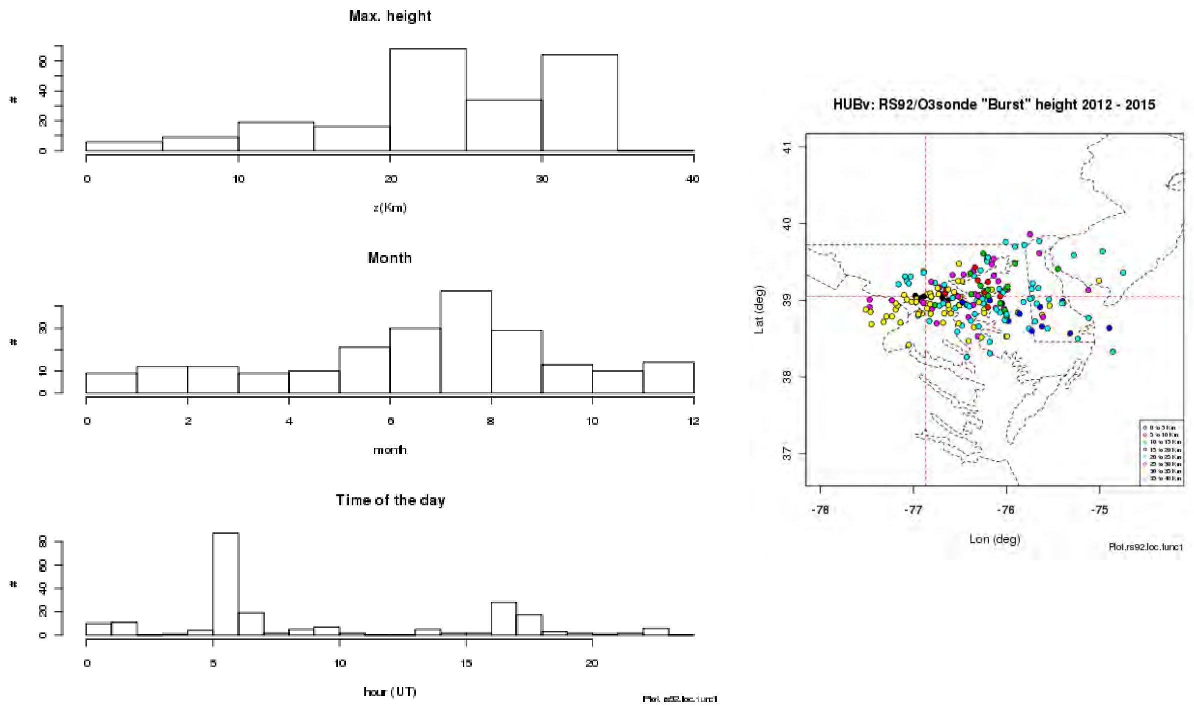
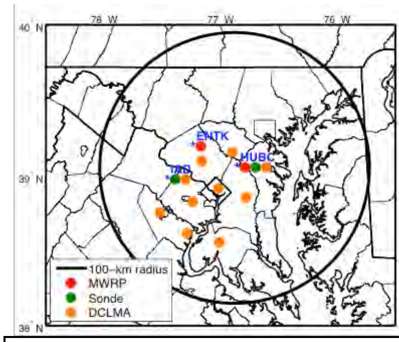


Figure 1: Statistics of RS92 launches at HU Beltsville site: Number of satellite coordinated launches by year; histogram of altitude reached and number of sondes at that altitude; number launched by month and time of day. Also shown is the balloon burst altitude through the years. Finally a distribution of the balloon drift position, color coded with burst altitude is shown.

- Establishing a direct link of data feed for the NOAA Products Validation System (NPROVS+) at NOAA STAR. While Beltsville data is submitted to GRUAN lead center on time, the GRUAN based processing does take time and this delay created processing complications to the NPROVS+ group. A direct communication and delivery with the groups has been established. This archive is expected to grow and include other ancillary remote sensing data sets in the future. NPP-coordinated launch has proceeded without operational interruption. Plot of the statistics of launches so far and QA for each sounding is shown below (figures 2 and 3). A comprehensive review of the radiosonde launches is also in progress as part of GRUAN certification of the HU Beltsville site. This includes firming up NWS collaborations and other personnel issues at the site. Data latency issues with respect to data delivery to NOAA/STAR for NUCAPS and NPROVS+ directory for cal/val use have been solved through use of temporary storage in a computer cloud (Dropbox), sounding data is shared within 7 days after the launch.

- A coordinated sonde launch have been initiated between NWS/Sterling office and Howard University. Sondes are released around local noon at same time from both locations to study spatial -variations. Three sondes have been collected so far but he work will continue and collect statistical data for SASBE studies. The project will also be used as a validation for the recent acquisition of an auto-sonde launcher by NWS/Sterling, VA.



Studies	Koffi et al. [2007]	Chan and Hon [2011]	Madhulatha et al. [2013]	Cimini et al. [2015]	Cimini et al. [2015]	*Pending* Cooper et al. [2016]	*Pending* Cooper et al. [2016]
Radiosonde Launch Site	Bern, Switzerland	Hong Kong, China	Gadanki, India	Whistler, Canada	Lindenberg, Germany	Beltsville, Maryland	Sterling, Virginia
Campaign Period	Jun-Aug 2004	Jun'08-May'09	Jun-Dec 2011	Feb. 2010	May-Jun 2010	Jun-Aug 2012	Jun-Aug 2012
Correlation	*R*	*R*	*R*	*R*	*R*	*R*	*R*
KI	0.35	0.78	0.91	0.88	0.88	0.80	0.77
TT	0.18	0.66	0.58	0.85	0.87	0.56	0.48
LI	0.60	-	0.18	0.91	0.93	0.50	0.78
CAPE	0.35	0.81	0.32	0.57	0.72	0.39	0.74

Figure-2: Correlation of Microwave Radiometer (MWR) derived Atmospheric Instability Indices to that of sonde derived values for Baltimore-Washington, DC region. NWS and HUBRC upper air sondes together with two MWR sites (HUBRC and Earth Networks (Germantown, MD) are used in the study. Further, comparisons of the findings are also compared to published results around the globe. The goal is to link these instabilities to lightning occurrence as measured by the DC-lightning network and future satellite products. Following most commonly used indices are reported: K-Index (KI), Total Totals Index (TT), Lifted Index (LI), Convective Available Potential Energy (CAPE). The paper is part of dissertation work by Dr. Lorenza Cooper, Howard University, and in in progress.

Planned work

- The goals of the project have not changed in terms of data collection.
- Continue the weekly Vaisala RS-92 and monthly CFH launches, coincident with the overpass of the Suomi National Polar-orbiting Partnership satellite (NPP).
- Continue data sharing with NESDIS/STAR personnel for NPROV+ - this data is shared in semi realtime for NOAA scientists to ingest into NPROV validation studies.
- Continue collaboration with GRUAN and submission of all previous radiosonde data sets and continue quality controlling the data archive.
- Continue collaboration with STAR personnel for validation of the EDRs, contributing to and the NOAA/NWS Sterling Testing Facility scientists on CFH training.
- Continue the monthly CFH launches and contribute for the development of the CFH GRUAN data product.

Publications

None for this reporting period

Products
A weekly, Satellite coordinated radiosonde data.

Presentations
Please list

Other
Data and radiosonde launch made possible by this task is used in education and training of graduate students at Howard University. The data is used for dissertation and masters research topic use.

Performance Metrics	
# of new or improved products developed (please identify below the table)[1]	**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	**2**
# of undergraduate students mentored during the year	**2**

[1]the goal of this task is to provide weekly radiosonde launch as part of the NOAA/GRUAN work. These data are continually produced and archived for NOAA/STAR scientist use in satellite validation studies. See figure-1 for the statistics of the data produced so far.

Long-Term Changes in Cloudiness from Surface Observations

Task Leader: Hyelim Yoo
Task Code: HYHY_LTCC_15
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 Observation Networks
Contribution to NOAA goals (%): Goal 1: 50%; Goal 2: 10%; Goal 3: 40%
Highlight: Cloud cover in four state-of-the-art global reanalysis products is compared with a homogeneity-adjusted dataset of total cloud cover from ground observations over the US. The reanalysis products generally capture in simulating the main characteristics of inter-annual variability of cloud cover for long-term means. However, the reanalysis products show lower cloud cover than visual weather station data and this underestimation causes to be overestimated in downward surface shortwave fluxes when compared with the Surface Radiation Network. In addition, the discrepancies in magnitudes of cloud cover trends are seen between the reanalysis products and weather station data.
Link to a research web page: None

Background

Clouds are important in climate and weather forecasting models since they strongly interact with radiation and energy balance. Although considerable efforts have been made to improve cloud representation in models, clouds on a global scale vary from model to model since cloud is not assimilated into models but instead is predicted by models. So cloud cover from models or reanalysis is a subject to errors related to cloud microphysics and parameterizations used in models. Previous studies have compared climatological cloud cover in operational models to satellite cloud data or ground-based remote sensing cloud products. However, only a few papers have reported inter-annual or decadal scales in cloudiness from models or reanalyses to those in observations. We examine total cloud cover in four current reanalysis products from 1979 to 2009 with a homogeneity-adjusted dataset. Also, we assess the relation of biases in cloud cover to biases in surface shortwave fluxes in the reanalysis products.

Accomplishments

The Climate Forecast System Reanalysis (CFSR), the Modern-Era Retrospective Analysis for Research and Applications (MERRA), the European Centre for Medium-Range Weather Forecasts (ECMWF) interim reanalysis (ERA-Interim), and the Japanese 55-year Reanalysis Project (JRA-55) products are used in this work. All reanalyses show lower total cloud cover than the surface observations for all regions which suggests that there may be a bias in cloud-related physics shared by those climate models. The U.S. mean difference is ~9% for MERRA and CFSR, ~15% for ERA-Interim, and ~19% for JRA-55. Reanalysis biases of cloud cover at individual stations vary from slightly positive to -27%. ERA-Interim biases are negative at all stations; the other three reanalyses have negative biases at all but a handful of stations. Biases for 1800 UTC diurnal means from reanalysis data are generally within 3% of those for the entire 24-h cycle, and are sometimes larger despite the observations being more closely matched in time, especially for MERRA. CFSR, ERA-Interim, and JRA-55 tend to give larger annual cycles than those in the station data, while MERRA gives a slightly smaller cycle in the U.S. mean and does not reproduce the summer minimum in cloud cover seen in the station data.

The underestimate of cloud cover in the United States is similar to findings in a number of earlier studies for other regions. We used reanalysis cloud cover for all hours of the day, while our station dataset is limited to daytime hours. However, since results for 1800 UTC are generally similar to those for whole-day means, we conclude that the mismatch of observation times is not a significant source of differences between reanalyses and station data or between different reanalysis products.

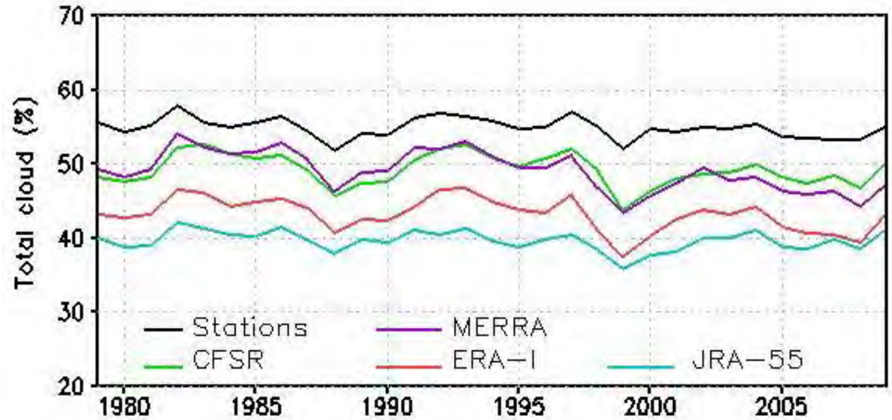


FIG. 1. Annual-mean total cloud cover from four reanalyses and weather station data averaged over 154 U.S. locations using gridded station and reanalysis data.

Pearson correlation coefficients between monthly anomaly time series from reanalyses and weather stations for individual stations (Fig. 2) range from 0.31 for JRA-55 at San Clemente, California, to 0.88 for ERA-Interim at Klamath Falls, Oregon. For all but MERRA, there is a tendency for the best correlations to occur at stations in the Northwest, in Texas, and in the Southeast and the worst in California. For U.S. mean monthly reanalysis time series, correlations with station data are highest for ERA-Interim (0.90) and lowest for MERRA (0.81) (Table 1), with CFSR (0.89) very close to ERA-Interim. The high correlation between the reanalysis products and surface data could be attributed to reliable inter-annual signals from assimilated observations including temperature and moisture that are used in cloud parameterization.

All reanalysis products show the best correlations with station data in the fall or winter and the worst correlations in summer (Table 2). MERRA has much lower correlations in summertime with both military and NWS stations, and this appears to be the primary reason for its lower overall correlation. The poorer correlations in summer and in California, which are also shown in satellite cloud products, could be related to greater small-scale spatial or temporal variability in cloud cover captured by the weather stations, or to issues with the representation of specific cloud types that are more common in summer and in certain regions. Specifically, small cumulus clouds tend to be more frequent in the summer, and those clouds are more likely to be ‘‘seen” differently by observers than by a model or satellite, whereas the stratus clouds that are common in the winter are more likely to produce similar estimates from both top-down and ground observers.

Examination of low and high cloud cover or individual cloud types might help indicate the reasons for differences between reanalyses and station data. However, individual cloud types similar to those recorded by weather observers are not generally available from reanalyses, and the availability of low cloud and other cloud type information from the U.S. weather stations is much more limited since the 1990s than before then, making such comparisons difficult.

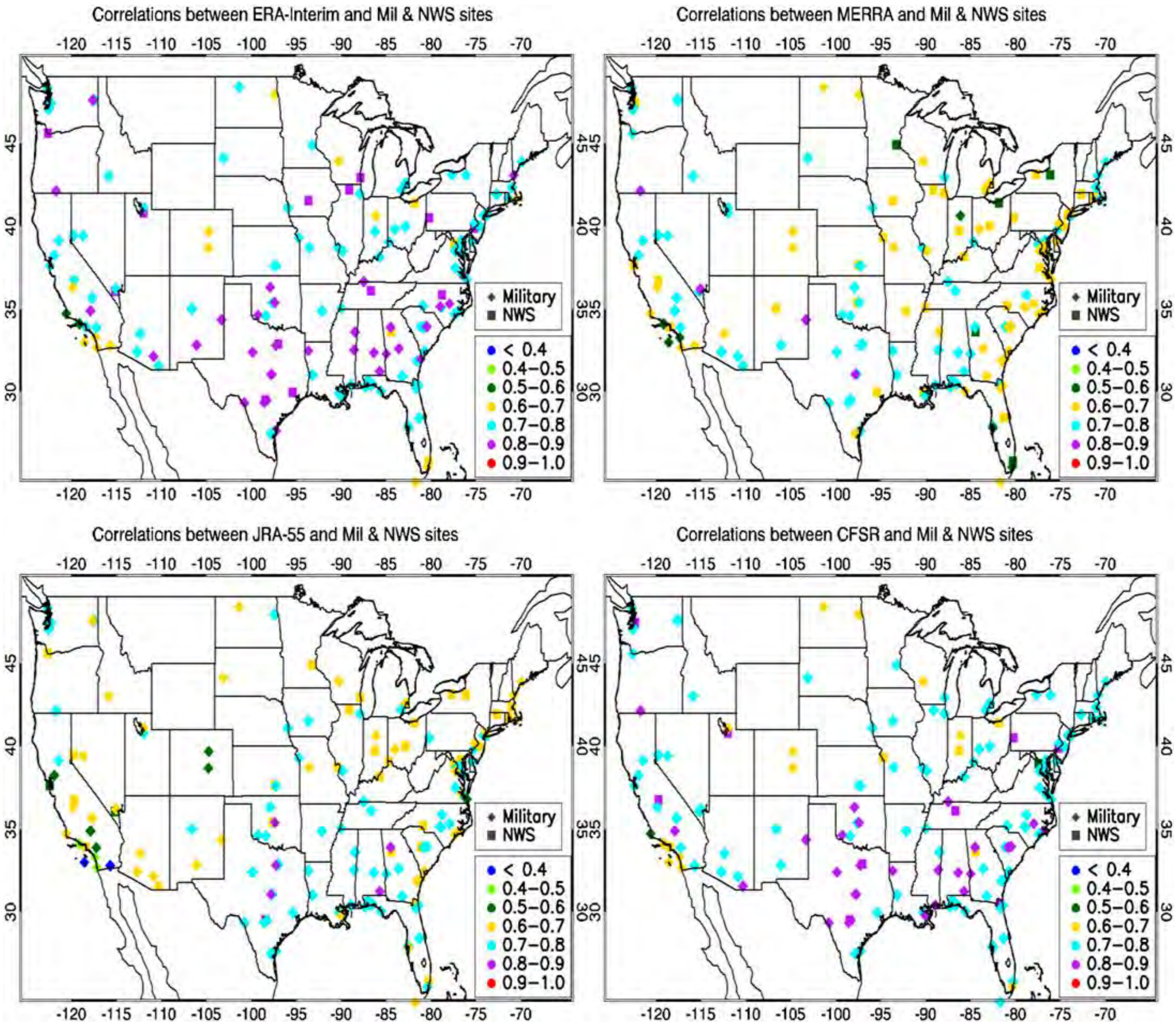


FIG. 2. Correlations between reanalysis total cloud cover time series and weather station data for U.S. locations for 1979–2009.

Planned work

- This project has ended.

Publications

Free, M. Sun, B., Yoo, H., (2016) Comparison between Total Cloud Cover in Four Reanalysis Products and Cloud Measured by Visual Observations at U.S. Weather Stations. *J. Clim.,* DOI: http://dx.doi.org/10.1175/JCLI-D-15-0637.1.

Sun, B., Free, M., Yoo, H., Foster, M., Heidinger A., Karlsson, K. (2015) Variability and trends in U.S. cloud cover: ISCCP, PATMOS-x, and CLARA-A1 compared to homogeneity-adjusted weather observations. *J. Clim.,* 28, 4373-4389.

Presentations

- This work was presented in the annual 2016 AMS meeting

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

AOSC Support for Air Quality Projects at the Air Resources Laboratory

Task Leader Russ Dickerson
Task Code RDRD_AQS_14 & RDRD AQS_15 (Summary)
NOAA Sponsor Rick Artz
NOAA Office OAR/ARL CUMULATIVE HEADING
Contribution to CICS Research Themes (%) Theme 1: 0%, Theme 2: 33%, Theme 3: 67%
Main CICS Research Topic: Surface Observation Networks
Contribution to NOAA goals (%) Goal 1: 3%, Goal 2: 57%, Goal 3: 40%

CUMULATIVE 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	3
# of peer reviewed papers	36
# of non-peered reviewed papers	5
# of invited presentations	48
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Annual Report
CICS ARL Projects
R. R. Dickerson, Team Leader

1. Tianfeng Chai
2. Alice Crawford
3. Paul Kelly
4. Hyun Cheol Kim
5. Fong Ngan
6. Li Pan
7. Xinrong Ren
8. Youhua Tang
9. Daniel QuanSong Tong

Tianfeng Chai
Tianfeng.Chai@noaa.gov

Task Name Participation in Climate Research Activities at the Air Resources laboratory NOAA
Task Leader R.R. Dickerson, R. Draxler, A. Stein
Task Code RDRD_AQS_14 & RDRD AQS_15 (1 of 9)
NOAA Sponsor Air Resources Laboratory, R. Artz
NOAA Office Oceanic and Atmospheric Research
Contribution to CICS Research Themes (%) Theme 1: 0%, Theme 2: 0%, Theme 3: 100%
Main CICS Research Topic: Climate Research, AQ Forecasting and Modeling
Contribution to NOAA goals (%) Goal 1: 0%, Goal 2: 80%, Goal 3: 0%, Goal 4 0%, Goal 5: 20%

NOAA HYSPLIT (HYbrid Single Particle Lagrangian Integrated Trajectory) Inverse Modeling

Task Leader: Roland Draxler /Ariel Stein
Background: The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model developed at NOAA Air Resources Laboratory has been widely used to study the atmospheric pollutant transport and dispersion in both forward and backward modes. Among those applications, the backward trajectory of a single pollutant particle is often used to identify the potential source locations. An improvement can be made by employing the dispersion module to quantify the source strength by utilizing the concentration information.

Accomplishments:

1) After Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) backtracking capability was implemented into NWS (National Weather Service) NCEP (National Centers for Environmental Prediction) on September 30, 2014, it has been operating to provide results to CTBTO requests. The system was also employed for a 2-week operating exercise runs initiated by the CTBTO in late October, 2015. Several updates were made to the system, including allowing more meteorological files and longer run time (currently not in operational version, but being tested in the parallel version). A new feature of generating KMZ/KML files for GOOGLE Earth displays is also added.
2) A HYSPLIT inverse system to assimilate MODIS satellite retrieval of ash cloud top height and mass loading has been developed. Using the 2008 Kasatochi eruption as an example, the system can estimate the volcanic ash emissions as a function of time and height.
3) Participated in an atmospheric transport modeling (ATM) challenge to predict the impact of radioactive xenon releases from medical isotope production on a CTBTO sampling station. Our HYSPLIT modeling results were included in a summary paper that has been accepted for publication.

Planned Work: Continue to support NWS in CTBTO backtracking capability test and future operations. Complete the volcanic ash emission inversion system development. Summarize and document results for the 2008 Kasatochi eruption test. Further develop the HYSPLIT inverse system and test it with more applications.

Publications

1. "Premature deaths attributed to source-specific BC emissions in six urban US regions," by M. D. Turner, others, and **T. Chai,** *Environ. Res. Lett.,* **10**, 114014, *doi:10.1088/1748-9326/10/11/114014*, 2015

2. "Using optimal interpolation to assimilate surface measurements and satellite AOD for ozone and $PM_{2.5}$: A case study for July 2011," by Y. Tang, **T. Chai**, L. Pan, P. Lee, D. Tong, H.C. Kim, and W. Chen**,** *J. Air Waste Manage. Assoc.,* **65**(10), pp. 1206-1216, *doi:10.1080/10962247.2015.1062439*, 2015

3. "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

4. "Potential Use of Transport and Dispersion Model Ensembles for Forecasting Applications," by Stein A. F., F. Ngan, R. R. Draxler, and **T. Chai,** *Weather and Forecasting, doi:10.1175/WAF-D-14-00153.1*, 2015

5. "Improved Western US Background Ozone Estimates via Constraining Non-local and Local Source Contributions using Aura TES and OMI Observations," by Huang, M., K. W. Bowman, G. R. Carmichael, M. Lee, **T. Chai,** S. N. Spak, D. K. Henze, A. S. Darmenov, A. M. da Silva, *J. Geophys. Res, doi:10.1002/2014JD022993*, 2015

6. "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

7. "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

Presentations:

1. "HYSPLIT inverse modeling" by **Chai, T.**, and A. Stein, *4th Annual CICS-MD Science Meeting*, College Park, Maryland, USA, November 23-24, 2015.
2. "Development of HYSPLIT inverse modeling technique to improve particulate matter ($PM_{2.5}$) forecasts in the US" by **Chai, T.**, and A. Stein, *7th International Workshop on Air Quality Forecasting Research (IWAQFR)*, College Park, Maryland, USA, September 1-3, 2015.
3. "Estimation of radionuclide releases from the Fukushima nuclear accident using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model and the International Monitoring System (IMS) air concentration measurements" by **Chai, T.**, R. Draxler, A. Stein, *CTBT: Science and Technology 2015 Conference (SnT2015)*, Vienna, Austria, June 22-26, 2015.
4. "Improve volcanic ash simulation with Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) dispersion model by assimilating satellite observations" by **Chai, T.**, A. Crawford, B.

Stunder, R. Draxler, M. J. Pavolonis, and A. Stein, *2015 NOAA Satellite Conference*, Greenbelt, Maryland, USA, April 27 - May 1, 2015.

5. "Evaluate and constrain modeled ozone and its source contributions in the US using satellite trace gas observations" by Huang, M., K. Bowman, G. Carmichael, M. Lee, D. Fu, **T. Chai,** D. Tong, P. Lee, and Y. Tang, *2015 NOAA Satellite Conference*, Greenbelt, Maryland, USA, April 27 - May 1, 2015.

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	**7**
# 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**

Alice Crawford

Task Name Participation in Climate Research Activities at the Air Resources laboratory NOAA
Task Leader R.R. Dickerson
Task Code RDRD_AQS_14 & RDRD AQS_15 (2 of 9)
NOAA Sponsor Air Resources Laboratory
NOAA Office Oceanic and Atmospheric Research
Contribution to CICS Research Themes (%) Theme 1: 0%, Theme 2: 0%, Them3: 100%
Main CICS Research Topic: Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%) Goal 1: 0%, Goal 2: 80%, Goal 3: 20%
Highlight
Link to a research web page http://www.arl.noaa.gov/VolcAsh.php

Background

Dr. Alice Crawford works on volcanic ash applications for the HYSPLIT pollutant transport and dispersion model.

(1) NOAA/ARL provides support to Volcanic Ash Advisory Centers (VAACs) in Washington and Anchorage, which run HYSPLIT operationally to help produce ash forecasts for aviation. Because many volcanoes are located in remote areas, forecasters rely heavily on space-based instruments to observe eruptions and the resultant ash clouds. Improved algorithms in which use data from passive imaging sensors on satellites to identify the spectral signature of ash and then retrieve properties of the ash cloud such as mass loading have been developed at NESDIS as well as other organizations. NOAA/ARL is developing ways of using this information to produce a better model initialization and to produce model output evaluation metrics to guide model development and inform forecasters of model output uncertainty. Information from space-based lidar is also currently under-utilized as a tool for model evaluation.

(2) Create a volcanic ash resuspension algorithm for HYSPLIT by adapting the current dust resuspension algorithm. The ash resuspension algorithm will be used initially to assess the impact of a potential volcanic eruption of Mt. St. Helens on the nuclear waste management facility at Hanford, WA. This work is being done in partnership with the department of energy (DOE), US Geological Survey (USGS) and the desert research institute (DRI). In the long term, the resuspension algorithm may be utilized by the United States VAAC's to forecast resuspension from ash deposits for aviation purposes.

(3) In the previous year, a proto-type web page for exchanging model information among VAACs was developed and access to the page was given to the IAVWOPSG (International Airways Volcano Watch Operations Group) ad-hoc group for evaluation. IAVWOPSG has since been disbanded and the topic is now under the jurisdiction of the Meteorology Operations Group.

Accomplishments

(1) Dr. Crawford continued to work on using satellite data from the MODIS and CALIOP instruments for the 2008 eruption of Kasatochi in the Aleutian Islands. The accuracy of HYSPLIT output is dependent on the accuracy of the initialization: the initial position, size distribution and amount of ash as a function of time. Satellite observations from passive infrared sensors (MODIS) were used

both to construct the initialization term and for verification. Space-based lidar observations (CALIOP) were used for further verification. Model output produced using different initializations for the 2008 eruption of Kasatochi was compared. Simple source terms such as a uniform vertical line or cylindrical source above the vent were compared to initializations derived from satellite measurements of position, mass loading, effective radius and height located at the observed downwind cloud position. Using satellite measurements of column mass loading of ash to constrain the source term produced better long-term predictions than using an empirical equation relating mass eruption rate and plume height above the vent. Even though some quantities, such as the cloud thickness, had to be estimated, initializations that were located at the position of the observed ash cloud produced model output, which was comparable to or better than the model output produced with source terms located above and around the vent. Lidar data, passive IR retrievals of ash cloud top height, and model output agreed well with each other and all suggested that the Kasatochi ash cloud evolved into a complex three dimensional structure. The results from this study were submitted for publication in the Journal of Geophysical Research Atmospheres.

Dr. Crawford also attended the Intercomparison of Satellite-based volcanic ash retrieval Algorithms within WMO SCOPE-Nowcasting activity meeting in Madison, Wisconsin in June 2015.

(2) A two-year project to assess the impact of a potential volcanic eruption of Mt. St. Helens on the nuclear waste management facility at Hanford, WA was begun. This project is a collaboration between DOE, USGS, DRI and NOAA/ARL. For this project Dr. Crawford will develop and test new ash re-suspension algorithms that will be incorporated into the HYSPLIT modeling system. Work to date has included the following:
   a. Collaborating with the project partners to determine scope of work, information flow, and procedures. NOAA / ARL will use empirical data collected by DRI to develop the resuspension algorithm. NOAA / ARL will use model outputs produced by USGS on possible ash deposit footprints as inputs into the HYSPLIT model.
   b. Identifying datasets to be used for verification.
   c. Identifying areas of HYSPLIT code which will need to be modified
   d. Reviewing and providing feedback on quality assurance documents

(3) Dr. Crawford made changes to the web-site in response to feedback provided by the VAACs in August 2015. The Meteorology Operations Group will take the lead in any further development of the website with NOAA/ARL providing a lesser amount of support as needed.

Planned Work

(1) Explore which types of statistics are best for assessing model skill using satellite analyses of volcanic ash and identify possible ways such assessments may aid forecasters and guide model development.
(2) Develop ash resuspension algorithm for HYSPLIT using historical datasets as well as experimental data provided by DRI.
(3) Develop method to use HYSPLIT model output to provide DOE with an assessment of probabilities of ash concentrations due to resuspension of ash in the event of an eruption of Mt. St. Helens.

Publications

Alice Crawford, Barbara Stunder, Michael Pavolonis, "Initializing HYSPLIT with satellite observations of volcanic ash: A case study of the 2008 Kasatochi eruption." Submitted to *Journal of Geophysical Research, Atmospheres* on 01/11/2016. Currently under review.

Products

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

Presentations

(Invited) NOAA ARL: HYSPLIT and Satellite Observations, Volcanic ash forecasting and other applications. Presented at the CICS-MD Science meeting November 23-24 2015.

Dr. Crawford presented a poster, "Using Satellite Based Volcanic Ash Products to Improve HYSPLIT Transport and Dispersion Model Predictions" at the WMO Seventh International Volcanic Ash Workshop in Anchorage, Alaska from October 19-23.

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

Proto-type of web page for exchanging information between Volcanic Ash Advisory Centers. Developed in previous year. Revised in current year.

Paul Kelly

Participation in Climate Research Activities at the Air Resources Laboratory NOAA

Task Leader	Russ Dickerson
Task Code	RDRD_AQS_14 & RDRD AQS_15 **(3 of 9)**
NOAA Sponsor	Richard Artz
NOAA Office	OAR / ARL
Contribution to CICS 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: 20%; Goal 2: 20%; Goal 3: 60%

A improved standard addition system has been developed that permits standard addition calibration of a commercial Tekran mercury analyzer using the full inlet-to-detector flow path during both the sampling period and desorb periods. Previously only the flow path internal to the 2537B analyzer was calibrated. Testing at our Beltsville, MD site has shown the conversion of element mercury injected at the inlet into fictive particulate mercury during periods of extremely low dew points (< -18 C).

Background:

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

Accomplishments:

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

NOAA / ARL has installed and maintained three ground stations that are devoted to long term monitoring of speciated atmospheric mercury and operates them according to National Atmospheric Deposition Program sampling protocols (AMNET). The site in Beltsville, MD has a 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 2015 was made to the Grand Bay, MS site and to our Mauna Loa, HI site to repair instruments and perform calibrations.

Tekran Hg speciation systems (models 2537B, 1130, 1135) are calibrated by automatic injection of permeation-sourced GEM into a dry air matrix only through the flow path internal the detector. Standard additions using the Tekran 1120 controller can also be performed using the same internal flow into a matrix of ambient air. These standard additions are of limited use for a number of reasons:

- They fail to include the quartz RGM denuder and Regenerable Particulate Filter (RPF), two sample filters, a soda lime trap, a number of couplers & valves, and 16m of heated umbilical tubing in flow path. Any leaks or losses or conversion of GEM into fictive RGM or FPM in this part of the system would not be accounted for using internal standard additions.

- Any matrix or environmental effects on the external system would not be accounted for.

- The internal standard additions during the GEM sampling period suffer from uncertainty generated by the pressure difference between the permeation oven and the gold traps (known as the "Whoosh Effect"). This pressure difference is a function of flow restrictions in the external system (i.e. which denuder or RPF is installed, how loaded are the sample filters, how much soda lime is packed in the traps, etc.), as well as the ambient pressure (altitude) and flow rates.

- Internal standard additions do not correct for changes in the ratio of 2537B sample flow to 1130 pump module flow.

- The Tekran 1120 controller is not programmable for anything more than simple repeats of a single injection at a fixed interval with a fixed injection duration. Back-to-back injections into both Au traps are not possible.

For these reasons a new standard addition system was constructed using Labview to monitor the state of the 2537B detector. The software also provides a GUI for the operator, as well as permit internal calibration requests of the detector. Timing and duration of standard addition valve openings are read from an array file, while the LabView program writes a detailed log file with timestamps to help in post-processing of data. Permeation flow is switched using a three-way valve at the inlet, with another 2-way valve to flush the 1/8" PFA tube with argon. This arrangement allows flexibility to generate complex patterns of standard additions using any combination of sample and desorb periods, as well as internal and external injection.

Period	Injection Point	Normalized Area Slope	Normalized Area Intercept	r^2	N
Desorb Hour	External	0.995	- 0.001	0.998	50
Desorb Hour	Internal	1.020	+ 0.008	0.999	40
Sample Hour	External	1.023	- 0.021	0.997	20
Sample Hour	Internal	1.002	+ 0.076	0.993	60

Table 1. Linear regression of standard addition Hg injection duration (ranging from 30s to 240s) as a function of net area response. Both net area response and injection duration were normalized by the nearest calibration.

Table 1 shows results from this system obtained over a week of testing at Beltsville, MD. Injection duration was varied from 30sec to 240sec, while normal calibrations had a fixed 120sec injection duration at an interval of 40hrs. The net area response of the standard addition was normalized by the net area response of the nearest calibration. Standard addition injection duration was also normalized by the calibration injection duration of 120sec. Ideally, the linear regression should be a slope of 1.0 and an intercept of 0.0 if the response of the standard addition matched the internal calibration of the 2537B instrument.

For standard additions during the desorb hour, both the internal and external injections had a linear regression slope within two percent of unity and incepts within one percent of the neat internal calibrations; showing that the external glassware and plumbing has no losses or conversion of GEM under these conditions. For the external sample hour standard additions the slope was 2.3% greater than the neat internal calibrations with an intercept of -2.1%. The slope of the regression for external sample hour standard additions is dependent on the ratio of flows between the pump module and the 2537B instrument, and may reflect changes in these flow rates. This is the only combination of period and injection point that is dependent on the ratio of flow rates.

The "whoosh effect" can be seen in the last row of Table 1 when standard additions were made during the sample hour and injected internal to the 2537B instrument. While the linear regression slope is very close to unity, the intercept is 7.6% greater than expected. This is believed to be a result of the larger pressure difference between the permeation source manifold and the gold traps. During sample hour about 8 time s more flow is pulled through the external system as compared to the desorb period. This is different than the situation during calibrations when there is a small positive pressure on the supply going to the gold traps. At Mauna Loa where the ambient pressure is about 680mb and the pumps are running at a higher speed to maintain flow, this intercept is on the order of 100%.

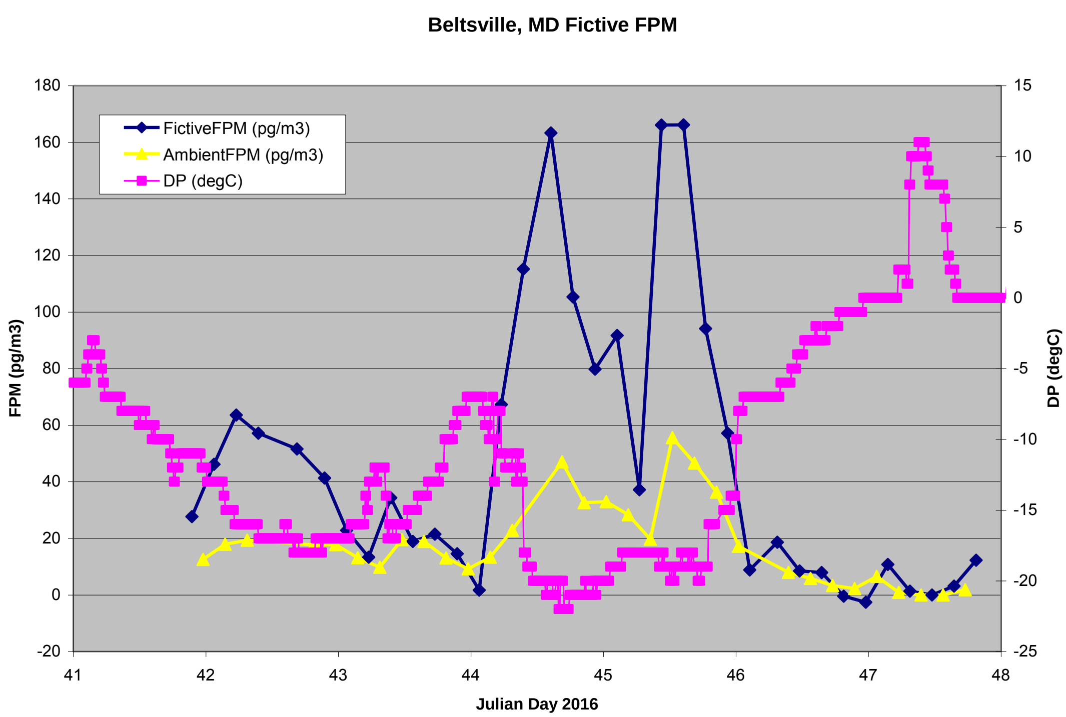


Figure 1. Dew Point, ambient and Fictive FPM at Beltsville, MD.

Figure 1 shows a week of data when eight identical Hg standard additions were made into the inlet of the denuder during alternating sample hours. Ideally the injected GEM should not generate higher FPM on the following desorb hour. Under moist ambient conditions this is the case, however at dew points below -18C the following hour's desorb shows an increase in FPM. This fictive FPM increases dramatically starting at Julian day 44. As the dew point increases starting at Julian day 46, fictive FPM falls sharply.

Planned Work

-Continue support for long-term Hg monitoring at the three AMNET sites.

-Install at least one standard addition system at Mauna Loa.

Publications:

None, acknowledged in publications by X. Ren.

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 (*authored by X. Ren*)	**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**

Hyun Cheol Kim

RDRD_AQS_14 & RDRD AQS_15 (4 of 9)

Research Topics

Evaluation of modeled surface ozone biases as a function of cloud cover fraction

A regional air-quality forecast system's model of surface ozone variability based on cloud coverage was evaluated using satellite-observed cloud fraction (CF) information and a surface air-quality monitoring system. We compared CF and daily maximum ozone from the National Oceanic and Atmospheric Administration's National Air Quality Forecast Capability (NOAA NAQFC) with CFs from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the US Environmental Protection Agency's AirNow surface ozone measurements during May to October 2014. We found that observed surface ozone shows a negative correlation with the MODIS CFs, showing around 1 ppb decrease for 10% MODIS CF change over the contiguous United States, while the correlation of modeled surface ozone with the model CFs is much weaker, showing only ~0.5 ppb per 10% NAQFC CF change. Further, daytime CF differences between MODIS and NAQFC are correlated with modeled surface-ozone biases between AirNow and NAQFC, showing 1.05 ppb per 10% CF change, implying that spatial and temporal misplacement of the modeled cloud field might have biased modeled surface ozone level. Current NAQFC cloud fields seem to have fewer CFs compared to MODIS cloud fields (mean NAQFC CF = 0.38 and mean MODIS CF = 0.55), contributing up to 35% of surface-ozone bias in the current NAQFC system. This study was published in the *Geoscientific Model Development*.

OMI NO_2 column densities over North American urban cities: the effect of satellite footprint resolution

Nitrogen dioxide vertical column density (NO_2 VCD) measurements via satellite were compared with a fine-scale regional chemistry transport model, using a new approach that considers varying satellite footprint sizes. Spaceborne NO_2 VCD measurement has been used as a proxy for surface nitrogen oxide (NO_x) emission, especially for anthropogenic urban emission, so accurate comparison of satellite and modeled NO_2 VCD is important in determining the future direction of NO_x emission policy. The NASA Ozone Monitoring Instrument (OMI) NO_2 VCD measurements, retrieved by the Royal Netherlands Meteorological Institute (KNMI), were compared to a 12 km Community Multi-scale Air Quality (CMAQ) simulation from the National Oceanic and Atmospheric Administration. We found that the OMI footprint-pixel sizes are too coarse to resolve urban NO_2 plumes, resulting in a possible underestimation in the urban core and overestimation outside. In order to quantify this effect of resolution geometry, we have made two estimates. First, we constructed pseudo-OMI data using fine-scale outputs of the model simulation. Assuming the fine-scale model output is a true measurement, we then collected real OMI footprint coverages and performed conservative spatial regridding to generate a set of fake OMI pixels out of fine-scale model outputs. When compared to the original data, the pseudo-OMI data clearly showed smoothed signals over urban locations, resulting in roughly 20–30% underestimation over major cities. Second, we further conducted conservative downscaling of OMI NO_2 VCDs using spatial information from the fine-scale model to adjust the spatial distribution, and also applied averaging kernel (AK) information to adjust the vertical structure. Four-way comparisons were conducted between OMI with and without downscaling and CMAQ with and without AK information. Results show that OMI and CMAQ NO_2 VCDs show the best agreement when both downscaling and AK methods are applied, with the correlation coefficient R=0.89. This study suggests that satellite footprint sizes might have a considerable effect on the measurement of fine-scale urban NO_2 plumes. The impact of satellite footprint resolution should be considered when using satellite observations in emission policy making, and the new downscaling approach can provide a reference uncertainty for the use of satellite NO_2 measurements over most cities. This study is accepted to *Geoscientific Model Development*.

The impact of observation nudging on simulated meteorology and ozone concentrations during DISCOVER-AQ 2013 Texas campaign

Dr. Kim collaborated with the University of Houston for meteorology and ozone simulation over Houston, Texas during DISCOVER-AQ campaign. Accurate meteorological fields are imperative for correct chemical transport modeling. Observation nudging, along with objective analysis, is generally considered a lowcost and effective technique to improve meteorological simulations. However, the meteorological impact of observation nudging on chemistry has not been well characterized. This study involved two simulatio ns to analyze the impact of observation nudging on simulated meteorology and ozone concentrations during the 2013 Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) Texas campaign period, using the Weather Research and Forecasting (WRF) and Community Multiscale Air Quality (CMAQ) models. The results showed improved correlations between observed and simulated parameters. This study has been accepted by the journal *Atmospheric Chemistry and Physics*.

Publications

Journal publications and submission

1. **Kim, H. C.**, P. Lee, L. Judd, L. Pan, and B. Lefer, 2015: OMI NO_2 column densities over North American urban cities: the effect of satellite footprint resolution, *Geosci. Model Dev.*, 8, 8451-8479, doi:10.5194/gmdd-8-8451-2015, *Accepted.*
2. Li, Xiangshang, Y. Choi, B. Czader, **H. Kim**, B. Lefer, and S. Pan: The impact of observation nudging on simulated meteorology and ozone concentrations during DISCOVER-AQ 2013 Texas campaign, , *Atmos. Chem. Phys.,* 16, 3127-3144, *Accepted.*
3. **Kim, H. C.,** P. Lee, F. Ngan, Y. Tang, H. L. Yoo, and L. Pan, 2015: Evaluation of modeled surface ozone biases as a function of cloud cover fractions, *Geosci. Model Dev.*, 8, 2959-2965,doi:10.5194/gmd-8-2959-2015.
4. Tang, Y., T. Chai, L. Pan, P. Lee, D. Tong, **H. Kim** and W. Chen, 2015: Using Optimal Interpolation to Assimilate Surface Measurements and Satellite AOD for Ozone and $PM_{2.5}$: A Case Study for July 2011, J. of Air & Waste Manag. Assoc., DOI:10.1080/10962247.2015.1062439.
5. 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.*, 107, 70-84, doi:10.1016/j.atmosenv.2015.01.035.

Presentations and Posters

1. **Kim, H.**, P. lee, S. Kim, J. Mok, H. Yoo, C. Bae, B.-U. Kim, Y.-K. Lim, J.-H. Woo, and R. Park, 2015: Satellite-observed NO_2, SO_2, and HCHO vertical column densities in East Asia: Recent changes and comparisons with regional model, *2015 AGU Fall Meeting*, San Francisco, CA

2. Bae, C., S. Kim, **H. Kim**, and B.-U. Kim, 2015: Evaluation of Air Quality Forecasting Models with Flight Measurements during the MAPS-Seoul Field Campaign, *2015 AGU Fall Meeting*, San Francisco, CA (Poster)
3. Kim, E., S. Kim, C. Bae, **H. Kim**, and B.-U. Kim, 2015: Evaluation of CMAQ and CAMx Ensemble Air Quality Forecasts during the 2015 MAPS-Seoul Field Campaign, *2015 AGU Fall Meeting*, San Francisco, CA (Poster)
4. Bae, M., **H. Kim**, S. Kim, B.-U. Kim, and P. Lee, 2015: Labor Policy, Lifestyle Change and Ozone Weekend Effect in Seoul Metropolitan Area, Korea, *2015 CMAS conference*, Chapel Hill, NC (Poster)
5. Bae, C., S. Kim, **H. Kim**, and B.-U. Kim, 2015: Improvement of PM Forecast using PSAT-based Customized Emission Inventory over Northeast Asia, *2015 CMAS conference*, Chapel Hill, NC
6. **Kim, H**., P. Lee, F. Ngan, Y. Tang, H.-L. Yoo, L. Pan, and I. Stajner, 2015: Evaluation of modeled surface ozone biases as a function of cloud cover fraction, *2015 CMAS conference*, Chapel Hill, NC
7. Kim, E., S. Kim, **H. Kim**, B.-U. Kim, J. Jo, C. Bae, 2015: Ensemble Approach of Particulate Matter Forecast over South Korea using GFS/WRF and UM Meteorological Models, *2015 CMAS conference*, Chapel Hill, NC (Poster)
8. Pan, L., **H. Kim**, P. Lee, Y. Tang, D. Tong, I. Stajner, W. Chen, 2015: Evaluating fire signal capture capacity of HMS-Bluesky-SMOKE-CMAQ system in the fire events during Southeast Nexus (SENEX) field experiment by comparing CMAQ model simulation results with different observation data sets, , *2015 CMAS conference*, Chapel Hill, NC (Poster)
9. Tong, D., **H. Kim**, L. Pan, Y. Tang, W. Chen, T. Chai, M. Huang, P. Lee, J. McQueen, J. Huang, H.-C. Huang, M. Wang, S. Kondragunta, L. Lamsal, K. Pickering, I. Stajner, 2015: Recent Progress in NAQFC Emission Forecasting, 7th International Workshop on Air Quality Forecasting Research, College Park, MD
10. Lee, P., T. Tang, J. McQueen, B. Pierce, G. Carmichael, T. Russell, D. NcNider, S. Kondragunta, L. Pan, I. Stajner, T. Chai, D. Tong, **H. Kim**, M. Liu, S. Lu, J. Wang, J. Szykman, R. Saylor, A. Stein, Y. Liu, M. Huang, J. Huang, S.-P. Chen, H.-C. Huang, 2015: AQ OSSE, Forecasting & Reanalysis (optimizing assimilation of column AOT & sfc data), 7th International Workshop on Air Quality Forecasting Research, College Park, MD
11. **Kim, H.**, P. Lee, J. Judd, B. Lefer, and L. Pan, 2015: OMI NO2 column densities over North American urban cities: The effect of satellite footprint resolution, 7th International Workshop on Air Quality Forecasting Research, College Park, MD
12. Kim, E., C. Bae, **H. Kim**, B.-U. Kim, J. Cho, and S. Kim, 2015: Ensemble Particulate Matter Forecast System over North East Asia / Korea during 2012-Present, 7th International Workshop on Air Quality Forecasting Research, College Park, MD (poster)
13. You, S., B.-U., Kim, **H. Kim**, J.-H. Woo, and S. Kim, 2015: Impact of Foreign Emissions on Simulated Ozone in South Korea, 7th International Workshop on Air Quality Forecasting Research, College Park, MD (poster)
14. Bae, C., B.-U. Kim, **H. Kim**, and S. Kim, 2015: Comparison of Air Quality Forecasts over Korea with CMAQ and CAMx during 2014, 7th International Workshop on Air Quality Forecasting Research, College Park, MD (poster)

15. Kim, S., C. Bae, E. Kim, B.-U. Kim, **H. Kim**, J.-H. Woo, C.-K. Song, J.-S. Han, I.-S. Jang, J.-B. Lee, and Y.-M. Lee, 2015: Improving Air Quality Forecasting system in Korea, 7th International Workshop on Air Quality Forecasting Research, College Park, MD (poster)
16. Kim, O., B.-U. Kim, **H. Kim**, and S. Kim, 2015: Influence of Fossil-fuel Power Plant Emissions on the Surface PM2.5 in the Seoul Metropolitan Area, South Korea, 7th International Workshop on Air Quality Forecasting Research, College Park, MD (poster)
17. **Kim, H.**, P. Lee, S. Kim, F. Ngan, Y. Tang, H. L. Yoo, and L. Pan, 2015: Evaluation of modeled surface ozone biases as a function of cloud cover fraction, 1st International Workshop on SLCP in Asia: Chemistry-climate modeling and its applications, Seoul, Korea (Invited talk)

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	**5**
# of non-peered reviewed papers	**0**
# of invited presentations	**17**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**

Fong "Fantine" Ngan

RDRD_AQS_14 & RDRD AQS_15 (5 of 9)

Tasks Summary

1. Development and evaluation of WRF-HYSPLIT inline coupling

Background: NOAA/ARL's dispersion, HYSPLIT, has been coupled (inline) to the Advanced Research WRF meteorological model. In the published paper Ngan et al. (2015), we introduced the inline WRF-HYSPLIT and demonstrated the inline approach was able to improve the tracer experiment for a case in the fine spatial and temporal resolution over a complex terrain but it did not provide any advantage over the offline method for the regional scale dispersion.

Accomplishments: The inline HYSPLIT was upgraded to the latest WRF version (v3.7.1) in which new features of PBL schemes that may be beneficial for fine scale meteorological model are available. The model was further modified that the inline dispersion calculation can be run with WRF decomposed domains. The CPU associated with the decomposed domain in which the particle is located will compute the transport and mixing of that particle. Communication between CPUs takes place when particles move from the current to the neighboring CPU, or at the output time step for the tracer concentrations.

We have transferred the inline HYSPLIT to the WRF model development group in NCAR. It was tested successfully on NCAR's machine and generated reasonable results for test cases in comparing with our results. An inline WRF-HYSPLIT web page is now available on ARL's web site (http://www.arl.noaa.gov/WRF_inline.php) to provide instructions of using the inline HYSPLIT. The WRF-ARW user web page (http://www2.mmm.ucar.edu/wrf/users/) also has a link to direct users to the inline HYSPLIT.

The inline HYSPLIT was applied to another fine scale tracer experiment (Project Sagebrush) conducted in Idaho in October 2013. The tracer for IOP3 was released at 1230 MST in the valley and the sampling network took tracer concentration for 2 hours in 5 minutes interval. Inline HYSPLIT showed significant improvement compared to the offline approach for the Sagebrush case. The fractional bias of the inline plume was much lower than that of the offline plume calculated with different meteorological model resolutions.

2. Support of HYSPLIT modeling by providing WRF-ARW meteorological data

Background: WRF-ARW meteorological model simulations were conducted to create a long-term archive for driving dispersion applications. The WRF dataset will be available in ARL format to provide meteorological data compatible to the HYSPLIT dispersion model. It can also be used for dynamic downscale providing initial and boundary conditions for WRF simulations at a finer resolution.

Accomplishments: A domain in 27-km horizontal grid spacing was configured with 33 vertical layers and simulations were initialized with data from the North American Regional Reanalysis. Different PBL schemes and nudging options were tested to understand the sensitivity of the WRF performance and the subsequent impacts on dispersion calculations. HYSPLIT was set to simulate controlled tracer experiments focusing on regional scale transport and dispersion.

The wind comparison shows that the WRF runs using the YSU, QNSE, and MYNN2 PBL schemes had the best statistical performance among all PBL schemes evaluated. However, HYSPLIT runs driven by WRF data based on the QNSE and MYNN2 PBL schemes show the lowest statistical performances while the top three scores for HYSPLIT results were those using ACM2, UW and GBM PBL schemes. The dispersion results using nudged meteorology were equal to or slightly better than those driven by non-nudged WRF data. A manuscript summarizing this study is in preparation for publication.

Planned Work

- Conduct and evaluate the inline HYSPLIT simulations for other episodes during the Project Sagebrush tracer experiment. Further develop the inline WRF-HYSPLIT to include other capabilities such as Transfer Coefficient Matrix available in the offline HYSPLIT.
- Create a long-term meteorological archive using the WRF-ARW model with the configuration evaluated with past tracer experiments to provide meteorological re-analysis data for HYSPLIT dispersion modeling.

Peer-Reviewed Publications

Ngan, F., A. Stein and R. R. Draxler, 2015: Inline coupling of WRF-HYSPLIT: model development and evaluation using tracer experiments. *J. Appl. Meteor. Climatol.*, Vol. 54, 1162-1176.

Stein, A., R. R. Draxler, G. Rolph, B. Stunder, M. Cohen and **F. Ngan**, 2015: NOAA's HYSPLIT atmospheric transport and dispersion modeling system. *Bulletin of the American Meteorological Society*, **96,** 2059-2077.

Kim, H. C., P. Lee, **F. Ngan**, Y. H. Tang, H. L. Yoo and L. Pan, 2015: Evaluation of model surface ozone biases as a function of cloud cover fraction. *Geosci. Model Dev.*, 8, 2959-2965.

Eslinger, Paul and co-authors (**F. Ngan**), 2016: International Challenge to Predict the Impact of Radio xenon Releases from Medical Isotope Production on a Comprehensive Nuclear Test Ban Treaty Sampling Station. Journal of Environmental Radioactivity, accepted.

Presentations

Ngan, F., A. Stein and R. Draxler, 2015: Inline coupling of WRF-HYSPLIT: model development and evaluation using tracer experiments. 16th WRF Users' Workshop, Boulder, CO, NCAR.

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	**4**
# 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**

Li Pan

RDRD_AQS_14 & RDRD AQS_15 (6 of 9)

Task Name **Participation in Climate Research Activities at the Air Resources laboratory NOAA**
Task Leader **R. R. Dickerson**
Task Code **RDR-PMFA_13 and RDRD_AQS_14**
NOAA Sponsor **Air Resources Laboratory, R. Artz**
NOAA Office **Oceanic and Atmospheric Research**
Contribution to CICS Research Themes (%) Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic: Climate and Satellite Observations and Monitoring
Contribution to NOAA goals (%) Goal 1: 0%, Goal 2: 80%, Goal 3: 20%,
Highlight:
Research Website

Background

The National Air Quality Forecast Capability (NAQFC) provides air quality forecast and numerical guidance for issuance of warnings to the public when poor air quality conditions arise. The NOAA/OAR Air Resources Laboratory (ARL) cooperated with the NOAA National Weather Service (NWS) to support NAQFC in 2015.

Accomplishments

A new NAQFC system has been implemented in February, 2016. The number of CMAQ vertical layers was increased from 22 to 35. The thicknesses of vertical layers in the model height from 1000 m to 5000 m above ground level has been increased, but CMAQ model vertical structure below 1000 m, especially for the layers close to ground, has remained unchanged. This modification prevents high ozone concentrations due to stratosphere ozone intrusions quickly moving downward to the surface and consequently leading to model high ozone bias over the ground. The new NAQFC system is coupled with a global model NGAC (NEMS (NOAA Environmental Modeling System) GFS Aerosol Component). NGAC provides CMAQ with a dynamic boundary condition. Consequently, influence from transboundary aerosol has been taken into account in NAQFC. Although this is for the dust components only presently, it will include other PM species from sources such as for wildfire and anthropogenic constituents soon.

Frequently, the occurrence of wild fire events is an important issue in NAQFC. A fire emission evaluation system is likewise critical. An evaluation system based on the SENEX field experiment was developed to assess the HMS-BlueSky-SMOKE fire emission calculation algorithm used in NAQFC. This system involves multiple data sets from different observations (ground, airplane, and satellite). We found that the current fire system in NAQFC is capable of predicting reasonably well fire signals in the observations. Some missing events appear to be due to prescribed small fires and fire plume transboundary transport.

Planned Work

- Upgrading PREMAQ to enable CMAQ5.0.2 coupling with NAM;
- Upgrading operational CMAQ version in NAQFC from 4.6 to 5.0.2;
- 24-hour CMAQ retrospective run to provide an initial condition for next 48-hour forecasting;
- New BlueSky fire emission in NAQFC;

Publications

1. Kim, H. C., Lee, P., Ngan, F., Tang, Y., Yoo, H. L., & **Pan, L**. (2015). Evaluation of modeled surface ozone biases as a function of cloud cover fraction. Geosci. Model Dev. Discuss., 8, 3219–3233, 2015 www.geosci-model-dev-discuss.net/8/3219/2015/ doi:10.5194/gmdd-8-3219-2015.
2. Tang, Y., Chai, T., **Pan, L**., Lee, P., Tong, D., (2015), Using Optimal Interpolation to Assimilate Surface Measurements and Satellite AOD for Ozone and PM2.5: A Case Study for July 2011, the Journal of the Air & Waste Management Association, 65.10 (2015): 1206-1216, doi:10.1080/10962247.2015.1062439.
3. Huang, Min, D. Tong, P. Lee, **L. Pan**, Y. Tang, I. Stajner, R. B. Pierce, J. McQueen, and J. Wang. "Toward enhanced capability for detecting and predicting dust events in the western United States: the Arizona case study." Atmospheric Chemistry and Physics 15, no. 21 (2015): 12595-12610.
4. Tang, Y., **L. Pan**, P. Lee, D. Tong, D., H. C. Kim, J. Wang and S. Lu. The Performance and Issues of a Regional Chemical Transport Model During Discover-AQ 2014 Aircraft Measurements Over Colorado. In Air Pollution Modeling and its Application XXIV (pp. 635-640, Chapter 103). ISBN:978-3-319-24476-1, Springer International Publishing, 2016.

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	**4**
# 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**

Fire emission evaluation system for HMS-BlueSky-SMOKE algorithm used in NAQFC.

Xinrong Ren
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Task Name **Participation in Climate Research Activities at the Air Resources laboratory NOAA**
Task Leader **R. R. Dickerson, W. T. Luke, X. Ren (self)**
Task Code **RDRD_AQS_14 & RDRD AQS_15** (7 of 9)
NOAA Sponsor **Air Resources Laboratory, R. Artz**
NOAA Office **Oceanic and Atmospheric Research**
Contribution to CICS Research Themes (%) Theme 1: 0%, Theme 2: 100%, Theme 3: 0%
Main CICS Research Topic: Climate and Satellite Observations and Monitoring

Contribution to NOAA goals (%) Goal 1: 0%, Goal 2: 80%, Goal 3: 20%

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 con duct measurements of a variety of trace gases along with atmospheric mercury to facilitate source identification.

Accomplishments:

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

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

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) Inter-annual, seasonal and diurnal variations of atmospheric mercury species and source-receptor correlation the Beltsville site, and (2) Long-term trends of atmospheric mercury species at a coastal site in the northern Gulf of Mexico. One paper has been submitted based on the results from the first study.

Planned Work

- To continue the monitoring of mercury compounds (GEM, GOM, and PBM) at the three EPA Atmospheric Mercury Network (AMNet) sites operated by NOAA ARL.

- To conduct data analysis for the atmospheric mercury observations at the Grand Bay and Mauna Loa AMNet sites made over the past 9 years.

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Nault, B. A., C. Garland, P. J. Wooldridge, W. H. Brune, P. Campuzano-Jost, J. D. Crounse, D. A. Day, J. Dibb, S. R. Hall, G. Huey, J. L. Jimenez, X. Liu, J. Mao, T. Mikoviny, J. Peischl, I. B. Pollack, X. Ren, T. B. Ryerson, E. Scheuer, K. Ullmann, P. O. Wennberg, A. Wisthaler, Li Zhang, and Ronald C. Cohen, Observational Constraints on the Oxidation of NOx in the Upper Troposphere, J. Chem. Phys. A, doi:10.1021/acs.jpca.5b07824, 2015.

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Aburn, G., Jr., R. R. Dickerson, J. C. Hains, D. King, R. Salawitch, T. Canty, X. Ren, A. M. Thompson, and M. Woodman, Ground-level ozone: A path forward for the Eastern United States, Environmental Manager, 20-26, May 2015.

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Pacyna, M. Pilote, L. Poissant, D. Ratte, X. Ren, F. Steenhuisen, A. Steffen, R. Tordon, B. Wiens, S. Wilson, Modeling the global atmospheric transport and deposition of mercury to the Great Lakes, submitted to Elementa, 2016.

Mazzuca, G. M., X. Ren, C. P. Loughner, M., M. Estes, J. H. Crawford, K. E. Pickering, and R. R. Dickerson, Ozone production and its sensitivity to NOx and VOCs: Results from the DISCOVER-AQ Field experiment, Houston 2013, submitted to Atmos. Chem. Phys., 2016.

Mok, J., N. A. Krotkov, A. Arola, O. Torres, H. Jethva, M. Andrade, G. Labow, T. F. Eck, Z. Li, R. R. Dickerson, G, L. Stenchikov, S, Osipov, and X, Ren, Impacts of brown carbon from biomass burning on surface UV and ozone photochemistry in the Amazon Basin, submitted to Nature Geoscience, 2016.

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Barth, M. C., M. M. Bela, A. Fried, P. O. Wennberg, J. D. Crounse, J. M. St. Clair, N. J. Blake, D. R. Blake, C. R. Homeyer, W. H. Brune, L. Zhang, J. Mao, X. Ren, T. Ryerson, R. C. Cohen, B. A. Nault, L. G. Huey, X. Liu and C. A. Cantrell, Convective Transport of Peroxides by Thunderstorms Observed over the Central U.S. during DC3, submitted to J. Geophys. Res., 2015.

Presentations

Ren, X., W. Luke, P. Kelley, M. Cohen, D. Tong, R. Artz, M. L. Olson, D. Schmeltz, Mercury Speciation at a Suburban Site in the Mid-Atlantic United States: Seasonal and Diurnal Variations and Source-Receptor Correlations, International Conference on Mercury as a Global Pollutant, Jeju, Korea, June 14-19, 2015.

Luke, W., X. Ren, P. Kelley, M. Olson, N. Kobayashi, A. Colton, D. Schmeltz, Assessment of Mercury Measurement Fidelity by an Automated Tekran Speciation Unit, International Conference on Mercury as a Global Pollutant, Jeju, Korea, June 14-19, 2015.

Ren, X., W. Luke, P. Kelley, M. Cohen, J. Walker, R. Cole, R. Artz, and M. L Olson, Long-term Monitoring of Atmospheric Mercury Species at a Coastal Site in the Northern Gulf of Mexico, Acid Rain 2015 Fall NADP Meeting and Scientific Symposium, Rochester, NY, October 19-23, 2015.

Luke, W., X. Ren, P. Kelley, M. Olson, N. Kobayashi, A. Colton, D. Schmeltz, Measurement Artifacts of Gaseous Oxidized and Particulate-Bound Mercury in a Commercial Mercury Speciation System, Acid Rain 2015 Fall NADP Meeting and Scientific Symposium, Rochester, NY, October 19-23, 2015.

Ren, X., S. Sahu, D. Hall, C. Grimm, H. He, R. Dickerson, O. Salmon, A. Heimburger, and P. Shepson, Fluxes of Greenhouse Gases from the Baltimore-Washington Area: Results from the Winter 2015 Aircraft Observations

Salmon, O. E., P. B. Shepson, R. M. Grundman II, B. H. Stirm, X. Ren, R. R. Dickerson, J. D. Fuentes, Investigation of the Potential Impact of Urban-Derived Water Vapor on Chemistry and Clouds, American Geophysical Union Fall Meeting, San Francisco, December 14-18, 2015.

Martin, C. R., N. Zeng, X. Ren, R. R. Dickerson, K. J. Weber, B. N. Turpie1, Implementing Environmental Corrections to Increase the Accuracy of a Low-Cost CO_2 Sensor, American Meteorological Society Annual Meeting, New Orleans, LA, January 10-14.

Ahn, D, J. R. Hansford, R. J. Salawitch, X. Ren, M. Cohen, Barbara Stunder, R. R. Dickerson, Identification of Carbon Dioxide Emission Sources in Baltimore/Washington Metropolitan Area, American Meteorological Society Annual Meeting, New Orleans, LA, January 10-14.

Hansford, J. R., D. Ahn, R. J. Salawitch, X. Ren, M. D. Cohen, B. Stunder, R. R. Dickerson, Identification of Methane Emission Sources in the Baltimore-Washington Metropolitan Area, American Meteorological Society Annual Meeting, New Orleans, LA, January 10-14.

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 on mercury (total)	2(7)
# of non-peered reviewed papers	0
# of invited presentations	9
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Youhua Tang

Task Name	RRD
Task Leader	Youhua Tang
Task Code	**RDRD_AQS_14 & RDRD AQS_15** (8 of 9)
NOAA Sponsor	ARL
NOAA Office	
Contribution to CICS Research Themes (%)	Theme 3 100%
Main CICS Research Topic	
Contribution to NOAA goals (%)	
Highlight	
Link to a research web page	

Background

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

Accomplishments

In 2015, I examined the lightning NOx schemes used in the current air quality model, and reviewed their impact. Most of these schemes, which derived lighting NOx from model convective precipitation rate, have issues of capturing lightning in the correct location and at the correct time. I also tested CMAQ 5.1, the latest version, and its bidirectional NH_3 scheme, which generally helps with PM2.5 prediction. All these efforts are about exploring methods to improve air quality forecast and analysis. In order to support the NCEP's operational air quality forecast, I helped develop the GRIB2 decoder for air quality application.

Planned work

In 2016, I plan to enable GSI to assimilate CMAQ 5.1' species, using both aerosol optical depth (AOD) and in-situ data. We expect to have a new meteorological preprocessor to replace aged PreMAQ for NCEP operational usage that will require my attention. The performance of current AQ forecasting may be improved by the addition of bidirectional NH3 flux with higher spatial resolution.

Publications

Tang, Y., T. Chai, L. Pan, P. Lee, D. Tong, H.-C. Kim and W. Chen . Using Optimal Interpolation to Assimilate Surface Measurements and Satellite AOD for Ozone and PM2.5: A Case Study for July 2011. *Journal of the Air & Waste Management Association*. DOI:10.1080/10962247.2015.1062439, 65(10):1206–1216, 2015.

Tang, Y., L. Pan, P. Lee, D. Tong, D., H. C. Kim, J. Wang and S. Lu. The Performance and Issues of a Regional Chemical Transport Model During Discover-AQ 2014 Aircraft Measurements Over Colorado. In *Air Pollution Modeling and its Application XXIV* (pp. 635-640, Chapter 103). *ISBN:978-3-319-24476-1*, Springer International Publishing, 2016.

Huang, M., Tong, D., Lee, P., Pan, L., **Tang, Y.**, Stajner, I., Pierce, R. B., McQueen, J., and Wang, J., Toward enhanced capability for detecting and predicting dust events in the western United States: the Arizona case study, *Amos. Chem. Phys.*, 15, 12595-12610, doi:10.5194/acp-15-12595-2015, 2015

Kim, H. C., P. Lee,, F. Ngan, **Y. Tang**, H. L. Yoo, and L. Pan, Evaluation of modeled surface ozone biases as a function of cloud cover fraction, *Geosci. Model Dev.*, doi:10.5194/gmd-8-2959-2015, 8, 2959–2965, 2015.

Presentations

Youhua Tang, Li Pan, Pius Lee, Jeffery T. McQueen, Jianping Huang, Daniel Tong, Hyun-Cheol Kim, Min Huang, Dale Allen and Ken Pickering, Comparison of CMAQ Lightning NOx Schemes and Their Impacts, 14th Annual CMAS Conference, Chapel Hill, NC, Oct 2015.

Youhua Tang, Li Pan, Pius Lee, Daniel Tong, Hyun-Cheol Kim, Jun Wang, Sarah Lu, The Performance and Issues of a Regional Chemical Transport Model during Discover-AQ 2014 Aircraft Measurements over Colorado, 34th International Technical Meeting on Air Pollution Modelling and its Application, Montpellier, France, May 2015.

Youhua Tang, Li Pan, Pius Lee, Daniel Tong, Hyun-Cheol Kim , Min Huang, Jun Wang, Sarah Lu, Jeff McQueen, and Rick Artz, Multiple Sensitivity Testing for Regional Air Quality Model: Comparison with Discover-AQ 2014. AGU Fall Meeting, San Francisco, CA. Dec 2015.

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, F. Ngan, **Y. Tang**, H.-L. Yoo, L. Pan, and I. Stajner, Evaluation of modeled surface ozone biases as a function of cloud cover fraction, 2015 CMAS conference, Chapel Hill, NC. Oct 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	**1**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**4**
# 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**

Daniel QuanSong Tong

TASK NAME: Participation in Climate Research Activities at the Air Resources Laboratory

Task Leader	Dickerson
Task Code	**RDRD_AQS_14 & RDRD AQS_15** (9 of 9)
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Percent contribution to CICS Themes	Theme 3, 100%
Percent contribution to NOAA Goals	Goal 3, 100%

Highlight: 1) CICS scientists generated high-quality emission products to support day-to-day operations of NOAA O_3 and $PM_{2.5}$ real-time forecast; 2) CICS scientists have successfully developed a new satellite product of marine isoprene; 3) New projects launched to use fused satellite and ground observations to rapidly update anthropogenic emissions; 4) CICS and NOAA released new isoprene products to "early adopter" users.

Background

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

Accomplishments

In the past year, Daniel Tong has completed the following tasks on a 75% part-time schedule:

1. NOAA National Air Quality Forecasting Research and Operation:

Daniel led the team's efforts to generate high quality emission data products to support day-to-day operations of the NOAA National Air Quality Forecast Capability (NAQFC). Recent years saw dramatic changes in the emissions of air pollution across the country, with major events including the economic recession and recovery, shale gas drilling, etc. All of these events have impacted air quality to different extent. To incorporate such impacts into the real-time air quality forecasting system, Daniel has worked with his colleagues to vigorously update emission inventories using data collected from several federal agencies. In addition, Daniel has developed a novel technology, called emission data assimilation, to significantly reduce uncertainty in the emission dataset. Products generated from this effort include four large datasets required by the National Weather Service (NWS) to NOAA air quality forecast operations and research:

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

2. Satellite Retrieval: Marine emission products from Suomi-NPP VIIRS

Daniel serves as the PI to a NOAA Joint Polar Satellite System (JPSS) project that attempts to develop a new algorithm to estimate marine isoprene emissions using multiple JPSS ocean products and NWS global meteorology. Built upon several pioneering works that use satellite data to quantify marine and terrestrial isoprene emissions (Palmer and Show, 2005; Arnold et al., 2009; Gantt et al., 2009), the JPSS algorithm has been improved in several ways. This algorithm considers and integrates more biological and environmental variables that control oceanic isoprene emissions. Marine isoprene emission is controlled by a number of environmental variables, including chlorophyll concentration (Broadgate et al., 1997; Shaw et al., 2003), light intensity (Gantt et al., 2009), phytoplankton speciation (Gantt et al., 2009), sea surface temperature and wind speed (Wannickhof et al., 1999), biological and chemical processes that consume isoprene in water and air (Palmer and Shaw, 2005). Most existing algorithms consider one or several of these factors, but not all. Benefiting from the timely availability of multiple ocean color products, the JPSS algorithm is able to reflect the effects of key parameters on the variability in marine isoprene emission. Meanwhile, our team has compiled a comprehensive dataset from ship measurements of marine isoprene that are used to further improve the parameterization in the algorithm. Finally, this algorithm takes advantage of NOAA in-house global weather forecasting by incorporating real-time meteorology data to capture the effects of environmental factors. Figure 1 shows the spatial patterns for the produced marine isoprene emission in January, April, July, and October. Overall, the estimated marine isoprene emissions capture the spatial and temporal features of marine biogeochemical cycles that are reported in previous studies (Mann and Lazier, 2006; Winder and Cloern, 2010).

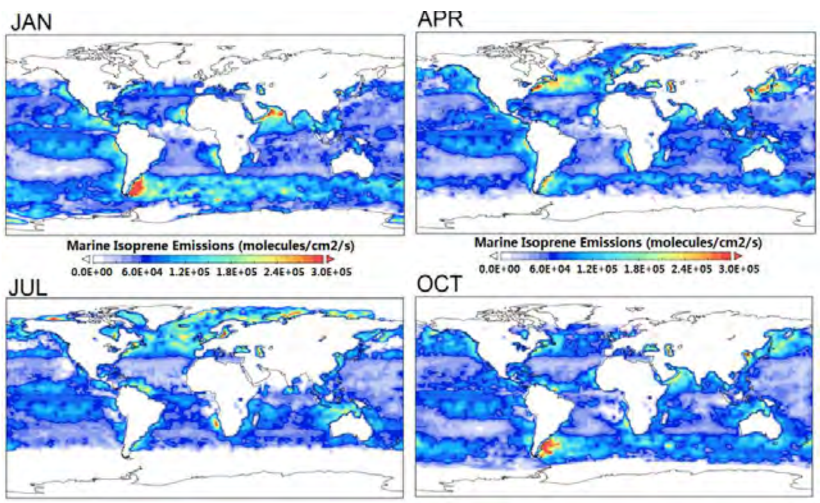


Fig. 1 Spatial distribution of SNPP-VIIRS estimated isoprene emissions over oceans in January, April, July, and October of 2014.

3. Rapid refreshing of anthropogenic emissions through fused satellite and ground observations

Daniel is the co-PI (with Pius Lee of NOAA ARL) of a new US Weather Research Program (USWRP) project that aims at developing a new capability to rapidly update NOAA emission data used to drive NAQFC. The time lag inherent in emission inventory updates is a bottleneck for NOAA to improve the accuracy of O_3 and $PM_{2.5}$ forecasts. In addition, the planned U.S. EPA updates of the 2011 national emission inventories are expected to cause an immediate set back of NAQFC forecast performance. To alleviate the combined effects of time lag and change in the basis of emission projections, we propose to develop an emission data assimilation capability for rapid refreshing of NAQFC NOx emissions. The proposed work is comprised of three activities: 1) updates of NAQFC emission inventories and CMAQ to build a realistic base case; 2) adjustment of base emission inventories with fused ground and satellite observations; and 3) evaluation of the effect on NAQFC forecast performance. This project is on-going and Daniel is preparing a manuscript to GRL to report their findings.

Planned Work

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

Publications

1. Lei, Hang, Julian XL Wang, Daniel Q. Tong, and Pius Lee. "Merged dust climatology in Phoenix, Arizona based on satellite and station data." *Climate Dynamics* (2016): 1-15.
2. Tang, Y., L. Pan, P. Lee, D. Tong, D., H. C. Kim, J. Wang and S. Lu. The Performance and Issues of a Regional Chemical Transport Model During Discover-AQ 2014 Aircraft Measurements Over Colorado. In *Air Pollution Modeling and its Application XXIV* (pp. 635-640, Chapter 103). *ISBN:978-3-319-24476-1*, Springer International Publishing, 2016.
3. Dong, X., Fu, J. S., Huang, K., and Tong, D.: Model development of dust emission and heterogeneous chemistry within the Community Multiscale Air Quality modeling system and its application over East Asia, Atmos. Chem. Phys. Discuss., 15, 35591-35643, doi:10.5194/acpd-15-35591-2015, 2015.
4. Chen, W., D Tong, S Zhang, M Dan, X Zhang, H Zhao, 2015. Temporal variability of atmospheric particulate matter and chemical composition during a growing season at an agricultural site in northeastern China. Journal of Environmental Sciences 38, 133-141.
5. Zhang, X., Q Zhou, W Chen, Y Wang, DQ Tong, 2015. Observation and modeling of black soil wind-blown erosion from cropland in Northeastern China. Aeolian Research 19, 153-162.
6. 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*, 107,70-84, doi:10.1016/j.atmosenv.2015.01.035.
7. 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.
8. Huang, M., Tong, D., Lee, P., Pan, L., Tang, Y., Stajner, I., Pierce, R. B., McQueen, J., and Wang, J.: Toward enhanced capability for detecting and predicting dust events in the Western United States: the Arizona Case Study, Atmos. Chem. Phys. Discuss., 15, 20743-20774, doi:10.5194/acpd-15-20743-2015, 2015.
9. Tang, Y., T. Chai, L. Pan, P. Lee, Daniel Tong, H. Kim, and W. Chen, Using Optimal Interpolation to Assimilate Surface Measurements and Satellite AOD for Ozone and $PM_{2.5}$: A Case Study for July 2011. *Journal of the Air & Waste Management Association*, doi:10.1080/10962247.2015.1062439, 2015.

Presentations

1. Daniel Tong, Li Pan, Weiwei Chen, Pius Lee, Hyun-Cheol Kim, Youhua Tang, and Lok Lamsal. 2016. Rapid refreshing of anthropogenic NOx emissions through assimilating fused ground and satellite observations to support NOAA National Air Quality Forecast Capability. The 96th AMS Annual Meeting, January 10-14, New Orleans, LA.
2. Tong D., Hyuncheol Kim, Li Pan, Youhua Tang, Weiwei Chen, Tianfeng Chai, Min Huang, Pius Lee, Jeff McQueen, Jianping Huang and Ho-Chun Huang, Menghua Wang and Shobha Kondragunta, Lok

Lamsal and Kenneth Pickering, Ivanka Stajner, 2015. Recent Progress in NAQFC Emission Forecasting, The 7th International Workshop on Air Quality Forecasting Research, September 1-3, 2015, College Park, MD.

3. Menghua Wang, Daniel Tong, Pius Lee, Hang Lei, Li Pan, Global Marine Isoprene Emission Data Derived from Satellite Ocean Color Measurements. The 7th International Workshop on Air Quality Forecasting Research, September 1-3, 2015, College Park, MD.
4. Weiwei Chen, Daniel Tong and Pius Lee, 2015. Global PM10 and PM2.5 emission inventories from agricultural tilling and harvesting. The 7th International Workshop on Air Quality Forecasting Research, September 1-3, 2015, College Park, MD.
5. Pius Lee, Youhua Tang, Jeff McQueen, Brad Pierce, Greg Carmichael, Ted Russell, Dick McNider, Shobha Kondragunta, Li Pan, Ivanka Stajner, Chai Tianfeng, Daniel Tong, Hyuncheol Kim, Mark Liu, Sarah Lu, Jun Wang, Jim Szykman, Rick Saylor, Ariel Stein, Yang Liu, Min Huang, Jianping Huang, Sheng-Po Chen, Ho-Chun Huang, 2015. AQ OSSE, Forecasting & Reanalysis (optimizing assimilation of column AOT & sfc data). The 7th International Workshop on Air Quality Forecasting Research, September 1-3, 2015, College Park, MD.
6. Nina Randazzo, Daniel Tong, Pius Lee, Min Huang, 2015. Evaluation of CMAQ prediction of carbon monoxide vertical profiles against SENEX. The 7th International Workshop on Air Quality Forecasting Research, September 1-3, 2015, College Park, MD.
7. Daniel Tong, Menghua Wang, Hang Lei, Li Pan, Pius Lee, Brett Gantt, Sarwar Golam, Jeff McQueen, and Ivanka Stajner. Global high-resolution marine isoprene emission derived from VIIRS-SNPP and MODIS-Aqua ocean color observations. The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
8. Youhua Tang, Li Pan, Pius Lee, Jeffery T. McQueen, Jianping Huang, Daniel Tong, Hyun-Cheol Kim, Min Huang, Dale Allen, and Ken Pickering. Comparison of CMAQ Lightning NOx Schemes and Their Impacts. The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
9. Pius Lee, Robert Atlas, Youhua Tang, Li Pan, Hyuncheol Kim, Daniel Tong, Sean Casey. Variation in future observation systems for the global numerical weather prediction systems influences accuracy in regional air quality forecast. The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
10. Min Huang, Li Pan, Pius Lee, Daniel Tong, Youhua Tang, Ivanka Stajner, Jeff McQueen, Ariel Stein, Julian Wang. Enhancing the Capability for Detecting and Predicting Dust Events in the Western US. The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
11. Li Pan, Hyun Cheol Kim, Pius Lee, YouHua Tang, Daniel Tong, Ivanka Stajner, and Weiwei Chen. Evaluating fire signals in HMS-Bluesky-SMOKE-CMAQ system during Southeast Nexus (SENEX) field experiment. The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
12. Ivanka Stajner, Jeff McQueen, Pius Lee, Ariel Stein, Jinaping Huang, Li Pan, Daniel Tong, Ho-Chun Huang, Perry Shafran, Jerry Gorline, Phil Dickerson, Sikchya Upadhaya. National Air Quality Forecast Capability: Towards prediction of fine particulate matter (PM2.5). The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
13. Nina Randazzo, Daniel Tong, Pius Lee, Li Pan, Min Huang, Evaluation of CMAQ predictions of carbon monoxide surface concentrations and vertical profiles. The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
14. Dong, X., J. Fu, K. Huang and D. Tong, Improvement of Dust Module in CMAQ and Implement of Dust Chemistry. The **14th Annual CMAS Conference**, October 5-7, 2015, Chapel Hill, NC.
15. Huang, M., Tong, D., Lee, P., Pan, L., Stajner, I., 2015. Toward Enhanced Capability for Detecting and Predicting Dust Events in the Western US. NASA AQAST 9, St Louis, MO, June 2-6, 2015,
16. Huang, M., Tong, D., Lee, P., Pan, L., Tang, Y., Stajner, I., Pierce, R. B., McQueen, J., and Wang, J.,

2015. Toward Enhanced Capability for Detecting and Predicting Dust Events in the Western US. The 7th International Workshop on Air

17. Huang, M., Tong, D., Lee, P., Pan, L., Tang, Y., Stajner, I., Pierce, R. B., McQueen, J., and Wang, J. 2015. Enhancing the Capability for Detecting and Predicting Dust Events in the Western US. The **14th Annual CMAS Conference,** October 5-7, 2015, Chapel Hill, NC.
18. Huang, M., Tong, D., Lee, P., Pan, L., Tang, Y., Stajner, I., Pierce, R. B., McQueen, J., and Wang, J. 2015. Dust events in Arizona: Long-term satellite and surface observations, and the National Air Quality Forecasting Capability CMAQ simulations. AGU fall meeting, Dec 2015.
19. Daniel Tong, 2015. *VIIRS Marine Isoprene Product: Linking Ocean Phytoplankton to Air Quality and Climate*. STAR JPSS Annual Science Team Meeting, August 24-28, 2014, College Park, MD.

Other

1. **Grants Received**
   a) NOAA JPSS Proving Ground and Risk Reduction Program. Development, validation and implementations of three marine emission products (Isoprene, Dimethyl Sulfide and Primary Organic Aerosols) using multiple JPSS ocean products, Role: PI. $250,000, 2015-2018;
   b) US Weather Research Program (USWRP) 2015. Rapid refreshing of anthropogenic NOx emissions through assimilated fused satellite and ground observations. Role: Co-PI, with Pius Lee of NOAA, $128,000, 2015-2016.
   c) US Weather Research Program (USWRP) 2015. Toward a Unified National Dust Modeling Capability. Role: Co-I. $230,000, 2015-2016.
   d) NASA ROSES. Enhanced Dust Indicator (EDI): Guarding against future "Dust Bowl". Role: PI. Selected. 2016-2019.

2. **Community Services**
   As one of the local organizers, Daniel helped organize the 7th International Workshop on Air Quality Forecasting Research (IWAQFR) held on Sept 1-3, 2015 in the NOAA National Center for Weather and Climate Prediction, College Park, MD. Daniel also served as the session co-chair for the emissions session.

3. **Release of New Satellite Product**
   On September 2, 2016, Daniel Tong and ARL deputy director Richard Artz organized a town hall meeting at UMD to announce the release of a new satellite product that depicts marine isoprene emissions. This product was jointly developed by NOAA ARL, NESDIS/STAR, and academic partners. Members of the air quality forecasting community and other "early adapter" users participated in the town hall meeting. This research, funded by the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction Program, seeks to support NAQFC-like operations, as well as to improve climate models and Earth System models, all of which currently use predefined values to represent ocean-atmosphere exchange. A beta version of the new product was introduced to the air quality community at the 7th International Workshop on Air Quality Forecasting Research held in College Park, MD from September 1-3, 2015.

Performance Metrics	
# of new or improved products developed (see paragraph 3 above)	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	9
# of non-peered reviewed papers	1
# of invited presentations	19
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

END OF RDRD_AQS_14 & RDRD AQS_15 (1 –9)

4 Future Satellite Programs

Year 5 GOES-R/JPSS Visiting Scientist Program

Task Leader: Michael J. Folmer
Task Code: EBMF_GOESR_15/ EBMF_JPSS_15 (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 3: 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 Satellite System (JPSS) Satellite Proving Ground (PG) is a collaborative effort among the GOES-R Program Office, JPSS Program Office, and the National Oceanic and Atmospheric Administration (NOAA) Cooperative Institutes, Weather Forecast Offices, National Centers for Environmental Prediction (NCEP) National Centers, and Experimental Testbeds. The Proving Ground is a project in which proxy GOES-R and JPSS products can be tested and evaluated before launch of the GOES-R series and JPSS 1 & 2. Proxy GOES-R and JPSS products are generated using combinations of currently available GOES data and higher-resolution data provided by instruments on polar-orbiting satellites (e.g., MODIS) and S-NPP as well as model synthetic satellite data.

A full-time visiting scientist (VS) is required for the GOES-R and JPSS PG efforts based at the NOAA National Weather Service (NWS) Weather Prediction Center (WPC), Ocean Prediction Center (OPC), National Hurricane Center (NHC) Tropical Analysis and Forecast Branch (TAFB), and the National Environmental Satellite, Data, and Information Service (NESDIS) Satellite Analysis Branch (SAB) in College Park, Maryland as part of the Marine, Precipitation, and Satellite Analysis Proving Ground (MPS PG). The GOES-R and JPSS VS coordinates the evaluation effort, helps facilitate product availability, generates combined reports, trains forecasters on product applications, provides feedback to product developers, and coordinates local GOES-R and JPSS Day 1 Readiness.

Accomplishments

The 2015 demonstrations featured many significant milestones in the PG. The overarching theme of the PG was heavy rainfall, explosive cyclogenesis, and fog/low stratus. The Overshooting Top Detection (OTD), GLD-360 Lightning Density, GOES-R Convective Initiation, CIRA Layered Precipitable Water, and Nearcast Model were used for convective monitoring and heavy rainfall. The RGB and some convective products were used for analyzing and forecasting explosive cyclones. The Fog/Low Status, GeoColor, and Night-time Microphysics products were used for monitoring and forecasting fog formation in the marine zones of OPC and TAFB. Many forecasters found the products to be beneficial to their operations and continue to use it now along with the successful implementation of the Air Mass RGB products. The GOES-14 super rapid scan operations for GOES-R (SRSOR) have been a major success in the MPS PG since about 2012 and this continued in June and August 2015. There were many examples of use for diagnosing some heavy rain events associated with deep convection in the southern U.S. along with some fire monitoring for SAB.

The following are some projects that were started or completed in 2015:

- Some new projects were started in 2015, including some collaboration among OPC, WPC, and AK region related to introducing how the centers are utilizing the Air Mass RGB for analyzing hurricane-force extratropical storms. The CICS RA traveled to each of the Weather Forecast Offices (WFO) in Juneau, Anchorage, and Fairbanks to collaborate with the forecasters and AK region satellite liaisons.
- Himawari-8 imagery was first introduced experimentally to forecasters at OPC, SAB, and WPC in July 2015 and was made operationally available in early December 2015. A brief introduction was provided via small training groups and a more robust training session is in the works for 2016.
- The CICS RA is also heavily involved in the Satellite Training Advisory Team (STAT) that was assembled to guide the various training partners on the future direction of GOES-R and eventually JPSS training for the National Weather Service (NWS).
- In preparation for Himawari, GOES-R, and JPSS, the CICS RA helped lead a team that was responsible for changing the satellite paradigm at OPC, SAB, and WPC from the far inferior 30-min temporal cadence and diminished spatial resolutions to the routine and rapid scan temporal cadences and improved, native spatial resolutions of GOES-13/15, Meteosat-10, Meteosat-7, MTSAT-2 (decommissioned on 12/4/15), and now Himawari-8. By making these changes now, the forecasters are better prepared for GOES-R and this helps the technical staff gauge what hardware/software configurations will be needed for GOES-R, JPSS, and other future satellites.
- Finally, the CICS RA and OPC have been hosting interns that have studied offshore marine convection, fog and low stratus in marine zones, hurricane-force extratropical storms, and comparing the High Resolution Rapid Refresh (HRRR) model lightning threat algorithm against real time lightning detection in the offshore zones.

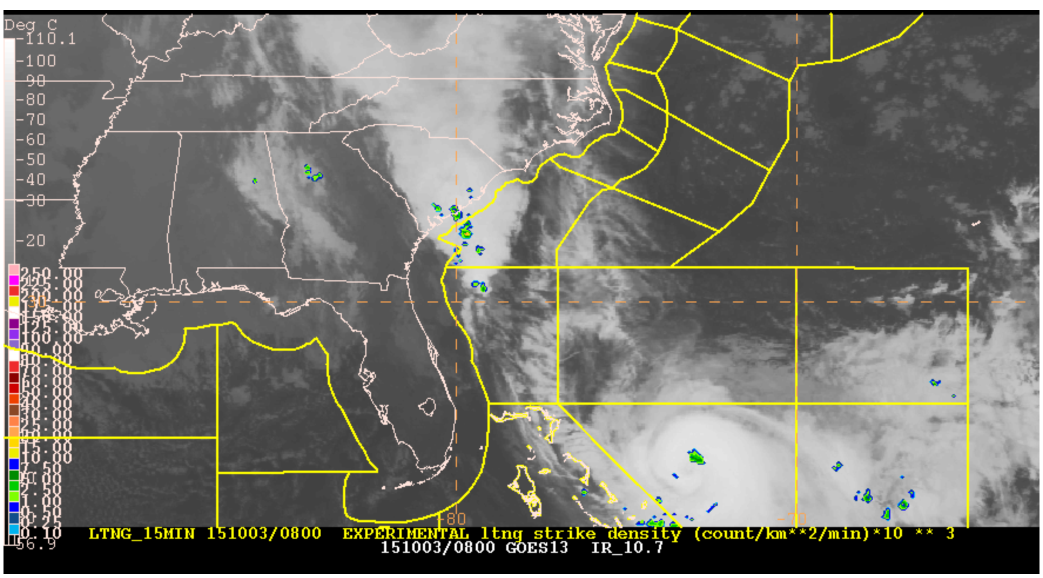


Figure 1: GOES-13 10.7 um Infrared imagery overlaid with the GLD-360 Lightning Density product that was developed as a collaboration among CICS, NESDIS, and OPC. This example shows the moisture plume (atmospheric river) that was responsible for the tremendous rainfall observed in SC and NC in early October 2015. Hurricane Joaquin in the lower portion of the image was responsible for the sinking of the El Faro cargo ship and indirectly contributed moisture to the aforementioned moisture plume. OPC, SAB, TAFB, and WPC all used the lightning density along with other PG products to better analyze and monitor the evolution of both systems.

The main goals of MPS Proving Ground for 2016 are 1) training forecasters to use new products and become much more familiar with Himawari-8 in preparation for GOES-R; 2) identifying different applications for each product; 3) identifying weaknesses or errors for each product; and 4) gathering user feedback. The 2016 MPS PG will continue to focus on convection, explosive cyclones, heavy precipitation, and fog/low stratus with some new products and expand on the use of multispectral imagery in operations. As part of the JPSS portion of the PG, additional S-NPP products will be explored. The new Global Precipitation Monitoring (GPM) mission will add another level of support for the NOAA satellites program by helping users understand/validate products like the GOES-R rain rate and cloud properties products. One very important goal is to transition the PG into the AWIPS II era in time for the OPC operational transition sometime in FY17, which includes integrating the various GOES-R and JPSS products into the National Centers Perspective so the forecasters can continue to evaluate the products in their new setting. Finally, the CICS RA will continue to be involved in the development and roll-out of official NWS GOES-R and JPSS training following the launches of GOES-R in October 2016 and JPSS-1 in January 2017.

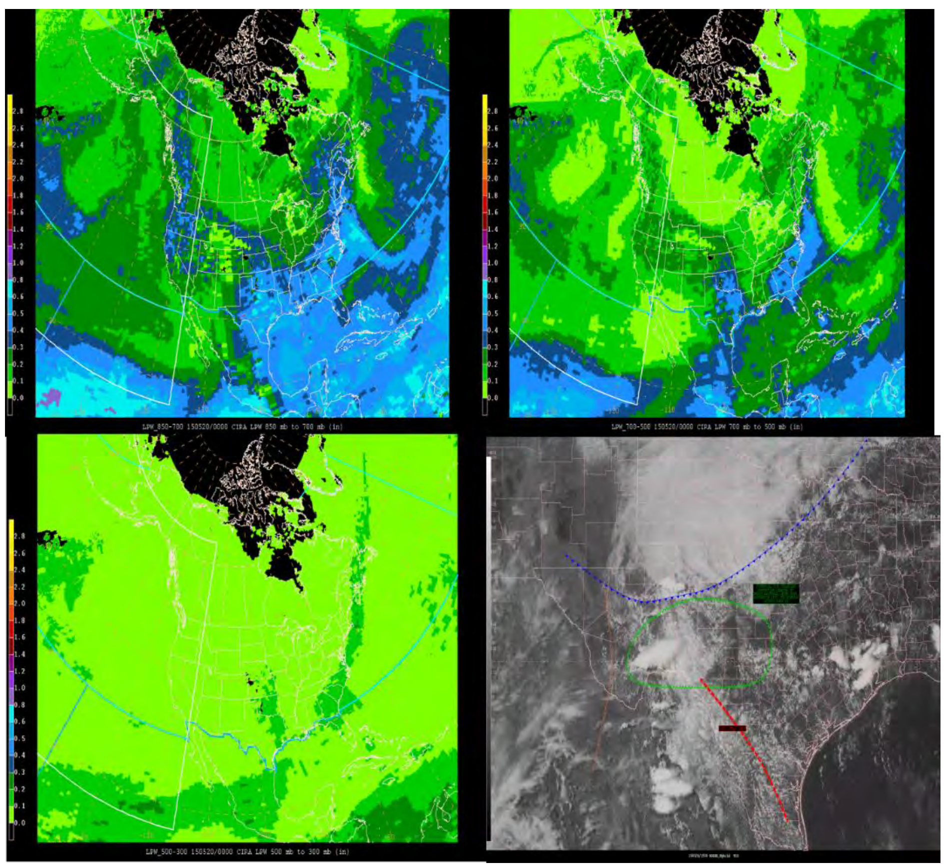


Figure 2: The CIRA Layered Precipitable Water product pictured above was new for the 2015 Demonstrations and was funded as a JPSS project for future improvements. This product was very helpful to SAB during the heavy rain events in TX and LA in mid-May 2015 as it helped identify the moisture sources and levels of interest. Of all products introduced to the MPS PG, this one has seen the most positive feedback to date.

Performance Metrics	FY13
# of new or improved products developed	N/A
# of products or techniques transitioned from research to ops	6
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	11
# of graduate students supported by a CICS task	N/A
# of undergraduate students supported by a CICS task	N/A

Planned Work

- Products to be Demonstrated as a GOES-R and/or JPSS Proving Ground Activity in the PG:
  - Phase I: Winter (15 Feb – 15 May 2016)
    - NESDIS Snowfall Rate – new (JPSS, WPC/SAB)
    - NUCAPS – new (JPSS, all centers)
    - Fog and Low Stratus – 2nd year (GOES-R/JPSS, OPC/TAFB)
    - GeoColor – 2nd year (GOES-R/JPSS, all centers)
    - Nighttime Microphysics RGB – 2nd year, new training (GOES-R/JPSS, all centers)
    - CIRA Layered Precipitable Water – 2nd year (GOES-R/JPSS, all centers)
    - Air Mass RGB – continued (GOES-R/JPSS, all centers)
    - Dust RGBs – continued (GOES-R/JPSS, SAB/TAFB)
      - Dust RGB – EUMETSAT/CIRA
      - Pseudo-Natural Color RGB – CIMSS)
      - SAL Split-Window – CIMSS)
    - Ozone Products – continued (JPSS, all centers)
      - NUCAPS
      - AIRS
      - IASI
    - GOES-14 SRSOR – continued (GOES-R, all centers)
    - VIIRS Imagery – continued (JPSS, all centers)
  - Phase II: Convective Season (15 May – 30 November 2016)
    - Atmospheric Motion Vectors – new (GOES-R, all centers)
    - Daytime Convection RGB – new (GOES-R, all centers)

- Daytime Microphysics RGB – new (GOES-R, all centers)
- QPE/Rainfall Rate – new (GOES-R, SAB/TAFB/WPC)
- NUCAPS – new (JPSS, all centers)
- Cloud Products – new (GOES-R/JPSS, all centers)
  - Cloud Top Temperature
  - Cloud Top Height
- GeoColor – 2nd year (GOES-R/JPSS, all centers)
- Air Mass RGB – continued (GOES-R/JPSS, all centers)
- Dust RGBs – continued (GOES-R/JPSS, SAB/TAFB)
  - Dust RGB – EUMETSAT/CIRA
  - Pseudo-Natural Color RGB – CIMSS
  - SAL Split-Window – CIMSS
- Ozone Products – (JPSS, all centers)
  - NUCAPS
  - AIRS
  - IASI
- Overshooting Top Detection – continued (GOES-R, all centers)
- GOES-R Lightning Detection – continued (GOES-R, all centers)
- Convective Initiation – continued (GOES-R, all centers)
- Nearcast – new training (GOES-R/JPSS, all centers)
- GOES-14 SRSOR – continued (GOES-R, all centers)
- VIIRS Imagery – continued (JPSS, all centers)
- Himawari Baseline – new (GOES-R, all centers)

- Work with AWIPS-II experts to display GOES-R/JPSS products
- Train forecasters on Himawari imagery and prepare for GOES-R/JPSS
- Continue research collaborations with CICS scientists and other academic partners

Publications

- Berndt, E. B., B. T. Zavodsky, and M. J. Folmer, 2015: Development and Application of Atmospheric Infrared Sounder Ozone Retrieval Products for Operational Meteorology, IEEE Transaction on Geoscience and Remote Sensing, **54** (2), 958-967, DOI: 10.1109/TGRS.2015.2471259, http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7265047.
  -
- Folmer, Michael J., Mark DeMaria, Ralph Ferraro, John Beven, Michael Brennan, Jaime Daniels, Robert Kuligowski, Huan Meng, Scott Rudlosky, Limin Zhao, John Knaff, Sheldon Kusselson, Steven D. Miller, Timothy J. Schmit, Chris Velden, and Brad Zavodsky, 2015: Use of satellite tools to monitor and predict Superstorm Sandy 2012: Current and emerging products, Atmos. Res., 166, 165-181, http://dx.doi.org/10.1016/j.atmosres.2015.06.005.

Presentations (* indicates invited)

Folmer, M.J., E. Berndt, J. Halverson, J. Dunion, and M. Goldberg, 2015: An Analysis of the Extratropical Transition of Hurricane Arthur (2014) from a JPSS Proving Ground Perspective. 2015 American Geophysical Union Annual Meeting, San Francisco, CA.

Folmer, M.J., 2015: GOES-R Series Program Update and User Readiness. Visit to Eureka, CA WFO.*

Folmer, M.J., J. Sienkiewicz, J. Clark, A. Orrison, D. Novak, J. Kibler, H. Cobb, N. Ramos, S. Goodman, and M. Goldberg, 2015: Closing in on Launch: How are GOES-R and JPSS convective proxy products changing the forecast process at the Proving Ground for Marine, Precipitation, and Satellite Analysis? 40th Annual National Weather Association Meeting, Oklahoma City, OK.

Folmer, M.J., 2015: GOES-R Series Program Update and User Readiness. Visit to Juneau, Anchorage, and Fairbanks, AK WFOs.*

Folmer, M.J., E. Guillot, 2015: Preparing for GOES-R and JPSS in the National Weather Service. SOO-DOH National Meeting, College Park, MD.*

Folmer, M.J., G. Mandt, S. Goodman, T. Schmit, J. Gerth, and B. Ward, 2015: GOES-R Series Program Update and User Readiness. Visit to Raleigh, Newport/Morehead City, and Wilmington, NC WFOs.*

Folmer, M.J., G. Mandt, S. Goodman, T. Schmit, J. Gerth, and B. Ward, 2015: GOES-R Series Program Update and User Readiness. Seminar during the Flash Flood and Intense Rainfall Experiment (FFAIR), NCWCP, College Park, MD.*

Folmer, M.J., G. Mandt, S. Goodman, T. Schmit, J. Gerth, and B. Ward, 2015: GOES-R Series Program Update and User Readiness. Visit to Sterling, NWS WFO (LWX), Sterling, VA.*

Folmer, M.J., B. Line, A. Terborg, and A. Schumacher, 2015: Current State of RGB User Readiness. 2015 NOAA Satellite Proving Ground and User Readiness Meeting, Kansas City, MO.*

Folmer, M.J., B. Line, A. Terborg, and A. Schumacher, 2015: Current State of the Geostationary Lightning Mapper User Readiness. 2015 NOAA Satellite Proving Ground and User Readiness Meeting, Kansas City, MO.*

Folmer, M.J., 2015: How the Satellite Proving Ground is Complimenting OCONUS Activities at OPC and TAFB. OCONUS Technical Exchange Meeting, Anchorage, AK.*

Folmer, M.J., 2015: The Satellite Proving Ground for Marine, Precipitation, and Satellite Analysis: 2014 Demonstrations. NOAA Testbeds and Proving Grounds Workshop, Boulder, CO.

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.

Other: Outreach

- Co-mentoring a student at Saint Louis University (SLU)
- Co-mentoring a PhD student at the University of Alabama-Huntsville (UAH)
- Co-mentoring two University of Maryland Interns at OPC
- Visiting WFOs when possible to update on GOES-R and introduce the MPS PG

Facilitating Direct CICS Support for Satellite Proving Ground Efforts & Supporting ProbSevere Development

Task Leader: E. Hugo Berbery
Task Code: EBSR_GOESR_15/EBEB_PGTC_15/EBEB_EPSD_15
NOAA Sponsor: Steven Goodman, Mitch Goldberg, Mike Kalb
NOAA Office: NESDIS - GOES-R / JPSS / NESDIS-STAR
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%
Highlight: Following nearly three years of effort, a NOAAPORT Satellite Broadcast Network (SBN) antenna, receiver, and server have been installed at CICS-MD. The NOAAPORT will provide nearly identical feeds to those received at National Weather Service (NWS) offices, allowing CICS-MD to simulate operational environments for the first time.
Link to a research web page: http://cicsmd.umd.edu/

Background

The JPSS and GOES-R programs have provided 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. Target products include ATMS and SSMIS snowfall rates, regional AMSR-2 products for the OCONUS, and lightning enhanced precipitation products. The PGTC will help with additional JPSS product lines being developed by NESDIS/STAR scientists located adjacent to SCSB/CICS-MD at the NCWCP (e.g., aerosol and fire products). The proposed research will develop satellite education and training materials through e-learning modules, seminars, weather event simulations, and special case studies. The PGTC seeks to produce graduates with remote sensing experience ready to staff future NESDIS activities as support contractors and civil servants.

The NOAA/CIMSS ProbSevere model statistically integrates satellite-derived, radar-derived, and NWP-derived data to forecast the probability of the first severe weather occurrence in developing thunderstorms. The statistical model (a naïve Bayesian framework) employs multi-scale, multi-sensor object identification and tracking, and uses temporal trends in satellite fields, radar intensity metrics, and NWP environmental parameters as predictors. Severe storm reports are integral to the Bayesian framework, limiting current ProbSevere development and implementation to the Contiguous United States (CONUS). CICS-MD has begun working to investigate how to best incorporate lightning data into the ProbSevere model, and explore its potential as a severe storm indicator in the OCONUS.

Accomplishments

- A NOAAPORT Satellite Broadcast Network (SBN) antenna, receiver, and server have been installed at CICS-MD. The NOAAPORT will provide nearly identical feeds to those received at National Weather Service (NWS) offices, allowing CICS-MD to simulate operational environments for the first time. This equipment is integral to the planned CICS-MD Proving Ground and Training Center, which will promote interactions between scientists, students, and forecasters.

- AWIPS-II, WDSS-II, and McIDAS have been implemented to visualize real-time and archive data from satellite- and ground-based sensors.

- An LDM Server has been built to obtain experimental products from the other cooperative institutes. This server will eventually serve out demonstration products, and allowing CICS-MD scientists to help promote their smooth transition into operations.

- A local governance structure has been defined to provide a centralized approach to addressing many of the common PG challenges facing CICS-MD/STAR scientists. Our project management framework and local governance structure will help ensure project success.

- The ProbSevere portion of this project has increased collaboration between the STAR/CoRP branches (i.e., CICS and CIMSS). This increased collaboration provides an avenue for sharing lightning data and expertise with CIMSS.

- Several of the individual ProbSevere components have been implemented (i.e., McIDAS, WDSS-II, IDL, MRMS, while a few others have yet to be installed (e.g., Geocat).

Figure Caption: SBN Antenna atop the M-Square research building that houses CICS-MD.

Planned Work

- 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.
- Continue to advise Shobha Kondragunta (NESDIS/STAR) and Ivan Csiszar (NESDIS/STAR) as they work to implement their aerosol and smoke products in NWS operations.
- Work with Huan Meng (NESDIS/STAR/SCSB) and NASA SPoRT as they investigate the visualization, training, and gathering of user feedback regarding the NESDIS/STAR snowfall rate product.
- Implement the Community Software Processing Package (CSPP) – Although the SBN is the main NWS data distribution tool, other (newer) data sets often must be gathered using different means. The CSPP provides a standardized means for interacting with the direct broadcast community, and thus provides an essential tool for product developers.
- Implement the remaining ProbSevere components and integrate them to compute ProbSevere probabilities over CONUS (archive and real-time).
- Maximize the impact of lightning data on ProbSevere development
- Determine the feasibility of meaningful ProbSevere implementation in the OCONUS
- Investigate the usefulness of the GLD360 data within the ProbSevere framework
- Intercompare CIMSS ENTLN results with the CICS-MD GLD360 findings
- Conduct GOES-R Visiting Scientist travel (John Cintineo, UW/CIMSS) to assist in our implementation of ProbSevere. 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.

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

4.1 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%.

Highlight: We have developed an operational evapotranspiration and drought monitoring system using GOES Land Surface Temperature product, meteorological data and other ancillary satellite remote sensing data. The GET-D product has been operational at NOAA OSPO.

Background

The GOES ET and drought product system (GET-D) has been developed and operational at the NOAA Office of Satellite and Product Operations (OSPO) in 2016. The GET-D system is based on a surface energy balance model specifically adapted for geostationary satellite data to calcu- late 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 tem- perature (LST), hourly down- welling short and long-wave radiation, and leaf area index. We have spearheaded use of anomalies in the remotely sensed ET/PET fraction (f_{PET}) generated with ALEXI as a drought monitoring tool that samples variability in water use, and demonstrating complementary value in combination with standard drought indices that reflect water supply. ALEXI provides a framework for interpreting LST and vegetation index remote sensing drought signals within the context of a physically based energy balance model. This is the first ET and drought monitoring data product that are operationally supported at NESDIS from GOES. Figure 1 presents high-level design and data flow of the GET-D system.

Accomplishments

The GOES ET and drought product system (GET-D) has been developed and operational at the NOAA Office of Satellite and Product Operations (OSPO) in 2016. In the past funding cycle, we have finished the system test, system readiness review, operational readiness review and SPSRB briefing. We also updated the GETD Algorithm Theoretical Basis Document (ATBD) and rele- vant description documents. The project deliverables (documentation and software) and mile- stones have been accomplished as planned. Figure 2 presents an example of 2/4/8/12-week composite of ESI generated from the GET-D sys- tem at 8km resolution over the North American domain (March 07th, 2016).

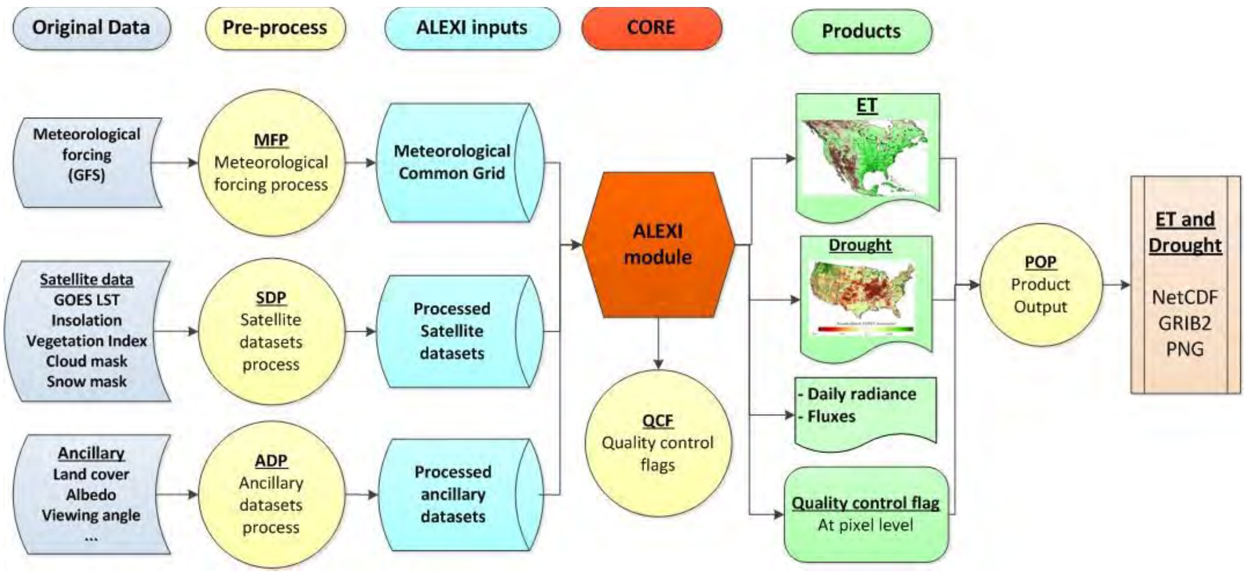


Figure 1. GOES Evapotranspiration and Drought Product (GET-D) system design.

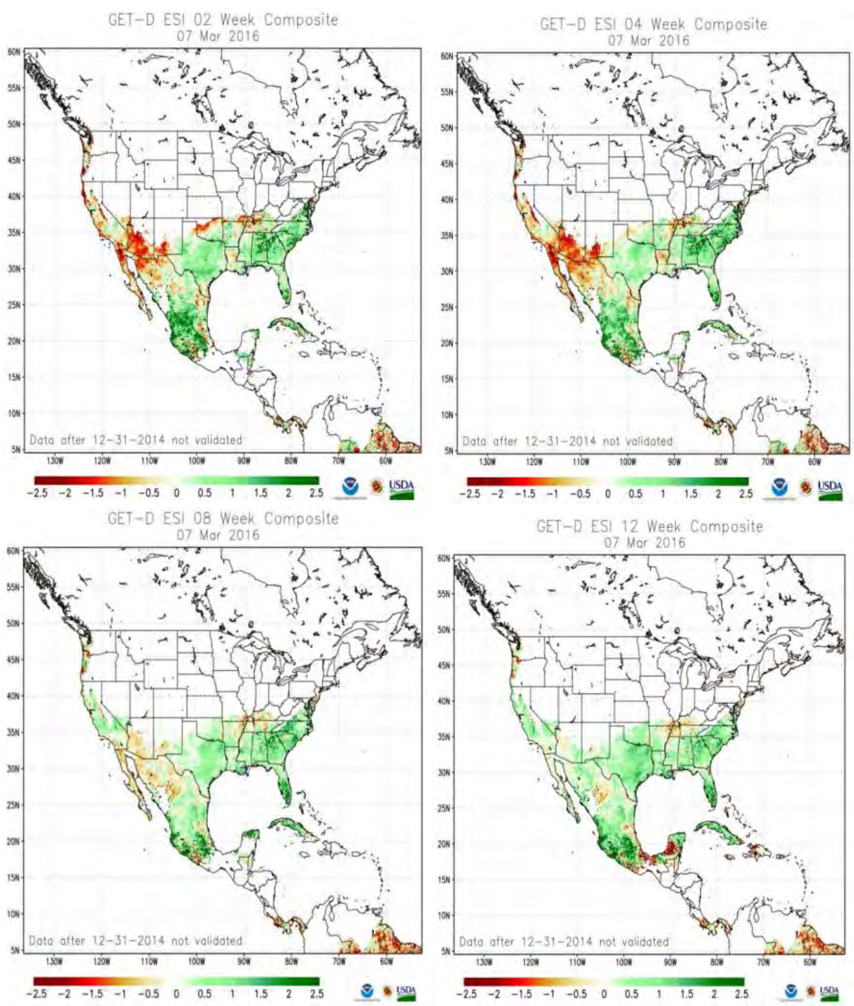


Figure 2. Example ESI composites from the GET-D system

Planned Work

N/A

Publications

Anderson, M.C., Zolin, C., Hain, C.R., Semmens, K., Tugrul Yilmaz, M., and Gao, F. 2015: Comparison of satellite-derived LAI and precipitation anomalies over Brazil with a ther- mal infra-red-based Evaporative Stress Index for 2003-2013, J. Hydrol., 526, 287–302. http://dx.doi.org/10.1016/j.jhydrol.2015.01.005

Otkin, Jason A., Martha C. Anderson, Christopher Hain, and Mark Svoboda, 2015: Using Tem- poral Changes in Drought Indices to Generate Probabilistic Drought Intensification Forecasts J. Hydrometeor, 16, 88–105. http://dx.doi.org/10.1175/JHM-D-14-0064.1

Otkin, Jason A. , Mark Shafer, Mark Svoboda, Brian Wardlow, Martha C. Anderson, Christo- pher Hain, and Jeffrey Basara, 2015: Facilitating the Use of Drought Early Warning Information through Interactions with Agricultural Stakeholders, Bull. Amer. Meteor. Soc., 96, 1073–1078 http://dx.doi.org/10.1175/BAMS-D-14-00219.1

Crow,W. T., F. Lei, C. Hain,M. C. Anderson, R. L. Scott, D. Billesbach, and T. Arkebauer, 2016 Robust esti-mates of soil moisture and latent heat flux coupling strength obtained from triple col- location, Geophys. Res. Lett., 42, http://dx.doi.org/10.1002/2015GL065929 (In Press)

Fang, Li, Christopher R. Hain, Xiwu Zhan and Martha C. Anderson, 2016: An inter-comparison of soil moisture data products from satellite remote sensing and a land surface model, Int. J. Appl. Earth Ob-serv. Geoinf. ,http://dx.doi.org/10.1016/j.jag.2015.10.006 (Accepted)

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

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

Products

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

Presentations

Chris Hain, M. C. Anderson, J. Otkin, T. R. H. Holmes, and W. T. Crow, Implementing the Re- motely Sensed Evaporative Stress Index Globally Using MODIS Day/Night Land-surface Tem- peratures, poster in AMS 96th Annual Meeting, New Orleans, LA, 2016

Zhengpeng Li, C. Hain, L. Fang, X. Zhan, and M. C. Anderson, GOES Evapotranspiration and Drought Product System (GET-D), poster in AMS 96th Annual Meeting, New Orleans, LA, 2016

Berbery, E. Hugo, Christopher Hain, Martha Anderson, Xiwu Zhan, Jicheng Liu, Ralph Ferraro, Robert Adler and Huan Wu, Consistency analysis of the water cycle from recently derived satel- lite products, AGU Fall Meeting, San Francisco, CA, 12/14/2015 to 12/18/2015.

Holmes, Thomas, Christopher Hain, Richard de Jeu, Martha Anderson, and Wade Crow, Effects and Mitigation of Clear Sky Sampling on Recorded Trends in Land Surface Temperature (invit- ed), AGU Fall Meeting , San Francisco, CA, 12/14/2015 to 12/18/2015.

Holmes, Thomas, Wade Crow, Christopher Hain, Martha Anderson and William Kustas, Micro- wave based implementation of two source energy balance model to estimate Evaporation, AGU Fall Meeting, San Francisco, CA, 12/14/2015 to 12/18/2015.

Kustas, William, Martha Anderson, Christopher Hain, John Albertson, Reggio Emilia, Feng Gao, and Yun Yang, Upscaling and Downscaling of Land Surface Fluxes with Surface Temperature (invited), AGU Fall Meeting, San Francisco, CA, 12/14/2015 to 12/18/2015.

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	**7**
# 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**

Performance Metrics Explanation

This year, we developed a new 8-km North American domain drought monitoring product (1) and the product has been operational. Seven peer-reviewed papers were published in 2015 high- lighting the use of GET-D products. Six presentations summarizing the product and its applica- tions were made at various scientific conferences and workshops.

Washington D.C. Lightning Mapping Array Maintenance and Outreach & Real-time Monitoring of Lightning Detection Network Performance

Task Leader: E. Hugo Berbery
Task Code: EBSR_DCLMA _15, EBSR_RMLD_15
NOAA Sponsor: Steven Goodman, Jaime Daniels
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%
Highlight: Several recent projects have helped improve the visibility of the DCLMA and demonstrate its value for severe weather analysis and public outreach.
Link to a research web page: http://cicsmd.umd.edu/

Background

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

Many meteorological applications use lightning observations from both ground- and space-based lightning detection systems. As the number of networks and variety of users expands, it becomes increasingly important to understand the detection capabilities of these networks. Both Rudlosky and Shea (2013) and Rudlosky (2015) evaluated the performance of ground-based lightning detection networks relative to observations from the Tropical Rainfall Measurement Mission (TRMM) Lightning Imaging Sensor (LIS). The GOES-R Geostationary Lightning Mapper (GLM) Science Team also has developed several tools for validating lightning detection networks. This project will implement real-time lightning monitoring tools in support of operational GOES-R GLM users and long-term monitoring requirements. It then will composite inter-comparison and validation results from GLM Science Team members and identify the best means for disseminating this valuable information. Finally, it will improve our understanding of ground- and space-based lightning detection systems to better inform scientists and forecasters using these data for weather research, modeling, and forecasting applications.

Accomplishments

The DCLMA remained operational with at least 7 sensors reporting during all of calendar year 2015. These data were shared with operational users and also to develop training materials for National Weather Service (NWS) forecasters. Two undergraduate students have been trained to work on the DCLMA sensors, and also to use the Warning Decision Support System – Integrated Information (WDSS-II) to interrogate these data alongside radar and model observations. This ongoing research uses the DCLMA and Earth Networks Total Lightning Network (ENTLN) along with WDSS-II which allows visualization and clustering of convective storms in an interactive, 3-D graphic display, to provide detailed insights into the structure and evolution of convective storms. We examined specific lightning cases to match lightning paths, heights, and strike locations with lightning photographs. This project led to collaborations with the Washington Post's Capital Weather Gang and two posts on their blog.

This project began by delving more deeply into the dataset created by Rudlosky (2015) to investigate the properties of lightning flashes that were observed by the LIS and those that were not. These results have been communicated to members of the GOES-R GLM science team to help with their investigation of the fraction of lightning flashes that come to ground. CICS-MD connected to real-time lightning feeds (e.g., NLDN, ENTLN, DCLMA) via a new Satellite Broadcast Network (SBN) antenna. Data from private vendors is presently provided by commercial software systems that allow for the real-time visualization of these data. We attended a workshop in Huntsville, AL to explore lightning validation tools developed by other GLM Science Team members. We have begun the process of implementing these tools in real-time to determine which validation procedures are best for this purpose.

Planned Work

- Continue collaborations with scientists at the University of Alabama Huntsville and NASA Marshall Space Flight Center
- Take advantage of new LMA installment at Wallops Island for collaborations and to gain interesting insights into storms along the Delmarva Peninsula.
- Explore the potential for merging the D.C. and Wallops Island LMAs to cover a larger region.
- Compile a DCLMA archive and continue to document significant severe weather, lightning induced structural damage, and any lightning casualty events
- Support hourly undergraduate researchers who visit sensors that fail to bring them back online
- Continue exploring lightning validation tools developed by other GOES-R GLM Team Scientists to determine which procedures are best suited for real-time implementation.
- Implement selected procedures to compute performance statistics in near real-time for both the GOES-R GLM and ground-based networks (e.g., the National Lightning Detection Network - NLDN and Earth Networks Total Lightning Network - ENTLN).
- Composite these statistics over seasonal and annual periods, and report the findings periodically through manuscript publications and conference presentations.
- Merge the new procedures with the existing CICS-MD Cal/Val Center and planned PGTC. These capabilities will be developed in conjunction with the STAR/CICS-MD Precipitation Cal/Val Center and the newly emerging CICS-MD PGTC. Various paths will be explored to determine the optimal method for sharing these performance statistics with lightning data users.
- Determine the optimal method for sharing performance statistics with lightning data users. Data initially will be provided via a webpage modeled after the CICS-MD Precipitation Cal/Val Center. As

the CICS-MD PGTC grows, additional tools will become available for distributing performance statistics in near real-time. We anticipate that this information will benefit both operational weather forecasters and numerical modelers.

Presentations

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

Kahn, D. and S. Rudlosky, 2016: Capabilities and Limitations of New Lightning Data Sets in Operations, *AMS Annual Meeting*, New Orleans, LA, P440.

Other

Douglas Kahn, an UMD/AOSC undergraduate won 3rd place for his presentation in the research to operations session at the AMS annual meeting. This accomplishment was even more impressive since he was competing with graduate students. Keenan Eure, an UMD/AOSC undergraduate was selected for a Research Experience for Undergraduates (REU) program at Colorado State University during summer 2016. Keenan is also in the running for a coveted spot as a NOAA Hollings Scholar.

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	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**2**

Updating CRTM for Supporting GOES-R AWG Applications

Task Leader: Hu Yang
Task Code: HYHY_CRTM_15
NOAA Sponsor:
NOAA Office:
Contribution to CICS Research Themes (%):
Main CICS Research Topic : Future Satellite Programs-Scientific support for GOES-R Mission
Contribution to NOAA goals (%)

Background

Preparing for the incoming launch of the GOES-R, we will update the current CRTM to accommodate to both the scientific and operational needs for the future GOES-R applications. For GOES-R algorithm developments, such activity includes updating the CRTM capability for simulating hot spots, visible channel reflectance for aerosols and clouds. Meanwhile, the associated look-up-tables (LUT) for clouds, aerosols and precipitations will be updated with refinements. Moreover, new high-spatial resolution surface emissivity models for IR wavelength will be developed. To enhance the calibration and validation (CalVal) science activities for the both GOES-R, CRTM will be extended from the current scalar to vector radiative transfer model. By doing so, the new vector version of CRTM can provide solution of the full Stokes vector with the coupled information. In addition, we will continue working on improving the current emissivity models of polarized surfaces (e.g., ocean and land). Implementing such new surface emissivity models to the vector CRTM will also play a key role to the instrument CalVal process. This task includes the following parts: Update CRTM to accommodate to the future satellite applications and new polarized surface emissivity models.

Accomplishments

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.

For the testing of new scattering coefficient, there are slight differences for ATMS low frequency window channels 1 to 3 and gas absorption channels 4 to 15. But the differences in millimeter and sub-millimeter channels 16 to 22 are obvious. Figures 1 and 2 show the impacts of DDA model. The new scattering coefficient correct the overestimating of CRTM brightness temperature around deep convective area, but that also cause more underestimating in the center of typhoon. The impact of typhoon Neoguri is similar to Rammasun. Overall, the new scattering coefficient also does slight improvements the simulation of other channels, and the improvement of high frequency channels is more obvious then low channels.

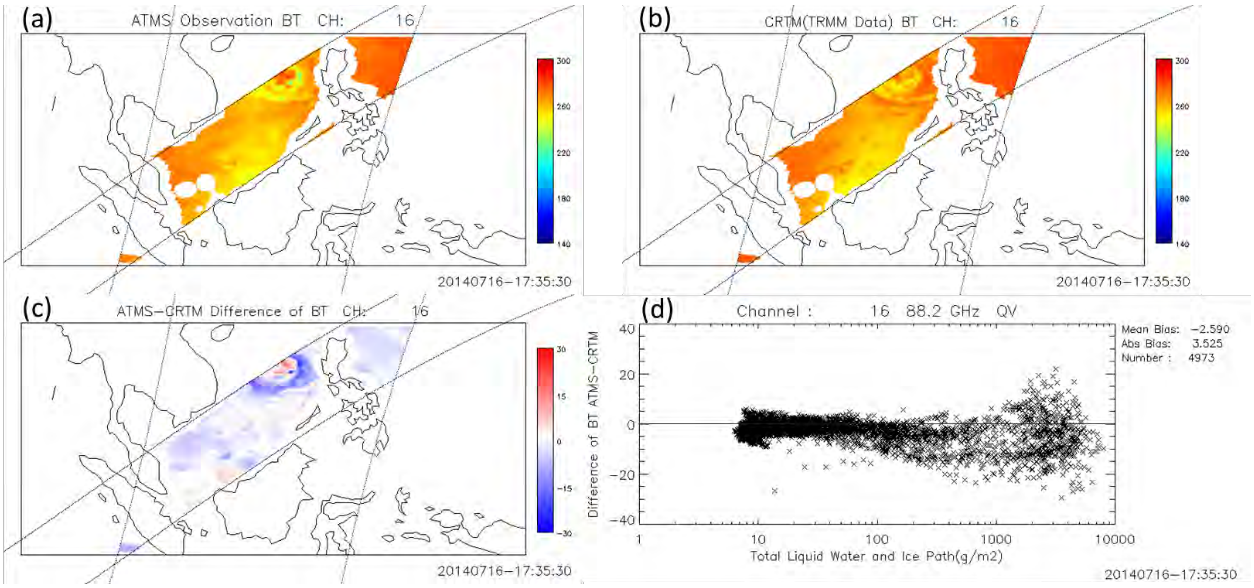


Figure 1: The simulation of typhoon Rammasun in channel 16 with original coefficient. (a) The ATMS brightness temperature observation; (b) The simulation of CRTM; (c) The bias distribution of Observation and simulation; (d) Scatter plot for bias and cloud water and ice contents.

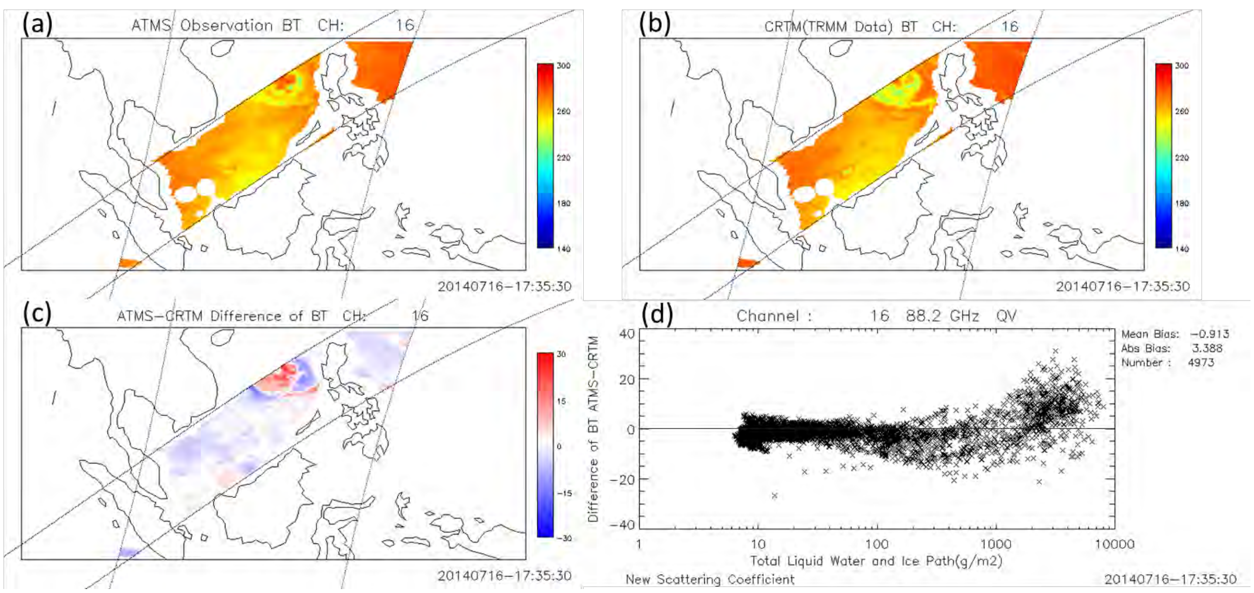


Figure 2: Same as the figure above except for a new scattering coefficient.

Planned work

- Operational software and codes for vector radiative transfer model
- Briefing materials

Products

[1] Software and source code of surface emissivity models for full polarized radiative transfer
[2] Emissivity data bases from SNPP CRIS and VIIRS

UAH GOES-R GLM Lightning Jump Algorithm: A National Field Test for Operational Readiness

Task Leader Lawrence D. Carey (UAH) and Kristin Calhoun (OU CIMMS/NSSL, Project co-PI)
Task Code LCLC_GCLM_15
NOAA Sponsor Steven J. Goodman (NESDIS, GOES-R Program Senior Scientist)
NOAA Office GOES-R
Contribution to CICS Research Themes (%) Theme 2: Climate and Satellite Observations and Monitoring (100%).
Main CICS Research Topic 4. Future Satellite Programs a. Scientific support for the GOES-R Mission
Contribution to NOAA goals (%) 1. To understand and predict changes in climate, weather, oceans and coasts (90%); and 2. To share that knowledge and information with others (10%)
Highlight Lightning Jump Algorithm tested at Hazardous Weather Testbed (HWT) in Spring 2015 across CONUS and will again shortly in Spring 2016.
Link to a research web page http://hwt.nssl.noaa.gov/ewp/

Background

A fully automated, real-time Lightning Jump Algorithm (LJA) was evaluated for the second time in the operational environment of the Hazardous Weather Testbed (HWT) in Spring 2015 and is being prepared for testing again in Spring 2016 HWT. The LJA was designed to highlight rapid intensification in thunderstorms preceding severe weather such as tornadoes, hail and straight-line winds at the surface by tens of minutes. While the GOES-R Geostationary Lightning Mapper (GLM) provides a general path to operations for the use of continuous total lightning observations and the lightning jump concept over a hemispheric domain, the operational implementation of the LJA pre-GLM in the 2015 HWT experiment was produced using data from the Earth Networks Total Lightning Network (ENTLN). The addition of ENTLN data allowed for the evaluation of the LJA by forecasters on a daily basis throughout the experiment; this was possible due to the continental United States coverage of the ENTLN as opposed to the limited range the Lightning Mapping Arrays (LMA) that were utilized in the 2014 evaluation period. While the detection efficiency of the ENTLN is less than the LMA, this addition ultimately provided more feedback regarding the algorithm display, integration within the warning-decision process, and best practices for future implementation. Both LMA and ENTLN based implementation of the LJA are available for testing in 2016 HWT. The LJA remained one of the most highly utilized products in the warning process for the 2015 GOES-R proving ground evaluation. We continued to refine and expand our understanding of the relationship between radar and lightning jump intensity metrics in a wide variety of storm types, which provides a physical basis for incorporating the jump into ProbSevere and other multi-sensor/parameter algorithms.

Accomplishments

We continue to improve upon our national test of the LJA at HWT. During Spring 2015, we incorporated Earth Network's Total Lightning Network (ENTLN) into our real-time algorithms to evaluate LJA on a national scale with no data gaps. Before, we were limited to using total lightning from a handful of regionally available LMA's (e.g., Alabama, Colorado, Oklahoma, Texas Panhandle and Washington DC). The addition of ENTLN to the Spring 2015 NOAA HWT Experimental Warning Program (EWP) allowed the LJA to be tested more comprehensively by forecasters by increasing the number and diversity of severe weather events that could be interrogated during the program. Feedback from forecasters continues to be positive and suggestions are being incorporated into the algorithm. For example, updated algorithm code and LJA products to reflect forecaster feedback and suggestions from Spring 2015 HWT field test have been prepared for the Spring 2016 evaluation. An example of a recent forecaster suggestion was to incorporate a visual metric of negative lightning jumps (or rapid decreases in lightning) that could be related to the weakening of the updraft and subsequent severe weather (e.g., hail core collapse, downburst winds, and increased tornado probability associated with strengthening rear flank downdraft).

We began integration of total lightning and the lightning jump into the ProbSevere algorithm as a way to include lightning into a multi-sensor "forecaster-over-the-loop" algorithm. Forecaster feedback has shown that while an integrated algorithm is desired, the lightning jump algorithm with the inclusion of additional metadata (e.g., storm flash rate trends) would be a useful algorithm on its own.

We published a peer-reviewed paper on the relationship between radar kinematic, microphysical and intensity parameters and the lightning jump, paving the way for a better understanding of how to merge radar and lightning jump intensity metrics (Schultz et al. 2015). We have also submitted an additional two peer-reviewed manuscripts that continue to refine our understanding of how the convective updraft is related to the lightning jump (Schultz et al. 2016a) and how best to configure a real time lightning jump algorithm to maximize forecasting outcomes (Schultz et al. 2016b).

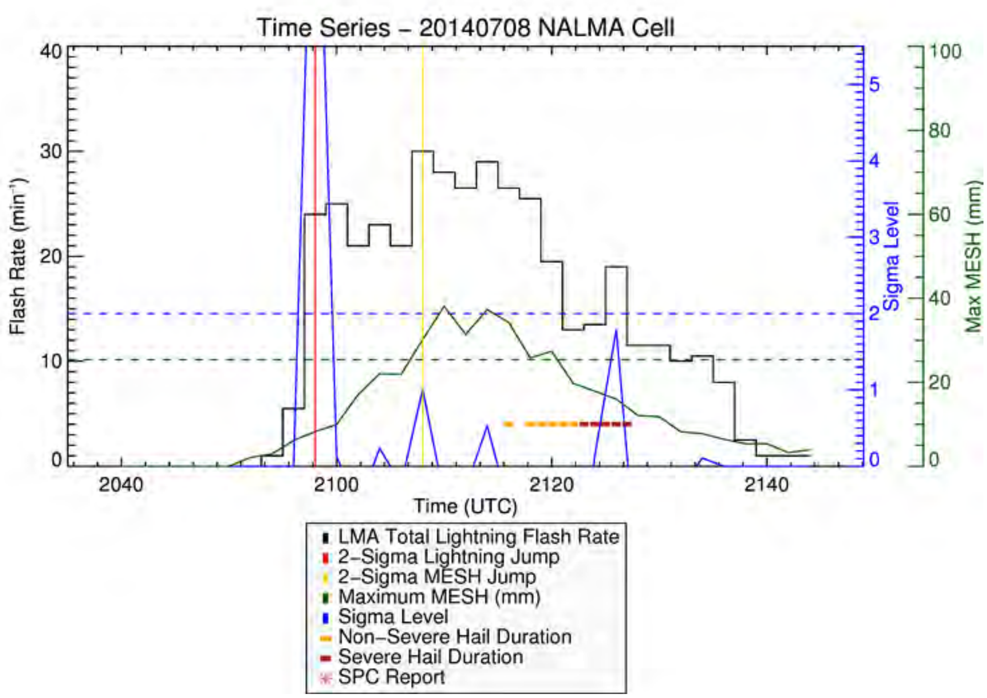


Figure 1. Example of SHAVE and radar Maximum Expected Size of Hail (MESH) verification of the total lightning jump for a case over Northern Alabama LMA on 2014-07-08. Lightning jump occurred 25 minutes before the severe hail occurrence according to SHAVE and also prior to rapid increase (jump) in MESH and maximum MESH.The lightning and radar MESH are fairly well correlated in this case (as MESH increased, lightning increased and both decreased simultaneously.) The large majority of cases (75% to 80%) followed this behaviour.

We completed our study of the relationship between radar, lightning jump and severity in a large number of 1) tornadic and non-tornadic supercells (Stough et al. 2015, AGU; Stough 2015, MS thesis) and 2) tornadic and non-tornadic quasi-linear convective systems (QLCS's) (Williams 2015, MS thesis). Peer-reviewed journal manuscripts are in preparation on these topics.

Continued to extend our study of the relationship between radar, lightning jump and severity in a large number of hail storms (about 35-40 so far) using SHAVE cases, LMA and WSR-88D products. We have found that the overwhelming majority of severe SHAVE cases are preceded by a lightning jump by 10-20 minutes (e.g., **Figures 1, 2**). Interestingly, in a small number of cases, mostly over Colorado and West Texas LMA's, the lightning after the initial lightning jump actually rapidly decreases or remains constant as the hail threat (as ascertained by increasing MESH or SHAVE reports) continues to increase (**Figure 2**). We speculate that this subsequent anti-correlation between lightning rates and MESH/SHAVE after the initial lightning jump may be due to the effect of wet growth on large hail. Wet growth would tend to decrease the efficiency of the non-inductive charging process due to decreased rebounding collisions between hail and small ice. These decreases in lightning may be indicative of negative lightning jumps that could be an additional signature for forecasters to consider in severe weather nowcasting.

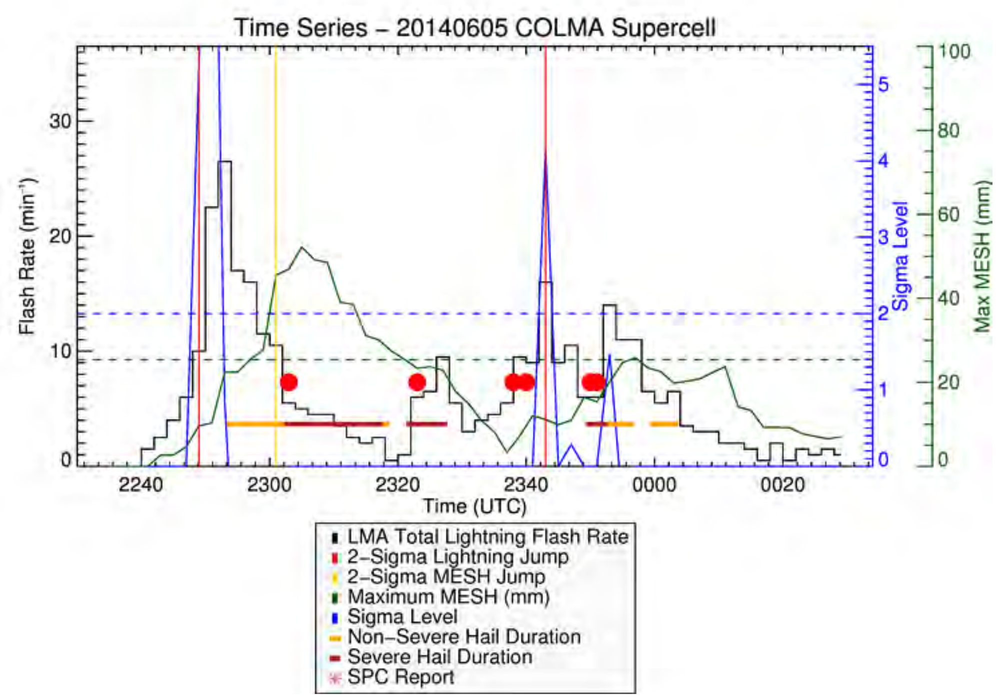


Figure 2. Similar to Figure 1 except for case over Colorado LMA on 2014-06-05. Lightning jump leads severe hail by 13 minutes in this case. Interestingly, after the initial jump in lightning, the lightning begins to dramatically decrease during the jump in MESH, the subsequent peak in MESH and the continued occurrence of severe SHAVE reports. A minority of cases (~20-25%) had similar behaviour. In all of these cases, the lightning jump preceded hail on the ground but the lightning decreased or remained constant as the hail threat continued. It is speculated that inefficient charging due to wet growth of large hail may be responsible for this behaviour. Interestingly, most of these cases occurred in Colorado or West Texas LMA domains.

Planned work

- Conduct final, extended real-time field test of the LJA in the HWT during the GOES Proving Ground Experiment (Apr 18 – May 13, 2016). Evaluation include updates based on forecaster feedback from previous experiments, including a new 5-min product that will be created for 2016 that denotes the maximum value of the jump for the previous 5 min.

- Following a successful evaluation, initial plans include deployment via the Multi-Radar / Multi-Sensor. (MRMS) product suite to NWS operations as part of MRMS version 12.

- Incorporate results from Stough (supercell tornado), Williams (QLCS tornado) and Young (hailstorm) theses into LJA training and methods during HWT 2016. Peer-reviewed papers are also being pursued for the Stough and Williams MS theses.

- Complete our study of the relationship between radar, lightning jump and severity in a large number of hail storms using Severe Hazards Analysis & Verification Experiment (SHAVE) reports with a goal of 50-60 cases total. Alex Young will complete his MS thesis on this topic in Spring 2016. We will pursue a peer-reviewed paper on this subject.

Publications

Peer-Reviewed

Schultz, C. J., L. D. Carey, E. V. Schultz, and R. J. Blakeslee, 2015: Insight into the physical and dynamical processes that control lightning jumps. *Weather and Forecasting*, **30**, 1591-1621. doi: http://dx.doi.org/10.1175/WAF-D-14-00147.1.

Schultz, C., L. D. Carey, E. V. Schultz, and R. J. Blakeslee, 2016a: Kinematic and microphysical significance of lightning jumps versus non-jump increases in total flash rate. *Weather and Forecasting*, **submitted**.

Schultz, E. V., C. J. Schultz, L. D. Carey, D. J. Cecil, and M. Bateman, 2016b: Automated storm tracking and the lightning jump algorithm using GOES-R Geostationary Lightning Mapper (GLM) proxy data. *Journal of Operational Meteorology*, **in revision**.

Student MS Theses

Stough, Sarah, *M.S. thesis*, 2015: "Exploring the Relationship between Lightning Activity and Rotation in Supercell Thunderstorms", University of Alabama in Huntsville, defended August 2015.

Williams, Brett*, M.S. thesis*, 2015: "Assessing the Utility of Total Lightning and the Lightning Jump to Assist in the QLCS Tornado Warning Decision Process", University of Alabama in Huntsville, defended August 2015.

Products

- Lightning Jump Algorithm (LJA) using CONUS ENTLN lightning within EWP of HWT.

Presentations

Joint MTG LI Mission Advisory Group & GOES-R GLM Science Team Workshop, Centro Alti Studi per la Diesa (CASD), Rome, Italy, 27-29 May, 2015.

Carey, L. D. et al. (invited), 2015: Lightning jump science and applications.

AMS 37th Conference on Radar Meteorology, 14-18 Sept 2015. Norman, OK,

Carey, L. D.: ARMOR: 10-years of Serving Science and Society, Invited Keynote Speaker, Session 3: Mesoscale and Severe Weather.

2015 NWA Annual Meeting, 17-22 Oct 2015. Oklahoma City, OK

Calhoun, K. M., D. M. Kingfield E. C. Bruning, T. Meyer, C. J. Schultz, J. Jordan, S. Cobb, G. Stano, E. Schultz, and L.D. Carey: Total Lightning R20 development and evaluation in the HWT and NWS.

2015 AGU Fall Meeting, 14-18 Dec 2015. San Francisco, CA

Calhoun, K. M. et al. (invited): Looking Forward to the GOES-R Geostationary Lightning Mapper: Use of Total Lightning Information within Short-Term Forecasts and Hazardous Weather Warnings. Abstract **AE12A-01.**

Stough, S., L. Carey, and C. Schultz: Total lightning as it relates to rotation in supercell thunderstorms, Abstract **AE12A-03**.

Other

We advised three UAH graduate students: 1) Sarah Stough (defended MS thesis in August 2015), 2) Brett Williams (defended MS thesis in August 2015), and 3) Alex Young (expected defense of MS thesis in May 2016).

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	**3**
# of graduate students supported by a CICS task	**3**
# of graduate students formally advised	**3**
# of undergraduate students mentored during the year	**0**

The LJA algorithm was improved to incorporate user feedback and to utilize CONUS-wide ENTLN lightning data.

UAH: Toward An Operational Use of Stroke Level Lightning Data in Severe Weather Forecasting

Task Leader Phillip Bitzer
Task Code PBPB_GOESR_15
NOAA Sponsor Steve Goodman
NOAA Office
Contribution to CICS Research Themes (%) Theme 1: 90% Theme 2: 10%
Main CICS Research Topic Future Satellite Programs: Scientific Support for the GOES-R mission
Contribution to NOAA goals (%) Goal 1: 10% Goal 2: 90%
Highlight

Background

Current research using lightning data in an operational forecasting environment utilizes flash-level data. While this has provided beneficial information including increased lead time and reduced false alarm rate in the forecasting of severe weather, the instruments that detect lightning do not directly detect flashes – this is a derived unit that can vary by detection system and the parameters used to sort the data into flashes. In addition, not all flashes contribute equally to the electrical energy budget of a storm, further complicating the relationship if lightning with the occurrence of severe weather.

There may be more information at a more fundamental level of lightning data. In particular, the use of stroke-level data may provide more information in the underlying energetics of storm development. This work leverages existing space-based optical emission data from the Lightning Instrument Sensor (LIS) to explore the utility of stroke-level data, using the classification of a group (roughly equivalent to a stroke). However, LIS is low earth orbit, which limits the ability to analyze an evolving storm. To overcome this limitation, this research also uses ground-based instrumentation that is sensitive to stroke level data. Initial work will relate the ground-based detections to LIS detections to develop a proxy data set for a dynamic storm and to demonstrate the differences in lightning detection from the ground and space.

Since the Geostationary Lightning Mapper (GLM), a joint NOAA-NASA instrument, will provide similarf data to that of LIS across the Western Hemisphere from geosynchronous orbit, this task provides an important step to understanding the information provided from space-based measurements. Further, this task explores the detection of continuing current, a known type of lightning that neutralizes much more charge than typical lightning discharges.

Accomplishments

This task is on-going, yet some important results have already emerged relating ground-based systems to space-based systems that detect lightning. In particular, a comparison between the ground-based Earth Networks Total Lightning Network (ENTLN) to the LIS determined that ENTLN detects 26.9% of LIS groups near North America and 13.3% of LIS groups in the Western Hemisphere. Further, LIS detects 52% of ENTLN pulses (strokes), and this is largely domain independent. An improved methodology utilizing Bayesian techniques to assess the detection efficiency of these instruments has been developed to show that, of all discharges detected by ENTLN and/or LIS near North America, ENTLN detects 41% and LIS detects 81%. Figure 1 shows the relative detection efficiency of ENTLN, given a LIS group occurred.

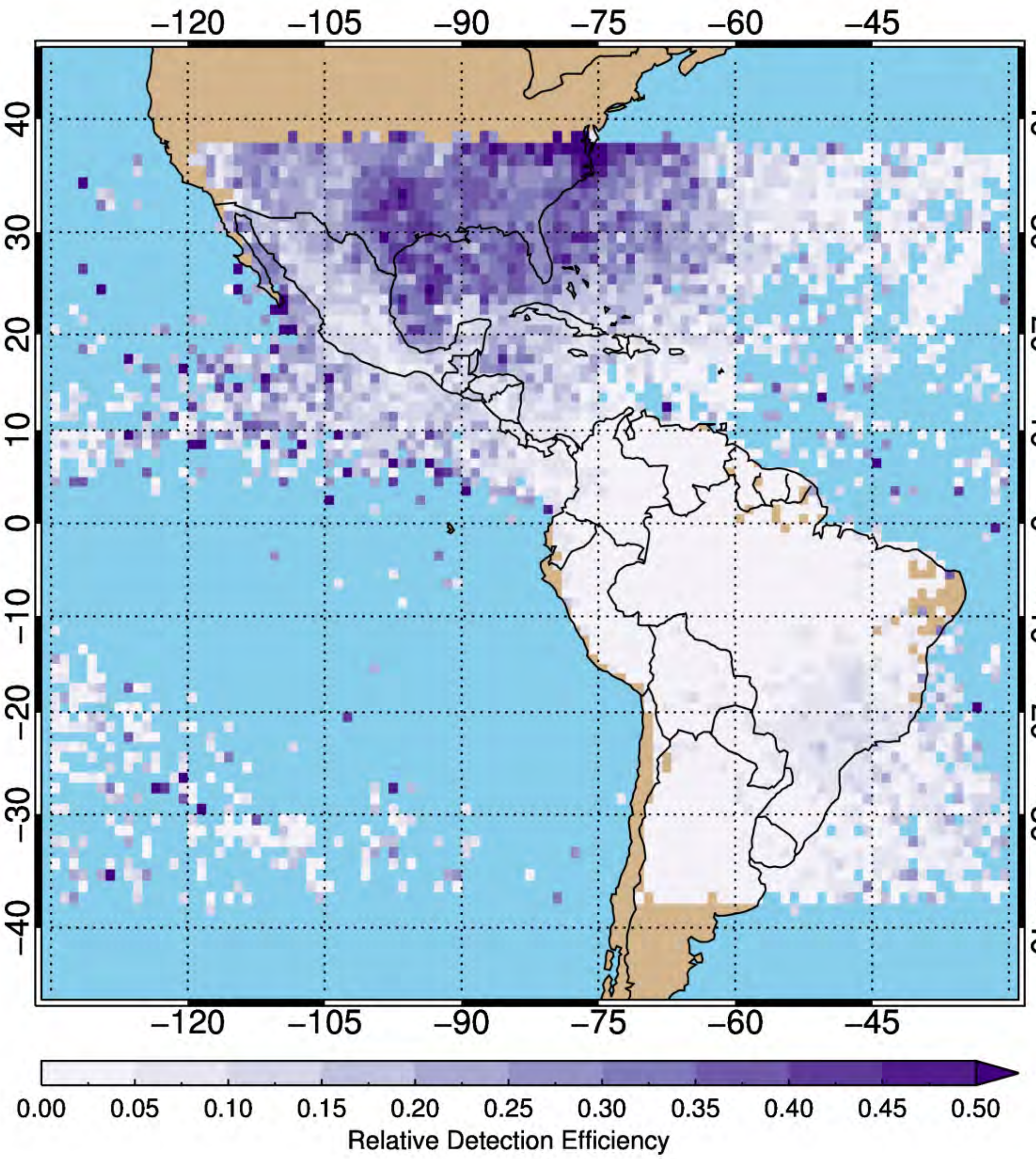


Figure: The relative detection efficiency of ENTLN, given a LIS group occurred. For the year 2013, ENTLN detected 13.3% of LIS groups in this domain. Near North America, ENTLN detects 26.9% of LIS groups.

In addition, work on the occurrence of continuing current lightning using space-based measurements has found that 11% of all flashes contain continuing current. Space-based measurements that detect the optical signature from lightning are well suited to this determination. Figure 2 shows the global distribution of lightning with continuing current, the first such map ever produced. Further, these flashes are more likely to occur when flash rates are relatively low, e.g., over oceanic regions and during winter months.

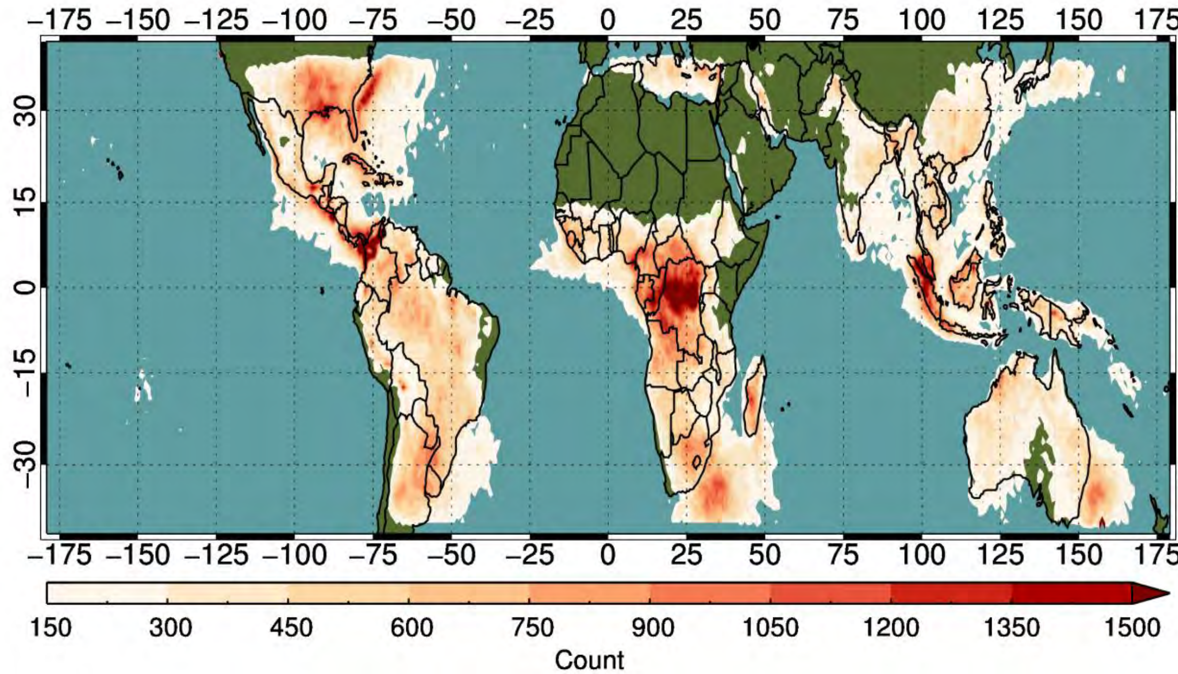


Figure: The number of flashes with continuing current detected by LIS from 2002-2013. Overall, 11% of flashes detected by LIS contain at least seven milliseconds of continuing current.

Finally, work relating ground-based systems such as ENTLN and the Huntsville Alabama Marx Meter Array (HAMMA) has produced a preliminary model to predict the occurrence of the detection of a lightning discharge from a space-based system. The current model successfully predicts a group 75% of the time, with a false alarm rate of 30%. This model is currently being refined, with the goal of analyzing a entire storm evolution to explore the benefit of utilizing stroke (group) level data.

Planned work

- Refine the model to predict the occurrence of a space-based detection of a lightning discharge
- Use the model to analyze a storm evolution
- Explore techniques to determine anomalous lightning behavior that indicate a strengthening storm capable of producing severe weather

Publications

Peer Reviewed:

Bitzer, P. M., Burchfield, J. C., and Christian, H. J. (2016). A Bayesian approach to assess the performance of lightning detection systems. Journal of Atmospheric and Oceanic Technology, 33(3):563–578.

Submitted:

Bitzer, P. M. (2016). Global distribution and properties of continuing current in lightning. Geophysical Research Letters, submitted.

Products

Model to predict dateable optical emission from space based on VLF parameters (in development)

Presentations

Ringhausen, J. and Bitzer, P. M. (2016). A comparison of the VLF waveform and optical emissions using ground based and spaced based lightning detection methods. Presented at 2016 Meeting of the American Meteorological Society.

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	0
# of peer reviewed papers	1
# 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	0

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

Task Leader: Peng Yu
Task Code: PYPY_GOESR_15
NOAA Sponsor: Yunyue Yu
NOAA Office: NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%): Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic: Scientific support for the GOES-R Missions
Contribution to NOAA goals (%): Goal 1: 40%; Goal 2: 60%; Goal 3: 0%
Highlight
Link to a research web page

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 revision validation tool delivery in 2013, and the validation tool package in 2014, the major works for FY15 are on the algorithm improvement, maintenance, continuity of the validation methodology and data collection, and validation tool development. The algorithm maintenance includes the algorithm integration at STAR Algorithm Integration Team (AIT), local environment GOESR LST computation capability, and documentation updates.

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 was fine tuned to meet the operational requirement. Considering that emissivity is one of the primary input data and the LST retrieval quality greatly relies on the emissivity data quality, the development of a good quality, dynamic emissivity has been researched and tested. Meanwhile, development of an enterprise LST retrieval algorithm is ongoing.

Accomplishments

The LST validation and algorithm evaluation tool has been updated and fine tuned to meet the operational need of the GOES-R LST product. The tool has been combined with the site validation component of the long term monitoring tool. This component processes LSTs from multiple sensors and outputs matchup data between each sensor's LST and each ground site's in-situ observations with a unified format. The matchup data can be directly fed to the validation tool so that preprocessing component of the validation tool can be replaced and this task is routinely carried out along with the routine validation of each sensor's LST. The tool (Figure 1) will be mainly used for the LST validation with respect to different case studies and evaluates multiple retrieval algorithms.

More than 20 LST retrieval algorithms have been tested with data from different sensors. This serves the need for the GOES-R LST retrieval as well as the future enterprise algorithm. As a result, a new algorithm is proposed to be the candidate (1).

$$T_s = C + A_1 T_{11} + A_2 (T_{11} - T_{12}) + A_3 \varepsilon + A_4 \varepsilon (T_{11} - T_{12}) + A_5 \Delta\varepsilon \quad (1)$$

Different from the current ABI LST algorithm, it includes an emissivity difference term and replaces the angular term by retrieval stratification based on different sensor zenith angle ranges. Based on the validation results with VIIRS data and SURFRAD LSTs, it outperforms the current IDPS surface type algorithm and the ABI LST algorithm.

A validation and monitoring system has been completed for the GOES-R LST. It was designed to serve different needs in different GOES-R LST phases. It consists of three main components, the initial data check, the routine validation, and the product monitoring. All three components will be run automatically after the GOES-R launch. The initial data check component checks the main statistics of the retrieved LST and generates report for each time for the three LST products, Full Disk, CONUS, and Meso scale. The site validation component validates the ABI LST with SURFRAD in-situ observations on a daily basis, generates matchup data pairs for validation tool, and initiates warning messages to the LST AWG team when anomalies occur. The monitoring component generates LST images for visual inspection of the product. The system has been completed and tested with the DOE-3 data. All the results are released at ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/LTM/single/GOESR_ABI/. Figure 1 shows an example of the output graphics.

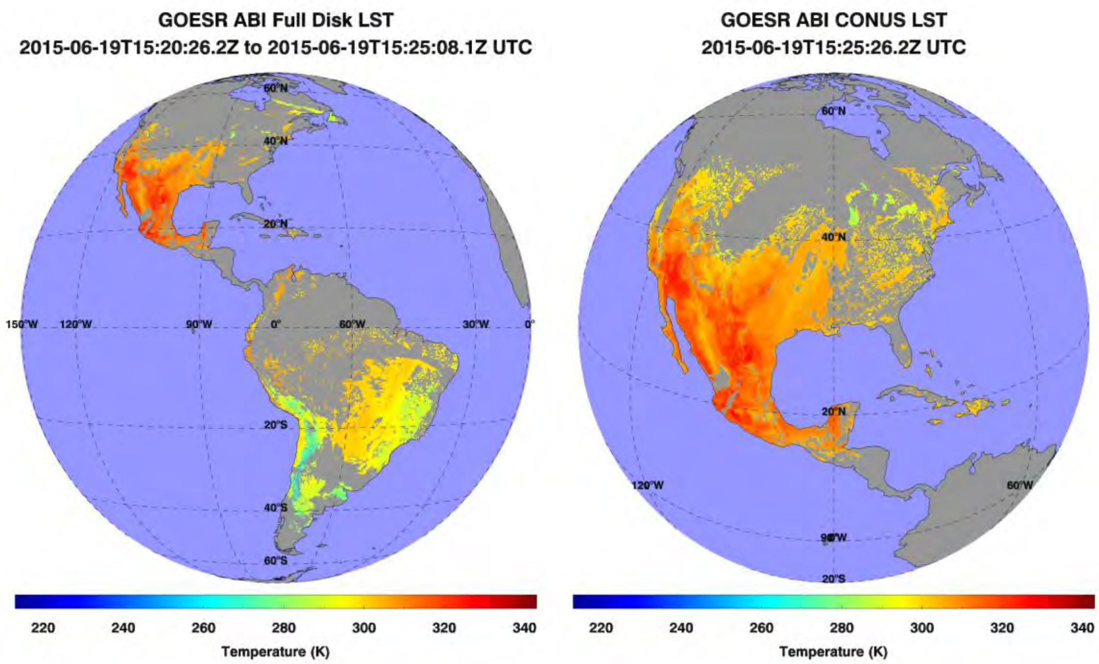


Figure 1. GOES-R LST (DOE-3) Full Disk (Left) and CONUS (Right) at 15:25 Jun. 19, 2015.

To better serve the emissivity based retrieval algorithm, an emissivity retrieval algorithm has been developed and tested. It based on a static climatology field and dynamic input from VIIRS GVF, snow cover to generate a dynamic emissivity product (Figure 2) for different sensors. This product's spatial resolution is 0.09° and has a global coverage. It has been used in the evaluation of different LST retrieval algorithms.

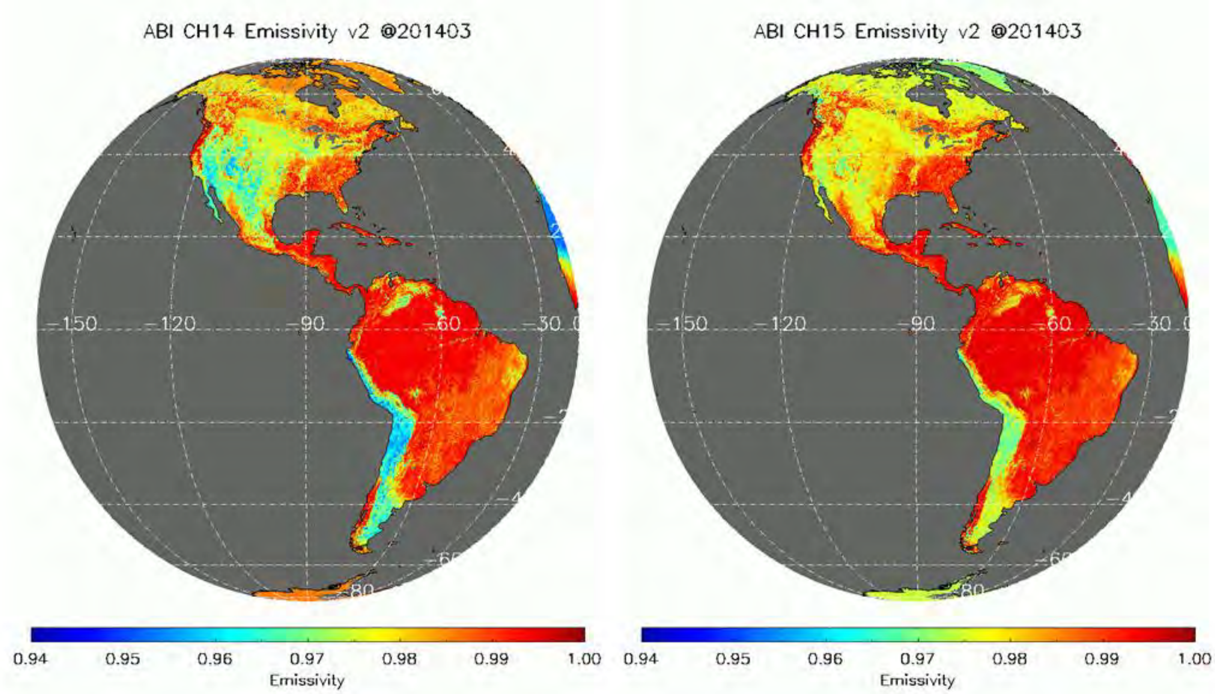


Figure 2. Emissivity product for GOES-R ABI split window bands (March 2013)

The long term monitoring tool has been extended to more sensors, *e.g.*, GOES-West, GOES-East, SEVIRI, and all results can be found at ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/pyu/. Besides, the SNPP VIIRS and AQUA MODIS monitoring results are included in the STAR JPSS website (Figure 3) at http://www.star.nesdis.noaa.gov/jpss/EDRs/products_LST.php#.

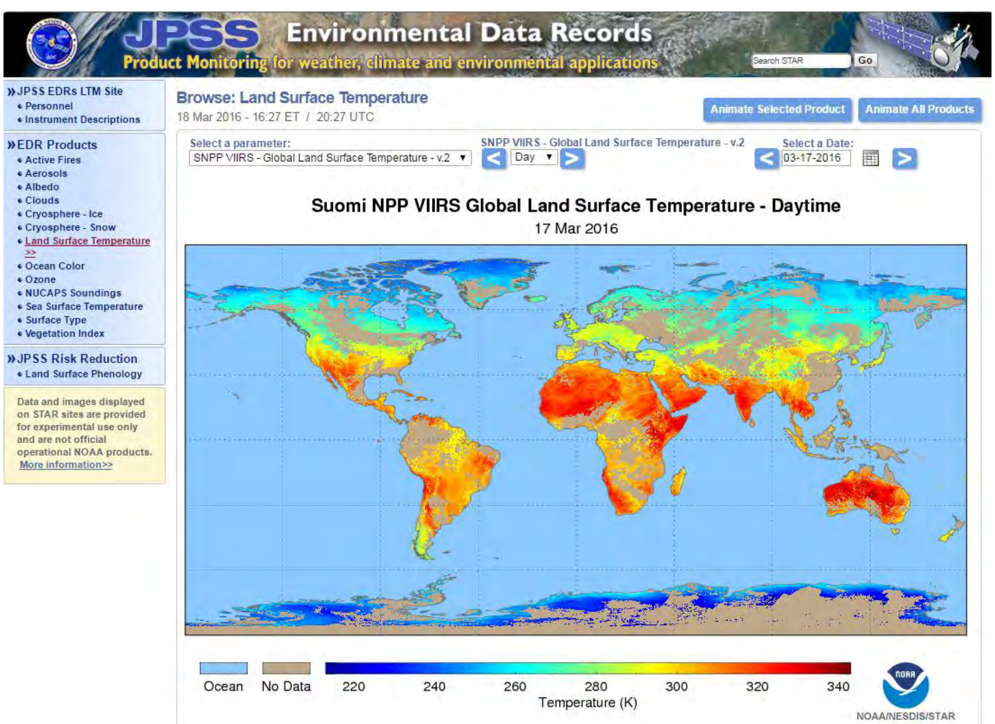


Figure 3. STAR JPSS website for SNPP VIIRS LST product monitoring.

As a perfect proxy for GOES-R ABI, the Himawari-8 AHI data has been extensively used to evaluate the ABI algorithm. An automatic LST generation tool using ABI algorithm has been established and the output images can be found at ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/yrao/AHI_monitoring/. The validation of this product with different in-situ observations and comparison with LSTs from other sensors (VIIRS) are ongoing.

Planned work

- Carry out multiple activities for the GOES-R operational LST product, including the initial check, the routine validation and deep dive of the multiple GOES-R LST products at different product phases.
- Work closely with industrial contractors (the vender) for validating and maintaining the LST package that has been delivered to the vender. Make updates when necessary.
- Maintain and fine tune the validation tool with effective satellite to ground data match-up system and ensure that it meets the need of the GOES-R LST operational production validation
- Continue the satellite and *in situ* data collection for global data coverage and compare them with LSTs multiple sensors
- Continue work to evaluate and improve the performance of the ABI LST retrieval algorithm, including the operational GOES-R retrieval algorithm and the enterprise LST algorithm
- Update, maintain, and fine tune the emissivity product for GOES-R ABI split window channels
- Maintain and update the multi-sensor LST monitoring and evaluation tool to other sensors
- Update corresponding documents related to the above tasks

Publications

Zhi, H., R. Zhang, F. Zheng, P. Lin, L. Wang, and **P.** Yu, 2016: Assessment of interannual sea surface salinity variability and its effects on the barrier layer in the equatorial Pacific using BNU-ESM, *Adv. Atmos. Sci.*, Vol. **33(3)**, 339-351, doi: 10.1007/s00376-015-5163-y

Liu, Y., Y. Yu, **P. Yu**, F. M. Göttsche, and I. F. Trigo, 2015: Quality Assessment of S-NPP VIIRS Land Surface Temperature Product, *Remote Sensing*, **2015**, **7(9)**, 12215-12241, doi: 10.3390/rs70912215

Products

- Emissivity product for GOES-R ABI split window channels.
- Updated LST validation and algorithm evaluation tool
- Updated long term monitoring system for multiple satellite sensors

Presentations

Yu. P, Y. Yu, Y. Liu, and H. Wang, Production of Satellite Land Surface Temperature Dataset at STAR, 2015 CICS Annual Science Meeting

Yu, P., Y. Yu, Y. Liu, and H. Wang, Evaluation of Emissivity Explicit Land Surface Temperature Retrieval Algorithms for VIIRS, 2015 STAR JPSS Annual Meeting

Liu, Y., Y. Yu, and **P. Yu**, VIIRS LST Validation with Group Based Measurements, 2015 STAR JPSS Annual Meeting

Yu, P., Y. Yu, Y. Liu, and Z. Wang, Testing of Emissivity Explicit Retrieval Algorithms for VIIRS Land Surface Temperature, 2015 NOAA Satellite Conference

Liu, Y., Y. Yu, and **P. Yu**, Quality Assessment and Uncertainty Estimation of S-NPP VIIRS LST Product, 2015 GlobTemp workshop

Yu, Y, Y. Liu, **P. Yu**, Y. Rao, and I. Csiszar, Production of Satellite Land Surface Temperature Dataset at STAR, 2015 NOAA Satellite Conference

Liu, Y., Y. Yu, **P.** Yu, and Z. Wang, Quality Assessment of Suomi NPP VIIRS Land Surface Temperature Product, 2015 NOAA Satellite Conference

Yu, P., Y. Yu, Z. Wang, and Y. Liu, A system for satellite LST product monitoring and retrieval algorithm evaluation, 2015 NOAA Satellite Science Week

Yu, Y., Y. Liu, **P. Yu,** J. Daniels, Land Surface Temperature Production for GOES-R and JPSS Missions, 2015 NOAA Satellite Science Week

Yu, Y., Y. Liu, **P. Yu**, Z. Wang, and I. Csiszar, Issues in Developing and Validating Satellite Land Surface Temperature Product, 2015 AMS Meeting

Other

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	**1**
# of peer reviewed papers	**2**
# 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	

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

Task Leader: Peng Yu
Task Code: PYPY_VGLS_15
NOAA Sponsor: Yunyue Yu
NOAA Office: NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%): Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic: Scientific support for the GOES-R Mission
Contribution to NOAA goals (%): Goal 1: 40%; Goal 2: 60%; Goal 3: 0%
Highlight
Link to a research web page

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 FY15 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 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

AHI has very similar sensors with the GOES-R ABI. As a perfect proxy for the ABI, evaluation of the ABI algorithm with its data is very useful. Based on its spectral response functions, multiple LST retrieval algorithms have been generated, including the GOES-R ABI algorithm listed in the ATBD and a few other algorithm candidates. The routine LST validation tool has been used to evaluate multiple retrieval algorithms with AHI data.

In order to utilize the routine validation tool package for future validation effort, a new component of using Himawari-8 AHI data as proxy data has been added to the validation package. Based on the data format of Himawari Standard Data User's Guide and GOES-R ABI LST Algorithm Theoretical Basis Document (ATBD), several IDL scripts have been written to pre-process AHI data. These scripts would read original binary AHI data, calculate geolocation (latitude and longitude) for AHI data, pre-process ancillary dataset (total precipitable water from NCEP, and emissivity for each channel), calculate satellite zenith angle and solar zenith angle, calculate satellite land surface temperature from original DN value, and conduct match-up between satellite data and ground site data. These scripts have been successfully tested using both sample data available on JMA website and real Himawari-8 AHI data stored in NOAA NESDIS STAR SCDR. Figure 1 presents the brightness temperature for AHI channel 14 and channel 15, satellite zenith angle and calculated land surface temperature using the IDL scripts in the routine validation tool package.

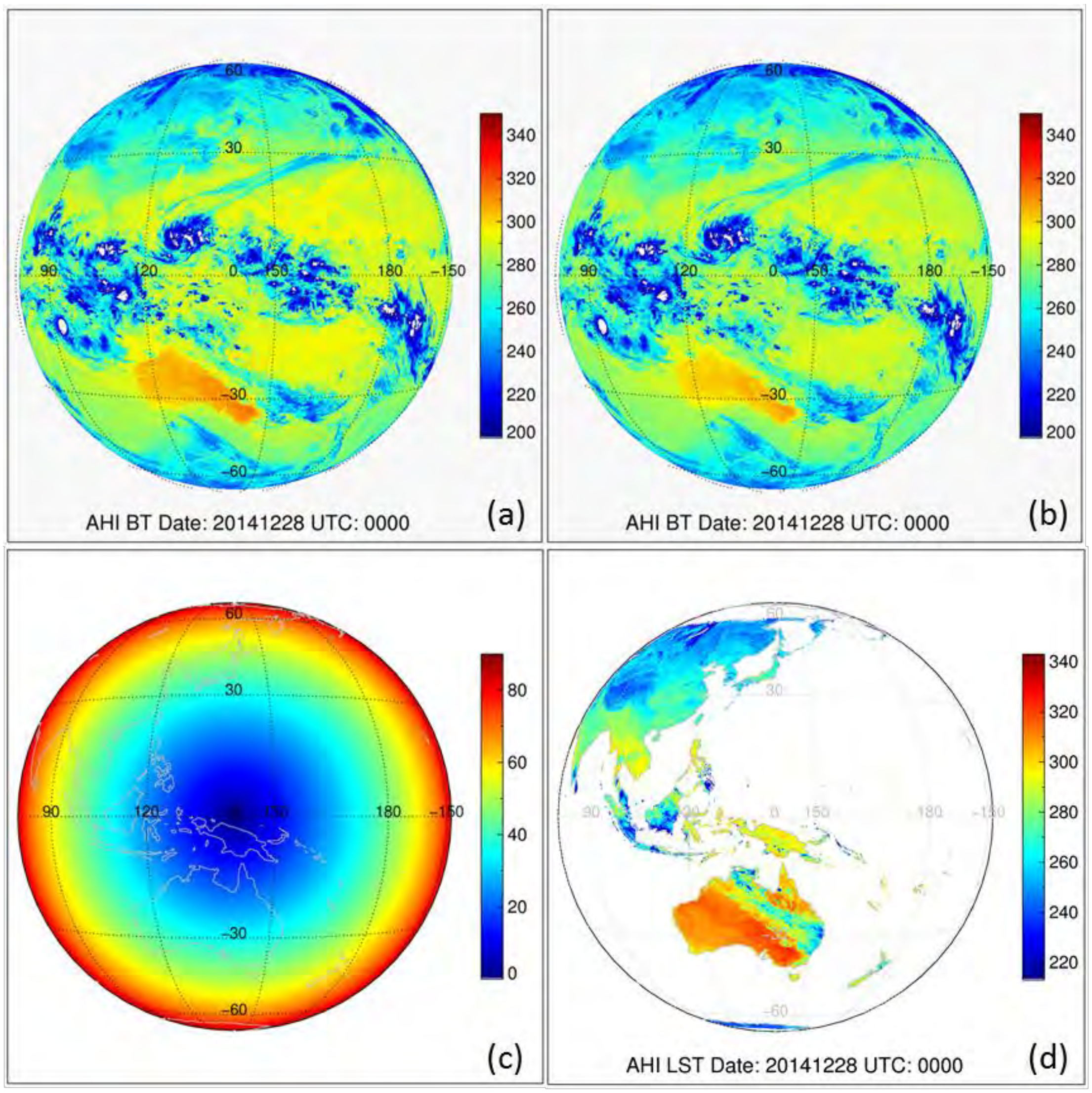


Figure 1. Examples of processed AHI data (a) brightness temperature (BT) of channel 14, (b) BT of channel 15, (c) satellite zenith angle and (d) calculated LST for December 28, 2014, UTC time 0:00.

An automatic AHI LST generation and monitoring system has been established. It acquires necessary input data from multiple sources, conducts the LST retrieval, generates the Full Disk LST graphics, and releases it at ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/yrao/AHI_monitoring/. The LST retrieval is based on the enterprise algorithm (1)

$$T_s = C + A_1 T_{11} + A_2 (T_{11} - T_{12}) + A_3 \varepsilon + A_4 \varepsilon (T_{11} - T_{12}) + A_5 \Delta\varepsilon \quad (1)$$

Figure 2 shows an example graphics of the LST FD image.

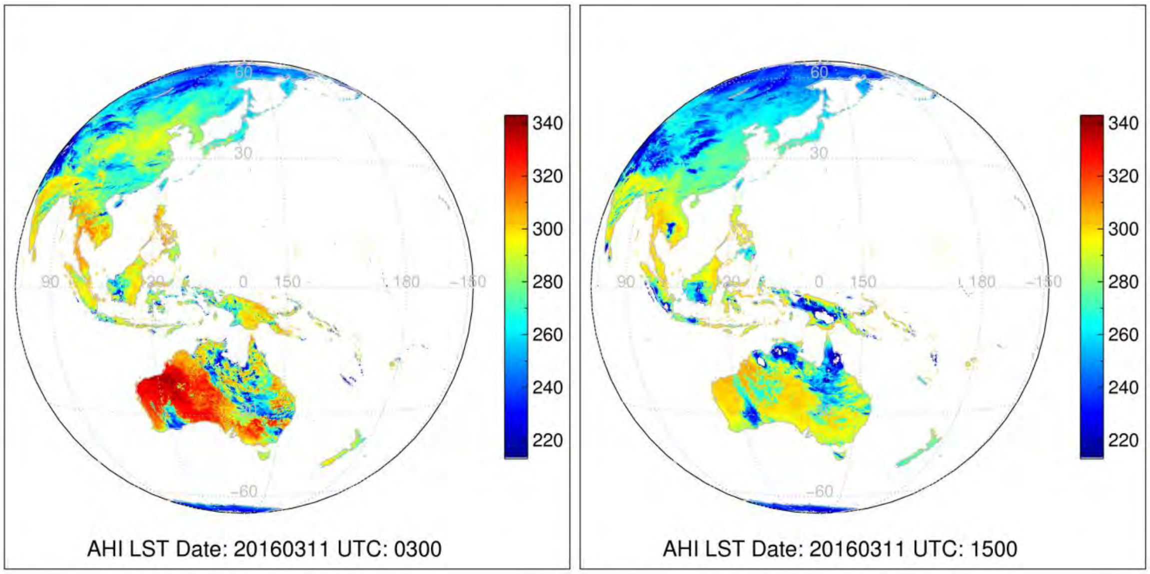


Figure 2. AHI Full Disk LST at 3:00 (Left) and 15:00 (Right), Mar. 11th, 2016.

AHI LST were compared with the VIIRS LST at multiple regions, including Australia and Asian areas (Figure 3). The large difference of the two LSTs at Australia is mainly due to the lack of cloud data.

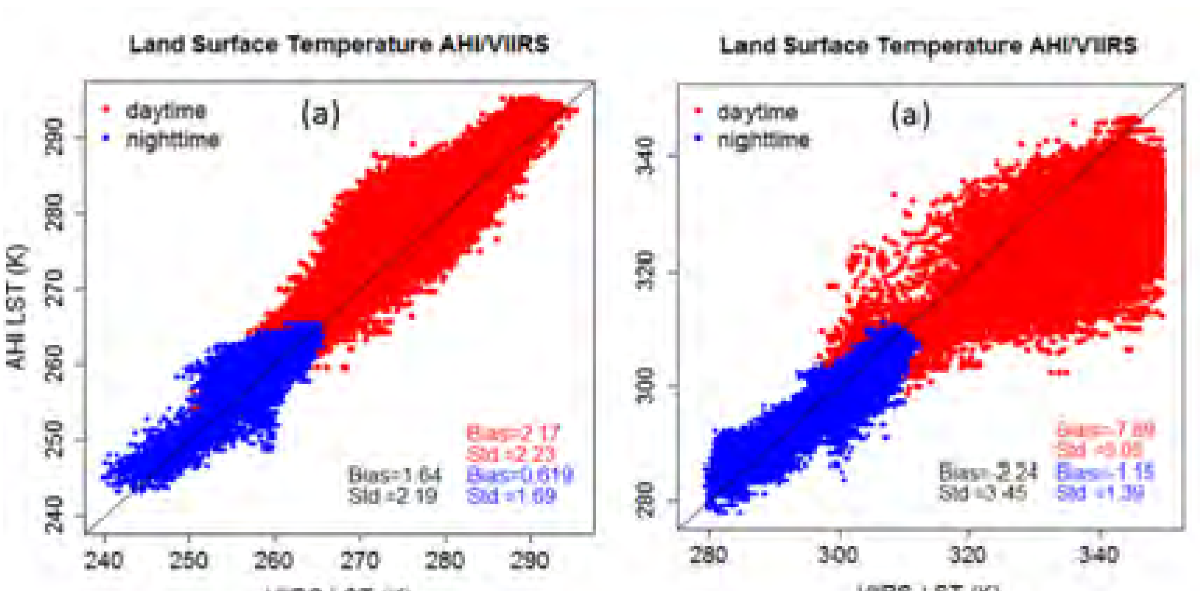


Figure 3. Scatter plots between the VIIRS LST and AHI LST over Asia (Left) and Australia.

The statistics is being analyzed with respect to different satellite zenith angle ranges, total precipitable water conditions, different surface types, and multiple retrieval algorithms. Due to the lack of an official cloud product, alternative way to screen the potential cloud is being researched.

In-situ observations in areas covered by Himawari-8 have been collected and processed, including sites from BSRN and OZFlux. The study of the characteristics and data quality of these sites and the validation of AHI LST are ongoing.

Planned work

- Collect and process ground station data covered by Himawari-8 AHI; collect and process the corresponding JMA/AHI data
- Find alternative ways for screening cloud information for AHI data
- Participate field campaign, collaborating with the NOAA scientists, to measure the in-situ data
- Continue to collect and identify potential field measurements, and examine feasibility of current field data
- Evaluate the ABI LST algorithm through comparisons of the AHI LST (conducted from the ABL LST algorithm) with LSTs from other sensors and available in-situ observations
- Applies the enterprise LST retrieval algorithm for AHI data

Publications

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

Products

- ABI-like AHI LST retrieval and monitoring system
- An updated LST routine validation tool which incorporated the AHI data.

Presentations

Yu. P, Y. Yu, Y. Liu, and H. Wang, Production of Satellite Land Surface Temperature Dataset at STAR, 2015 CICS Annual Science Meeting

Yu, P., Y. Yu, Y. Liu, and H. Wang, Evaluation of Emissivity Explicit Land Surface Temperature Retrieval Algorithms for VIIRS, 2015 STAR JPSS Annual Meeting

Yu, P., Y. Yu, Z. Wang, and Y. Liu, A system for satellite LST product monitoring and retrieval algorithm evaluation, 2015 NOAA Satellite Science Week

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	
# of undergraduate students mentored during the year	

Development of Algorithms for Shortwave Radiation Budget from GOES-R

Task Leader Rachel Pinker
Task Code RPRP_DASR_14, RPRP_DASR_15
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 and tested narrow-to-broadband transformation coefficients based on simulated ABI data in preparation for actual ABI observations.
Link to a research web page: In preparation

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). 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. During the current reporting period the NTB transformations and ADMs have been developed using ABI simulated data in preparation for the use of actual ABI observations. The algorithms were delivered to the AWG for testing and incorporation by the AIT team.

Accomplishments

Following key areas were the focus of research during 2015.

- *Algorithm development using ABI real-time proxy data*
- *Selection of optimal ABI channel combinations*
- *Computing ABI NTB coefficients for multiple viewing angles*
- *Producing TOA radiative fluxes with ABI real-time proxy data*

1 Algorithm development using ABI real-time proxy data

Geo-location of ABI data

We worked with the simulated ABI data as available from ftp://ftp.ssec.wisc.edu/ABI/REALTIME_PROXY.

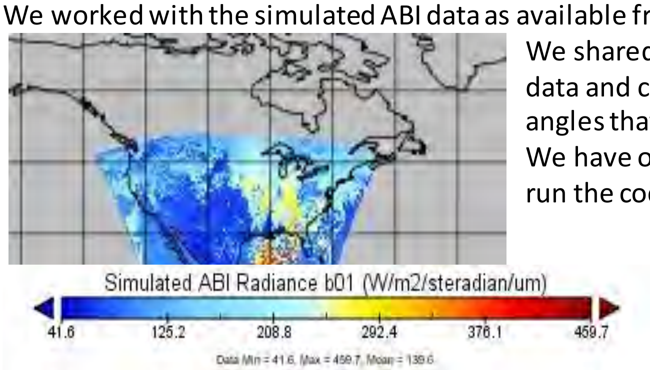


Figure 1: Simulated ABI radiances from 1800 UTC on 12/24/14.

We shared a code from the NOAA ABI group to geo-locate the data and calculate the satellite and solar zenith and azimuth angles that are necessary for computing TOA flux estimates. We have overcome problems with netCDF libraries required to run the code, and successfully calculated the angles and geolocated the data. An example of simulated ABI radiances from 1800 UTC on 12/24/14 is shown in **Figure 1.**

Separate clear-sky from cloudy-sky cases so the proper NTB coefficients and ADMs can be applied

We investigated different methods for making the clear/cloudy determination. A cloud screening algorithm for ABI is available. Another option is to modify our GOES cloud screening methodology for ABI, for generating the radiative fluxes from ABI proxy data.

2 Selection of optimal ABI channel combinations

At our meeting with the NOAA ABI group we discussed strategies for ensuring the quality of the ABI narrow-to-broadband coefficients. One idea was to select the optimal channel combinations to use in the same manner that we selected the MODIS channels. There are 6 visible and near-IR ABI channels that can be used in the radiative flux calculations, as shown in **Table 1**.

Table 1. ABI Visible and NIR channels.

Channel	*Spectral Band*
1	0.590-0.690
2	0.846-0.885
3	0.450-0.490
4	1.371-1.386
5	1.580-1.640
6	2.225-2.275

We followed the procedure we used previously to select optimal MODIS channels by calculating the Residual Standard Deviation (RSD) for all of the channel combinations **(Table 2)** and selecting the combinations that minimized this quantity. RSD is defined as:

$$RSD = \sqrt{\frac{\sum(\rho_{bb} - \rho_{bb}^{est})^2}{n-2}}$$

Where ρ_{bb} is the "true" broadband reflectance by using integration calculation from radiance; ρ_{bb}^{est} is the "estimated" broadband reflectance using regression equation; and n is the sample size. In the case of MODIS, the optimal channel combination for clear-sky and ice clouds differed from the optimal combination for water cloud. Therefore, two combinations were selected and applied based on the sky condition.

Table 2. Channel combinations of ABI visible and NIR bands

Combination	1	2	3	4	5	6
Bands	1+2	1+2+3	1+2+4	1+2+5	1+2+6	1+2+3+4
Combination	7	8	9	10	11	12
Bands	1+2+3+5	1+2+3+6	1+2+3+4+5	1+2+3+4+6	1+2+3+5+6	1+2+3+4+5+6

3 Computing ABI NTB coefficients for multiple viewing angles

Our initial delivery of NTB coefficients computed with the ABI spectral response functions were stratified by solar zenith angle only. We have re-run the regressions between broadband and narrowband albedos to stratify the coefficients by viewing and azimuth angles as well. These following have been delivered to STAR:

- **coef.abi.clear.all.txt** – Contains ABI NTB coefficients stratified by solar zenith angle and all viewing angles for 12 surface types under clear conditions
- **coef.abi.cloud.altrostratus.all.txt** - Contains ABI NTB coefficients stratified by solar zenith angle and all viewing angles for 4 surface types for altostratus clouds with 5 different cloud optical depth (COD) categories
- **coef.abi.cloud.ice.all.txt** - Contains ABI NTB coefficients stratified by solar zenith angle and all viewing angles for 4 surface types for ice clouds with 5 COD categories
- **coef.abi.cloud.water.all.txt** - Contains ABI NTB coefficients stratified by solar zenith angle and all viewing angles for 4 surface types for water clouds with 11 COD categories

All files contain the NTB coefficients for the 6 ABI visible/near IR channels. Some of the coefficients for channels 5 and 6 have large values, particularly for the highest solar zenith angle (87.5°). Further testing will be needed to determine if it is advisable to use all 6 channels.

4 Producing radiative fluxes with ABI real-time proxy data

Several steps are needed to develop the code to produce top-of-atmosphere (TOA) shortwave radiative fluxes using the simulated ABI radiance data available at ftp://ftp.ssec.wisc.edu/ABI/REALTIME_PROXY.
In the input/output module, we added a subroutine to read in the IGBP surface type data. This information is necessary for applying the ADMs and NTB transformation coefficients. We have re-mapped IGBP surface classifications over CONUS at 2-km ABI grid **(Figure 2).** The International Geosphere-Biosphere Programme (IGBP) land classification is used as data source. The dataset is at 1/6 degree resolution and includes 18 surface types. We have completed the conversion of 1/6 degree resolution to the ABI is 2-km grid over CONUS using nearest grid method. The method is assigning surface type for the 2-km grid from its closest 1/6 degree box. Surface classification on this 2-km grid further regrouped to IGBP 12 types. The Clouds and Earth's Radiant Energy (CERES) Angular Distribution Models (ADM) clear sky uses 6 classifications which are

derived from IGBP 12 types. The Narrow to Broadband (N2B) transformation for cloudy sky uses 4 surface types and also derived from IGBP 12 types.

We developed a module that applies the ADMs and NTB coefficients to the ABI radiances. We have made some modifications specific to ABI. One issue we need to address is obtaining the cloud optical depths (CODs) necessary to implement the code. The simulated ABI cloud optical depth (COD) data were downloaded it from the NOAA/STAR ftp server. The ADMs and the ABI NTB coefficients are stratified by COD for cloudy sky cases.

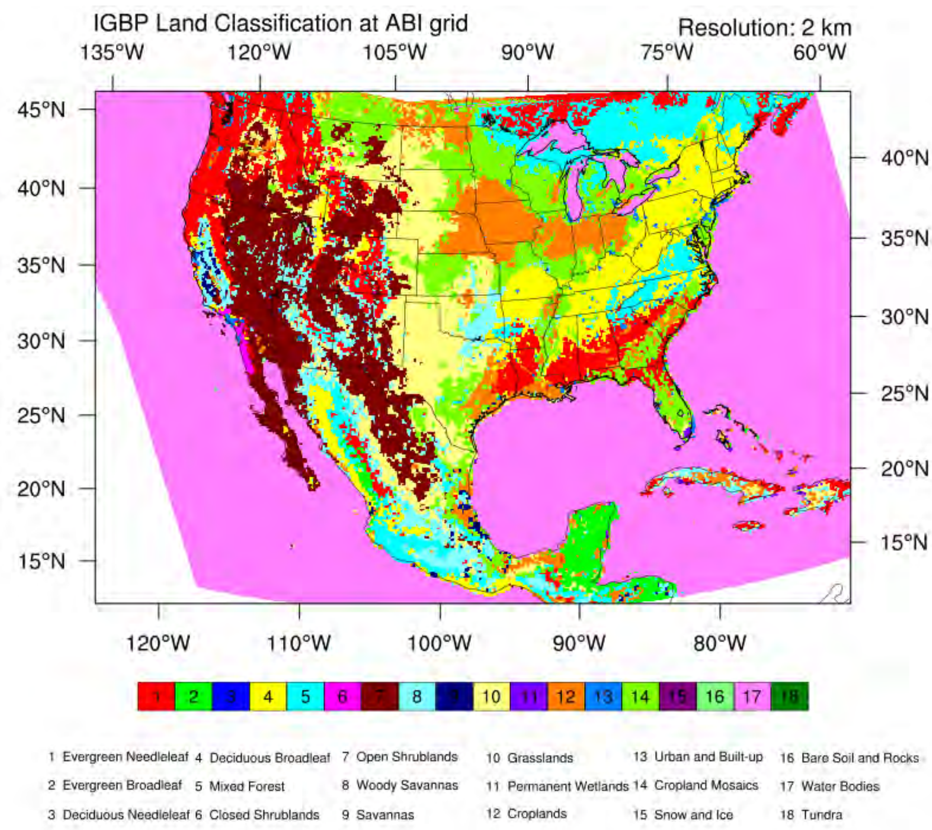


Figure 2: Re-mapped IGBP surface classifications over CONUS at 2-km ABI grid.

Planned Work

- Completion of testing routine and deep dive product validation "tools" for RSR from indirect path algorithm with ABI simulated and AHI data.
- Generation and analysis of Level-2 products using routinely available simulated ABI radiance datasets.
- Development of new simulations for utilizing H-8/AHI data. Used will be atmospheric profiles (ECMWF 137-level profiles) to represent global and seasonal variability to be selected from a collection of 25,000 atmospheric profiles extending from surface up to 0.01 hPa.
- Utilization of available cloud products generated for ABI to allow validation against clear and cloudy conditions from CERES; if CERES data not available for ABI/H-8/AHI overlap, use will be made of the *FLASHFlux* product of near real-time TOA radiative fluxes as provided at http://flashflux.larc.nasa.gov/

- Support GOES-R Program Data Operations Exercises (DOEs), especially DOE-4 data, via verification/inspection of Level-2 product output and exercising/demonstrating product validation tools, and support the GOES-R Ground Segment Project with the reviewing of applicable GOES-R Product User Guide (PUG) documents as relevant to RSR.
- Maintain/update indirect-path RSR algorithm by applying and testing new narrow-to-broadband coefficients developed for AHI and ABI; and deliver updates to RSR algorithm software and/or data interfaces to STAR team.
- Update of documentation of routine RSR validation tools, as necessary, and ATBD with description of latest narrow-to-broadband coefficients.
- Participate in Intensive Post-launch validation of L2 Radiation Budget product.

Products

1. ABI NTB coefficients for multiple viewing angles

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, needle-leaf forest, wooded grassland, closed shrub land, open shrub land, broadleaf forest, mixed forest, woodland, grasslands, cropland, desert, and snow/ice)

The following questions came up from STAR regarding the previous deliveries of NTB coefficients. Answers are denoted in red.

(1) STAR got two files for altostratus, coef.abi.cloud.altostratus.solar and coef.abi.cloud.altostratus.all. The first one has only solar zenith angle (SZA) dependence (SZA-only), the other has dependence on all angles ("ALL-angles"). These have different number of solar zenith angle bins. "SZA-only" has 7 SZAs (12.9, 30.8, 41.2, 48.3, 56.5, 63.2 and 69.5), while "ALL-angles" has 10 SZAs (all the SZAs in "SZA-only" plus 75.5, 81.4, and 87.2). We are wondering why? Is it by design? Or, maybe we got only a partial file of "SZA-only"?

Answer:

This was not by design. We discovered the cause of this problem, and it appears the wrong number of SZAs were used in the files coef.abi.cloud.water.solar.txt and coef.abi.clear.solar.txt as well. The file coef.abi.cloud.cirrus.solar.txt has the correct number of SZAs. The coefficients were regenerated so the complete set of coefficients for all of the files that had missing data are rovided.

(2) What are the 6 view zenith angle (VZA) values? Are they VZA /11.44, 26.1, 40.3, 53.7, 65.9, 76.3/? Are the rows in the file correspond to VZA in this order (increasing order?)

Answer:

Yes. The VZAs have the values listed here (and in the ATBD) and in the file they are presented in increasing order.

(3) What are the 8 relative azimuth angle (RAZI) values? Are they RAZI / 1.91, 9.97, 24.18, 44.02, 68.78, 97.55, 129.31, 162.89/?
Are the columns in the file correspond to RAZI in this order (increasing order?)

Answer:
Yes. The RAZIs have the values listed here (also in the ATBD) and in the file they are presented in increasing order.

2. ATBD
We have updated the ATBD to include information about testing with proxy ABI data.

This month we have updated the NTB coefficients as submitted previously; they contained the NTB coefficients stratified by SZA only for clear sky and 3 cloud types: water, altostratus, and cirrus. There was an error where we only printed out the coefficients for the first 7 SZAs instead of all 10. The attached files contain the updated coefficients.

When the spectral response functions (SRFs) for ABI became available, we generated new NTB transformation coefficients produced with these SRFs. We delivered new 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 described in the "Products" section below.

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

4.2 Scientific Support for the JPSS Mission

Analysis of an Observing System Experiment for the Joint Polar Satellite System

Task Leader	**Stephen Lord**
Task Code	**SLSL_NWS_16 (Part 1 of 3)**
NOAA Sponsor	**Dr. Ming Ji**
NOAA Office	**NWS Office of Science and Technology Integration**
Contribution to CICS Research Themes (%)	**Theme 1: 0%; Theme 2: 70%; Theme 3: 30%**
Main CICS Research Topic	**Future Satellite Programs (Scientific support for the JPSS Mission)**
Contribution to NOAA goals (%)	**Goal 1 (Climate A&M): 20%; Goal 2 (WRN) 80%; Goal 3 (Resilient CC&E): 0%**

Highlight: An Observing System Experiment was conducted to measure the impact of withdrawing data from the PM-orbit on global forecast skill; unique statistical processing reveals some quantitative impacts on risk assessment.

Link to a research web page: none

Background

The Joint Polar-orbiting Satellite System (JPSS) is a key contributor to the next generation, operational polar-orbiting satellite observing system. In the JPSS era, the complete polar-orbiting observing system will be composed of two satellites in the mid-AM and PM orbits, each with thermodynamic sounding capabilities from both microwave and hyperspectral infrared instruments. The JPSS will occupy the PM orbit while the "MetOp" system, sponsored by EUMETSAT, will occupy the mid-AM orbit.

While the current polar-orbiting satellite system has been thoroughly evaluated, information about its resilience and efficacy in the JPSS era is needed. A seven month (August 2012 to February 2013) Observing System Experiment (OSE) was run with the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS). Observations were selected from operational satellite data platforms to be representative of the polar-orbiting data in the JPSS era. In addition to all conventional and non-polar-orbiting observations, the control (CNTL) experiment used all JPSS-representative observations; in the No-PM orbit (NOPM) experiment all observations in the PM orbit were removed, and the operational observations (OPS) runs included all control observations and various usable satellite instruments available over the experimental period.

Accomplishments

Key results are as follows. Overall, removing data from the PM-orbit produced inferior scores, with the impact greater in the Southern Hemisphere (SH) than either the Northern Hemisphere (NH) or tropics. For the entire seven months, the time-mean 500 hPa Geopotential Height Anomaly Correlation (Z500AC) decreased by 0.005 and 0.013 in the NH and SH respectively (Fig. 1), both of which are statistically significant at the 95% level.

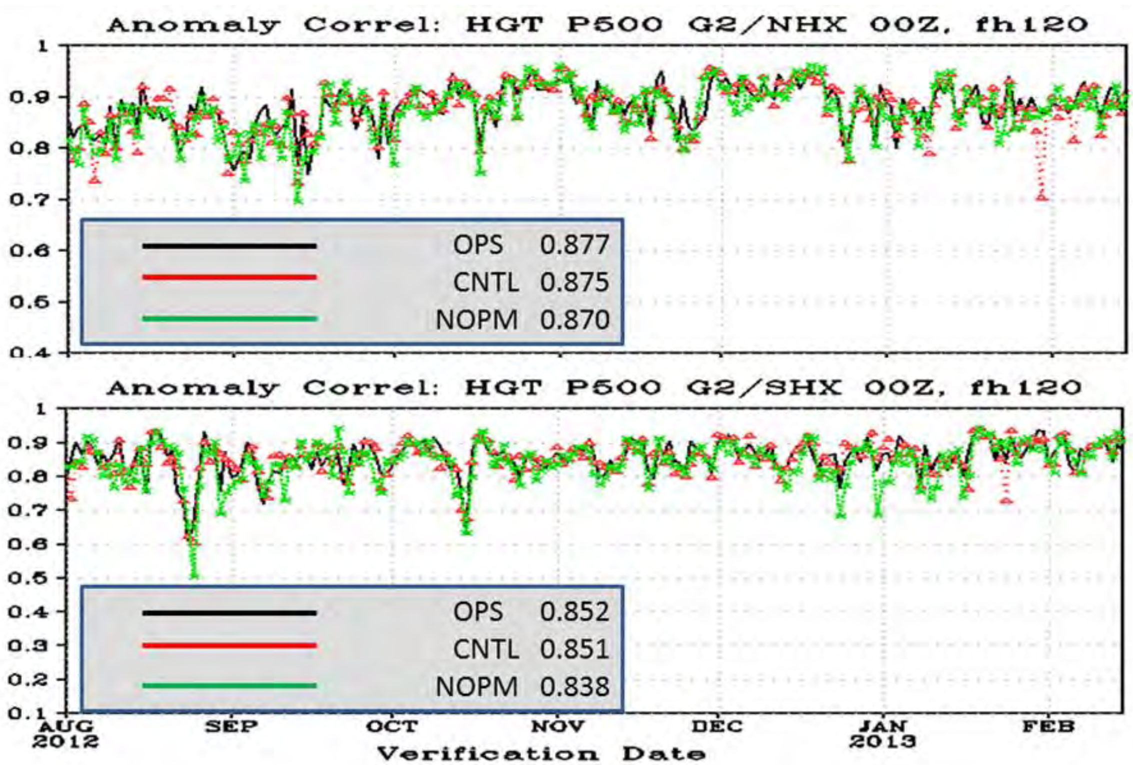


Fig. 1. Time series of 5-day Z500AC NH (top) and SH (bottom) scores for CNTL (red), NOPM (green) and OPS (black) forecasts at 00 UTC over the period 1 August 2012 – 15 February 2013. Mean scores are also shown.

A detailed statistical analysis of the distribution of Z500AC skill scores was performed and compared to historical accuracy data. It was determined that eliminating PM-orbit data resulted in a higher probability of producing low scores and a lower probability of producing high scores (Fig. 2), counter to the trend in GFS forecast skill over the last 20 years.

A manuscript was prepared, submitted to the Bulletin of the American Meteorological Society and accepted for publication in Fall 2016.

Planned work

This project is complete. No further work is planned.

Publications

Lord, Stephen, G. Gayno and F. Yang, 2016: Analysis of an Observing System Experiment for the Joint Polar Satellite System, Bull. Amer. Meteor. Soc., accepted for publication, November 2016.

Presentations

November 2015 CICS-NOAA meeting: S. Lord, George Gayno and Fanglin Yang: Analysis of an Observing System Experiment for the Joint Polar Satellite System.

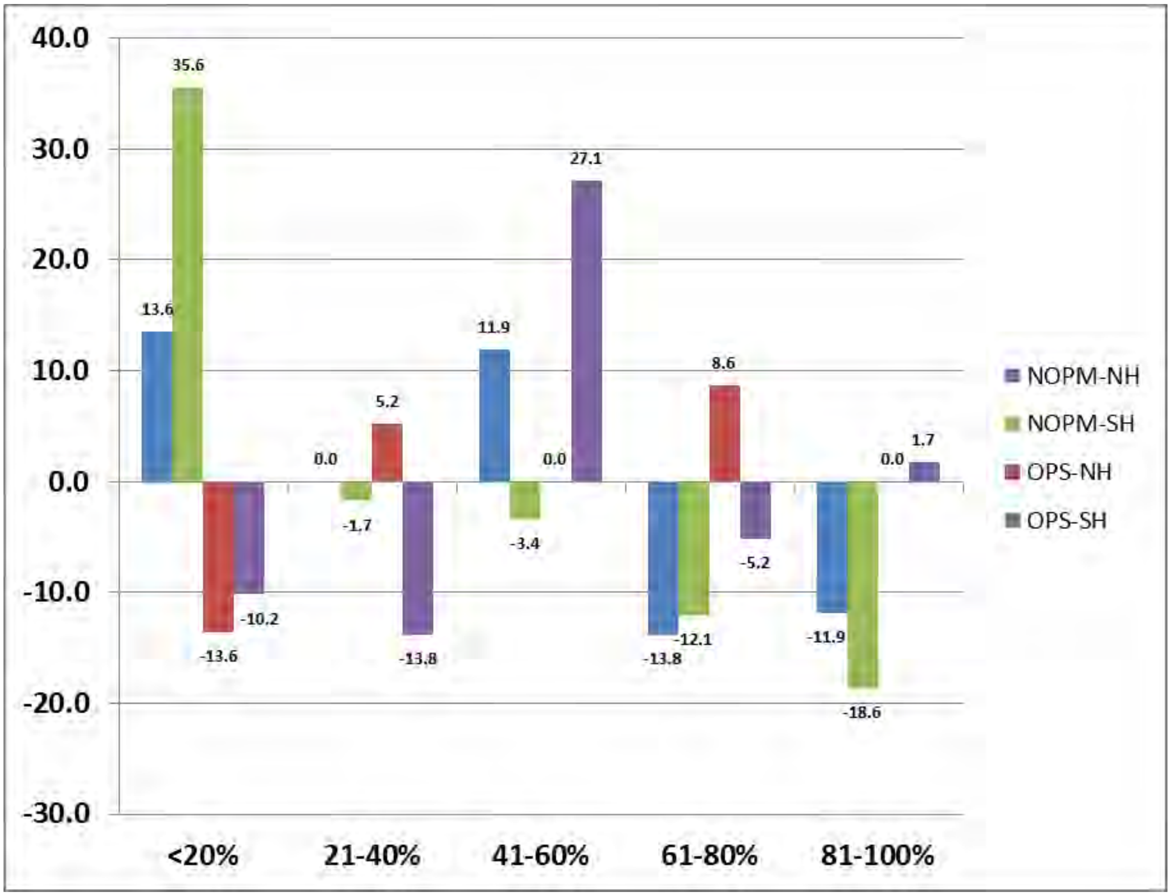


Fig. 2. Comparative fraction of 5-day NOPM and OPS Z500AC scores in each of the quintiles defined by Table 5 for the NH (blue, red) and SH (green, purple). Comparison measures the percent increase or decrease of NOPM and OPS scores in each quintile relative to CNTL, which is (by construction) equally populated in each quintile.

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	**1**
# of non-peered reviewed papers	
# of invited presentations	**1**
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Presentation given at November CICS-NOAA meeting. Manuscript accepted for publication in BAMS.

Next-Generation Global Prediction System (NGGPS) Planning

Task Leader	**Stephen Lord**
Task Code	**SLSL_NWS_15 (Part 2 of 3)**
NOAA Sponsor	**Fred Toepfer**
NOAA Office	**NWS Office of Science and Technology Integration**
Contribution to CICS Research Themes (%)	**Theme 1: 0%; Theme 2: 70%; Theme 3: 30%**
Main CICS Research Topic	**Future Satellite Programs (Scientific support for the JPSS Mission)**
Contribution to NOAA goals (%)	**Goal 1 (Climate A&M): 20%; Goal 2 (WRN) 80%; Goal 3 (Resilient CC&E): 0%**

Highlight: The NGGPS planning involves strategic issues for model and data assimilation development and an explicit community-based plan for advanced physical (scale-aware) parameterizations with improved coupling of physical processes across radiation, boundary layer, deep and shallow convection and surface fluxes. This project contributes to planning for the next-generation physics package(s) and the next-generation coupled data assimilation system and forecast model.
Link to a research web page: none

Background
The Next-Generation Global Forecast System (NGGPS) Program supports development of the next-generation, coupled forecast system for NCEP's operations. This system will enable extension of operational weather forecasts out to 30 days, and will improve the accuracy of weather and seasonal climate forecasts and analyses of the atmosphere, land, ocean, sea ice and aerosols. The effort is expected to take at least 5 years. Planning has involved building capabilities for advanced atmospheric physical parameterizations, including introduction of "scale-awareness" for such physical processes as deep convection, atmospheric turbulence and layer clouds.

Accomplishments
Planning documents were written, including the draft chapter (5.2) on "Physical Parameterization Development." This chapter defines major areas of scientific development ("scale-aware convective and boundary layer formulations, aerosol interactions with cloud microphysics and radiation, development of a "two-moment" cloud microphysics scheme, and a physically-based framework for stochastic sub-grid variability), outlines the various funded contributions to these areas, and proposes formation of scientific working groups to focus development in each of these areas and to interact for improved representation of the physical processes between each parameterization.

Planning also began for a second project: the Unified Global Coupled System (UGCS) for Weather and Climate Prediction. The UGCS is a baseline analysis and forecast system for the NGGPS development. It is composed of models for prediction of the atmosphere, land, ocean, waves, sea ice and aerosols and separate components for data assimilation into each model. Phase 1 of this project will assemble and couple model components within the NOAA Environmental Modeling System (NEMS), assemble separate prototype Data Assimilation systems and observations for each of the prediction domains, develop modernized UGCS workflow and scripting, and test this baseline system to ensure it is operating properly. Contributions included defining, scoping and documenting the project and discussing project focus and activities with both scientific contributors and managers.

Planned work

- Continue to assist in planning and execution of the NGGPS UGCS

Publications

Non-peer reviewed project report

- NGGPS Planning Document: wrote major draft of NGGPS Physics Team Plan (Section 5.2, Physical Parameterization Development) and contributed to Section on Atmospheric Data Assimilation.

Products

Reports and presentations as listed.

Presentations

The NGGPS Unified Global Coupled System (UGCS) Project Description (PPT) for the NGGPS Program

Other

Mentoring (discussed in a separate report)

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	

Items discussed in body of report.

Mentoring and Advising NWS Headquarters and Field Personnel on STI strategies

Task Leader	**Stephen Lord**
Task Code	**SLSL_NWS_16 (Part 3 of 3)**
NOAA Sponsor	**Dr. Ming Ji**
NOAA Office	**NWS Office of Science and Technology Integration (STI)**
Contribution to CICS Research Themes (%)	**Theme 1: 0%; Theme 2: 70%; Theme 3: 30%**
Main CICS Research Topic	**Future Satellite Programs (Scientific support for the JPSS Mission)**
Contribution to NOAA goals (%)	**Goal 1 (Climate A&M): 20%; Goal 2 (WRN) 80%; Goal 3 (Resilient CC&E): 0%**

Highlight: Mentoring by former NOAA employees can be a positive experience for younger managers and scientists as well as for the more experienced Federal employees as they adapt their workplace roles in a changing Federal environment. This project seeks to maximize the benefits of Dr. Lord's experience in organizing and initiating major efforts to improve NOAA's operational models and data assimilation systems.
Link to a research web page

Background

Mentorship can improve scientific development and results through discussions with NOAA scientists and managers. Mentorship was provided in each of the following programmatic areas. To add continuity to current NOAA development projects sponsored by the "Sandy Supplement," review and editing of monthly report input to the NWS Assistant Administrator on modeling and data assimilation projects is valuable. The Next-Generation Global Forecast System (NGGPS) Program seeks to develop the next-generation, coupled forecast system for NCEP's operations. It will be used to extend operational weather forecasts out to 30 days and improve the accuracy of weather and seasonal climate forecasts. The COASTAL Act was passed by Congress in 2012 and directs NOAA to develop an analysis system to depict the wind, storm surge, wave and precipitation fields at high temporal and spatial resolution and accuracy for landfalling tropical weather systems that have destroyed coastal property. The National Blend of Models Project is funded by the 2013 Disaster Relief Appropriations (DRA) Act (aka the "Sandy Supplement") and will develop multi-model weather guidance for NWS operations.

Accomplishments

Dr. Lord has mentored and advised in the following programmatic areas during 2015.

- NGGPS: advised program manager and staff on scientific strategy;
- COASTAL Act: advised and drafted Implementation Plan for NWS/STI;
- Sandy Supplement (SS) data assimilation projects: reviewed monthly input to NWS Assistant Administrator and edited summary presentation each month;
- SS Aircraft Observations Project: advised on observing system strategy, reviewed results of Aircraft Observing System Experiment, and reviewed acquisition and quality control of newly acquired observations funded by the SS;
- NGGPS Physics Development: consultant for NGGPS physics strategy, mentored individual scientists and wrote Physics Development plan;

- NGGPS Unified Global Coupled System Project (the next-generation prototype coupled forecast model and data assimilation prototype demonstration project): advised Project Manager on project organization and scope, developed presentation on project and submitted the NWS management;
- SS National Blend of Models project: mentored and advised Project Manager on “next-steps”;
- NCEP Environmental Modeling Center Global Climate and Weather Modeling Branch Chief: through weekly meetings, advised and discussed Branch strategies, particularly in regard to NGGPS Program.

Planned work

Mentoring will continue on all projects.

Publications

As a mentoring and consultation project, the outcomes are produced by discussion, drafting documents for Federal use, reviewing progress on various projects and advising key Federal employees. Scientific output is influenced by mentoring.

Products

(See Publications above)

Presentations

“The NGGPS Unified Global Coupled System (UGCS) Project Description” (February 2016 for NWS internal use)

Other

Seven Federal employees were mentored and advised.

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~~ Federal employees mentored during the year	**7**

Mentoring activities listed under Accomplishments above.

NESDIS STAR Science Enterprise Support for Satellite Programs and JPSS Ground Project Transition Plan

Task Leader Nai-Yu Wang
Task Code EBNW_GPTP_15
NOAA Sponsor Satya Kullari
NOAA Office NESDIS/STAR
Contribution to CICS Research Themes (%) Theme 1: 80%; Theme 2:20%
Main CICS Research Topic: Future Satellite Programs–Scientific Support for the JPSS Mission
Contribution to NOAA goals (%) 100% Goal 1 (Climate)
Highlight: Develop a JPSS risk reduction precipitation estimation algorithm for ATMS
Link to a research web page

Background

Develop the advanced sciences and software to support NESDIS/STAR/CoRP through the STAR enterprise system. Research activities include development of a JPSS risk reduction Bayesian precipitation retrieval algorithm for JPSS ATMS, and a GOES-R IR and lightning QPE algorithm for the NWS Pacific region. The goal of these research activities is to lead to a merged microwave and IR/lightning multi-satellite precipitation algorithm and product that support efforts to generate one-NOAA Precipitation products leveraging off GOES-R/JPSS Risk Reduction activities.

Accomplishments

3-26-15 NESDIS OSGS GEARS Precipitation Prototype Proposal presented to OSGS director

A NESDIS common ground system precipitation prototype proposal was developed by Dr Wang and vetted by STAR management. Dr Wang presented a proposal briefing to NESDIS OSGS director Steve Peterson on March 26, 2015. The presentation was well received. Due to OSGS funding limitations, STAR did not receive funding from this proposal. Components of this proposal such as the ensemble microwave precipitation estimates is being directed by Dr Wang and carried out by CICS Postdoctoral researche r Yalei You.

3-5-15 Collaboration between CICS-MD and NWS Pacific Regions

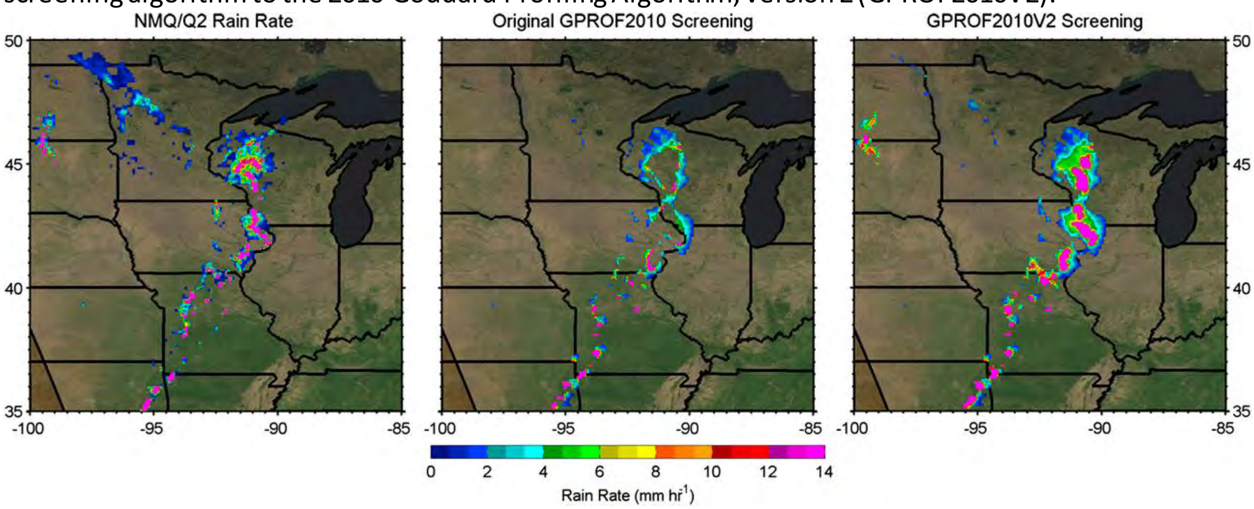
Bill Ward, the Pacific Regions SSD Chief for NWS, visited with SCSB and CICS-MD on March 6 to discuss topics of potential interest involving satellite products that can serve the NWS Pacific Region. The visit was organized by N-Y. Wang through conversations at the 2015 NOAA Satellite Science Week (Boulder, CO, the week of Feb. 23). As part of the effort to continue the collaboration, Dr Wang proposed to and is awarded by the GOES-R visiting scientist program (VSP). The VSP grant will enable Dr Wang to visit the NWS Pacific region headquarters in spring 2016 to present the convective features and rainfall algorithm, and initiate testing and training at the Honolulu Weather Forecast Office (WFO) and to attend and present results in the JPSS/GOES-R OCONUS science meeting in June 2016.

4-24-15 NASA GPM Algorithm Team Award

Ralph Ferraro and Nai-Yu Wang were part of a Robert Goddard NASA Group Achievement Award "for outstanding precipitation retrieval algorithm development to support the Global Precipitation Measurement (GPM) mission. They attended a small reception to receive their individual certificates at NASA/GSFC on April 23.

5-22-15 GPROF2010V2 Article Publish

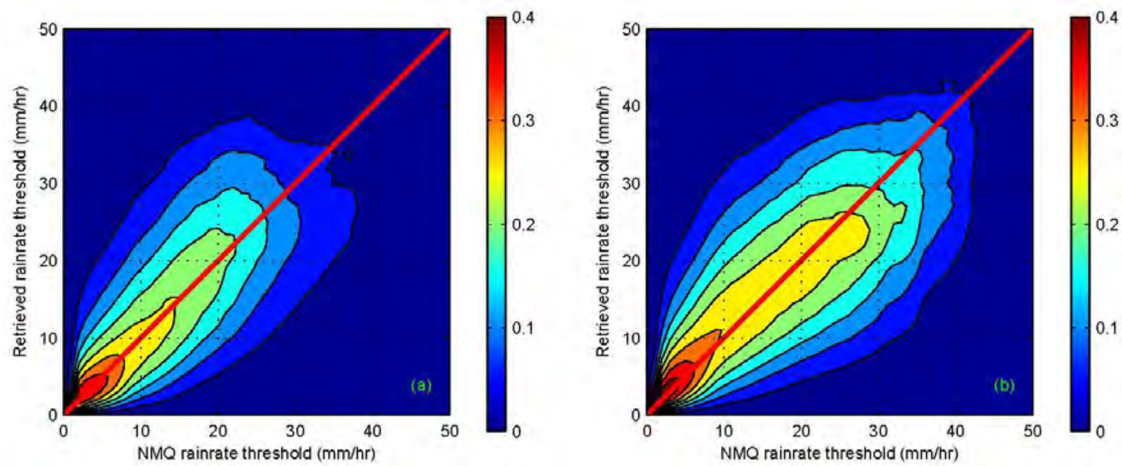
A journal article entitled "Updated Screening Procedures for GPROF2010 over Land and Utilization for AMSR-E" by Patrick Meyers, Ralph Ferraro, and Nai-Yu Wang was published in the May 2015 issue of the Journal of Atmospheric and Oceanic Technology. The article describes the addition of an improved surface screening algorithm to the 2010 Goddard Profiling Algorithm, version 2 (GPROF2010V2).



The figure above, from the article, shows (left) the observed rain rates for a line of convective storms from 1920 UTC 30 Apr 2010; (middle) GPROF2010 retrieval without updated screening procedures; and (right) GPROF2010V2. Without the update, large areas near the core of the convective cells were screened as potential ice surface, flagged, and removed. The new version eliminated screening for surface snow and accurately identifies precipitation in the convective core. Meyers, Patrick, Ralph Ferraro, and Nai-Yu Wang, 2015: Updated screening procedures for GPROF2010 over land and utilization for AMSR-E, J. Atmos. Oceanic Technol., 32, 1015–1028, DOI: 10.1175/JTECH-D-14-00149.1

6-19-15 A New Precipitation Prototype Algorithm published in JGR

CICS Scientists Yalei You along with Nai-Yu Wang have a new article accepted by the Journal of Geophysical Research: Atmospheres on April 15. It describes a prototype precipitation retrieval algorithm over land that uses a four-year National Mosaic and Multi-Sensor Quantitative Precipitation Estimation (NMQ) and Special Sensor Microwave Imager/Sounder (SSMIS) coincident datasets. One of the unique features of this algorithm is using ancillary parameters, such as surface type, surface temperature, land elevation and ice layer thickness, to stratify the single database into many smaller but more homogeneous databases, in which both the surface condition and precipitation vertical structure are similar. As the Figure below shows, results from the stratified databases significantly outperform that from a single database.



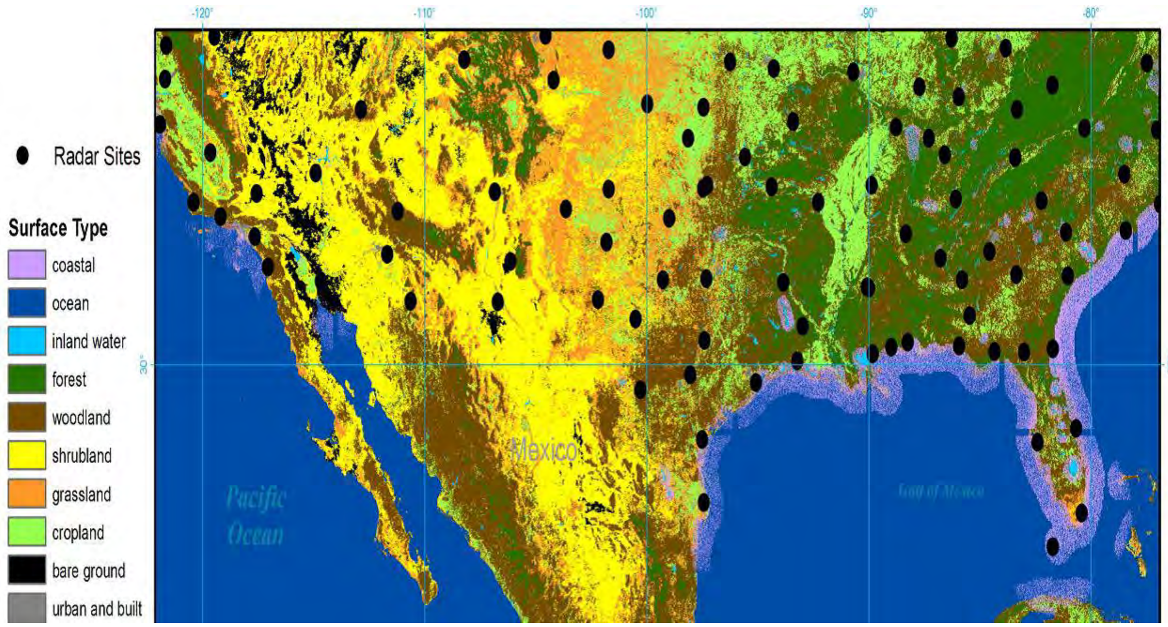
The figure above shows that the results from stratified databases significantly outperform that from this single database. You, Y., N.-Y. Wang, and R. Ferraro (2015), A prototype precipitation retrieval algorithm over land using passive microwave observations stratified by surface condition and precipitation vertical structure, J. Geophys. Res. Atmos., 120, doi:10.1002/2014JD022534.

<u>7-22-15 Collaboration with NASA on Global Precipitation Measurement Mission Proposed</u>

A proposal entitled "NOAA's Continued Contributions to the Development and Utilization of NASA's GPM Products" was submitted to NASA ROSES 2015 Precipitation Measurements Mission (PMM) Science Team solicitation. As has been done in the past, NOAA has submitted an "omnibus" proposal consisting of several NOAA PI's and affiliates that will be self-funded by NOAA (an arrangement agreed upon previously and is contained within an MOU between the two agencies). The proposal contains many tasks that benefit both NASA and NOAA: NOAA scientists help NASA by developing GPM based algorithms and validating them yet, at the same time, they exploit GPM products to improve current product lines at NOAA to help fulfill mission goals. *Importance*: NOAA's exploitation of GPM era data contributes to NOAA mission goals. *POC*: R. Ferraro, H. Meng, P. Meyers and N-Y. Wang.

<u>7-31-15 Rainfall Uncertainty over Different Land Types Paper Published</u>

The *Journal of Hydrometeorology* has just published a new article co-authored by Ralph Ferraro and Nai-Yu Wang evaluating the uncertainty for the Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI). That algorithm was developed by researchers at CICS-MD and SCSB.



The figure above show the surface classifications used in the study. The study found that the product was more accurate when the precipitation was entirely stratiform or entirely convective but less accurate when it was a mixture of the two. There was also poorer performance over dry and sparsely vegetated regions, probably because the surface radiation mimicked frozen precipitation signals. N. Carr, P.-E. Kirstetter, Y. Hong, J. J. Gourley, M. Schwaller, W. Petersen, Nai-Yu Wang, Ralph R. Ferraro, and Xianwu Xue, 2015: The Influence of Surface and Precipitation Characteristics on TRMM Microwave Imager Rainfall Retrieval Uncertainty. J. Hydrometeor, 16, 1596–1614, doi: http://dx.doi.org/10.1175/JHM-D-14-0194.1. *Importance*: Satellite rainfall measurements are critical to weather and climate forecasting and analysis and understanding uncertainties in these measurements places necessary limits of these predictions.

10-30-15 EUMETSAT Visitor

SCSB/CICS-MD hosted a three day visit by Dr. Jochen Grandell of EUMETSAT. Dr. Grandell is the Atmospheric and Imagery Applications Manager, who focuses on imagery products, as well as those related to precipitation and lightning. One of his projects, shown below, is the Lightning Imager for the Meteosat Third Generation mission, dedicated to meteorological and climate forecasts. He presented an ESSIC seminar on October 27 entitled "EUMETSAT - Almost 30 years of Earth Observation Missions". He also met with several scientists during his visit, including R. Ferraro, S. Rudlosky, H. Meng, P. Meyers and **N-Y. Wang**. *Importance*: Establishing strong scientific ties with international partners like EUMETSAT strengthens ongoing collaborations.

11-6-15 JAXA GPM Science Team Proposal Filed

N-Y. Wang (CICS-MD) submitted a proposal to JAXA's GPM Precipitation Team solicitation. The emphasis of the proposal is to help validate JAXA's primary precipitation product - GSMaP –using NOAA ground based radar assets, mainly the MRMS high resolution product over the CONUS. Y. You (CICS-MD), R. Ferraro (SCSB), J. Gourley (OAR) and P. Kirstetter (OAR) are collaborators on the proposal. *Importance*: International coordination and collaboration on hydrometeorological products will help expand NOAA's access to vital data to fill in observational gaps.

12-1-15 The 3rd Joint JCSDA-ECMWF Workshop on Assimilating Satellite Observations of Clouds and Precipitation into NWP Models
Dr Wang was a member of the scientific and organizing committee for the 3rd joint JCSDA-ECMWF workshop. This workshop came out of an action item from the 7th International Precipitation Working Group (IPWG) workshop to foster communications and collaborations between the satellite remote sensing and data assimilation communities in the improvement of the physical methods employed to invert the satellite data used in the NWP assimilation and satellite precipitation retrieval, for the determination of cloud and precipitation and other atmospheric and surface products obtained from satellite observations. Dr Wang was a co-chair of the IPWG and a organizer for IPWG 7 workshop.

12-18-15 NASA PMM Science Team Selection
The proposal entitled "NOAA's Continued Contributions to the Development and Utilization of NASA's Global Precipitation Measurement (GPM) Products" was selected as one of the 60 out of 135 submissions to be part of the new Precipitation Measurement Mission (PMM) Science Team. The no-cost to NASA proposal includes several co-investigators/collaborators across NOAA (including NESDIS, NWS and OAR) and its cooperative institutes (including **N-Y. Wang**, P. Meyers, C. Kongoli from CICS-MD). Funding for the NOAA proposal will be part "in kind" support and partially from other existing programs including JPSS and GOES-R. *Importance*: NOAA's collaboration with NASA on GPM accelerates the use of GPM products to support NOAA mission goals related to weather forecasting and climate monitoring.

2-12-16 JAXA GPM Science Team Proposal Accepted
Nai-Yu Wang's proposal to JAXA's Global Precipitation Measurement (GPM) Science Team was accepted as a collaborative, unfunded project (JAXA will cover travel expenses to their science team meeting). The project will focus on validating JAXA's primary GPM precipitation product (known as GSMAP) using high quality ground validation over the United States. *Importance*: NOAA's collaboration with JAXA on GPM accelerates the use of GPM products to support NOAA mission goals related to weather forecasting and climate monitoring.

Planned Work

- Develop an IR and lightning convective feature and precipitation estimation technique for the Hawaii islands, Guam, and the Pacific Ocean
- Develop a web-based service to test, validate, and transition the IR/lightning convective feature and precipitation technique to NWS Honolulu and Guam Weather Forecasting Office (WFO)
- Continue the microwave ensemble estimation technique by systematic weighting ensemble members from different microwave radiometer estimation methods with ground and space radars over land and ocean
- Continue a STAR representative in the JPSS Ground System Transition team, look after STAR's interests in JPSS ground system planning transition from NASA to NOAA IN 2019

Publications

Meyers, Patrick, Ralph Ferraro, and Nai-Yu Wang, 2015: Updated screening procedures for GPROF2010 over land and utilization for AMSR-E, *J. Atmos. Oceanic Technol.*, 32, 1015–1028, DOI: 10.1175/JTECH-D-14-00149.1.

N. Carr, P.-E. Kirstetter, Y. Hong, J. J. Gourley, M. Schwaller, W. Petersen, Nai-Yu Wang, Ralph R. Ferraro, and Xianwu Xue, 2015: The Influence of Surface and Precipitation Characteristics on TRMM Microwave Imager Rainfall Retrieval Uncertainty. *J. Hydrometeor*, 16, 1596–1614, doi: http://dx.doi.org/10.1175/JHM-D-14-0194.1

You, Y., N.-Y. Wang, and R. Ferraro (2015), A prototype precipitation retrieval algorithm over land using passive microwave observations stratified by surface condition and precipitation vertical structure, *J. Geophys. Res. Atmos.*, 120, 5295–5315, http://dx.doi.org/10.1002/2014JD022534 .

Presentations

Kirstetter, Pierre-Emmanuel, et al., Evaluating the Global Precipitation Measurement mission with NOAA/NSSL Multi-Radar Multisensor: Current status and future directions, *AGU Fall Meeting* (San Francisco, CA, 12/14/2015 to 12/18/2015).

Wang, Nai-Yu, Yalei You and Ralph Ferraro, Advances in Satellite Microwave Precipitation Retrieval Algorithms Over Land, *AGU Fall Meeting* (San Francisco, CA, 12/14/2015 to 12/18/2015)

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	**3**
# of non-peered reviewed papers	**0**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Development of Neural Network algorithms for retrieval of chlorophyll-a in the Chesapeake Bay and other coastal waters based on JPSS-VIIRS bands

Task Leader Alex Gilerson
Task Code AGAG_JPSS_14
NOAA Sponsor Mitch Goldberg
NOAA Office JPSSO
Contribution to CICS Research Themes (100 %) Theme 2
Main CICS Research Topic 4b Scientific support for the JPSS Mission
Contribution to NOAA goals 3 -100%
Highlight Several multi band algorithms for retrieval of chl-a which include 745nm band on the JPSS/VIIRS sensor are explored demonstrating very good performance on the field and satellite data for the Chesapeake Bay and potentially other coastal waters, additional tests are currently planned at NOAA with the goal to make these algorithms operational
Link to a research web page N/A

Background

Chlorophyll-a concentration [Chl] is one of the main products retrieved from the ocean color satellite imagery which is then used in the estimation of the ocean productivity, modeling of ecosystems, climate studies, evaluation of water quality, and detection of algal blooms. The accuracy of standard blue-green ratio algorithms decreases significantly in the coastal waters because of contamination of the blue and green reflectance signals from CDOM absorption and mineral scattering especially in such complex waters as Chesapeake Bay. Several Neural Network (NN) approaches and multi-band algorithms were explored and compared with standard ocean color (OC) algorithms. All newly developed algorithms showed good performance in coastal waters based on synthetic and field data. Multi-band algorithms were found to be more flexible in adjustment to satellite data which have its own features due to calibration and atmospheric correction issues in coastal areas. Original project duration July 2012 – June 2015; the project is currently in one year no cost extension till June 2016. Extension was necessary to acquire more VIIRS satellite data and to make more accurate assessment of algorithms performance.

Accomplishments

A synthetic dataset for over 1000 stations was developed based on a four component bio-optical model which includes pure water, chlorophyllous particles with a defined concentration of chlorophyll-a [Chl], non-algal particles (NAP) characterized by their concentration, and colored dissolved organic matter. Relationships to determine scattering and absorption coefficients of these components were similar to those in IOCCG dataset and Gilerson et al., Optics Express, 2007 with the main parameters taken in the ranges available from NOMAD dataset and previous field typical for the Chesapeake Bay. In addition, statistical relationships between phytoplankton, CDOM and non-algal particles absorptions at 443nm available from NOMAD were also taken into account to limit simulations to the most realistic combinations of water parameters. Rrs were simulated for the wavelengths 443, 488, 551, 665, 671, 708, 745 and 753nm which include central wavelengths for VIIRS, MODIS and partially MERIS satellite sensors to allow the testing of algorithms based on blue-green as well as red-NIR bands.
After the analysis of multiple combinations of bands, two algorithms yielded the most consistent and promising results: a) a combination of two ratios R1 = Rrs(488)/Rrs(550) and R2 = Rrs(671)/Rrs(745) and b) just one Rrs(671)/Rrs(745) ratio. The first algorithm is in the form of

$$chl\_calc1 = 10^{(a1 + a2*R1 + a3*R2)} \quad (1)$$

where a1, a2 and a3 are the fitting coefficients.

The second algorithm is based on the one which uses red-NIR bands at 708 and 665nm (Gilerson et al, Optics Express, 2010), which worked well in various water conditions. After the adjustment for 671 and 745nm bands available on VIIRS (instead of 665 and 708nm bands) the second algorithm was in the form:

$$chl\_calc2 = 0.4*(60.625*(1/R2) - 10.6125)^{1.389} \quad (2)$$

Algorithms (1) and (2) were tested on the matchups between VIIRS satellite data and in-situ [Chl] from the Chesapeake Bay program. VIIRS satellite data was acquired with a strict filtering procedure (Hlaing et al, Optics Express, 2014). VIIRS level 2 files do not contain Rrs at 745 nm, so SeaWiFS Data Analysis System (SeaDAS), version 7.2, was used in the processing. That resulted in a small number of points (<100) acquired during the period of VIIRS operation 2012-2015 which made difficult to assess performance of the algorithms.

To increase the number of points flags of stray light, moderate glint or both were suspended which allowed testing algorithms on different datasets. It is demonstrated that with minor adjustment of the coefficients from the synthetic dataset in the Eq (1) and (2) good performance of both algorithms is achieved on all datasets (with and without suspension of flags). Results for the set when stray light flag was suspended are shown in Fig. 1 which are very similar to the fully restricted dataset. Both algorithms Eq (1) and (2) perform very similar to each other, significantly better than standard OC3 algorithm and consistently with the results from the synthetic dataset predicting RMSE of 4-5mg/m3. It is clear that OC3V algorithm tend to overestimate [Chl]. This trend is obvious from the comparison of the satellite imagery processed by OC3V, Eq1 and Eq2 shown in Fig. 2:

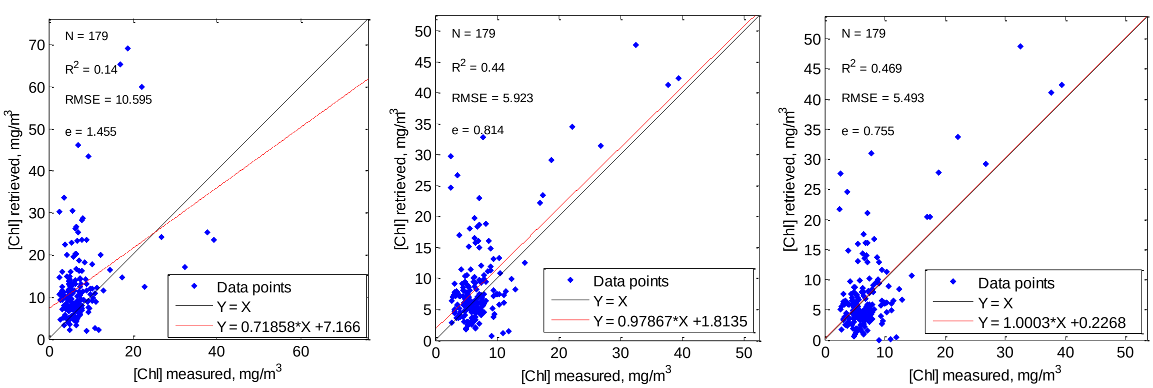


Fig. 1. Performance of algorithms on the VIIRS matchups with the field data for the Chesapeake Bay; stray light flag is suspended: a) OC3V algorithm, b) Eq(1) c) Eq(2).

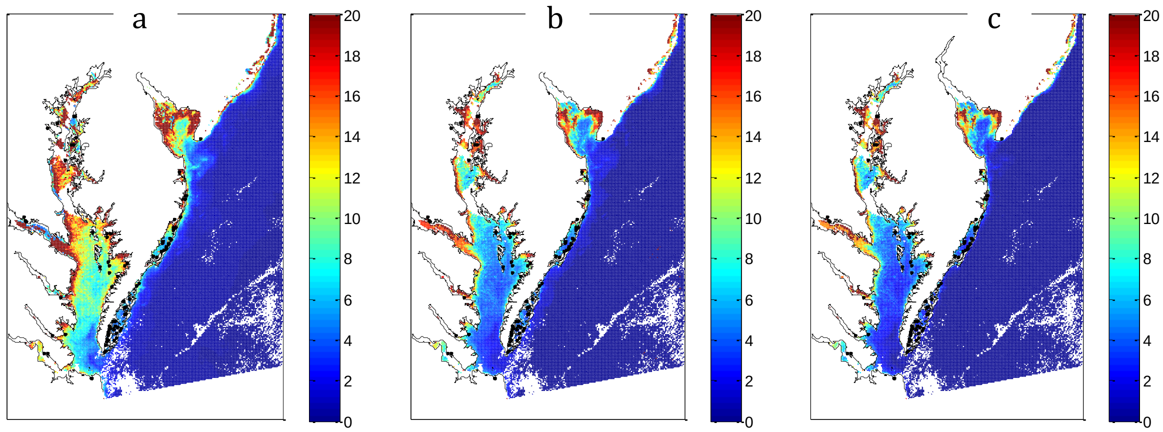


Fig. 2. [Chl] from VIIRS satellite data for the Chesapeake Bay on August 20, 2014: a) OC3V algorithm, b) Eq(1) c) Eq(2).

Algorithms based on Eq(1) and (2) should be recommended as operational for the Chesapeake Bay and possibly other coastal waters.

Planned work

- All available datasets of field, MODIS and especially VIIRS data will be further monitored for the possible algorithms improvement as more matchups are acquired with and without flags suspensions.
- Developed multi-band algorithms will be tested on other coastal waters datasets if possible.
- Interactions with NOAA scientists and managers involved in the operational Chesapeake Bay data will continue for possible applications of the new algorithms.

Publications

A. Gilerson, M. Ondrusek, M. Tzortziou, R. Foster, A. El-Habashi, S. P. Tiwari and S. Ahmed, "Multi-band algorithms for the estimation of chlorophyll concentration in the Chesapeake Bay," *Proc. SPIE* 9638, Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions 2015, 96380A (October 14, 2015); doi:10.1117/12.2195725

Products

Interaction with Dr. Richard Stumpf, NOAA National Centers for Coastal Ocean Science is in progress for testing of the algorithms at NOAA with the goal of conversion them to the operational products.

Presentations

A. Gilerson, M. Ondrusek, M. Tzortziou, R. Foster, A. El-Habashi, S. P. Tiwari and S. Ahmed, "Multi-band algorithms for the estimation of chlorophyll concentration in the Chesapeake Bay," SPIE RS Europe, Toulouse, France, Sept, 2015.

A. Gilerson, VIIRS RR and PG review, November 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	2
# of undergraduate students mentored during the year	2

JPSS Data Products & Algorithms: Validation of VIIRS Ocean Color products for the coastal and open ocean

Task Leader	Curtiss Davis
Task Code	CDCD_JPSS_15
NOAA Sponsor	Menghua Wang
NOAA Office	JPSS/IPO
Contribution to CICS Themes (%)	Theme 1: 10%; Theme 2: 80%; Theme 3: 10%.
Main CICS Research Topic	Scientific Support for the JPSS Mission
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 0%; Goal 3: 80%;

Highlight: We have developed a new procedure for above water reflectance measurements and validated it against HyperPRO data and Platform Eureka SeaPRISM data. We participated in the JPSS Ocean Color Validation Cruise in December 2015 further validating our remote sensing reflectance measurement methods. We are analyzing a two year time series of VIIRS data for the Southern California Bight using Platform Eureka SeaPRISM for validation.

Background

This report summarizes the work supported through CICS of the ongoing NOAA project entitled "JPSS Data Products & Algorithms: Validation of VIIRS Ocean Color products for the coastal and open ocean". This activity is part of the JPSS Ocean Environmental Data Record (EDR) calibration and product validation team effort led by Menghua Wang (NOAA/STAR) and Bob Arnone (U. Southern Mississippi (USM)). As part of that team we are working with NOAA/STAR, Bob Arnone and others to establish and execute a plan for maintaining the on-orbit calibration of the VIIRS Visible and Near IR (VNIR) channels and for validation of ocean products. Experience with SeaWiFS, MODIS and MERIS makes it clear that ocean products must be validated in the open ocean and in diversity of coastal regions. Our work at OSU focuses on the validation of ocean color products (water-leaving radiances and chlorophyll) for the coastal (West Coast of the US) and open ocean (Hawaii) waters. We validate VIIRS ocean color products using: (1) the Hawaii Ocean Time-series (HOT) HyperPRO data set at station Aloha in the North Pacific Gyre, and (2) Platform Eureka (a new SeaPRISM site off Southern California operated by Burt Jones (USC)) which is cross calibrated with the HyperPRO and above water remote sensing reflectance measurements. These time series are continuing and overlap with VIIRS on-orbit data collection.

Accomplishments

We are working with VIIRS data from STAR covering the entire Southern California Bight, and validating the VIIRS products using matchups with the Platform Eureka SeaPRISM data. Unfortunately The SeaPRISM at Platform Eureka off the Los Angles Coast has shown consistently lower radiances than the VIIRS product data (NASA and NOAA Star MSL12) while other SeaPRISMs, such as the Venice Platform Se aPRISM show good agreement. We made a validation cruise with the HyperPRO and SE Spectrometer in October 2015 and confirmed this issue. To track down the source of the bias, which is on the order of 20% a second SeaPRISM was installed at the site late summer of 2015. Initially it had some issues, and it to address those issues the two SeaPRISMs sensor heads were switched to the opposite tower, wiring and electronics. This resulted in a change in the bias, with the original sensor head now showing a high er result. The ideal result when comparing data from the two instruments is that the intercept is zero, and the slope (gain) 1. The observed result differs from that, most striking in channel 440, where the intercept jumps from ~0 to ~0.1

after the switch. We also note that if this 'offset' is subtracted, then the results show much better agreement as shown in Figure 1. We are currently looking at both an empirical correction (vicarious calibration) of the data in hand to correct for discrepancies, and we are also trying to trace the physical origin of the discrepancy.

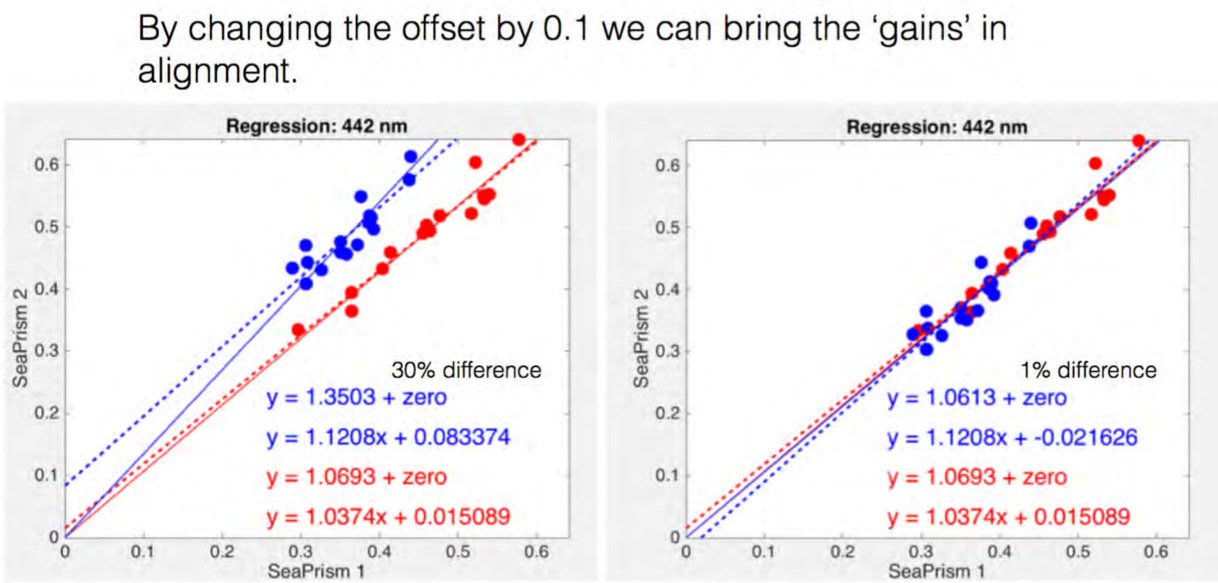


Figure 1. Regression of 442 nm water leaving radiance data from the two SeaPRISMs at Platform Eureka. Red is the regression before December 8, 2015 and blue is the regression after switching the sensor heads on December 8, 2015.

After the discrepancy is resolved we will complete a long term analysis of the VIIRS data products for Southern California waters as validated with the Platform Eureka SeaPRISM data and our associated *in situ* data. Progress on our validation efforts was presented at the STAR JPSS Team Meeting 24-28 August 2-15, in College Park, MD.

Nick Tufillaro participated in the annual NOAA VIIRS Validation cruise on the R/V Nancy Foster, out of Charleston, SC in December 2015. Nick operated two instruments (the OSU Satlantic HyperPRO and Spectral Evolution handheld Spectrometer) and participated in cross calibration and product validation activities on the cruise. On board, we compared our above water measurements with the new Spectral Evolution spectrometer with the more common ASD spectrometer using standard white and gray plaques from the Naval Research Labs and NIST. Initial on board results showed good agreement with our measurements and those from NOAA and NRL. Some of these results were presented at the 2016 Ocean Sciences Meeting, February 26, 2016 in New Orleans, LA. Ryan Vandermeulen is working up the official results for the above water reflectance. Our above water reflectance method using the SE spectrometer i ncorporates several improvements and a publication on this updated method is planned for this coming year. The group also compared the in-water measurements among the Satlantic HyperPROs during casts coordinated by Mike Ondrusek. We have finished processing our data and sent it to Mike Ondrusek at NOAA for detailed comparisons. An example of the OSU HyperPRO data is shown in Figure 2.

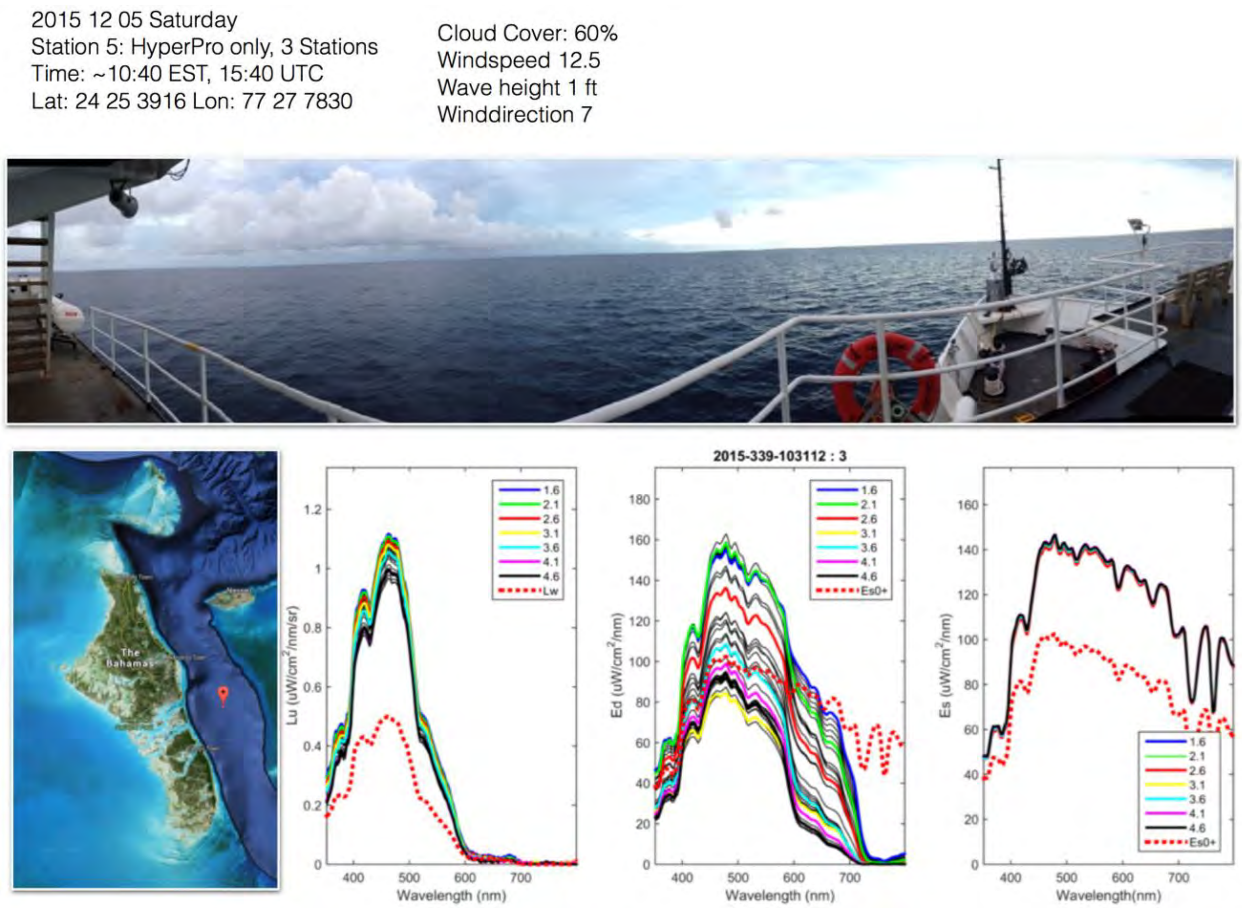


Figure 2. OSU HyperPRO data from one of the HyperPRO comparison stations in the Tongue of the Ocean, Bahamas.

For the HOT data at station Aloha there are very few matchups due to the infrequency of data collections (monthly), the cloudy conditions and sun glint in this area. However, when we have matched the standard product water leaving radiances from VIIRS with *in situ* HyperPRO measurements, the data show excellent agreement (e.g. Figure 3). During the past year and a half we worked with NOAA (Mike Ondrusek) and the instrument manufacturer Satlantic to refine our methods for the HyperPRO data collection and processing including incorporating the multicast method for the surface waters at HOT to obtain the best possible remote sensing reflectance from this data. This work resulted in a HOT training manual for making the HyperPRO measurements and approved procedures and processing software that is identical to that used by NOAA and others.

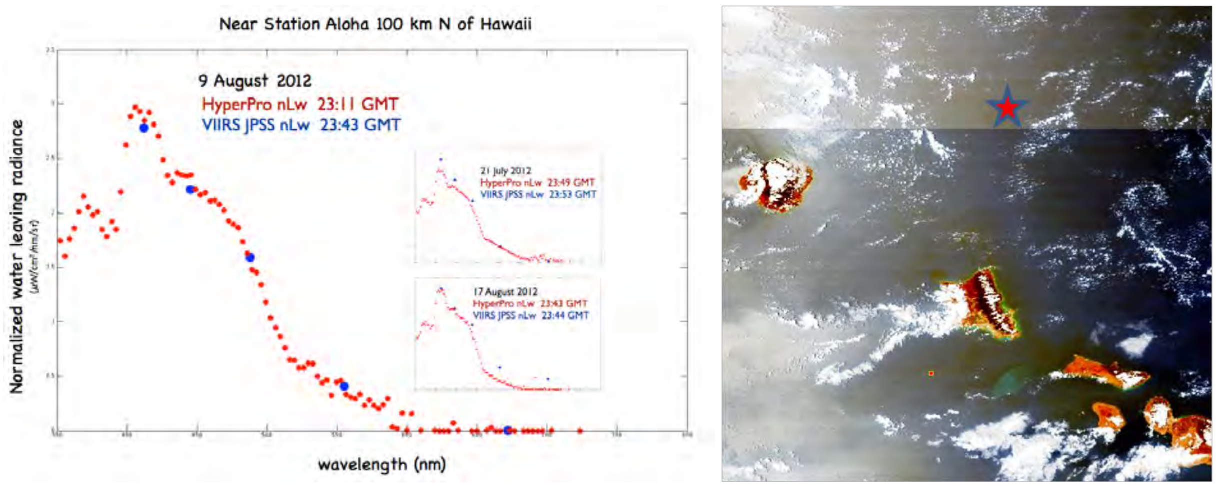


Figure 3. Left, Example spectral matches at Station ALOHA of VIIRS data with HyperPRO cruise data collected within one hour of each other. The VIIRS products shown here are computed with the JPSS processor obtained from the NOAA CLASS archive. Right, VIIRS image over Hawaii from 17 August 2012 (23:43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

VIIRS and other ocean color remote sensing data typically have striping issues which can cause problems for the spatial, spectral and temporal analysis techniques we are using. Nick Tufillaro has worked with Eric Bollt and collaborators to address this issue and provide a universal solution that can be applied in the spectral, spatial and temporal domains. Their method can be applied to the raw VIIRS data of the NASA de-striped product with equal success (Figure 4). This method has been submitted for publication to IEEE Geosciences and Remote Sensing.

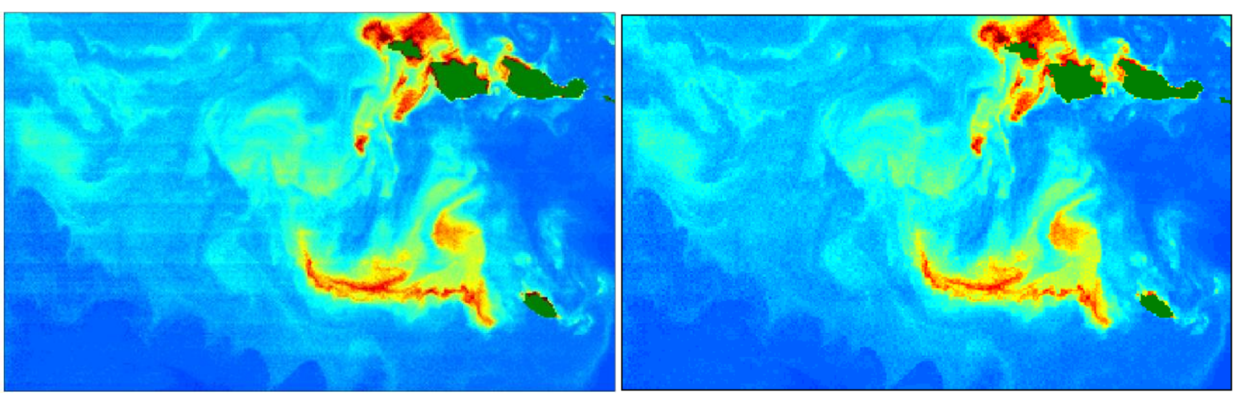


Figure 4. November 7, 2013 VIIRS image of waters off southern California. Left, the NASA's vicarious calibration of L2 (.nc) product which destripes the image using sensor characteristics measured during on-orbit calibration. While the NASA's vicarious calibration of L2 (*.nc) method does improve the raw image, there are still stripe artifacts present. Right, the destriped image of the NASA product almost completely removing the stripes.*

Planned Work

- Continue processing and analysis of Station Aloha HOT HyperPRO including match ups with VIIRS data for product validation
- Continue analysis of time series of VIIRS data for the Southern California Bight

- Participate in and present results at NOAA teleconferences and the NOAA STAR/JPSS Annual Meeting in August 2016.
- Participate in the 2016 NOAA VIIRS science cruise for cross calibration of instruments and methods for:
  - Above Water Rrs
  - HyperPRO optical profiles
- All *in situ* data provided to NOAA STAR for VIIRS data product validation
- Publication on above water reflectance methods
- Publication on the validation of VIIRS data with the Platform Eureka SeaPRISM time series including comparisons with other SeaPRISM sites.

Publications

Basnayake, R., E. Bollt, N. B. Tufillaro, J. Sun and M. Gierach, In review, Regularization Destriping of Remote Sensing Imagery with Missing Data Preprocessing, IEEE Transactions on Geoscience and Remote Sensing.

Products

- Monthly time series of HOT HyperPRO data delivered to NOAA/STAR
- *In situ* data from the NOAA VIIRS Science Cruises, HOT HyperPRO data and Platform Eureka Validation cruises provided to NOAA STAR.
- Publication on above water remote sensing reflectance measurement method
- Publication on the VIIRS time series analysis for the Southern California Bight

Presentations

Tufillaro, N. and C. Davis, Validation of VIIRS Ocean Color Products for the West Coast, STAR JPSS Team Meeting Talk 24-28 August 2-15, College Park, MD

Jenkins, J. Goes, Gomes, A. Chekalyuk, R. Arnone and N. Tufillaro, 2016, Community composition, biomass and photosynthetic competency of phytoplankton associated with microscale features and frontal zones of the Gulf Stream, ME54C-0940, Ocean Sciences Meeting, 26 February, 2016, New Orleans, LA.

PERFORMANCE METRICS	FY13
# of new or improved products developed	0
# of products or techniques transitioned from research to operations	0
# of peer reviewed papers	1
# 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

Performance Metrics Explanation

This project was previously supported through CIOSS at Oregon State University and has been supported through CICS for the last 18 months. Focus has been on developing a new above water reflectance measurement method and the validation of that method against the HyperPRO method particularly during the VIIRS Ocean Color Validation Cruise in December 2015. We are using these improved methods to continue our validation of VIIRS open ocean products from station Aloha using the Hawaii Ocean Time series (HOT) HyperPRO data and validation of coastal products for the Southern California Bight using data from the Platform Eureka SeaPRISM.

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

Task Leaders Chris Justice, Louis Giglio, Wilfrid Schroeder
Task Code CJLG_VIIRS_15
NOAA Sponsor Lihang Zhou
NOAA Office NOAA JPSS, Center for Satellite Applications and Research (STAR)
Contribution to CICS Research Themes (%) Theme 2: 100%
Main CICS Research Topic Scientific Support for the JPSS Mission
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%
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 was successfully ported to the revised Joint Polar Satellite System (JPSS) AF algorithm running at the NPP Data Exploitation (NDE) system at NOAA/NESDIS. 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 supported the implementation of the revised VIIRS AF algorithm at NDE. Algorithm testing and documentation (Algorithm Theoretical Basis Document and JPSS Calibration/Validation Plan) were successfully completed in 2015; the VIIRS AF began routine operation in NDE on 15 March 2016. Figure 1 shows a subset of a 5-min VIIRS AF Level 2 granule including the main distinctive pixel categories and fire retrieval (FRP) information output by the algorithm. A long-term quality monitoring system was implemented for the VIIRS AF product including graphic display of daily global fire pixels (Figure 2) and automatic email alerts triggered in response to potential data anomalies (e.g., lines of spurious fire pixels).

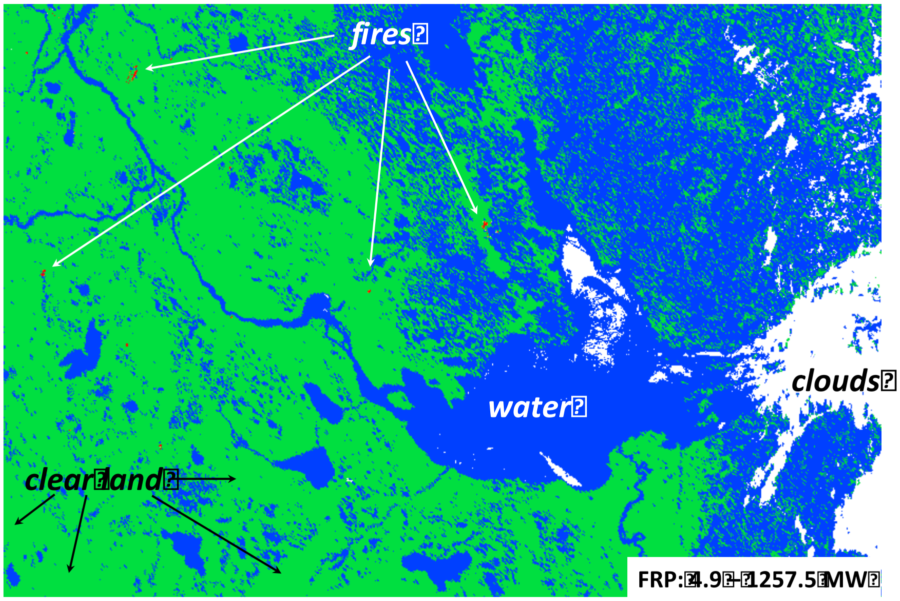


Figure 1: Subset of VIIRS AF algorithm output showing the 2D fire mask and the corresponding pixel classes including active fires (red), clear land (green), water (blue) and clouds (white). The range of FRP retrievals for all detected fire pixels is shown in the lower right corner.

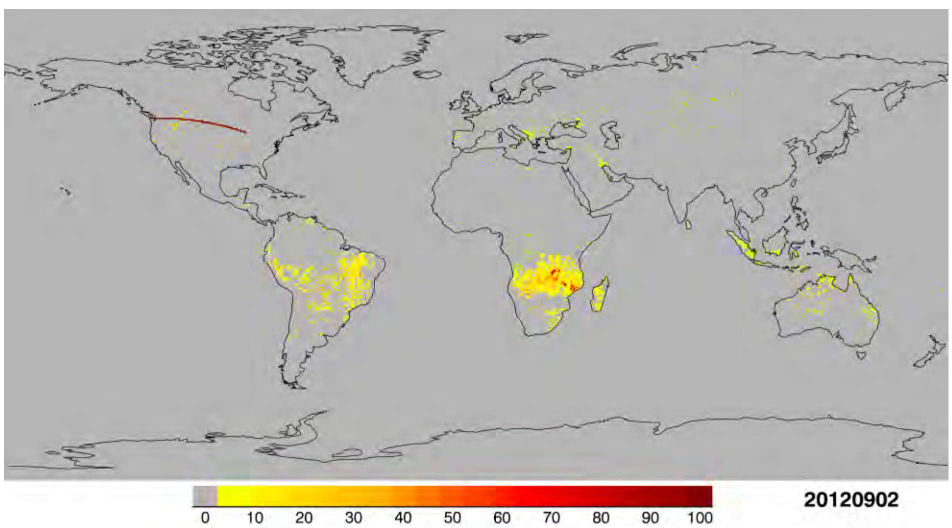


Figure 2: Density map of daily global fire detections (fire pixels / 0.5°) generated by the VIIRS AF algorithm on 02 Sep 2012. A band of spurious detections can be seen across North America; the corresponding data anomaly was later addressed following the implementation of a revised VIIRS L1B data processing software package.

Planned Work

- Maintain and update the VIIRS AF algorithm at NDE operations
- Port new VIIRS 375 m active fire detection algorithm to NDE

Publications

Giglio, L., Schroeder, W., and Justice, C.O., 2016. The collection 6 MODIS active fire detection algorithm and fire products. *Remote Sensing of Environment*, 178, 31-41.

Products

A revised VIIRS AF algorithm was implemented at NDE.

Presentations

Csiszar, I., Giglio, L., Schroeder , W., Wolf, W., Tsidulko, M., Mikles, V. (2016). VIIRS Active Fire Product Developments in NOAA's Operational System. 96th AMS Annual Meeting, New Orleans/LA, 10-14 January.

Csiszar, I., Kondragunta, S. (presenter), Ellicott, E., Schroeder, W., Giglio, L. (2015). The use of JPSS products to support fire management. International Geoscience and Remote Sensing Symposium (IGARSS), 26-31 July.

Csiszar, I., et al., Active Fire product update (2015). STAR JPSS 2015 Annual Science Team meeting, College Park/MD 24-28 August.

Csiszar, I., et al. (2016). Fire Monitoring from the Visible Infrared Imaging Radiometer Suite. Earth System Science Interdisciplinary Center (ESSIC) Seminar Series, College Park/MD, 22 February.

Tsidulko, M., Wolf, W., Csiszar, I., Giglio, L., Schroeder , W. (2016). VIIRS Active Fire algorithm integration in NOAA's Suomi NPP Data Exploitation environment: research to operations. 96th AMS Annual Meeting, New Orleans/LA, 10-14 January.

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	**1**
# 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**

Revised VIIRS active fire algorithm implemented at NDE

ATMS Derived Snowfall Rates to Support Weather Forecasting

Task Leader	Cezar Kongoli
Task Code	CKCK_ATMS_14
NOAA Sponsor	JPSS PGRR
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: ATMS snowfall detection and snowfall rate algorithms have been extensively evaluated using high quality in-situ and radar data.

Background

This report describes the work performed to evaluate 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. Evaluation of the SFR algorithm has also been conducted. As many as ten snowfall events have been selected and collocated with radar data.

Accomplishments

Evaluation resulted in parameter adjustments and an improved algorithm performance. Table 1 shows overall performance 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 1)

Table 1. Overall SD algorithm performance statistics

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

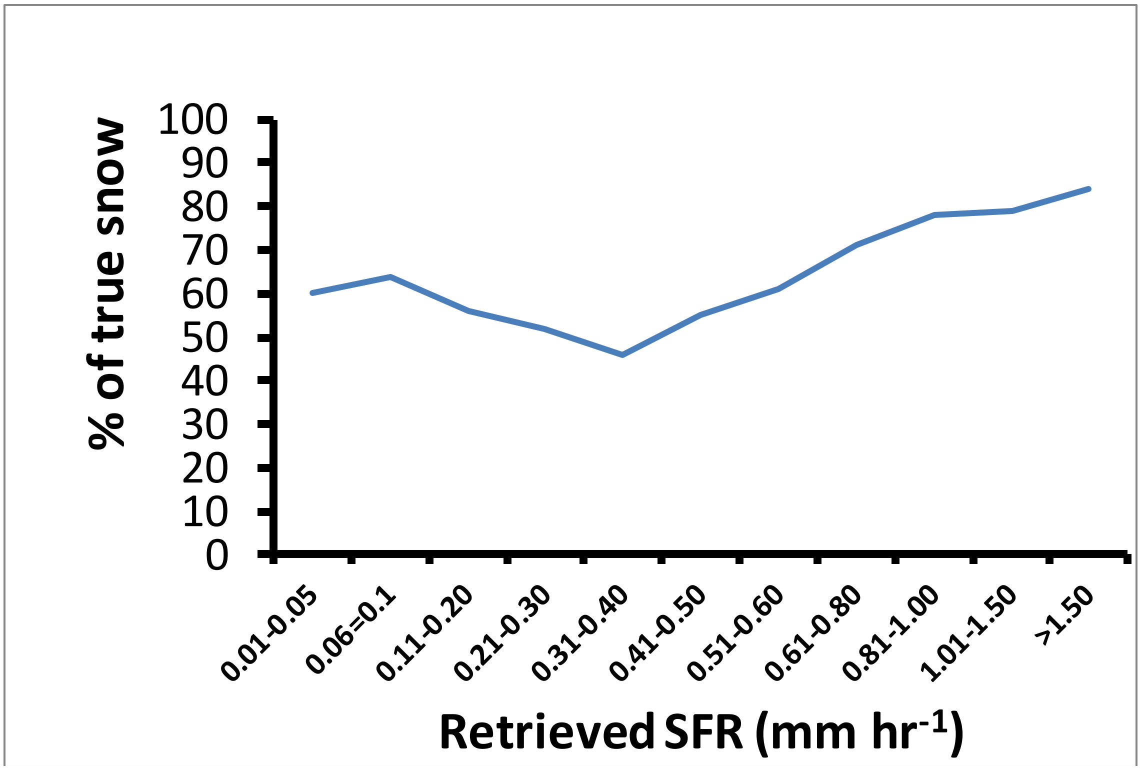


Figure 1. Percent of snowfall captures as a function of retrieved SFR. Moderate to high SFR over 1 mm hr-1 are associated with high fraction of retrieved snowfall of 80% ad higher.

Presentations

Meng, H., R.R. Ferraro, C. Kongoli, B. Yan, et al., 2015 (oral). Snowfall Rate Retrieval Using Passive Microwave Measurements and Its Applications in Weather Forecast and Hydrology, Annual American Meteorological Society Conference (AMS); 95th, Conference on Satellite Meteorology and Oceanography; 20th; 4-8 Jan. 2015; Phoenix, AZ; United States

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

Laviola S. J. Dong, C. Kongoli, H. Meng, R. Ferraro, and V. Levizzani, 2015. An intercomparison of two passive microwave snowfall detection algorithms over Europe, *Proceedings of the Geoscience and Remote Sensing Symposium (IGARSS), IEEE International*, Milan, Italy, DOI: 10.1109/IGARSS.2015.7325878

Products

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

Performance Metrics	FY15
# of new or improved products developed	1
# of products or techniques transitioned from research to ops	0
# of peer reviewed papers	1
# of non-peered reviewed papers	1
# of invited presentations	1
# of graduate students supported by a CICS task	N/A
# of undergraduate students supported by a CICS task	0

Explanation of Table

This year, we evaluated the SD and SFR algorithms, published one refereed paper (1), published one non-refereed paper (1) and made 1 presentation (1).

Validation of Cryospheric EDRs GCOM AMSR2

Task Leader	Cezar Kongoli
Task Code	CKCK_AMSR_15
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: A suite of AMSR2 operational algorithms for the retrieval of snow cover, snow depth and Snow Water Equivalent has been developed and transitioned to operations.

Background

A suite of AMSR2 operational snow algorithms have been developed and transitioned 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.

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.

	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

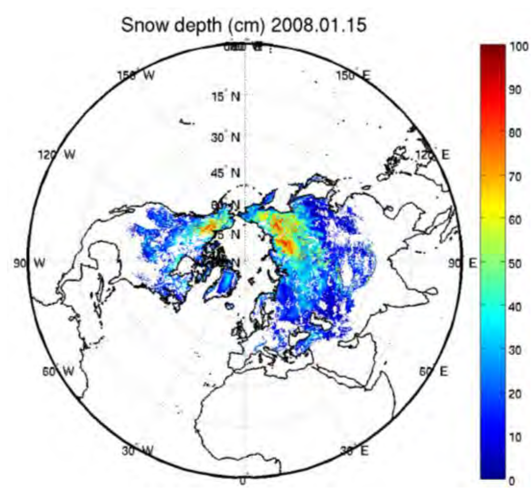


Figure 1. Snow Depth algorithm statistics with respect to in-situ stations (left) and a map of retrieved Snow Depth (right)

Publications

Lee, Y-K, C. Kongoli, and J. Key, 2015. An in-depth evaluation of NOAA's snow heritage algorithms, *J. Atmos. Oceanic Technol.*, 32, 2319–2336.

Planned Work

- Improve snow depth retrievals by adjusting coefficients and removing regional biases with respect to climatology
- Improve snow cover product

Performance Metrics	FY15
# of new or improved products developed	3
# of products or techniques transitioned from research to ops	3
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	N/A
# of undergraduate students supported by a CICS task	0

Explanation of Table

This year, three AMSR2 snow products have been improved (3) and transitioned to operations (3). One peer reviewed paper has been published (1).