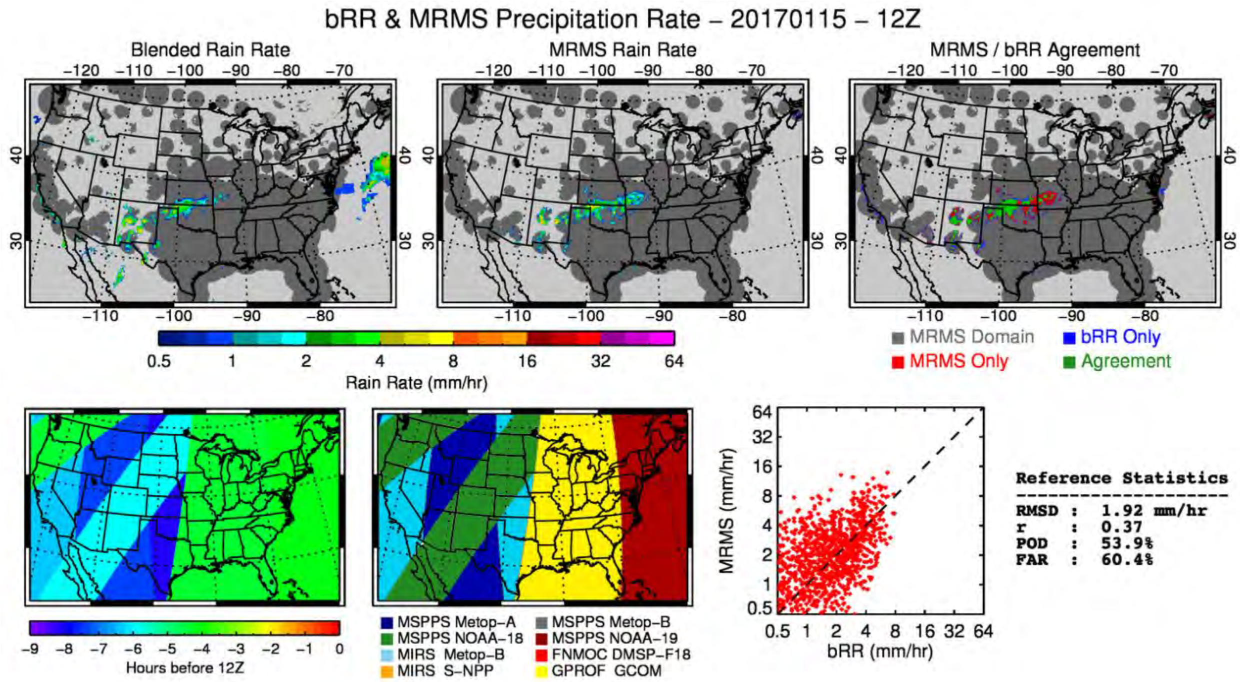


Figure. 1. Validation of the Blended Rain Rate product relative to MRMS over CONUS. The bottom panels show data latency, observing satellite, scatterplot, and validation statistics. AMSR2/GCOM-W was recently incorporated into the bRR product.

Correlation coefficient, root mean squared difference (RMSD), probability of detection (POD), and false alarm rate (FAR) are calculated for each time step. The most recent analyses are available online (http://cics.umd.edu/pmeyers/brr/). In addition to the bRR monitoring, routine monitoring of the stand-alone AMSR2 rain rate product is available through the CICS-MD International Precipitation Working Group website (http://cics.umd.edu/ipwg/NPPAMSR2.html). The effects of field of view (FOV) size on validation metrics were examined to create a more equitable evaluation of AMSR2 versus the Advanced Technology Microwave Sounder (ATMS). The ATMS FOVs range from 15km to 60km in diameter, relative to 5km for AMSR2, so direct comparisons of RMSD favor ATMS because lower rain rates, spatial smoothing, and reduced variance. Resampling AMSR2 to similar ATMS FOV sizes reduces RMSD by 50%, and performance metrics for both sensors are comparable.

Efforts were underway to reduce high false alarm rates over radiometrically cold land surfaces. The legacy GPROF2010 empirical screening procedures are incapable of discriminating between rain and cold semi-arid surfaces, so methods to reduce the false alarm rate have been explored. Initial results suggest applying a probabilistic cloud-free determination scheme (Turk et al. 2016) dramatically improves the Critical Success Index (CSI) and Heidke Skill Score (HSS), metrics of overall detection skill. This linear discriminant analysis method identifies scenes with a high probability that no clouds exist, which in turn can reduce false alarms by eliminating precipitation where clouds are not expected (Fig. 2). Using a variable threshold dependent on the surface vegetation and temperature, CSI improved from 0.37 to 0.46 and HSS improved from 0.52 to 0.62 in cold-season cases. This methodology will be further explored, developed, and implemented in the next version of GPROF2010 for AMSR2.

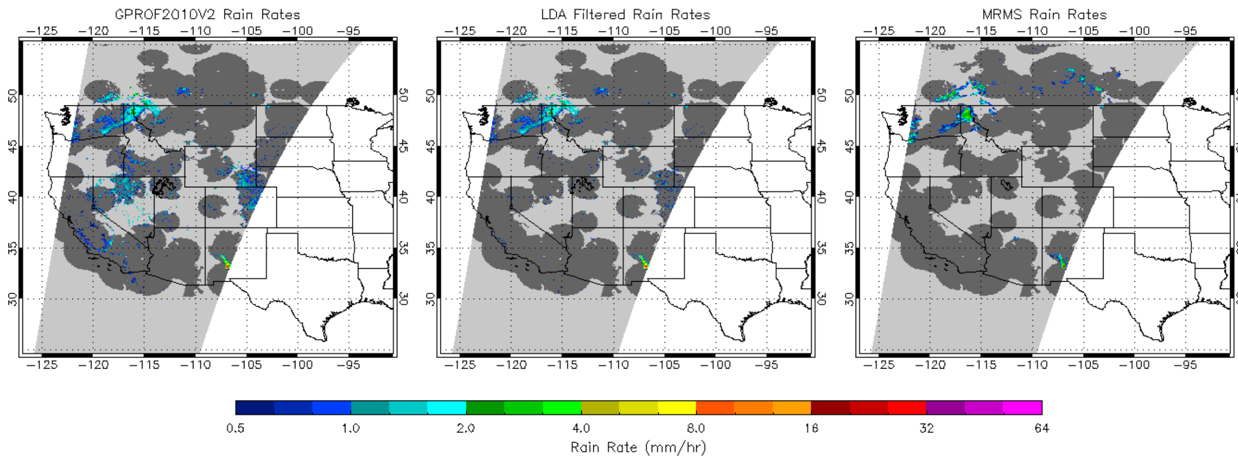


Figure 2. Example of the improved rain detection by using LDA to identify likely cloud-free scenes. The GPROF2010 AMSR2 retrieval (left) shows light rain throughout much of Nevada and California. Applying the LDA filtering (center) removes much of these false alarms relative to the MRMS radar-based ground truth (right).

Collaborations with the GPM Science Team aimed to evaluate NASA's next generation rain rate algorithm. GPROF2014 applies a Bayesian approach over all surface types, and largely eliminates the need for empirical surface screening. From one year of observations, CSI is improved by 15% relative to GPROF2010. GPROF2014 rain rates are reasonable, however the algorithm struggles to identify strong convection because of the searching method of the Bayesian database. Future versions of GPROF2014 developed by the GPM Science Team will aim to improve detection of deep convection.

Planned work

- Reduce cold scene false alarms by incorporating surface identification techniques
- Evaluate relative performance of GPROF2010V2 and GPROF2014
- Collaborate with related NASA/GPM and GOES-R projects
- Continue monitoring efforts of operational AMSR2 EDRs
- Continue product validation and identify algorithm deficiencies
- Recommend algorithm improvements for next version release of AMSR2 EDRs

Publications

Ferraro, R., P. Meyers, P. S. Chang, Z. Jelenak, C. Grassotti, and S. Liu: Application of GCOM-W AMSR2 and S-NPP ATMS Hydrological Products to a flooding event in the United States, J. of Sel. Top. Earth Obs. Remote Sens., under minor revision.

Products

NOAA/NESDIS/OSPO Operation GCOM-W1 AMSR2 Rain Rate EDR.

Presentations

Meyers, P. et al.: GCOM-W/AMSR2 precipitation EDR, JPSS Science Team Meeting, August 2016, College Park, MD.

Other

Advising a senior in the Atmospheric Science program at the University of Maryland for his senior research project related to satellite meteorology. Prepared and presented Validated Maturity Review materials.

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

Continued monitoring and development of the AMSR2 rain rate products. The product has reached the validated maturity level, which requires extensive documentation and exceeding performance metrics. A paper related to the performance of NOAA/STAR hydrological satellite products is under minor revision. An update was given at the JPSS science team meeting. One undergraduate is partially supported on a satellite meteorology project.

Scientific Support to JPSS ATMS Calibration	
Task Leader:	Hu Yang
Task Code:	HYHY_ICVS_16
NOAA Sponsor:	Quanhua Liu
NOAA Office:	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%):	Theme 2: 100%
Main CICS Research Topic:	Scientific Support for JPSS Mission
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

In 2015, ground TVAC test results shown several major issues of J1 ATMS instrument performance, which include receiver anomaly in channel 17, strong correlation between channel 18 and 19, speckles in all channels and strong stripping noise. These issues lead to rework for some of J1 ATMS channels. After the rework has been done in March, 2016, another TVAC test was carried out by Vendor, and results shown several major improvements regarding the previously identified issue. During the TVAC tests in 2015 and 2016, the CICS ATMS SDR team has been worked on the test data and provided the real-time technique support for Vendor and NOAA management team to make better understanding of the test results and decision making. ATMS SDR team in CICS also generated the key calibration parameters from TVAC and ground test datasets, such as nonlinearity correction parameters, instrument mounting matrix, antenna side lobe correction parameters, and band correction parameters for J1 block 2.0 IDPS PCT table updates. For ATMS on-orbit geolocation, based on the coastline inflection point geolocation evaluation/correction software package we developed last year, we further improved the geolocation correction algorithm by incorporating lunar observation in the algorithm.

Since J1 ATMS will be launched on September, 2017, the ATMS SDR team in CICS is working on the readiness of J1 ATMS calibration algorithm and preparing for intensified post-launch cal/val work.

Accomplishments

1. J1 ATMS ground test data analysis and PCT table updates for IDPS block2.0 software

During 2015 TVAC test we found several major issues of J1 ATMS performance, which include receiver anomaly in channel 17, strong correlation between channel 18 and 19, speckles in all channels and strong stripping noise. After rework in 2016 and 2017, most of these issues has been solved or get improvements. Compare to NPP ATMS, Stripping noise in J1 ATMS W and G bands was largely reduced, correction between channel 18 and 19 is still exist but with weaker magnitude. But the maximum nonlinearity of J1 ATMS is much larger than NPP for most of the channels.

Based on the TVAC test data and other ground test data delivered by Vendor and flight team, such as antenna pattern data and instrument mounting matrix measurements, we calculated the several key calibration and geolocation related parameters and delivered to J1 operational ground processing system for PCT updates. Table.1 is beam efficiency calculated for J1 and NPP ATMS. Results show that beam efficiency of J1 ATMS G band is much higher than NPP ATMS.

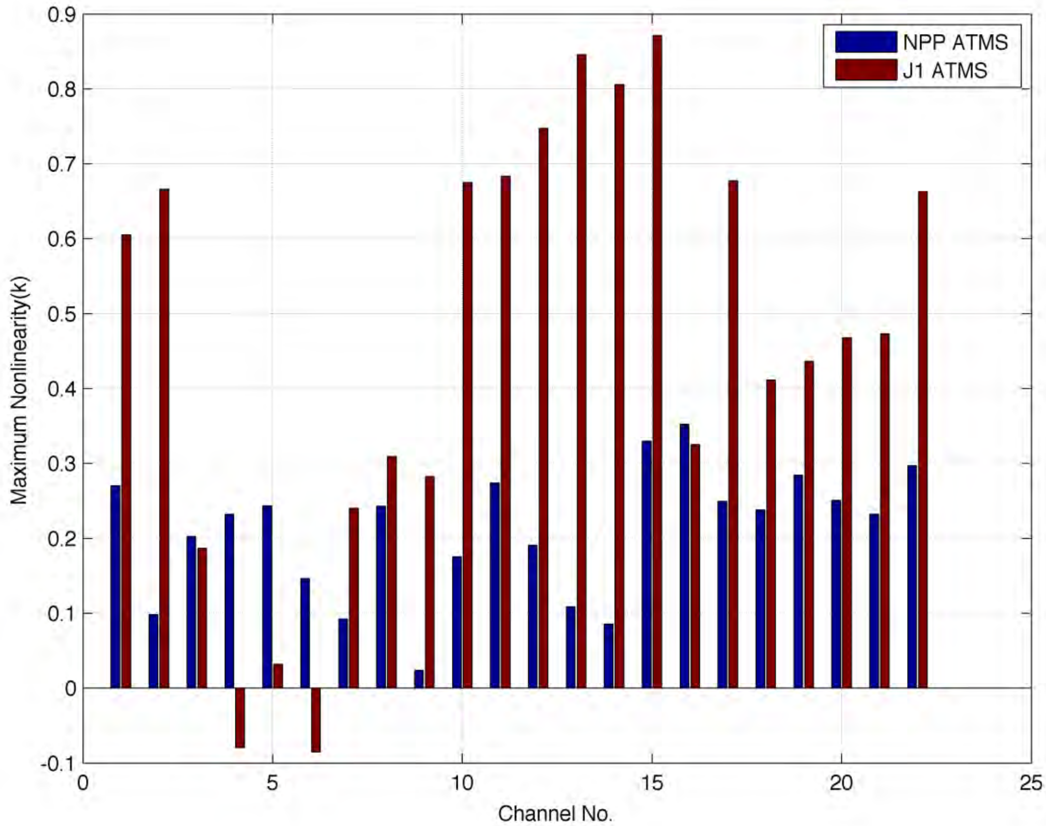


Figure 1. Comparison between NPP and J1 ATMS maximum nonlinearity across all 22 channels

2. ATMS long time gain stability monitoring by using Lunar observations

We also did some new study of assessing microwave radiometer long-term on-orbit calibration stability by taking the lunar observation as a reference. This method was applied to 5 years of NPP ATMS lunar observations, results show that ATMS calibration accuracy and stability can be well assessed by using the Moon as a reference target. Figure 2 shows the long-term stability assessment results for ATMS observations at channel 16 (89GHz center frequency) from Dec.03, 2011 to Jun. 13, 2016. Panels from top to bottom are Moon phase angle, Lunar observation angle, daily maximum observed lunar brightness temperature, daily maximum reference lunar brightness temperature, and daily average of the difference between observed and reference lunar Tb. It shows that for all lunar observation, the lunar phase varies between 100 to 120 degree, and minimum lunar observation angle varies between 0 to 2 degree. The observed lunar Tb is highly consistent with reference lunar Tb, with a mean bias of 0.05K and less than $1x10^{-4}$K /year trend. Similar results can be derived for other channels, which show that current calibration status of NPP ATMS is kept very stable after 5 years on-orbit operations.

Table 1. Beam Efficiency for J1 and NPP ATMS

Chan No.	J1-ATMS		NPP-ATMS	
	Beam Efficiency	Cross-Pol	Beam Efficiency	Cross-Pol
1	0.9598	0.0086	0.9584	0.0073
2	0.9702	0.0064	0.9699	0.0066
3	0.9631	0.0102	0.9661	0.0107
4	0.9684	0.0097	0.9668	0.0097
5	0.9714	0.0101	0.9669	0.0094
6	0.9729	0.0092	0.9685	0.0097
7	0.9690	0.0090	0.9654	0.0086
8	0.9724	0.0087	0.9703	0.0091
9	0.9714	0.0086	0.9673	0.0088
10	0.9756	0.0079	0.9766	0.0091
11	0.9756	0.0079	0.9766	0.0091
12	0.9756	0.0079	0.9766	0.0091
13	0.9756	0.0079	0.9766	0.0091
14	0.9756	0.0079	0.9766	0.0091
15	0.9756	0.0079	0.9766	0.0091
16	0.9597	0.0365	0.9457	0.0435
17	0.9394	0.0395	0.8768	0.0338
18	0.9389	0.0340	0.8933	0.0363
19	0.9389	0.0340	0.8933	0.0363
20	0.9360	0.0318	0.8973	0.0219
21	0.9360	0.0318	0.8973	0.0219
22	0.9360	0.0318	0.8973	0.0219

Planned work

- Documentation for advanced sciences in NPP ATMS calibration algorithm
- Readiness for intensified J1 ATMS post-launch cal/val activities

Publications

Peer-reviewed

[1]. Yang, Hu; Weng, Fuzhong; Anderson, Kent; 2016, ”Estimation of ATMS antenna emission from cold space observations”, IEEE Transactions on Geoscience and Remote Sensing, 54(8), 4479-4487

[2]. Yang, Hu; Weng, Fuzhong; 2016, "Corrections for on-orbit ATMS lunar contamination”,IEEE Transactions on Geoscience and Remote Sensing,54(4), 1918-1924

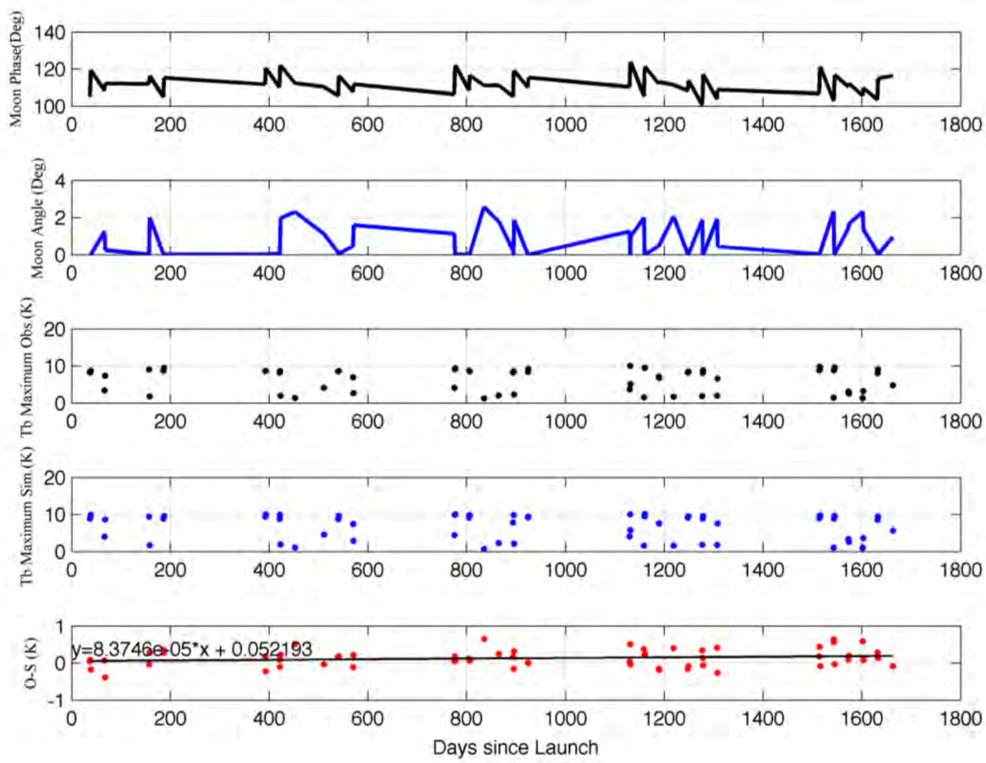


Figure 2. Long term stability assessment results for ATMS channel 16 observations from Dec.03, 2011 to Jun. 13, 2016. Panels from top to bottom are Moon phase angle, Lunar observation angle, daily maximum observed lunar brightness temperature, daily maximum reference lunar brightness temperature, and daily average of the difference between observed and reference lunar Tb

[3]. Weng, Fuzhong; Yang, Hu; 2016, ”Validation of ATMS calibration accuracy using Suomi NPP pitch maneuver observations”, Remote Sensing,8(4),332

[4]. Tang, Fei; Zou, Xiaolei; Yang, Hu; Weng, Fuzhong; 2016, "Estimation and correction of geolocation errors in FengYun-3C Microwave Radiation Imager Data”, IEEE Transactions on Geoscience and Remote Sensing, 54(1),407-420

[5]. Han, Yang; Weng, Fuzhong; Zou, Xiaolei; Yang, Hu; Scott, Deron; 2016,”Characterization of geolocation accuracy of Suomi NPP Advanced Technology Microwave Sounder measurements”, Journal of Geophysical Research:Atmospheres, 121(9),4933-4950

Conference Papers

[1]. Yang, John Xun; McKague, Darren S; Ruf, Christopher S; Yang, Hu; Weng, Fuzhong;2016, "Examining GMI intercalibration dependence on the full dynamic range of brightness temperature using cold and warm end tie points”,Geoscience and Remote Sensing Symposium (IGARSS), 2016 IEEE International, 864-867

[2]. Zhou, Jun; Yang, Hu; Weng, Fuzhong; 2016, ”Rebuild the instrument mounting matrix for microwave instrument on-orbit geometric calibration”, IEEE Geoscience and Remote Sensing Symposium (IGARSS), 860-863

[3]. Weng, Fuzhong; Ma, Yuan; Yang, Hu; Zou, Xiaolei;2016, "Potential Applications of small Satellite microwave observations for monitoring and predicting hurricanes and typhoons",Geoscience and Remote Sensing Symposium (IGARSS),5556-5558

Products

Reprocessing ATMS TDR, 2011-2016
Reprocessing ATMS SDR, 2011-2016

Presentations

1. "Estimation of ATMS Antenna Emission from Cold Space Observations", ITSC-20, Wisconsin
2. "On Calibration Error Budget Analysis for NPP/JPSS ATMS Instrument", Eumetsat conference 2016, Damstadt, Germany
3. "Validate FASTEM Model by Using Well-Calibrated ATMS Observations", AMS annual meeting 2016, Seattle

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	2
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	5
# of NOAA technical reports	3
# of presentations	3
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

For products or techniques submitted to NOAA for consideration in operations use, please see 'Accomplishments' section, for other items, please see according sections above.

Enhancement for Integrated Calibration and Validation System (ICVS) Collaborative Environment

Task Leader:	Hu Yang
Task Code:	HYHY_ICVS_16
NOAA Sponsor:	Quanhua Liu
NOAA Office:	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%):	Theme 2: 100%
Main CICS Research Topic:	Scientific Support for JPSS Mission
Contribution to NOAA goals (%)	Goal 2: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

Satellites data calibration and validation require a powerful computer system with sufficient CPUs to process the date and larger disk spaces to store them. The computer system input/output (I/O) performance is one of the most important factors to allow the system to perform massive scientific data processing. This project is devoted to enhance a High Performance Computer (HPC) for data processing.

Accomplishments

More computer CUPs, with Infiniband connection, were purchased. The current HPC computing power at ESSIC/UMD has been doubled. This provides the scientists and programmers a powerful computing environment to conduct their research and complete supported research tasks in a timely manner.

Planned work

Adding more computer nodes and high I/O performance storage to the HPC

Products

A total of 19 computer nodes, with 24cores, 64GB memory and infiniband port on each note, were purchased. Management, deployment and support service toward the nodes were purchased as well.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	19
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

This is the computer hardware.
For products or techniques submitted to NOAA for consideration in operations use, please see 'Accomplishments' section, for other items, please see according sections above.

Scientific Support to JPSS Life-Cycle Data Reprocessing

Task Leader:	Hu Yang
Task Code:	HYHY_ICVS_16
NOAA Sponsor:	Quanhua Liu
NOAA Office:	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%):	Theme 2: 100%
Main CICS Research Topic:	Scientific Support for JPSS Mission
Contribution to NOAA goals (%)	Goal 2: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

Since the SNPP launch, all the instruments are well calibrated and the sensor data records (SDR) and environmental data records (EDR) are generated through the JPSS ground Interface Data Processing System (IDPS) and operationally disseminated to NWP centers and other stakeholders. However, JPSS IDPS has undergone through many versions for maintenance (Mx) build code since its initial release. In each version, there are some important changes in instrument calibration, retrieval physics and quality flags and as a result, the quality of satellite products is improved. For example, in Mx8.11, the CrIS SDR products will be upgraded from normal (1306 channels) to full spectral resolution (2211). The algorithm changes in IDPS produce singularity in SDR and EDR time series and thus it is difficult to apply the SNPP data distributed from IDPS for more advanced applications such as NWP reanalysis and monitoring of long-term environmental changes. It is imperative that the JPSS calval science teams develop robust techniques to reprocess SNPP SDR and EDR data through this initiative.

Accomplishments

Developed reprocessing algorithm for VIRRS, CRiS, ATMS and OMPS instrument. Implemented the new algorithm to ADL software and generated 5 years of TDR/SDR products from level 0 data sets. The reprocessed TDR/SDR data products have been archieved in CICS linux server for user community download.

1.) Implementation of Embarrassingly-Parallel Scheme for ADL in Reprocessing of VIIRS

VIIRS reprocessing is a major challenge due to its very large data volume and huge amount of images taken every day. Each day, about 1013 VIIRS Raw Data Records (RDR) (~55GB) are processed into about 30,000 Sensor Data Record (SDR) files, with a total data volume about 540GB after compression, which requires high amount of CPU hours. These large data volume and high CPU demands certainly become a storage and processing bottleneck for reprocessing. For faster reprocessing of VIIRS SDR, an embarrassingly-parallel scheme has been implemented for the Algorithm Development Library (ADL), using current super clusters at University of Maryland (bamboo at CICS/UMD). With this super computer, the parallel reprocessing of one year of VIIRS SDR products will take only 8.5 days, about 1.1% of the time of the serial reprocessing (one CPU). Fig. V1 shows the schematic flow chart of the VIIRS reprocessing using CICS supercomputer bamboo.

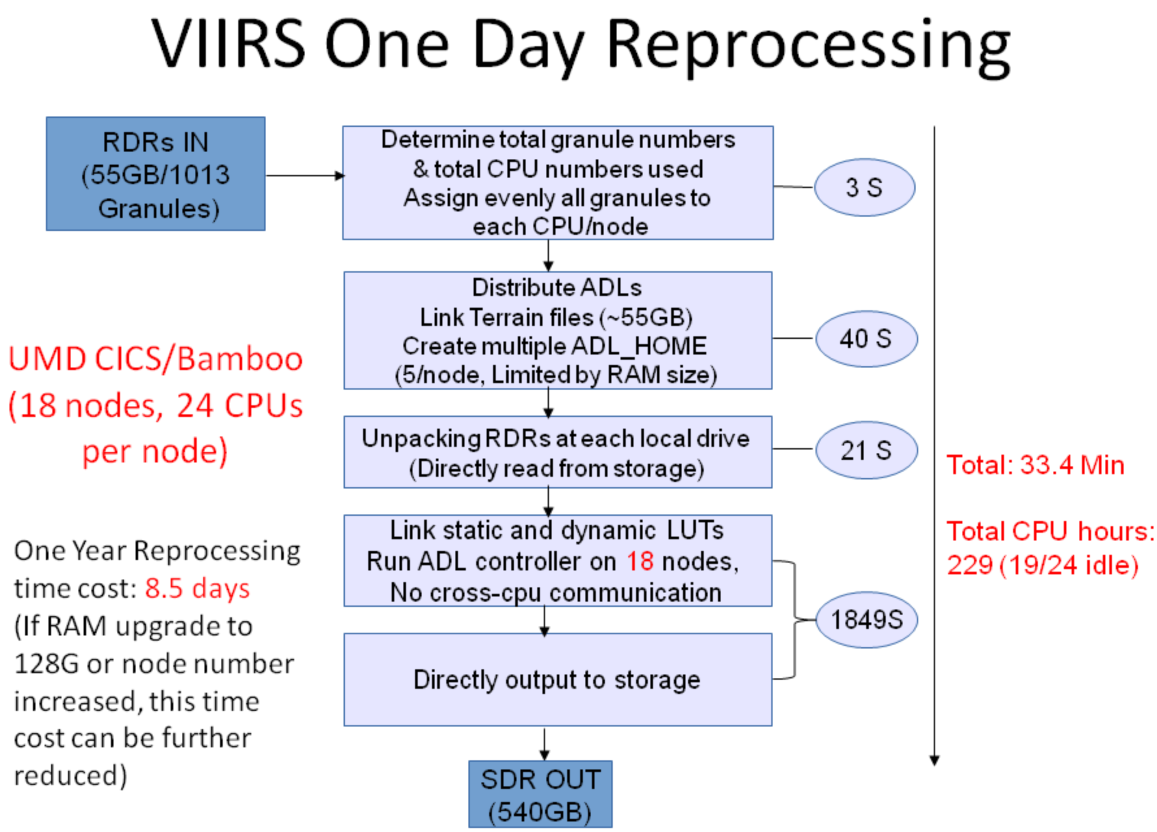


Figure V1. VIIRS SDR reprocessing flow chart on super computer bamboo at CICS/UMD

2.) Implementation of Reprocessing of the VIIRS 4 Weeks Dataset Using Ocean Color Team Provided F Factors

F factor represents the degradation of the VIIRS calibration instrument and reflects the long term drift in the calibration. However, IDPS F factors out of RSBAUTOCAL are different from those of Ocean Color team (STAR) derived F factors (e.g. about 2% difference in M2). Initial experiments were set to use OC team F factors to carry on the VIIRS reprocessing. We have generated look up tables using OC F factor and created 4 weeks VIIRS SDR datasets and compared with the IDPS version of VIIRS SDR, with the STAR reprocess version of VIIRS SDR and NASA VIIRS SDR, respectively. The reprocessed datasets have been evaluated by Environment Data Record (EDR) teams and feedback has been used for next step of reprocessing. Fig.V2 shows the radiance ratio between the VIIRS SDR using OC LUT versus IDSP results for band M1 and M2.

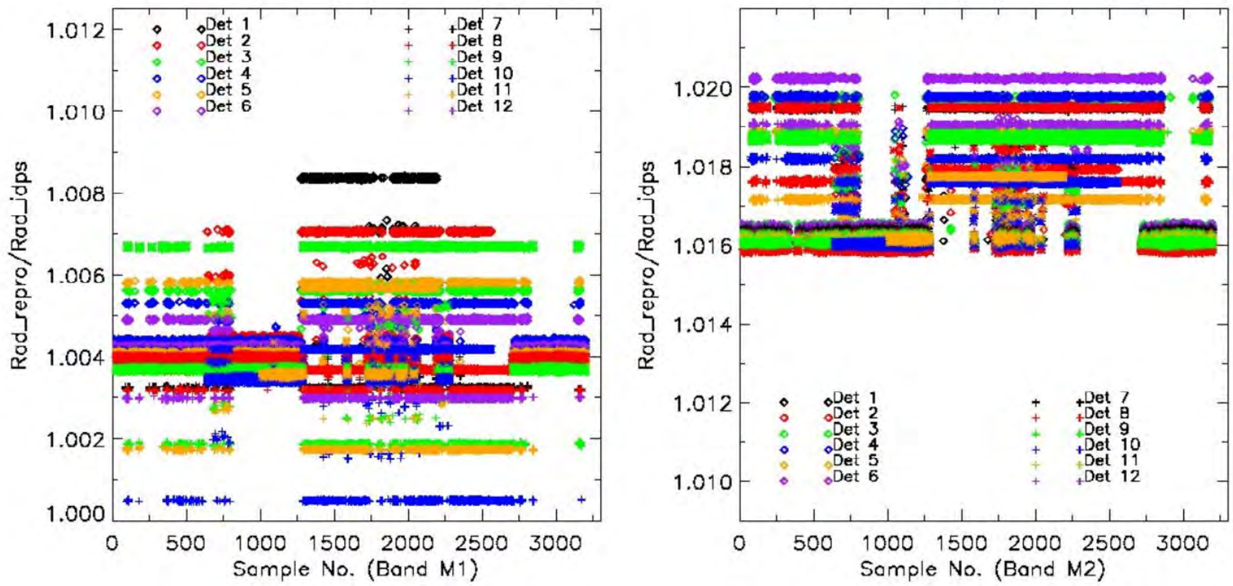


Figure V2. Radiane ratio of Band M1 and M2 between two SDR datasets using OC provided F factors and IDSP ones for granule at time 07/11/2015 19:46 UTC over Gulf of Mexico.

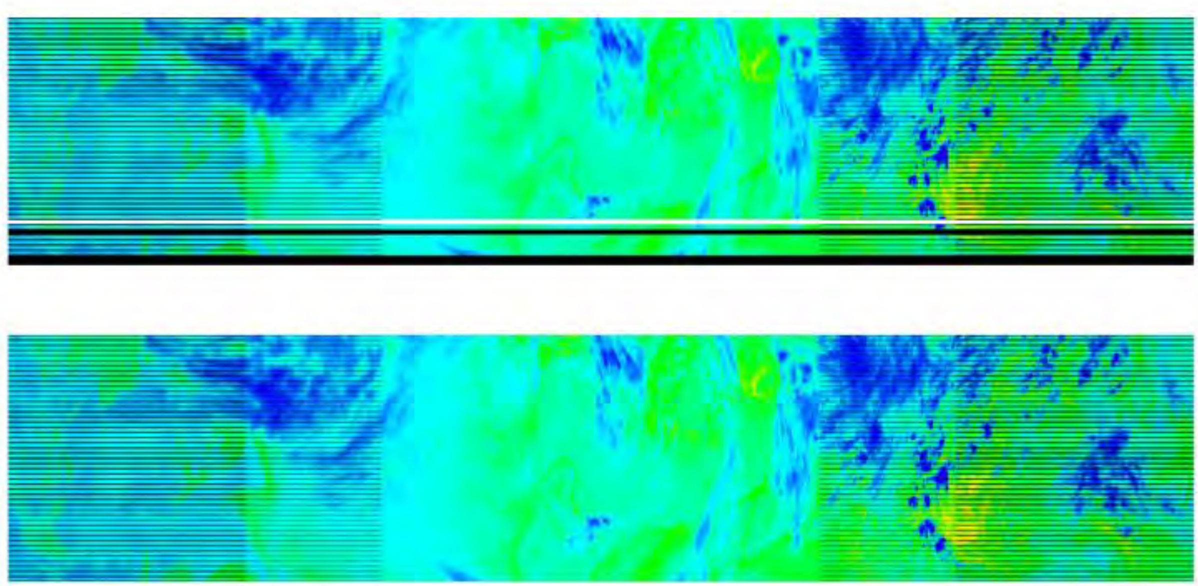


Figure V3. M13 radiance comparison between CLASS (above) and reprocessed (bottom) dataset at time 05/15/2015 19:56 UTC. All artifacts disappear after reprocessing.

3.) Implemented TEB VIIRS SDR Reprocessing.

VIIRS SST shows bias of 0.3k relative to independent models every three months during VIIRS Warm-Up-Cool-Down period. Several improvement algorithm has been proposed by STAR calibration team (2) and we have carried out reprocessing of VIIRS SDR dataset during WUCD period using new ADL code

and LUTs. The feedback from SST team on the new VIIRS SDR datasets is positive. The new algorithm will be used in the next step VIIRS SDR reprocessing.
Updated TEB look up tables using averaged Relative Spectral Response over M16A and M16B has been used in the VIIRS reprocessing. Reprocessing has been corrected multiple issues for the fire team (saturation, erroneous fire pixel detection etc) (Fig. V3).

4.) Implemented VIIRS DNB SDR Reprocessing
We have also included the DNB updated LUTs, especially low gain ratio LUT with continuously changing Relative Spectral Response functions (Fig. V4), in the 4 weeks reprocessing for improvement in radiometric accuracy, e.g. , straylight corrections, reducing the negative numbers in the DNB radiance and also improvements in geolocation accuracy with terrain corrected geolocation dataset added.

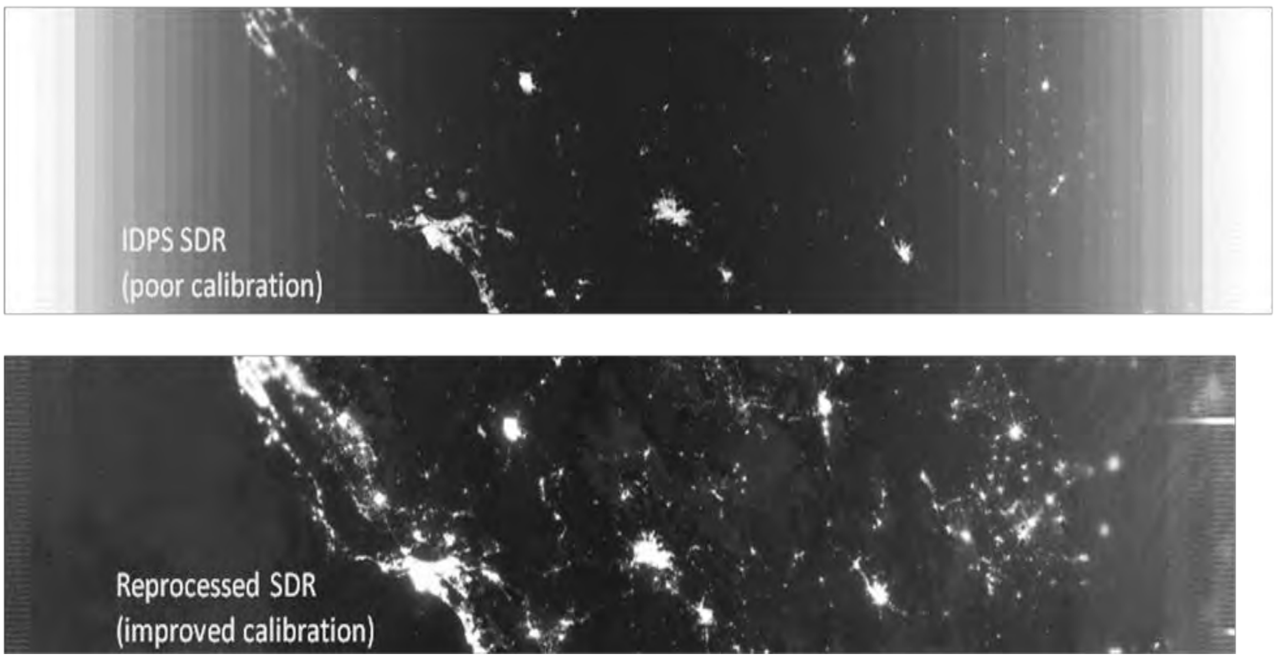


Figure V4. Before and after the reprocessing of a VIIRS DNB granule on March 20, 2012 with the improved gain ratio LUT

Publications
Submitted peer reviewed papers:
1. Cao, Changyong, Wenhui Wang, Slawomir Blonski and **Bin Zhang**, Radiometric traceability diagnosis and bias correction for the Suomi NPP VIIRS long-wave infrared channels during blackbody unsteady states, 2017, Journal of Geophysical Research-Atmosphere, in review

Submitted non-peer reviewed papers:
1. Weng, Fuzhong, Taeyoung Choi, Changyong Cao, **Bin Zhang**, Wenhui Wang , Sirish Uprety, Slawomir Blonski, Junqiang Sun and Menghua Wang, 2017, Review OF Current S-NPP VIIRS Product Quality From IDPS With Community Raised-Iuuses, IGARSS, Fort Worth, Texas, USA

Products

- 5 years of VIIRS TDR products from 2011 to 2016
- 5 years of ATMS TDR/SDR products from 2011 to 2016
- 5 years of CRiS TDR products from 2011 to 2016
- 5 years of OMPS TDR products from 2011 to 2016

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

For products or techniques submitted to NOAA for consideration in operations use, please see 'Accomplishments' section, for other items, please see according sections above.

NESDIS STAR Science Enterprise Support for Satellite Programs and JPSS Ground Project Transition Plan

Task Leader	Nai-Yu Wang
Task Code	EBNW_GPTP_16
NOAA Sponsor	Satya Kullari
NOAA Office	NESDIS/STAR/CoRP
Contribution to CICS Research Themes (%)	Theme 1: 80%; Theme 2: 20%
Main CICS Research Topic	Scientific Support for JPSS Mission
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Develop a JPSS risk reduction precipitation estimation algorithm for ATMS

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

1. OCONUS Rain Algorithm for NWS Pacific Region

Nai-Yu Wang visited the National Weather Service Pacific Region Headquarters in Honolulu from June 20 to July 1, 2016 to demonstrate a new satellite QPE capability of combining infrared and lightning observations from the upcoming GOES-R using the current geostationary satellite Himawari-8 and ground lightning network GLD360 data. She participated and presented a talk entitled "Combining IR and Lightning For Enhanced GOES-R Rain Estimates in the Pacific Region" on June 30 at the 2016 GOES-R/JPSS OCONUS Satellite Proving Ground Technical Interchange meeting.

The preliminary algorithm development makes use of IR channels from Himawari-8 on board of the Japanese Meteorological Agency (JMA) and lightning observations (flash occurrence) from ground lightning network GLD360. Figure 1 top panel shows the brightness temperatures (TBs) from IR window channel 13 from Himawari-8 satellite. The colder IR TBs signal higher cloud top height which implies higher vertical extent of the clouds and possible heavy rainfall. However, the correlations between IR TBs and surface rainfall are very weak. Methods of deriving surface rainfall using IR TBs through techniques of relating IR TBs and surface rainfall rate through linear or more complex regression methods have not yielded good results. A different methodology is used here and the initial assessment shows great promises. The bottom panel in Figure 1

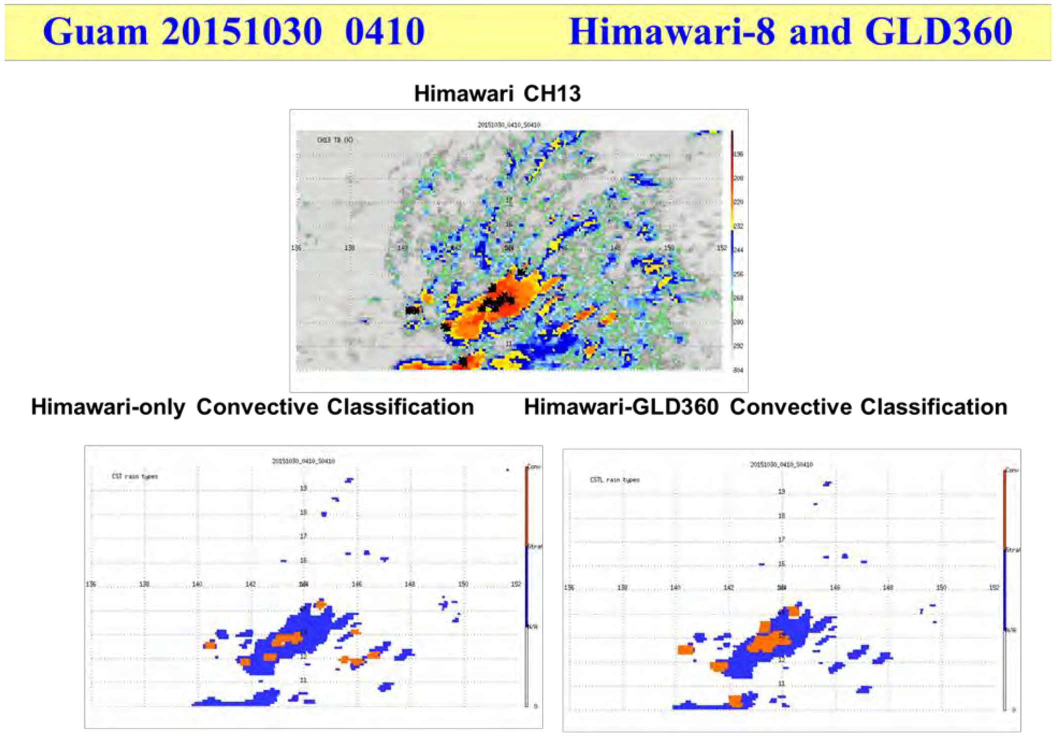


Figure 1. Himawari-8 Channel 13 IR imagery for 30 October 2015, 0410 UTC (top). The bottom panel shows the convective (red) and non-convective (blue) identified by the satellite QPE algorithm using IR only (on the left) and IR and lightning combination (on the right).

The rain storm pattern and amount between Quam radar and IR-lightning technique are highly comparable (see Figure 2). Further algorithm refinements on the lightning information for oceanic convective rigor and rainfall rate relationships, and the evolution of convective cells using frequent GEO-IR observations will be the focus for next year. Coincident Guam and Hawaii islands ground radars, space-borne radar and radiometer from GPM, and Himawari-8 are being collected for algorithm development and validation. Algorithm validation effort will be a focus for this project as well.

2. JAXA PMM Science Team Invited Presentation

Nai-Yu Wang was invited to give a presentation entitled "Evaluation of GSMaP Radiometer Rain Retrievals" at the JAXA Precipitation Measuring Mission Science Team meeting in Tokyo Japan on January 23, 2017. Nai-Yu Wang is a PI in JAXA Global Precipitation Mission science team.

3. NESDIS STAR Satellite Applications and the National Water Center Work Plan

Nai-Yu Wang developed a work plan to engage NESDIS STAR's satellite applications to the national water center (NWC). Satellite observations from NOAA and non-NOAA satellites can provide valuable information to the NWC in (1) meteorological forcing (2) land surface model initialization and update, (3) model forecast verification and adjustment, and (4) data assimilation to update model state. This work plan outlines areas of potential satellite applications to the National Water Model (NWM) and offers a path forward to demonstrate the benefits of satellite data into NWM and NWC hydrological predictions.

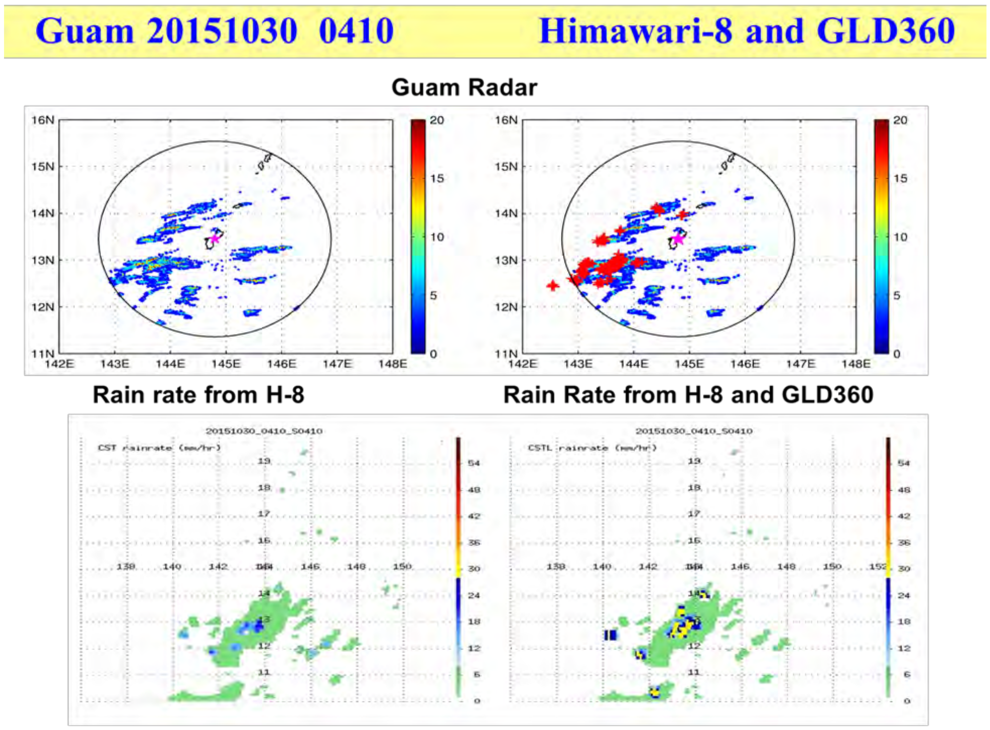


Figure 2 – For the same case as shown in Figure 1: top panel shows the rainfall rate (rainfall rate on the left, rainfall rate with overlaid lightning flashes on the right) from Guam radar, bottom panel shows the rainfall rate by the satellite QPE algorithm using IR only (on the left) and rainfall rate from the combination of IR and lightning (on the right) shows the identification of convective clouds (in red) and other precipitating clouds (in blue) through a local minimum temperature and temperature gradient technique (on the left), and convective cloud identification from combined IR TBs and lightning flashes. Figure 2 shows the instantaneous rainfall from Guam radar (top panel) and the rainfall derived from IR convective feature-rainfall functions (lower left), and the rainfall derived from the combined IR convective feature-lightning-rainfall functions (lower right).

4 **.Briefing to STAR Management on the NESDIS STAR Satellite Applications and the National Water Center Work Plan**

Nai-Yu Wang gave a presentation to the STAR acting director Harry Cikanek and Deputy Director Michael Kalb on the STAR satellite applications and the national water center work plan on March 2, 2017. The briefing and pilot studies identified on the plan was well received by STAR. Formal plans of implementation of the work plan are currently being discussed.

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) Develop a work plan for STAR to understand the current state and identify areas where satellite products can contribute to improvements to national water model and hydrological forecasts. Develop a gap analysis and identify users needs and approach to fill in the gap. Conduct pilot study to demonstrate the benefits of satellite data to hydrological predictions

Publications

You, Y., **N.-Y. Wang**, and R. Ferraro, 2016, A prototype precipitation retrieval algorithm for ATMS. *J. Hydrometeor.,* doi:10.1175/JHM-D-15-0163.1.

Christian Kummerow; David L. Randel; Mark Kulie; **Nai-Yu Wang**; Ralph Ferraro; S. Joseph Munchak; Veljko Petkovic, 2015, The Evolution of the Goddard Profiling Algorithm to a Fully Parametric Scheme, *Journal of Atmospheric and Oceanic Technology,* doi10.1175/JTECH-D-15-0039.1

Presentations

Nai-Yu Wang was invited to give a talk entitled "Combining IR and Lightning For Enhanced GOES-R Rain Estimates in the Pacific Region" on June 30, 2016 at the 2016 GOES-R/JPSS OCONUS Satellite Proving Ground Technical Interchange meeting in Honolulu Hawaii.

Nai-Yu Wang gave a poster entitled "Combining IR and Lightning for Enhanced Geostationary Satellite Rain Estimates" at the 8th International Precipitation Working Group (IPWG) workshop on October 4, 2016 in Bologna Italy.

Nai-Yu Wang was invited to give a talk entitled "Evaluation of GSMaP Radiometer Rain Retrievals" at the JAXA PMM 8th meeting of Science Team in Tokyo Japan on January 23, 2017.

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

CUNY CREST Support for IMS V3 Development

Task Leader	Peter Romanov
Task Code	PRPR_IMS3_16
NOAA Sponsor	Sean Helfrich
NOAA Office	STAR
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Scientific support for the JPSS Mission
Contribution to NOAA goals (%)	Goal 2: 100%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight : We have performed evaluation of the Southern Hemisphere snow and ice cover maps generated operationally at the National Ice Center and incorporated in the Interactive Multisensor Snow and Ice Mapping System (IMS). It was determined that the retrieval algorithm demonstrates robust performance and provides accurate characterization of the snow and ice cover in South America, Australia, New Zealand and Southern Africa.

Link to the operational web page:
http://satepsanone.nesdis.noaa.gov/southern_hemisphere_multisensor.html

Background

Information on snow and ice cover presents a critical input to NOAA's numerical weather prediction (NWP) and climate models. NOAA Interactive Multisensor Snow and Ice Mapping System (IMS) is a primary source of information on the snow and ice cover for NOAA NWP and climate models. Enhancement of this system and improvement of the quality of IMS products is important for further improvements of NOAA weather and climate prediction.

This work presents a part of a larger project lead by Dr. Sean Helfrich of NESDIS/STAR to upgrade to the current version of the NOAA Interactive Multisensor Snow and Ice Mapping System (IMS). The overall objective of the project consists in adding new capabilities to the system (e.g., information on the snow depth in addition to the snow extent), expanding the system coverage to the Southern Hemisphere, improving the spatial resolution and temporal resolution of the charts to 1 km and twice a day, correspondingly.

One of the weaknesses of the IMS system is the area coverage which is limited to the Northern Hemisphere only. In 2014-2015 we have implemented an automated satellite data-based system which generates daily snow and ice cover maps over the Southern Hemisphere at the spatial resolution of 2 km. This product has been used to complement the IMS product and deliver to the National Weather Service a new, global daily snow and ice cover map. In this project we have examined snow and ice maps over the Southern Hemisphere generated with the automated system to identify any possible issues in the product performance.

Accomplishments

The lack of in situ observations of snow cover in the Southern hemisphere precludes from a detailed comparison of the automated retrieval results with independent ground truth and quantitative assessment of their accuracy. Therefore only qualitative evaluation of the derived snow and ice cover maps has been performed. It included comparison of the derived snow and ice maps with the original satellite imagery as well as comparison of the ice cover maps with other passive microwave-based ice products in Antarctica. An example of the daily blended automated snow and ice cover map for the Southern Hemisphere is shown in Figure 1.

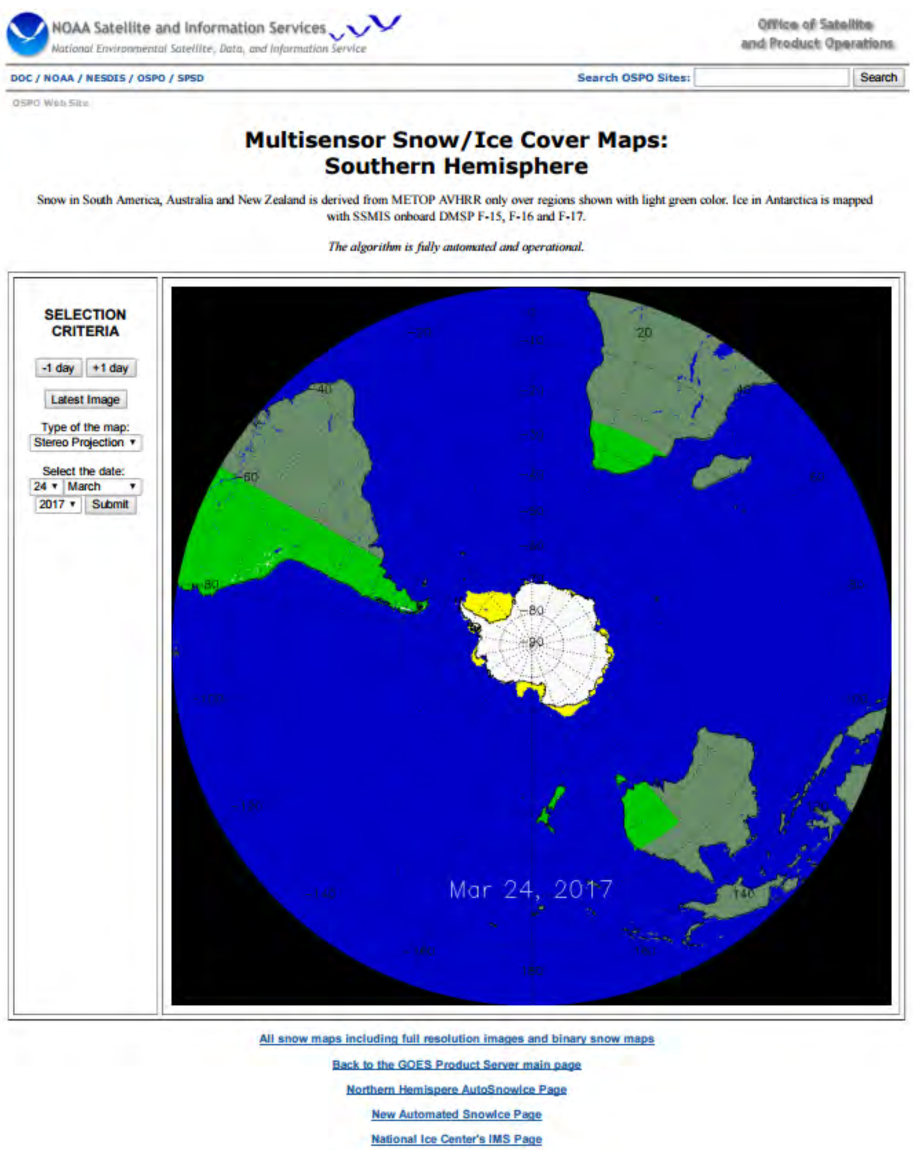


Figure 1. Southern Hemisphere automated daily snow and ice cover map.

It is important that in South America, Southern Africa, Australia and New Zealand snow cover is not mapped in areas where seasonal or perennial snow cover has never been observed. Antarctica is assumed snow-covered year-round. Snow cover is identified solely with visible and infrared observations of METOP AVHRR whereas ice cover in Antarctica is identified and mapped with observations in the microwave from DMSP SSMI and SSMIS instruments.

Qualitative assessment of the derived automated maps has shown that they realistically reproduce changes in the snow and ice cover distribution. An example of the automated snow cover map over the southern portion of South America presented in Figure 2 illustrate its good agreement with the snow cover distribution seen on a satellite false color image taken at the same day.

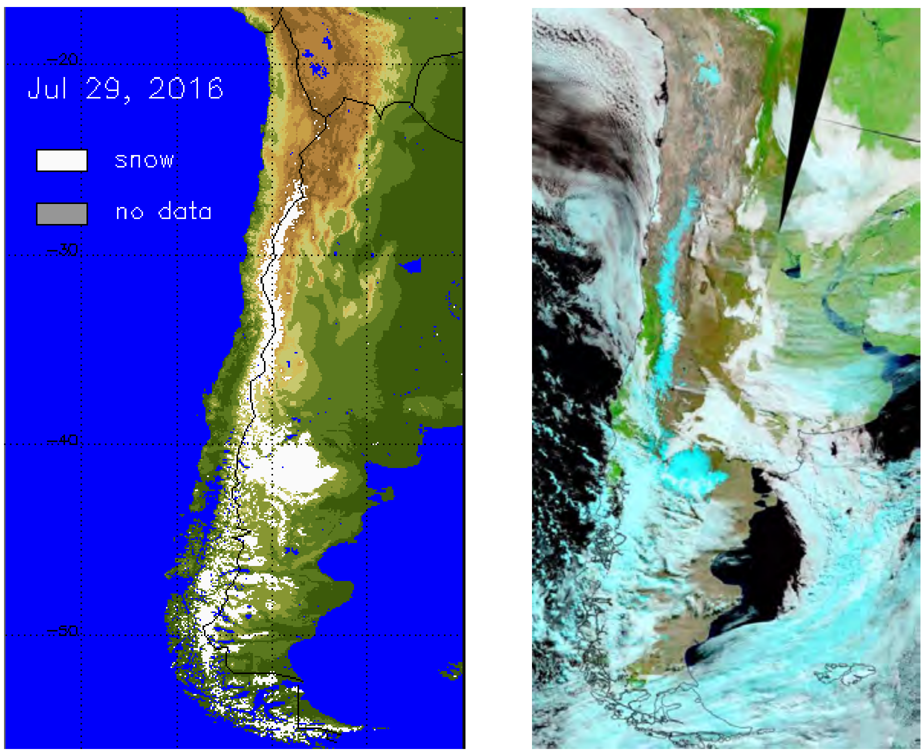


Figure 2. Example of snow cover map over South America (left) and corresponding false color satellite (right). In the false-color image snow has a bright light blue color.

Clouds present the major factor which affects the quality of the snow maps. Since the technique relies solely on satellite observations in the visible and infrared bands, retrievals are performed only in clear sky conditions. Therefore changes in the snow cover distribution on the ground may be reproduced in the map with a delay. The delay depends upon the cloud cover climatology in a particular location and on the season. Our estimates have shown that in the southern part of South America (Patagonia) and in New Zealand the mean number of consecutive cloudy days over a given location ranges within 2.10-2.11. This means that in most cases updates are available every third day. The mean probability for three or more and for seven or more consecutive cloudy days amounts ranges within 0.083-0.089 and

0.015 to 0.027 respectively. Clouds are less frequent in the southern part of South Africa with the mean number of consecutive cloudy days of 1.61.

Information on the ice cover in Antarctica derived within the system from observations of DMSP SSMIS was compared to several other microwave products produced at NOAA, NASA, JAXA and ESA. We have found that the automated algorithm implemented within our system provides a reasonable characterization of the ice cover distribution in Antarctica and its changes with time. The absolute area extent of ice mapped by the automated system was within the range of ice extent in other products but was somewhat smaller than in most other products. The absolute difference in the estimated daily ice extent generally remained within several percent throughout the year.

Planned work

The project has ended, no further work is planned

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

Albedo Algorithm Validation and Monitoring	
Task Leader:	Peng Yu
Task Code:	PYPY_AVVM_16
NOAA Sponsor:	Yunyue Yu
NOAA Office:	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%):	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic:	Scientific Support for the JPSS Mission
Contribution to NOAA goals (%):	Goal 1: 30%; Goal 2: 70%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

This report summarizes the ongoing NOAA project titled “Albedo Algorithm Validation and Monitoring”. The goal of this task is to provide STAR on-site scientific and technical support to the Surface Albedo product. Surface Albedo reflects how much incident radiation is reflected toward atmosphere, which is an operational product at NOAA, running for the S-NPP satellite since 2011 and will be run for JPSS 1 and JPSS 2 satellites. However, the algorithm only applies specific look-up-table (LUT) and climatology data for land surface but not the sea ice pixels. Sea ice occurs in both Arctic and Antarctic. Snow/ice surface has a much higher albedo compared to other earth surfaces (vegetation 0.1~0.3, sea water around 0.06). The albedo for snow-covered sea ice can reach 0.7~0.95, and that of the bare ice surface is around 0.5~0.6, while the ice with bubbles ranges 0.3~0.4. The high efficiency in reflecting solar radiation makes it an important impact to global radiation budget, particularly for the polar region. It became an important driving factor for weather and climate prediction.

For the past fiscal year, this task focuses on providing high-quality sea-ice albedo from a Bright Pixel Surface Algorithm (BPSA), as a granule product (EDR), from the VIIRS sensor onboard the S-NPP (and later J1 and J2) satellite. The algorithm uses information from nine VIIRS channels covering the whole shortwave range. The generated sea ice albedo has a spatial resolution of around 750m. It will be further processed for daily global gridded albedo product, meeting application needs from NOAA weather service.

Accomplishments

The task of VIIRS sea-ice albedo generation consists of three components. The first is to generate a VIIRS sea-ice albedo LUT from a MODIS-band LUT. The advantage of this LUT is the potential to generate high-accuracy continuous sea-ice albedo products with the historical observations from MODIS combined with VIIRS and future JPSS, which will provide a unique records for monitoring the long-term variation of surface albedo. This LUT will be integrated to the first version of NDE albedo algorithm. The second is to simulate the VIIRS sea-ice albedo LUT from sea ice/snow/water BRDFs. This LUT considered the band particularity of VIIRS and will be the updated version to calculate the NDE albedo product. At the final stage, the generated primary albedo will go through a temporal filtering and gap filling for the cloud-contaminated pixels. A prior knowledge dataset is indispensable in the filtering to provide the background value and climatology information for sea-ice albedo. It would be produced from statistics of historical sea-ice albedo. At this stage, the first version LUT and the background dataset have been generated and tested.

The BPSA algorithm derives surface sea ice albedo directly from TOA reflectance through linear relationship derived from a pre-computed and rigid coefficients LUT. As we worked on building comparable and continuous albedo products from both VIIRS and MODIS, it was determined to obtain a MODIS-consistent LUT for the first version of NDE sea-ice albedo LUT. To eliminate the difference caused by the spectral response difference between VIIRS and MODIS, a band conversion technique was adopted to link the LUT from MODIS-band to VIIRS-band. It relies on the autocorrelation at various wavelengths of surface spectral characteristics, where each VIIRS band is expressed as the linear combination of MODIS spectral reflectance. The band conversion coefficients are built based on abundant high quality spectra measurements covering common land cover types, to enhance the adaptability of the coefficients. The USGS spectra library was deployed to provide spectral reflectance information of typical land cover types. This spectral library covers the common land cover types including minerals, soils, rocks, coatings, liquids, artificial and plants. Most spectra range from 0.38 to 2.5 µm. As a statistical band conversion method, it requires further assessment strategy and criterion to test whether the resulted coefficients are reliable and effective. We verified both the conversion accuracy and the amount of invalid pixels of the band conversion coefficients. One index used is the RMSE between MODIS reflectance from direct integration of TOA spectra and that from band conversion of VIIRS TOA reflectance. The other index is the increased fraction of pixels with references beyond the valid range of albedo. Both of these indexes are expected to be held under 10%.

In the MODIS albedo LUT design, the white-sky-albedo and black-sky-albedo was the present form of albedo information. They still need user-provided diffuse skylight factor to be blended into the blue-sky-albedo. One reason for this design is in its representativeness of the overall situation within a 16-day cycle, corresponding to the temporal representativeness of its albedo. However, for real-time albedo product, the blue-sky albedo would be more convenient for users while the adaptability become the secondary, so the VIIRS albedo product has embedded the diffuse skylight factor β into the LUT. β was simulated using 6S under various atmospheric conditions. It has been verified that β can be expressed as a function of solar zenith angle while stable with solar azimuth angle.

The directly calculated albedo is often contaminated by cloud or degraded by large satellite view angles, which will be presented as data gaps or outliers. A temporal filtering algorithm was adopted, after which the completeness and continuity of the primary albedo will be improved. The filtered albedo can be expressed as,

$$A_f = \frac{\sum_{i=-8}^{i=8} \sum_{k=1,\ldots,nk} w_i (a_i A_{uf} + b_i)}{\sum_{i=-8}^{i=8} \sum_{k=1,\ldots,nk} w_i}$$

Where A_f is the filtered albedo, while A_{uf} corresponds to the unfiltered albedo. a_i, b_i, w_i are the filtering coefficients derived using a temporal filtering algorithm from a background prior knowledge dataset. The main task is to derive the prior knowledge dataset, i.e., a series of statistics from historical dataset, for sea-ice surface. The prior statistics include: (1) multiyear average albedo (2) multiyear standard deviation of albedo and (3) correlation coefficient for each day-pair. Some regions such as the polar night areas need post-processing, filling the average albedo using the data two days before polar night.

The derived albedo product has been evaluated with the GC-net observations in Greenland area as reference. Although the Greenland ice belongs to land-ice, the surface physical characteristics have similar characteristics with sea ice, so as the albedo. Figure 1 illustrates the VIIRS albedo distribution of Greenland. The comparison between time-series VIIRS albedo and GC-net observations at Tunu-N site is demonstrated in Figure 2.

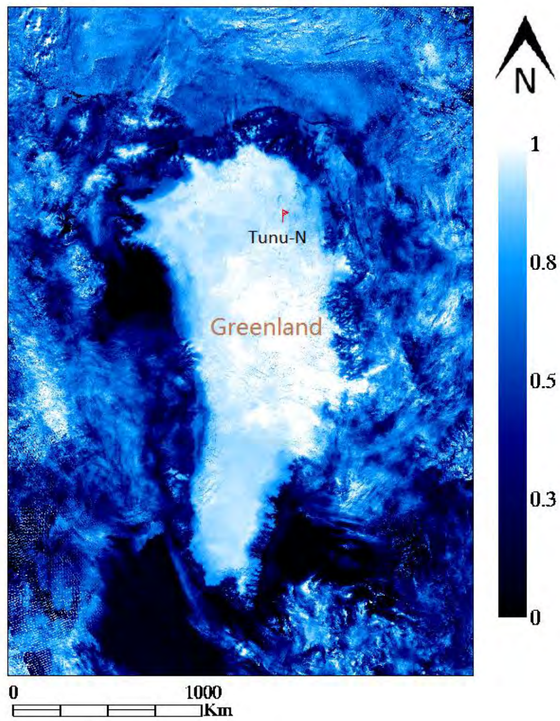


Figure 1. Local solar noon albedo in Greenland from VIIRS (Observed in Aug, 2015)

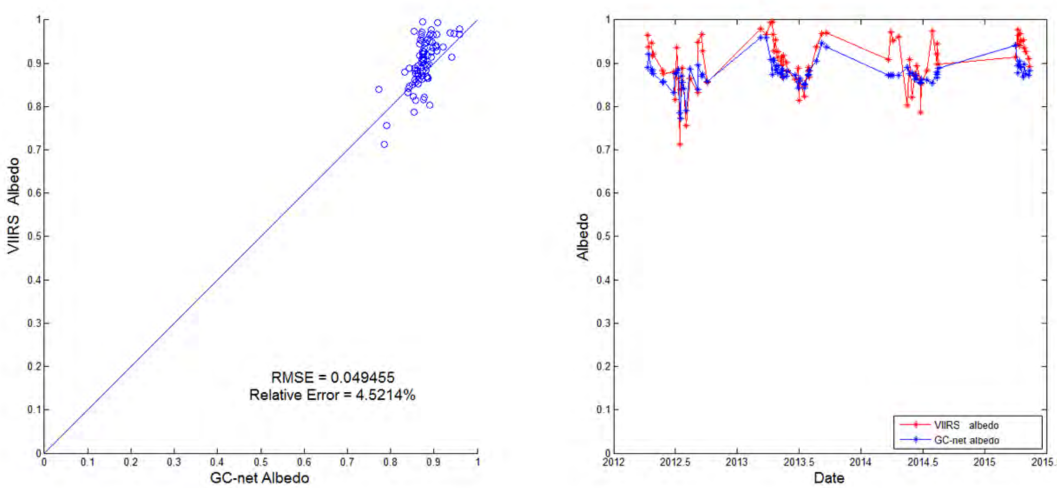


Figure 2. Comparison between VIIRS ice surface albedo with GC-net ground observations at Tunu-N site in Greenland (78.02N, 33.98W*)*

Planned work

- New sea-ice albedo LUT development: To further improve the accuracy and adaptability, we plan to train the coefficients LUT directly between broadband surface albedo and TOA reflectance based on a large volume prior bidirectional reflectance distribution function (BRDF) dataset and atmospheric simulation over sea ice surfaces. The task includes four main steps.
    - To build the simulation dataset: Simulating the sea ice surface BRDF dataset under different circumstances. The sea-ice surface BRDF varies according to the surface coverage, sea-ice age, depth, and components such as bubbles and soot content. More than ten thousand of BRDF datasets will be produced, including the BRDFs of sea-ice, snow cover and sea water.
    - Derivation of the surface broadband Albedo: The surface broadband albedo will be derived based on the BRDF dataset. This involves a hemispherical integration of each surface BRDF dataset.
    - The simulation of the TOA reflectance: This task will use atmospheric radiative transfer model 6S to obtain the TOA reflectance. Antarctic and Arctic areas will be separately dealt with given their different climate environment. This task is computationally intensive requiring parallel computation.
    - Regression analysis and LUT generation: Building the relationships between TOA reflectance and surface broadband albedo at each solar/view angular bin. Considering that the enterprise algorithm will take sea ice concentration data as input, 5-dimensional LUT including the region, ice concentration, solar zenith angle, view zenith angle and relative azimuth angle variations will be developed for sea ice albedo inversion.
- Support evaluation of the enterprise albedo algorithm
    - Long term monitoring tool development: Continue to work on the development of the data long term monitoring system. The system will automatically collect ground measurements over sites of FLUXNET, GC-NET, BSRN and SAFARI, also the subset VIIRS SDR and Albedo data. These data will help to validate VIIRS albedo at various land cover types. Matchup will be performed between the ground in-situ data and the subset data. The validation results will support the generation of periodical validation report
    - Cross comparison: Cross-validation will be conducted with satellite derived albedo products such as MODIS Albedo product, GOES-R Albedo Product and modeling albedo products. The seasonal and yearly variation tendency will be investigated in the cross-validation report.

Publications

Jingjing Peng, et al. “Modeling and validation of the angular clumping index of forest canopy.” IGARSS, 2017 (submitted)

Products

Sea-ice albedo LUT for NDE BPSA algorithm

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

Development and Implementations of Marine Isoprene Emission Product using Multiple JPSS Ocean Products to Support NAQFC Operations

Task Leader	Daniel Tong
Task Code	QTQT_VIIRS_16
NOAA Sponsor	Mitch Goldberg
NOAA Office	JPSSO
Percent contribution to CICS Themes	Theme 3, 100%
Main CICS Research Topic	Advanced Satellite Programs: JPSS
Percent contribution to NOAA Goals	Goal 3: 100%
Strategic Research Guidance Memo:	1. Integrated Earth System Processes and Predictions

Highlight: 1) CICS scientists have acquired new field campaign data that allow in-situ product validation; 2) CICS scientists have VIIRS isoprene validation using SPACES/OASIS and ASTRA-OMZ observations; 3) CICS scientists proposed and tested new improvement of isoprene retrieval algorithms in light of the new validation results.

Background

This work is part of the JPSS Proving Ground and Risk Reduction (PGRR) program to promote JPSS data utilization in the National Weather Service (NWS) operational forecasts. The specific task here is to develop and apply the VIIRS marine isoprene emission product to support the national air quality forecasting capability (NAQFC) and climate models. Global oceans are a large source for several trace gases and airborne aerosols that affect atmospheric chemistry, coastal air quality, cloud formation, and radiative budget. Isoprene is a reactive biogenic hydrocarbon that is important for the production of tropospheric ozone and secondary organic aerosols. Air quality and climate models rely on accurate emission data of trace gases and aerosols to simulate the chemical and physical processes that determine the status and trend of air quality and climate. *To date, there is no well-validated marine emission data available to support real-time air quality forecasting and long-term climate assessment.* As a result, the marine emissions are simply missing in the NAQFC system, or represented in the ESM system by prescribed monthly values empirically derived from sparse ground observations.

Accomplishments

In the past year, our team has completed the following tasks:

1. Acquisition of New Field Campaign Measurements

Since the launch of the S-NPP, there were no direct measurements of marine isoprene concentrations that can be used to conduct in-situ data validation. Consequently, all previous data validation was conducted using historic cruise data that do not match the satellite retrievals with time, but season (in different years) and location. After working with the leading scientists of several recent large-scale cruises, our team has obtained detailed field measurement data that are suitable for conducting point-to-point comparisons between the VIIRS isoprene product and the in-situ measurements.

Two campaigns were found particularly useful for VIIRS isoprene product validation. Figure 1 shows the cruise tracks of these campaigns. We used isoprene measurements from the SPACES/OASIS (June– July 2014, Indian Ocean) and ASTRA-OMZ (October 2015, eastern Pacific Ocean) cruises. Water samples (50 mL) were taken every 3 h from a continuously running seawater pump system located in the ship's moon pool at approximately 6 m depth. All samples were analyzed on board within 15 min of collection using a purge and trap system attached to a gas chromatograph/mass spectrometer operating in single ion mode (GC/MS; Agilent 7890A/Agilent 5975C; inert XL MSD with triple axis detector). Isoprene was purged from the water sample with helium for 15min and dried using a Nafion membrane dryer (Perma Pure; ASTRA-OMZ) or potassium carbonate (SPACES/OASIS). Before being injected into the GC, isoprene was preconcentrated in a trap cooled with liquid nitrogen. Gravimetrically prepared liquid standards in ethylene glycol were measured in the same way as the samples and used to perform daily calibrations for quantification. Gaseous deuterated isoprene (isoprene-d5) was measured together with each sample as an internal standard to account for possible sensitivity drift between calibrations. The precision for isoprene measurements was ±8 %.

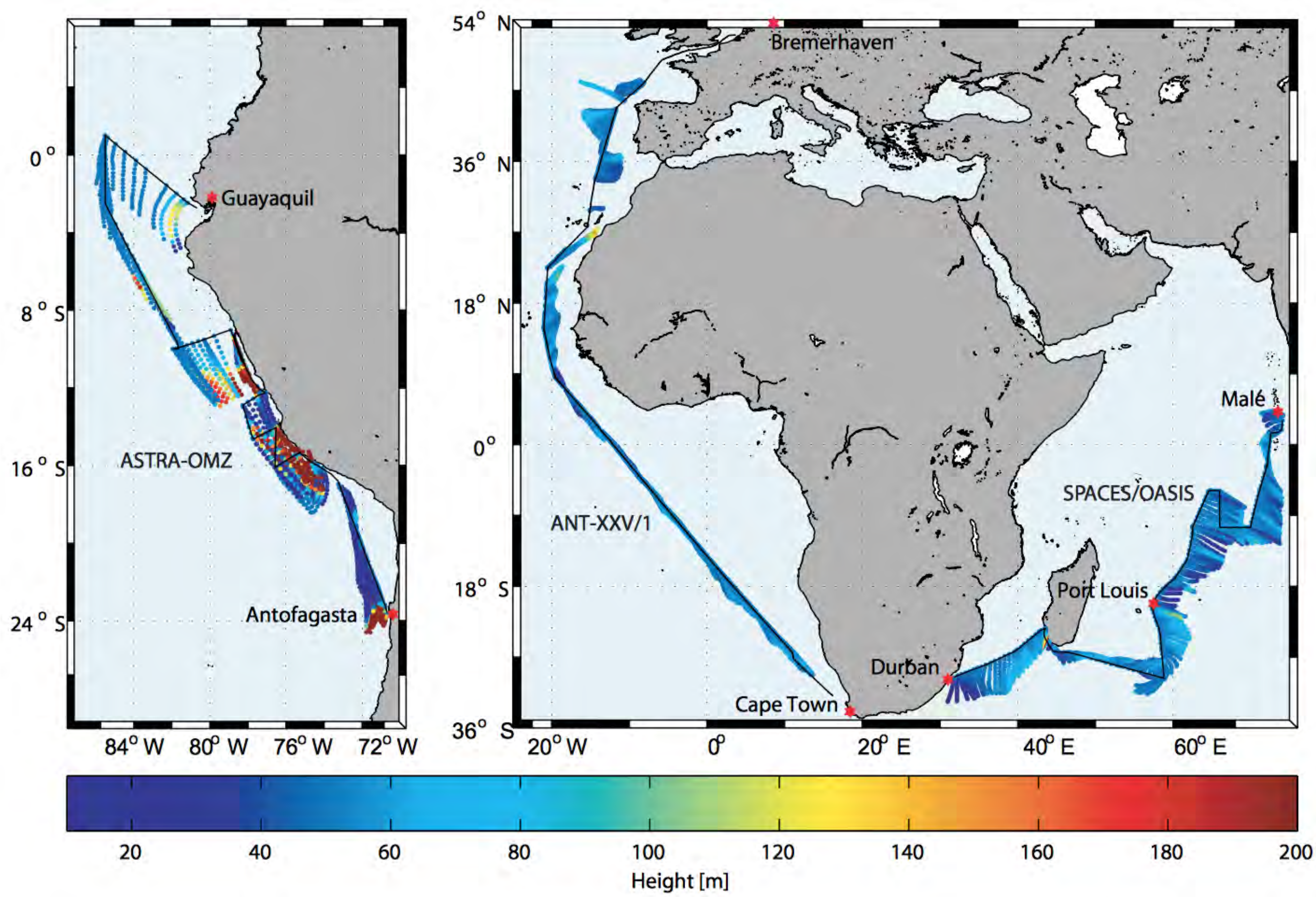


Figure 1. Cruise tracks (black) of SPACES/OASIS (June–July 2014, Indian Ocean) and ASTRA-OMZ (October 2015, eastern Pacific Ocean) (Source: D. Booge et al., 2016).

2. VIIRS isoprene validation using SPACES/OASIS and ASTRA-OMZ observations

The new field measurements represent the latest and probably the more reliable in-situ marine isoprene measurements since the launch of the S-NPP. Our team has dedicated much of the past quarter to conduct extensive product validation for the two campaign periods: July/August 2014 over the Indian Ocean, and October of 2015 over the eastern Pacific Ocean. Using observed wind speed, temperature, Chlor-a and Isoprene concentration in the ocean, we made calculation of Isoprene flux from ocean to air by employing the solar radiation data from "GFS" input. Because GFS data has 6-hour frequency, we have to interpret downward solar radiation from GFS to match the in-situ measurement time. We calculated the sea-to-air flux of isoprene (moles/cm^2/s) by the following equation: F= K*Cw (Matsunaga et al, 2002), where K is liquid phase transfer velocity and C_w is isoprene concentration in surface seawater.

We then compared our method and three of other models employed by previous scientists (Palmer et al., 205; Arnold et al., 2009; and Gantt et al., 2009) to the calculated flux (which is called obs. Flux in the Figures below). The time series plots are given in Figures 2 and 3. We also performed the statistical calculation including R^2, Correlation, NME (normalized mean error), NMB (normalized mean bias), MB (mean bias), and MAPE (mean absolute percentage error). All of these statistics are obtained by comparing each model result versus calculated flux. Based on the two plots and statistical tables, it seems all the four models perform different between the two cruises: all models tend to predict better during cruise SPACES/OASIS. Part of the reason may come from the terrestrial influence because cruise ASTRA-OMZ is close to land. The concentration of Chlor-a detected from the first cruise is almost 6 times of the second one. Overall, Palmer et al's method consistently underestimates Isoprene, especially in the first cruise. Gantt et al's method tends to always overestimate Isoprene during daytime. Arnold et al's and our methods perform better than the others especially during cruise in 201407. However, Isoprene is highly over-estimated during another cruise by Arnold et al's method when concentration of Chlor-a is high. Compared to the other three methods, uur method also has the least of NMB, NME and MAPE from both of the two cruises.

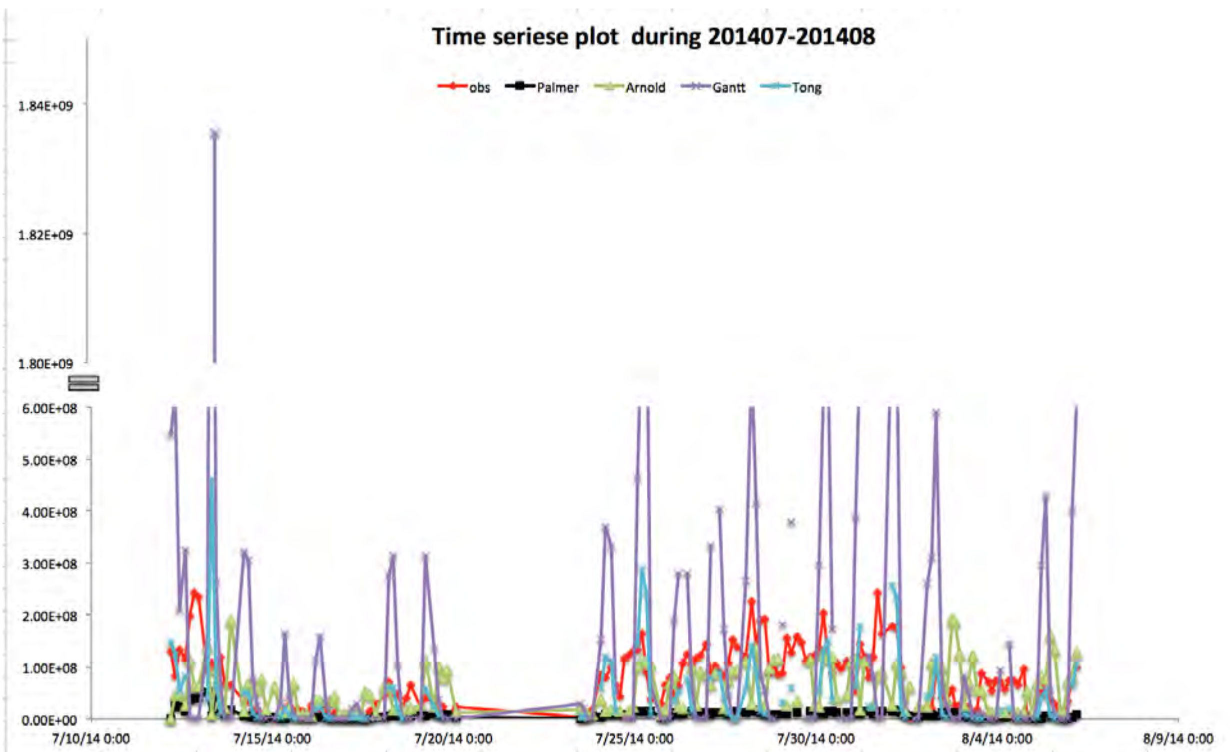


Figure 2: Model comparison time series for July and August 2014.

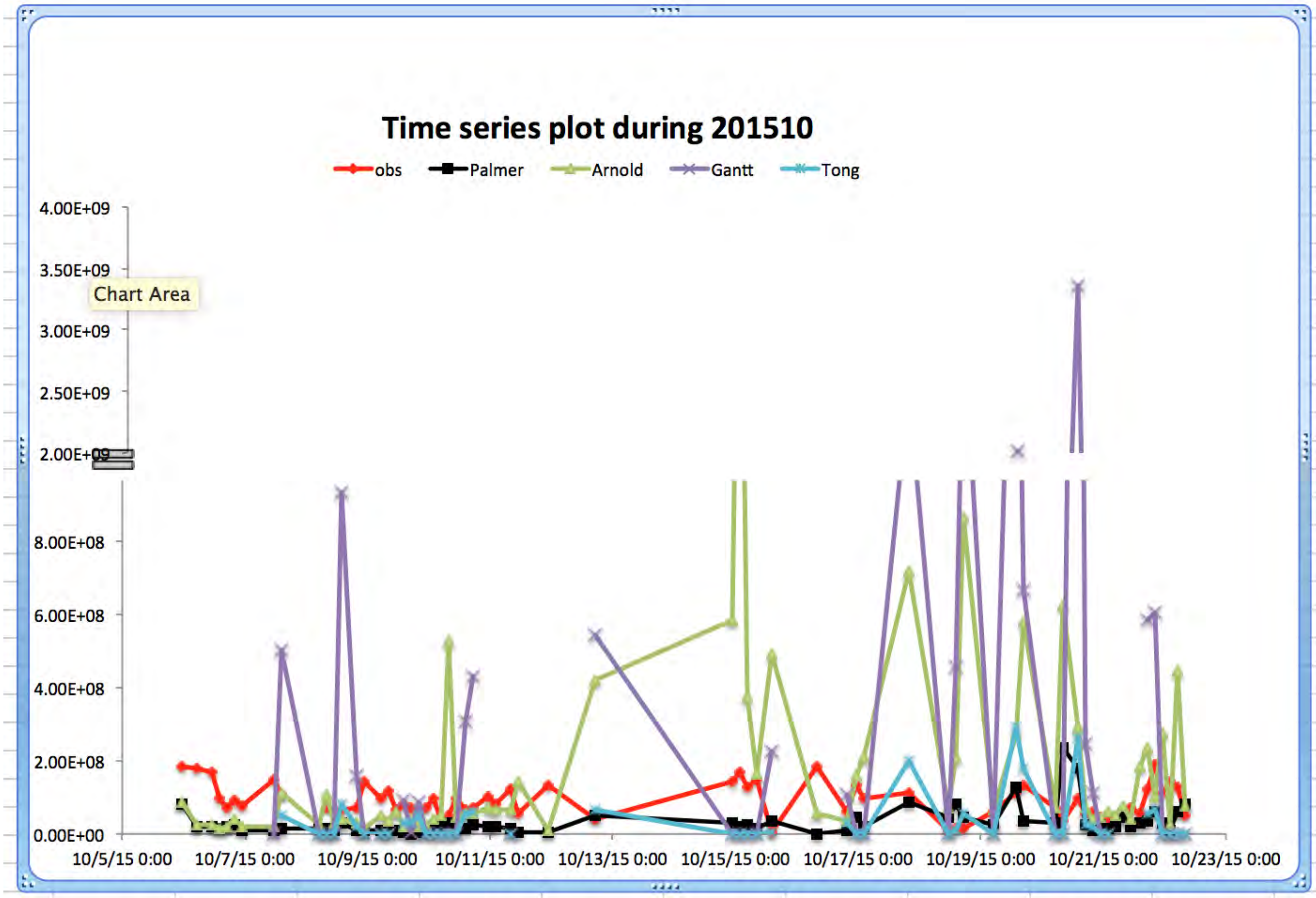


Figure 3: Model comparison time series for October 2015

3. Improvement of isoprene retrieval algorithms in light of the new validation results

The validation results show that all of these algorithms, when applied to VIIRS, require further improvement to better match the in-situ observations. Our team has made several efforts to improve these algorithms, and then compare the new algorithms with observations. Major revisions include: 1) New chemical loss rate of isoprene to OH in water detected by (Huang et al, 2011) and biological loss of isoprene in the water reported by Booge et al. (2016); 2) New Chl-a normalized isoprene production rates obtained for Prochlorococcus and cyanobacteria respectively based on the experiments of Bonsang et al (2010) and Shaw et al. (2003) and 3) the relationship of gas-transfer velocity (Kas) and Low wind speed less than 3.6m/s is also considered (Cole and Caraco, 1998). Due to the difference in these algorithms, the aforementioned revisions are applied when relevant. We further compared those revised methods against observations. The new results are shown in Tables 1 & 2 and Figures 4 & 5. All figures and and statistical metrics indicate the revised methods have better performance, and the revised Arnold approach generally outperforms the other ones.

Table 1. Statistics for cruise during 201407 and 201408 using improved methods (N=152)

	Palmer_new	Arnold_new	Palmer_new.kas
Correl	0.6	0.76	0.76
NME	0.65	0.46	2.02
NMB	0.59	0.34	0.41
MB	4.07E+07	2.37E+07	2.83E+07
MAPE	0.76	0.57	0.59

Table 2. Statistics for cruise during 201510 using improved methods (N=56)

	Palmer_new	Arnold_new	Palmer_new.kas
Correl	0.2	0.4	0.4
NME	0.99	0.95	0.87
NMB	-0.23	-0.25	-0.05
MB	-2.4 E+07	-2.6 E+07	-4.1 E+07
MAPE	2.44	1.14	1.22

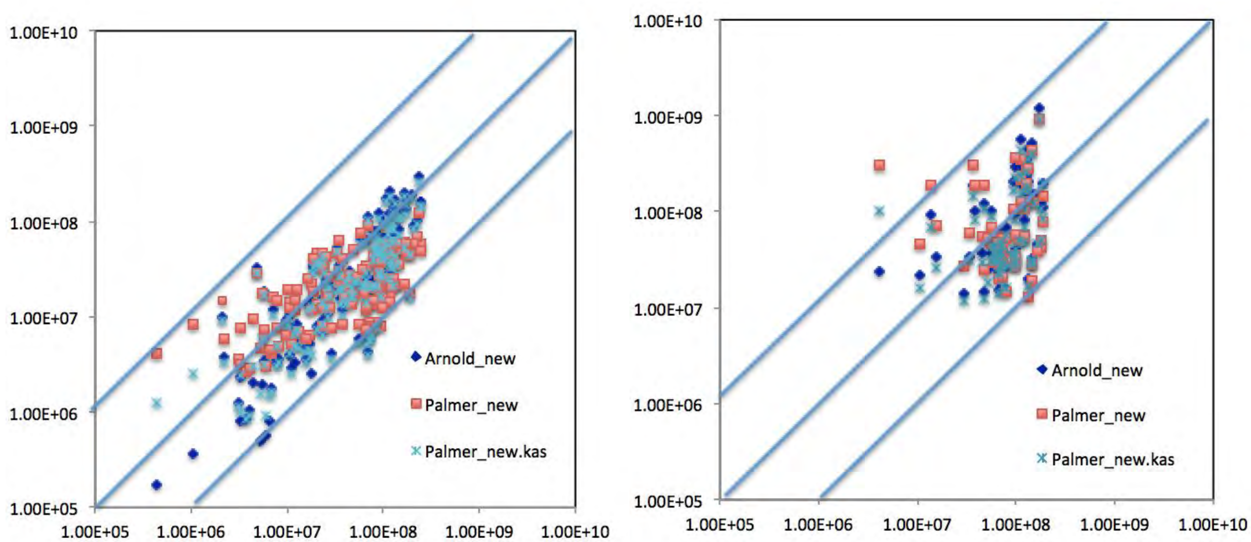


Figure 4. (Left) The scatter plot of simulated Isoprene flux versus in-situ observed flux during 201407-201408; (Right) The scatter plot of simulated Isoprene flux versus in-situ observed flux during October 2015. (Red square: simulated result using first improved method of Palmer et al (2005); dark blue diamond: simulated result using improved method of Arnold et al. (2009), light blue cross: simulated result using second improved method of Palmer et al (2005).

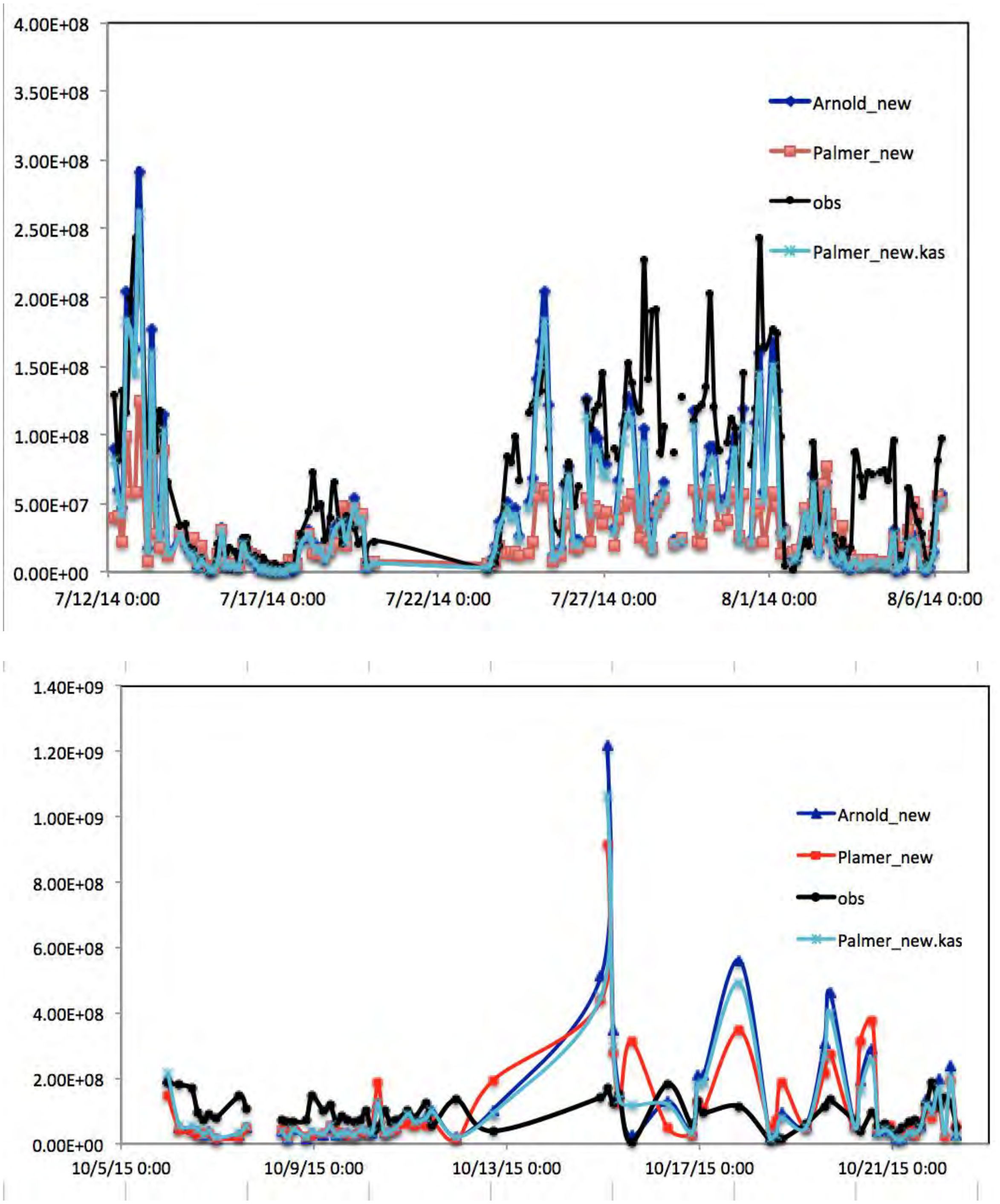


Figure 5. (Top) Comparison of simulated and observed seawater isoprene emission rates in the Indian Ocean along the cruise track of SPACES/OASIS in 2014; 4b (Bottom) Comparison of simulated and observed seawater isoprene emission rates in the Pacific Ocean along the cruise track of ASTRA-OMZ in 2015. (Black: observed isoprene emission rate; Red: simulated result using first improved method of Palmer et al (2005); dark blue: simulated result using improved method of Arnold et al. (2009), light blue: simulated result using the second improved method of Palmer et. al (2005).

Planned work

- Have the algorithm manuscript submitted to journal review;
- Start to generate multi-year VIIRS isoprene data to look at the spatial and temporal patterns;
- Test the revised isoprene with the NAQFC system.

Publications

1. Huang J, McQueen J, Wilczak J, Djalalova I, Stajner I, Shafran P, Allured D, Lee P, Pan L, Tong D, Huang HC. Improving NOAA NAQFC $PM_{2.5}$ predictions with a bias correction approach. Weather and Forecasting. 2016 Dec 21(2016).
2. Tong, D.Q., L. Pan, W. Chen, L. Lamsal, P. Lee, Y. Tang, H. Kim, S. Kondragunta, I. Stajner, 2016. Impact of the 2008 Global Recession on air quality over the United States: Implications for surface ozone levels from changes in NO_x emissions. Geophysical Research Letter, 43(17), 9280-9288, doi: 10.1002/2016GL069885.
3. Lee, Pius, Jeffery McQueen, Ivanka Stajner, Jianping Huang, Li Pan, Daniel Tong, Hyuncheol Kim, Youhua Tang, Shobha Kondragunta, Mark Ruminski, Sarah Lu, Eric Rogers, Rick Saylor, Perry Shafran, Ho-Chun Huang, Jerry Gorline, Sikchya Upadhayay, and Richard Artz (2017). NAQFC developmental forecast guidance for fine particulate matter ($PM_{2.5}$), Weather and Forecasting, 32(1), 343–360.
4. Richard Artz, Pius Lee, Rick Saylor, Ariel Stein & Daniel Tong, 2016. Introduction to a Special Issue of *JA&WMA* on NOAA's 7th International Workshop on Air Quality Forecasting Research (IWAQFR). *Journal of Air and Waste Management Association*, 66, 815-818.

Presentations

Daniel co-chaired the emission forecasting session at the 8th International Workshop on Air Quality Forecasting Research (IWAQFR) held on Jan, 2017 in Toronto, Canada.

Land Product Validation Research and Algorithm Refinement Science and Management Support for the S-NPP/VIIRS Active Fire Product

Task Leaders	Wilfrid Schroeder & Louis Giglio
Task Code	WSLG_VIRS_16
NOAA Sponsor	Lihang Zhou
NOAA Office	NESDIS/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%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Baseline VIIRS 750 m fire data have been produced routinely at NDE, and distributed via the NOAA/CLASS archive. Algorithm has been ported to Community Satellite Processing Package (CSPP) managed by the Cooperative Institute for Meteorological Satellite Studies (CIMMS). Refined VIIRS 375 m fire algorithm was ported to NOAA/NESDIS.

Background

The baseline 750 m resolution 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 originally implemented at the Integrated Data Processing Segment (IDPS) built 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]).

Complementing the baseline VIIRS fire product, an alternative 375 m resolution fire detection and characterization algorithm has been developed, combining the best of the 375 and 750 m multispectral data. The new algorithm shares conceptually similar fire detection and characterization methods with the 750 m fire product, while incorporating several custom features designed to optimize performance. The 375 m fire data show higher detection performance compared to the coarser resolution sibling, resolving significantly smaller lower/intensity fires while improving sub-daily mapping of larger wildfires.

Accomplishments

The VIIRS 750 m fire product was maintained at NDE, including investigation of spurious fire pixel occurrences associated with corrupted input data. Such anomalies are attributed to outstanding VIIRS data calibration errors upstream of the fire algorithm. A dedicated online long-term monitoring system was implemented for the product to help with routine data quality assessment (Figure 1). Calibration errors impacting VIIRS data generated by the NOAA processing system were compared against those generated independently by NASA; findings were shared with the calibration teams. The VIIRS 750 m fire algorithm was also released to CIMSS for further integration into the Community Satellite Processing Package (CSPP). The VIIRS fire team continues to work with CIMSS personnel supporting the full algorithm integration.

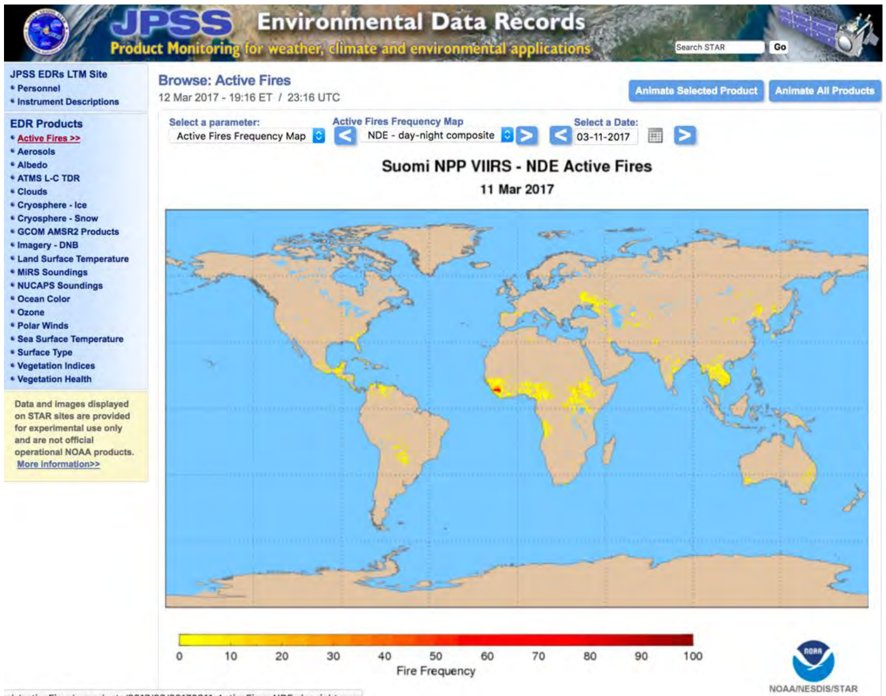


Figure 1: VIIRS 750 m Active Fires EDR long-term monitoring system implemented at NOAA/NESDIS (https://www.star.nesdis.noaa.gov/jpss/EDRs/products_activeFires.php).

A procedure to correct VIIRS sub-pixel fire retrievals for atmospheric attenuation effects was tested using the Moderate Resolution Transmission model (MODTRAN) and global model analysis data from the Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2). The analyses were performed for fire and background radiances used in the calculation of fire radiative power (FRP) retrievals available with the VIIRS 750 m and 375 m fire products. Preliminary results indicated good overall performance of the radiative transfer model and global analysis data over a wide range of observation conditions (Figure 2). The method will be further streamlined in order to increase effectiveness and reduce the computational power required to operate it.

A refined fire algorithm was developed for the VIIRS 375 m data. Major improvements include: (i) use of a land-water mask to assist in the analyses of thermal anomalies detected over water, (ii) implementation of a temporal filter designed to reduce spurious fire detections caused by data noise (i.e., anomalous brightness temperature in the input mid-infrared channels), (iii) calculation of sub-pixel FRP retrievals using 375 m and 750 m data fusion (Figure 3). The refined algorithm was delivered to NOAA/NESDIS in early January 2017, for subsequent integration into the NDE system.

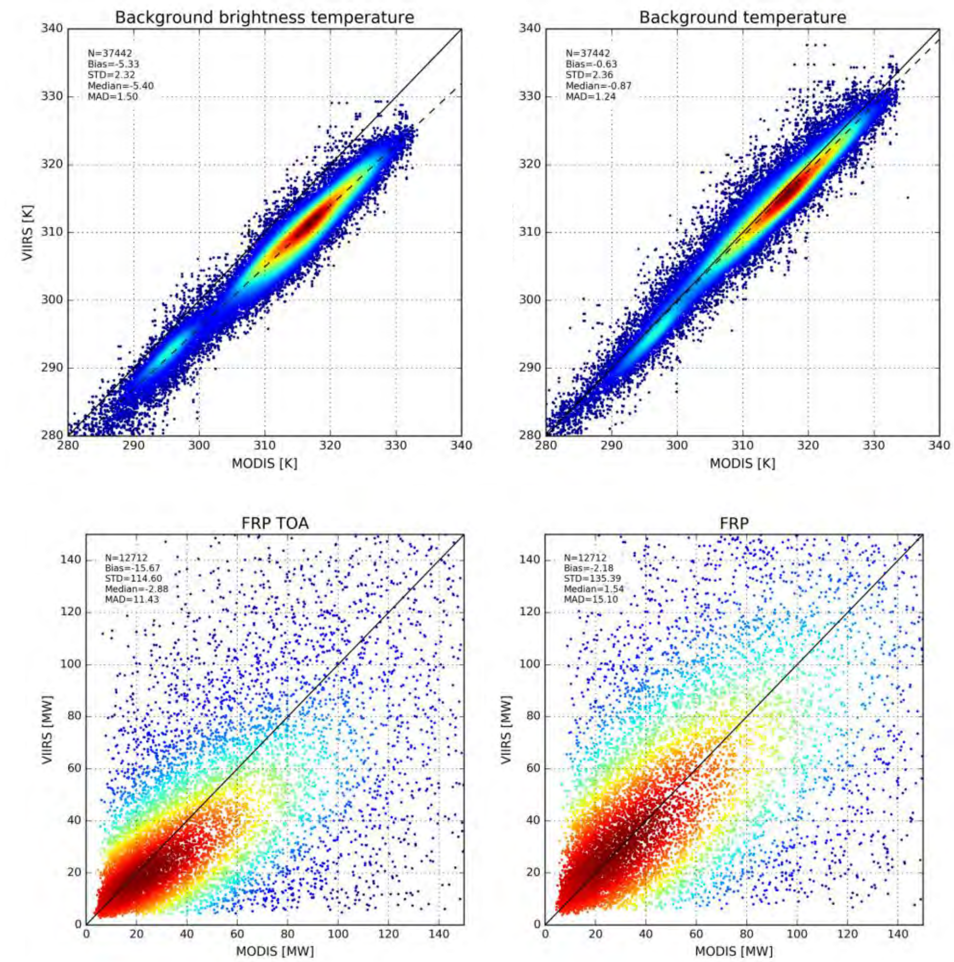


Figure 2: Comparison between near-coincident VIIRS and MODIS top-of-atmosphere (left panels) and bottom-of-atmosphere (right panels) fire-free background (top panels) and fire radiative power (bottom panels) data sets. Atmospheric attenuation correction performed using MODTRAN and MERRA-2 atmospheric profiles.

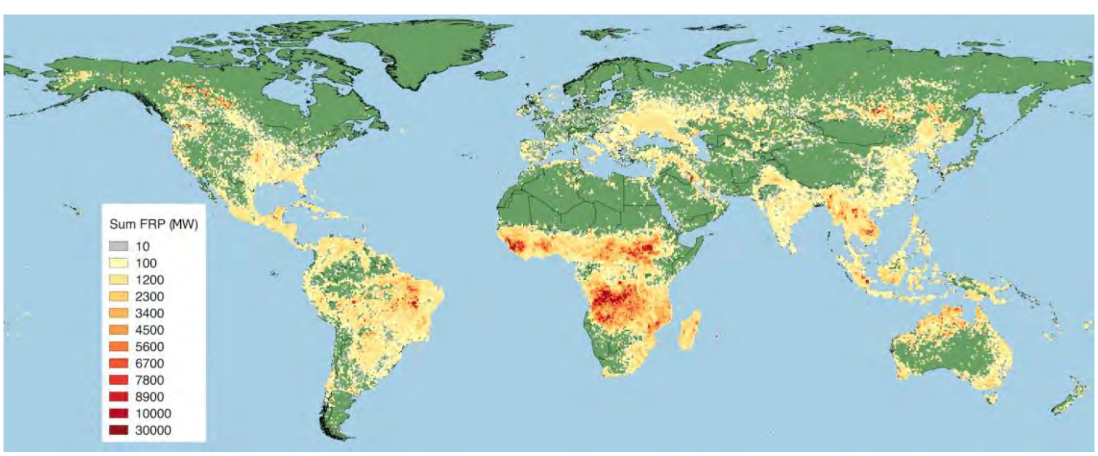


Figure 3: VIIRS 375 m global fire product showing cumulative (gridded) FRP for a 12-month data subset in 2015.

Planned work

- Maintain/refine VIIRS 750 m fire algorithm in the NDE (Jul 2017 – Jun 2018)
- Complete transition of VIIRS 375 m fire algorithm to NOAA/NESDIS, and subsequent implementation in the NDE (Jul 2017 – Jun 2018)
- Update documentation (Algorithm Theoretical Basis Document [ATBD] and user's guide) describing the VIIRS 375 m fire algorithm once implementation in the NDE is completed (Jul 2017 – Dec 2018)
- Monitor anomalies in input VIIRS L1B data files and output fire locations and fire radiative power retrievals (Jul 2017 – Jun 2018)
- Support JPSS-1 Level 1B and fire data testing and assessment activities (Dec 2017- Jun 2018)

Publications

https://www.star.nesdis.noaa.gov/jpss/documents/ATBD/ATBD_NDE_AF_v2.6.pdf

Products

VIIRS 750 m Active Fires EDR (fire detection and characterization product). Download interface:
https://www.class.ncdc.noaa.gov/saa/products/search?sub_id=0&datatype_family=NDE_L2&submit.x=22&submit.y=10 ; ftp://ftp-npp.class.ngdc.noaa.gov/

Presentations

Schroeder, W. (2017). Early detection and routine mapping of thermal anomalies. Thermal Summit, Chantilly/VA, 1-2 February (https://datahost.nga.mil/source/events/thermal2017/)

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

Csiszar, I., Zhou, L., Daniels, J., Tsidulko, M., Schroeder, W., Giglio, L., Ellicott, E., Schmidt, C. (2016). Updates on Suomi-NPP, JPSS and GOES-R fire data products. GOFC/GOLD Fire Implementation Team and ForestSat meeting, Santiago/Chile, 14-18 November (http://forestsat2016.com/).

Csiszar, I., Kondragunta, S., Tsidulko, M., Schroeder, W., Giglio, L., Ellicott, E. (2016). VIIRS active fire. NOAA/STAR JPSS Annual Science Team Meeting, College Park/MD, 8-12 August.

Other

VIIRS 750 m Active Fires EDR long-term monitoring system:
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_activeFires.php

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

[a] VIIRS 750 m Active Fires EDR available through NOAA/CLASS
[b] VIIRS 375 m fire algorithm submitted to NOAA for subsequent operational implementation at NDE
[c] VIIRS 750 m Active Fires EDR Algorithm Theoretical Basis Document

Technical Support of JPSS Land Surface Temperature and Albedo EDR Evaluation and Improvement

Task Leader	Yuling Liu
Task Code	YLYL_TSJL_15 Year 2
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0 %
Main CICS Research Topic:	Scientific Support for the JPSS Mission
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%; Goal 3: 0% *s*
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Our focus is on providing scientific and technical support on evaluation and improvement of the VIIRS Land Surface Temperature and Albedo EDR product to ensure it meets the NPP/JPSS mission requirement. It is also a continuous effort toward the readiness of the LST/Albedo EDR product for future JPSS satellite series.

Link to a research web page: https://www.star.nesdis.noaa.gov/jpss/lst.php

Background

This report summarizes the ongoing Joint Polar-Orbiting Satellite System (JPSS) project "Satellite Land Surface Temperature (LST) and Albedo". The S-NPP VIIRS LST product has been running at the JPSS Interface Data Processing Segment (IDPS) and has been archived at NOAA Comprehensive Large Array-data Stewardship System (CLASS) since FY2011.

In FY2016, the focus has been switched to the development of the enterprise LST algorithm that is applicable to different satellite missions. The enterprise LST algorithm is expected to run at JPSS Data Exploitation (NDE) system for JPSS-1 satellite. The enterprise LST algorithm is significantly different from the IDPS LST algorithm. It requires the land surface emissivity (LSE) as one of the input parameters explicitly rather than the surface type. And the water vapor is considered in the retrieval algorithm. The enterprise algorithm is also expected to be used for SNPP LST data reprocessing. For this purpose, maintenance, validation and calibration, long-term monitoring of the VIIRS LST product is continuously needed. In-situ data collection with the international cooperation, processing and match, as well as cross-satellite data match shall be performed for comprehensive evaluation of the VIIRS LST data, and for consistent high quality of the production. Meanwhile, as an important input for LST retrieval, the land surface emissivity (LSE) product development is therefore required for LST retrieval using emissivity explicit algorithm.

Accomplishments

During this funding cycle we mainly made following accomplishments: performed the evaluation and validation of the current VIIRS LST production as a continuous effort, and kept the maintenance schedule and milestone including ATBD update; developed the enterprise LST product; developed land surface emissiviity product, and the software package for both LST and LSE have been delivered for integration into the NDE system; developed the gridded global VIIRS LST product; improved the long-term monitoring tool. In detail, the accomplishments include:

1) **Evaluation and validation of the current VIIRS LST production**
   - o Extend the ground data validation network. Besides SURFRAD, we explored other ground data set from Atmospheric Radiation Measurement (ARM), Baseline Surface Radiation Network (BSRN) and Global Monitoring Division (GMD) network as well as ground observations from Africa, Australia and China. We have been collecting ground data as a routine task and actively involved in the international cooperation of LST validation work with the scientist from Europe and China.
   - o Extend the cross satellite comparison. Besides MODIS LST, AATSR LST and SEVIRI LST. AHI LST as a proxy for GOES-R have been included for cross comparison.

2) **Maintain the software package and related documentations**
   - o Maintenance of the LST software package
   - o Maintain and provide update on ATBD, OAD and some other related documentations.

3) **Development of the enterprise LST product**
   - o Algorithm development and test. Multiple LST algorithms have been tested and sensitivity and uncertainty of the algorithms have been analyzed.
   - o The enterprise LST algorithm has been tested over multiple sensors e.g. VIIRS, MODIS, SEVIRI and AHI. Algorithm performance is evaluated through the comparisons with the ground measurements and cross comparisons among different sensors.
   - o Provided support on the critical design review of the enterprise LST algorithm
   - o The science code development has been accomplished. Local implementation and test have been conducted. The code has been delivered to ASSIST for its integration into the framework.

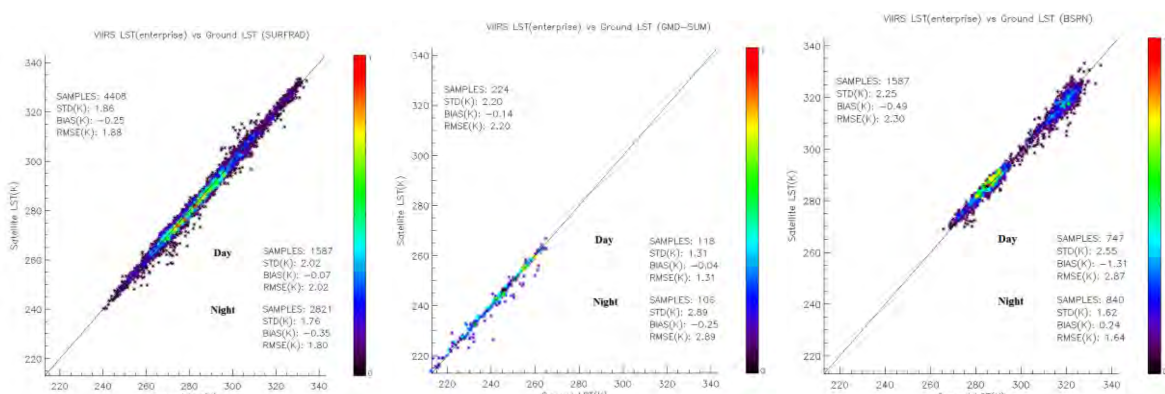


Figure 1. Preliminary validation of the enterprise VIIRS LST against ground data from SURFRAD(left), GMD(middle) and BSRN(right)

4) **Extended the simulation database** by involving the SEEBOR profile collection into the current simulation database so as to improve the global representativeness. Profile data is analyzed and the profile quality control is conducted. MODTRAN is used for forward radiative transfer calcula-

tion. The comprehensive simulation database is expected to be used as the primary database for future algorithm studies e.g. algorithm coefficients derivation, algorithm test and uncertainty analysis etc.

5) **Improved the validation tool and long-term monitoring tool**. Related Tools have been developed to support LST evaluation and calibration work including the regression package for algorithm coefficient, the routine validation and deep-dive system, and a long term monitoring (LTM).The LTM system monitors LST production from multiple satellites in near real time, including SNPP-VIIRS and MODIS-AQUA, AHI and GOES series. The LTM can be accessed via http://www.star.nesdis.noaa.gov/jpss/EDRs/products_LST.php. The global LST Animation and LST diurnal range are added into the monitoring tool.

6) **Produced Gridded VIIRS LST**. The L3 VIIRS gridded LST data provides two spatial resolutions: 0.009 degree and 0.036 degree, in which the 0.009 degree data is managed in the 2*4 tiles to reduce the file size. The gridded LST data with 0.036 degree resolution has been routinely generated in the local server and it has been used in the studies on the verification with the model output.

7) **Investigated the reprocessed SDR data** and its impact on the LST product

8) **Developed the emissivity product and conducted preliminary evaluation and calibration**:
    - The science code development has been accomplished. Local implementation and test has been conducted. The code has been delivered to ASSIST for its integration into the framework.
    - Provided support on the critical design review of the emissivity product.
    - Finished related documentations e.g. ATBD.

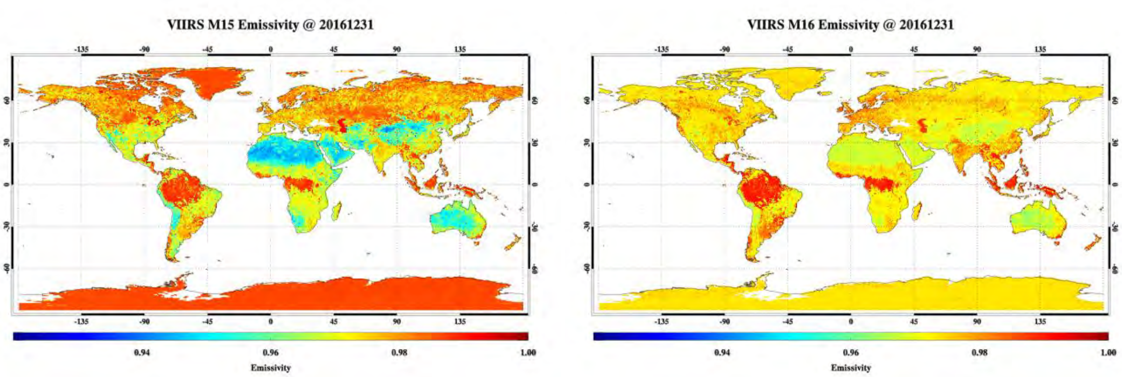


Figure 2. Land surface emissivity product for VIIRS band 15(left) and band 16 (right)

Planned work

- Continue to work on the evaluation and validation of the current LST production, maintenance schedule and milestone will be kept.

- The enterprise LST algorithm will be finalized for J-1 mission. It is expected to be in operation in Sep. 2017. Will provide support for all review processes and product test, evaluation and validation.
- Continue the simulation studies for algorithm test
- Supporting the long term monitoring tool improvement making it ready for monitoring of the J-1 LST product.
- Maintain and update LST software code and related documentation and support the NPP/JPSS Mission Management
- Provide support for the SNPP data reprocessing
- The land surface emissivity production will be further improved and tested.
- The L3 gridded LST data will be further improved and tested.

Publications

Yuling Liu, Yunyue Yu, Peng Yu and Heshun Wang, Ground Validation And Uncertainty Esitmation Of Viirs Land Surface Temperature Product, 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), pp. 6922 – 6925, Nov. 2016, DOI: 10.1109/IGARSS.2016.7730806.

Min Huang, Pius Lee, Richard McNider, James Crawford, Eric Buzay,John Barrick, Yuling Liu and Praveena Krishnan, Temporal and spatial variability of daytime land surface temperature in Houston: Comparing DISCOVER-AQ aircraft observations with the WRF model and satellites, Journal of Geophysical Research: Atmospheres, 121(1), 185–195, 16 January 2016; DOI: 10.1002/2015JD023996

Yunyue Yu, Yuling Liu and Peng Yu, Land Surface Temperature Product Development for JPSS and GOES-R Missions, book chapter for Vol. 5, Comprehensive Remote Sensing: Earth energy budget (Under review)

Products

- JPSS VIIRS Land Surface Temperature EDR product.
- Gridded global VIIRS LST product
- Land surface emissivity product

Presentations

1. Yuling Liu, Yunyue Yu, Peng Yu and Heshun Wang, Ground Validation And Uncertainty Esitmation Of Viirs Land Surface Temperature Product, 2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), July 8-15, 2016, Beijing, China (Oral)
2. Yunyue Yu, Yuling Liu, Peng Yu and Heshun Wang, JPSS Land Surface Temperature, STAR JPSS Annual Science Team Meeting, 8-12 August 2016, College Park, MD (Oral)
3. Yuling Liu, Yunyue Yu, Peng Yu and Heshun Wang, Development and Preliminary Evaluation of the Enterprise VIIRS LST Algorithm, CICS annual meeting, Nov, 2016, College Park, MD. (Poster)
4. Peng Yu, Yunyue Yu, Yuling Liu and Heshun Wang, The GOES-R Land Surface Temperature Product, CICS annual meeting, Nov, 2016, College Park, MD.(Poster)
5. Heshun Wang, Yunyue Yu, Peng Yu and Yuling Liu, Developing Land Surface Emissivity Product for JPSS and GOES-R Missions, AGU, San Francisco, Calif., 12-16 December 2016. (Poster)

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	3
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	3
# of NOAA technical reports	
# of presentations	5
# of graduate students supported by your CICS task	1
# of graduate students formally advised	
# of undergraduate students mentored during the year	

2.5 Climate Research, Data Assimilation, and Modeling

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

Task Leader:	Augustin Vintzileos
Task Code:	AVAV_CPC_15 Year 2
NOAA Sponsor:	Mike Halpert
NOAA Office:	Climate Prediction Center
Contribution to CICS Research Themes:	Theme 3: 100%
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals:	Goal 1: 100%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: The Task Leader continued working on the Subseasonal Excessive Heat Outlook System (SEHOS) that he designed and developed. During this year the Task Leader **(1)** introduced, developed and used a forecast calibration post-processing technique for the forecast of excessive heat events, **(2)** developed a dashboard to provide critical information to CPC forecasters, **(3)** executed realtime daily forecasts of heat events during summer 2016, **(4)** designed and developed a novel system for monitoring heat waves based on information by forecasters on the field, **(5)** investigated the capability of the SEHOS to forecast specific heat waves that occurred during summer 2016, **(6)** compared forecasts between the CFS and ECMWF models for specific events that occurred in summer 2016, **(7)** trained a contractor to understand methodology and operation of the above system, and **(8)** transitioned the experimental code for CFS Week3&4 forecasts to operational mode.
Link to a research web page: Web page internal to CPC

Background

Hot temperatures are associated with excess mortality due to cardiovascular, respiratory, and cerebrovascular diseases. It is expected that the most sensitive segment of the population (people over 65 years old) will significantly increase in the near future and that heat waves will increase in frequency, duration and intensity. Being able to forecast such excessive heat events as much in advance as possible will facilitate preparedness of relief organizations and thus increase resilience to heat waves. The difficulty in forecasting heat events is due to the very complicated nature of the impacts of heat on human physiology. Variables such as temperature, humidity, solar and infrared radiation and wind are related in convoluted and non-linear ways to affect human physiology. The second difficulty is how to define a heat wave in a way that (1) describes adequately tipping points in human physiology that lead to disease and (2) is predictable in subseasonal-to-seasonal lead times (S2S). In previous work the Task Leader developed a definition of excessive heat events based on the concept of consecutive Heat Days (HD). A HD is defined as a day for which the maximum Heat Index (HI) exceeds a certain percentile of the distribution of maximum HI for the time period within the warm season and the geographical location. The Task Leader developed a heat wave monitoring and forecasting system and developed a forecast verification methodology based on the Receiver Operating Characteristics (ROC) and the corresponding Area Under Curve (AUC). He executed retrospective forecasts of heat waves using reforecasts from the Global Ensemble Forecasting System (GEFS), the Climate Forecasting System (CFS), and the European Centre for

Medium range Weather Forecast (ECMWF) model. Central findings are that heat waves can be forecasted for Week-2 as a function of geographical location and that multi-model ensemble techniques increase forecast skill.

Accomplishments

1. Forecast Calibration

Forecasts at subseasonal-to-seasonal lead times are by nature probabilistic as their range exceeds the limits of weather predictability. In operational forecasting, this necessitates an ensemble of predictions with slightly modified initial conditions. However, 'overconfident' forecasts is the major issue for all models. One way to correct for this problem is to use calibration techniques comparing reforecasts with observations to calibrate the realtime predictions. The Task Leader introduced reliability mappings for the calibration of the probability of occurrence of excessive heat events. According to this technique, the reliability of model probabilistic forecasts is computed on each grid point for the entire warm period and then linear fitting provides the mapping to perfect reliability. This methodology was then successfully applied to the realtime SEHOS during summer 2016.

2. Realtime forecasting and the SEHOS dashboard

The SEHOS was used during summer 2016 for a quasi-operational experiment. The forecast model that provided input to SEHOS was the GEFS-Legacy i.e., the GEFS model version used to conduct the GEFS reforecast by NOAA/ESRL. The issues that should be taken into account when interpreting the SEHOS results for 2016 is that the GEFS-Legacy model is run only at 00Z producing 21 ensemble members per day in contrast to the GEFS-operational that is run at 00Z, 06Z, 12Z and 18Z producing 84 ensemble members per day. The Task Leader used the GEFS-Legacy model realtime forecasts because there was no reforecast available at the time for the GEFS-Operational. The experiment started on 15 May 2016 and ended in 15 September 2016.

One crucial consideration while designing the dashboard of the SEHOS for use by the forecasters is the constraint of providing the minimum amount of information that minimizes the number of critical decisions a forecaster has to make during the forecast process. The fields provided daily were defined after interaction with the forecasters. Some of the provided fields are shown in Figure 1.

3. The Valid Time Event Code (VTEC) monitoring system

Perception of dangerous heat depends from person to person, from area to area and from timing within the warm season. This is an important point to consider when trying to verify the SEHOS. One school of thinking for the verification process is to define a heat wave in a certain way (among the myriads existing) and then compare model forecast versus observation derived heat waves. So far, this approach was utilized by the Task Leader. The alternative approach introduced by the Task Leader is to take into account the subjectivity of what consists a heat wave. According to this approach, the forecast of whichever the definition of a heat wave is, should be compared with issuance of an excessive heat advisory or warning from local Weather Forecasting Offices (WFO) at the 1-5 day lead time; the assumption behind this approach is that heat wave forecast at the 1-5 day range is perfect. In other words, can we forecast (probabilistically) at S2S time scales what the weather forecaster will forecast at weather time-scales. To test this idea the Task Leader developed a monitoring system based on VTEC messages from the WFOs.

An example of a VTEC message for the duration and location of a heat event is /O.CON.KFWD.HT.Y.0001.000000T0000Z-160618T0100Z/. These messages were decoded and projected to the standard 1°x1° grid. A comparison with the Reanalysis-1 based monitoring is shown in the left column of Figure 2.

4. The ECMWF and CFS reforecasts of summer 2016

After the end of the 2016 CONUS warm season 'realtime' forecasts and corresponding reforecasts from the S2S-ECMWF database were downloaded for the CFS and ECMWF models in order to continue evaluating the importance of multi-model forecasting. An example of these forecasts (uncalibrated) is shown in the right column of Figure 2.

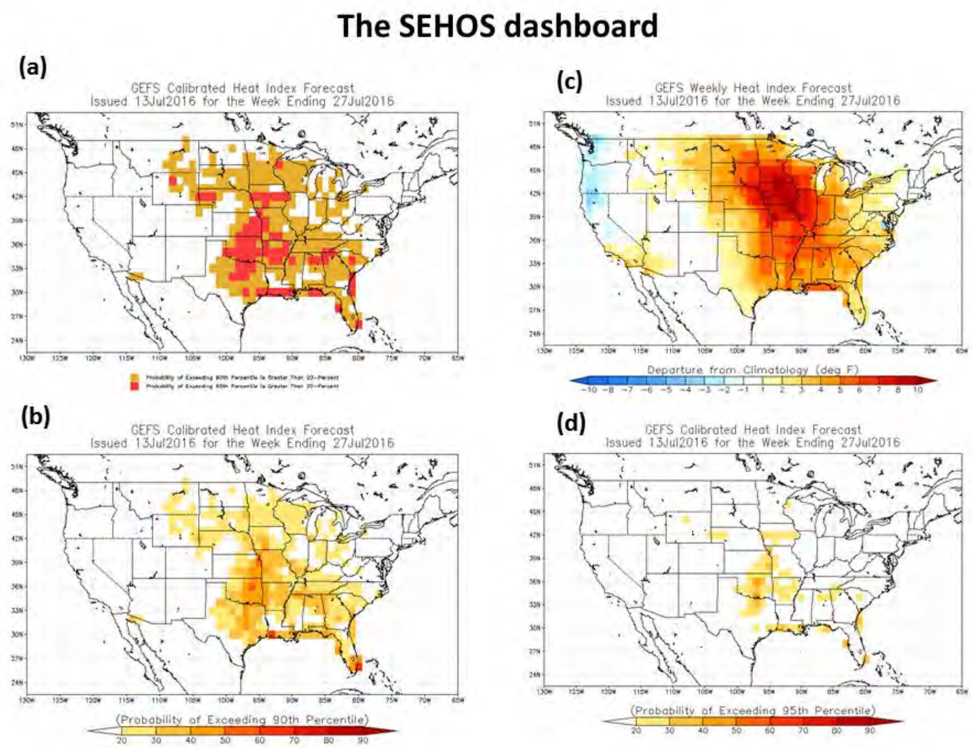


Figure 1. A portion of the SEHOS dashboard showing the forecast of a heat wave at Week-2 for the week ending 27 July 2016. Figure (a) shows the projection of the probabilistic to a categorical forecast, (b) calibrated probabilistic forecast for 90% level heat events, (c) forecast of weekly mean heat index anomalies and (d) probabilistic forecast for 95% level heat events.

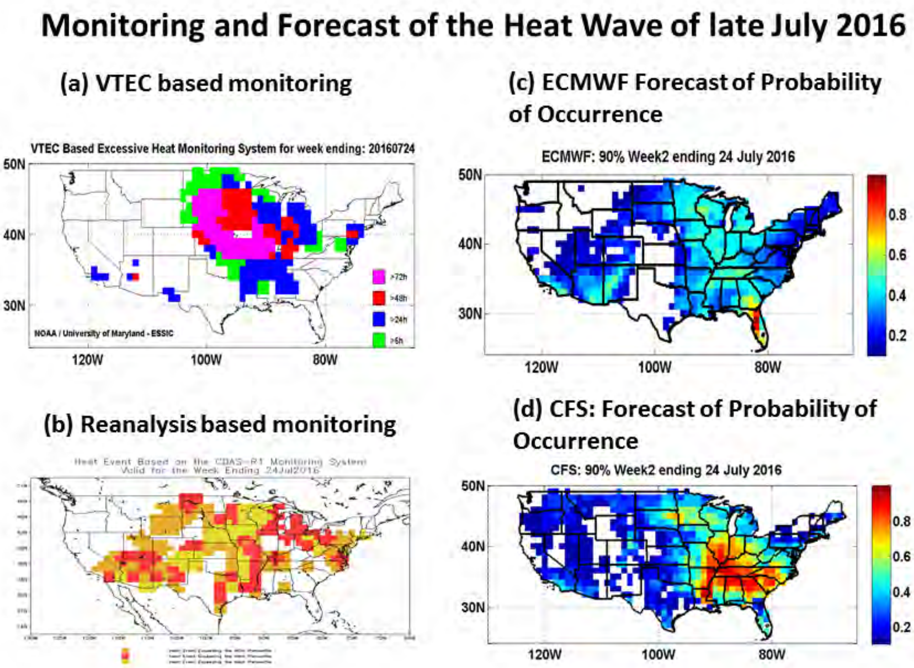


Figure 2. (a) the VTEC based heat wave monitoring system on a 1x1 grid showing a very strong heat wave in the central part of the CONUS compared to (b) the same heat wave as seen by the Reanalysis-1 monitoring system. The similarity is good with the exception of the mountains. The multi-model forecast (uncalibrated) of the same heat wave at 90% level (c) from the ECMWF and (d) from the CFS model.

Planned work

- Thus far the forecast heat index is calculated before removing systematic biases of temperature and humidity. Systematic bias removal requires gridded observations of temperature (already existing) and humidity. The systematic bias correction should be done in a bivariate way taking into account the non-linearities of the Heat Index formula.

- The calibration technique for the probabilistic forecasts requires improvements especially in the higher level heat events (98%).

- There are several definitions of heat waves. The predictability of these definitions must be explored.

- It was shown that multi-model forecasts of heat waves present improvements. How to optimally combine these forecasts is an active research subject.

- Develop a quantitative verification method based on the VTEC based methodology developed here.

- Explore the sources of predictability of heat waves.

Publications

Non-peer reviewed publications:

Vintzileos et al., 2016: Enhancing Resilience to Heat Extremes: Forecasting Excessive Heat Events at Subseasonal Lead Times (Week-2 to 4). Extended Abstract for the 41st Climate Diagnostic and Prediction Workshop. Bangor, Maine. **http://www.nws.noaa.gov/ost/climate/STIP/41CDPW/41cdpw-AVintzileos.pdf**

Products

Development of the operational code for the Week 3&4 forecast with the CFS to be implemented in the near future.

Presentations

Vintzileos et al., 2017: Enhancing Resilience to Heat Extremes: Multi-model Forecasting of Excessive Heat Events at Subseasonal Lead Times. American Meteorological Society Annual Meeting, 22-26 January, Seattle, WA.

Vintzileos et al., 2016: Enhancing Resilience to Heat Extremes: Multi-model Forecasting of Excessive Heat Events at Subseasonal Lead Times. S2S Extremes Workshop at International Research Institute for Climate and Society. 6-7 December, Palisades, NY.

Vintzileos et al., 2016: Enhancing Resilience to Heat Extremes: Multi-model Forecasting of Excessive Heat Events at Subseasonal Lead Times. 12-16 September, American Geophysical Union, Fall Meeting, San Francisco, CA.

Vintzileos et al., 2016: Enhancing Resilience to Heat Extremes: Multi-model Forecasting of Excessive Heat Events at Subseasonal Lead Times. 3-6 October. NOAA's 41st Climate Diagnostic and Prediction Workshop. Orono, Maine.

Vintzileos, A. 2016: Extreme Heat and Health: Towards Multi-Model Ensemble Forecasting of Excessive Heat Events at Subseasonal Lead Times (Week-2 to Week-4). George Mason University-COLA (INVITED), 28 June, Fairfax, VA.

Vintzileos, A. et al., 2016: Extreme Heat and Health: Towards Multi-Model Ensemble Forecasting of Excessive Heat Events at Subseasonal Lead Times (Week-2 to Week-4). CICS Executive Board Meeting (INVITED), 16 May, College Park, MD.

Vintzileos, A. et al., 2016: Towards Multi-Model Ensemble Forecasting of Excessive Heat Events at Subseasonal Lead Times (Week-2 to Week-4). NOAA/CPO/MAPP Webinar Series (INVITED), 28 April, Silver Spring, MD.

Other

The Task Leader received a Certificate of Recognition from the NOAA Climate Prediction Center. It was awarded for the development and issuance of the experimental United States 3-4 week Temperature and Precipitation Outlooks.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	
# of NOAA technical reports	
# of presentations	7
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

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

Task Leader	Mitchell A. Schull and Christopher Hain
Task Code	CHCH_JPSS_15 Year 2
NOAA Sponsor	Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 20%; Theme 2: 20%; Theme 3: 60%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 85%; Goal 2: 10%; Goal 3: 5%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight

1) Evaluated the improvements of real time green vegetation fraction (GVF) on Noah model-based soil moisture and soil temperature simulations, and near real time green vegetation fraction and albedo products are suggested to be used for better model performance;

2) Offer a viable approach for addressing the issues that merging microwave soil moisture retrievals to improve agricultural drought estimation is hampered by the uncertainty propagation of satellite data rescale-match and quality control.

3) Relative to subjectively equal weighted-average blending technique-based drought index, developed a objectively integrational drought blended index.

Background

Current Weekly U.S. Drought Monitor and Monthly North America Drought Monitor published at U.S. Drought Portal by NIDIS are mainly based on simulations of land surface models (LSMs) and experts' best judgment. The only satellite data products utilized in these for the drought monitoring are the multi-year climatology of Green Vegetation Fraction (GVF) derived from vegetation index (VI) and the multi-year averages of seasonal land surface albedo (Al). Near real time satellite data products of surface type (ST), land surface temperature (LST) and soil moisture (SM) are all not used in these LSM operational runs. With the near real time land EDRs from NPP/JPSS missions becoming operationally available, we propose to enhance the NLDAS and GLDAS simulations by assimilating these land EDR data products, namely the Surface Type (ST), Vegetation Index (VI), Land Surface Temperature (LST) and albedo (Al), and in turn to enhance the drought monitoring products for NCEP and NIDIS.

Thus, benefit of assimilating the NPP/JPSS data products for soil moisture estimation is evaluated by comparing field measurements of root-zone soil moisture. And benefit of assimilating the NPP/JPSS data products for drought monitoring is evaluated by comparing the root-zone soil moisture anomaly to the existing drought indices and the operational US Drought Monitor and the North American Drought Monitor maps

Accomplishments

Improvements of using near real time (NRT) surface types, GVF and albedo on Noah model performance have been evaluated. Additionally, a new blended drought index (BDI) has been generated by objectively merging the retrievals from thermal remote sensing land surface temperature-based evapotranspiration along with the remotely sensed and land surface modeling soil moisture (SM), and in turn to improve drought monitoring skill using the optimal signals retrieved from these resources and validated by the widely used drought indices.

With respect to the in situ SM and ST observations collected from 9 SCAN sites, the improvements of weekly GVF and monthly albedo on Noah LSM's performance in simulating the water fluxes (SM and ST) are tested. Figure 1 shows how the increase in the use NRT inputs brings soil moisture closure to the in situ measurements (black) compared to the model results without near real time (red). It can be found that the RMSE values for static case are significantly reduced by the real time GVF and albedo.

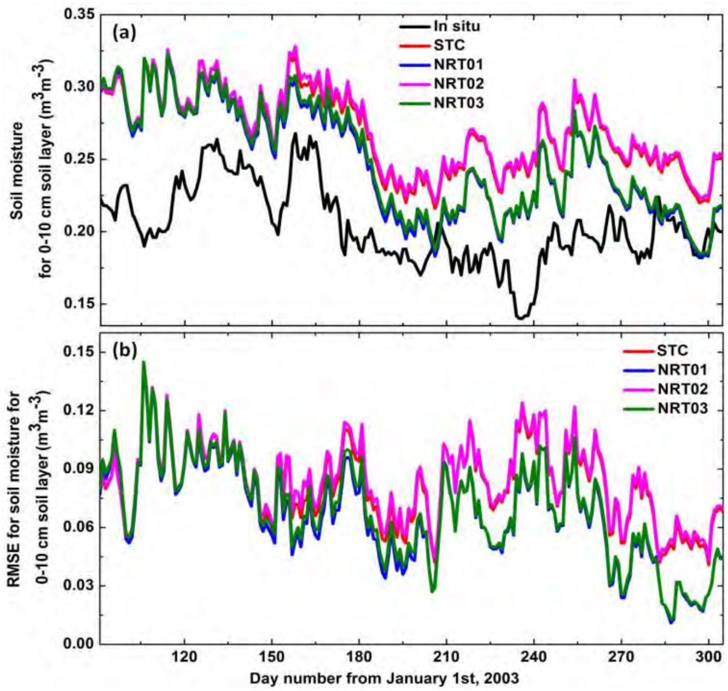


Figure 1. Model simulated [STC (static GVF and albedo), NRT01 (weekly GVF and static albedo), NRT02 (monthly albedo and static GVF) and NRT03 (weekly GVF and monthly albedo) cases] versus in situ soil moisture observations [In situ (black line)] from April 1st to October 31th 2003, (a) daily 0-10 cm soil layer soil moisture, (b) daily RMSEs (m^3m^{-3}) against the in situ measurements for 0-10 cm soil layer soil moisture.

Based on SM data derived from thermal infrared (TIR) observations of land surface temperature, L/C/X-band microwave SM products [Evaporative Stress Index-ESI, Noah 3.2 model-based SM-NLSM, Advanced Scatterometer-ASCAT, WindSat and NOAA Soil Moisture Operational Product System-SMOPS and Soil Moisture and Ocean Salinity-SMOS], drought estimations are assessed using the Triple Collocation Error Model (TCEM) and three blended drought indices (BDIs) are then introduced: (1) the BDI_s subjectively samples all of the available retrievals using an equal weighted-average blending technique; (2) the BDI_w uses weights based on error statistics assessed using the TCEM; and (3) the BDI_b framework objectively integrates drought estimations which exhibit the lowest TCEM-based root mean square errors (RMSEs). Of the three indices examined, the BDI_b shows the best performance, reasonably tracking drought development in terms of time evolution and spatial patterns of agricultural drought occurrences (Figures 2-3).

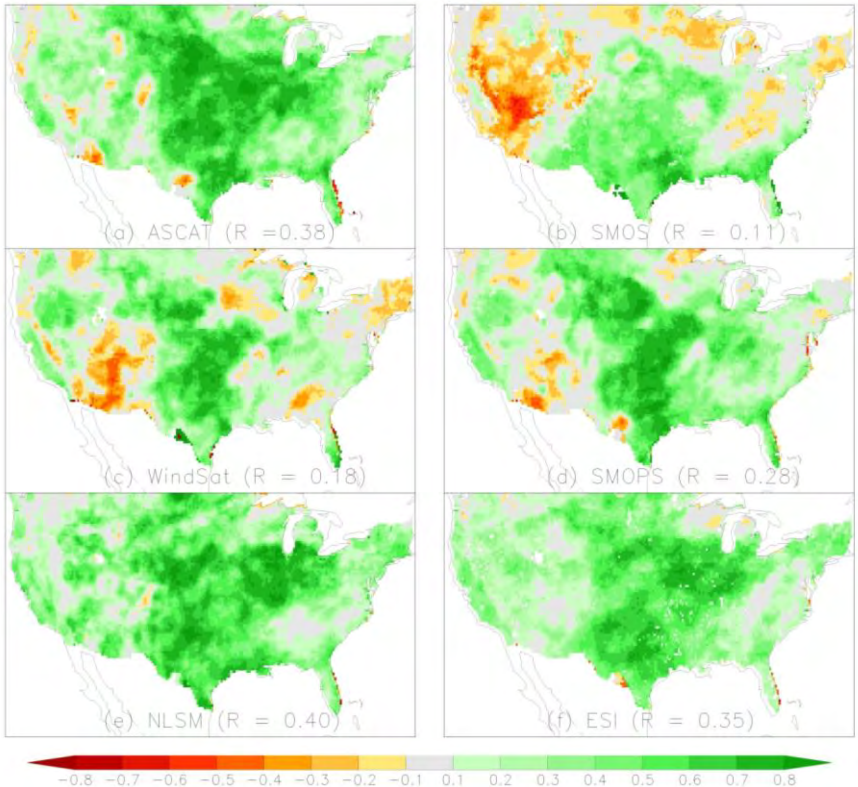


Figure 2. Correlation coefficients (R) between USDM and (a) ASCAT, (b) SMOS, (c) WindSat, (d) SMOPS, (e) NLSM and (f) ESI. The grey color indicates insignificant correlations.

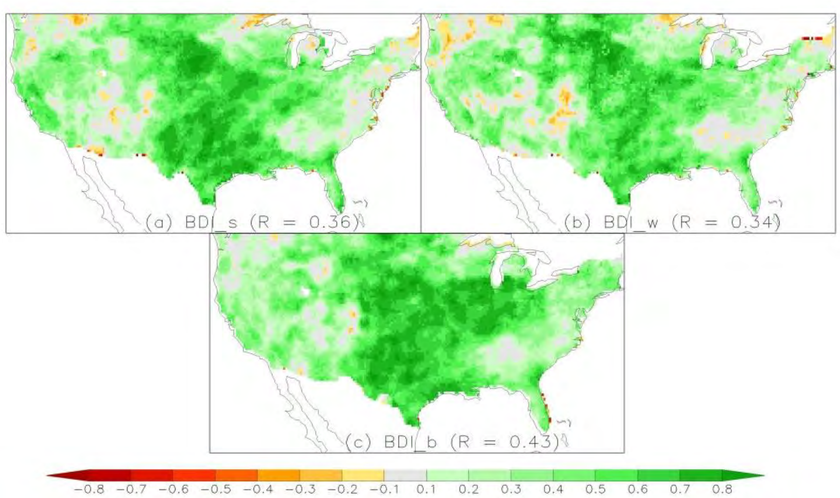


Figure 3. Correlation coefficients (R) between USDM and BDIs over the 2008-2014 period. The grey color indicates insignificant correlations.

Planned work

1) Develop and test a coupled system of GFS and the NASA Land Information System, then assimilate microwave soil moisture retrievals into the GFS using an ensemble Kalman Filter.
2) Develop the high resolution BDI using the downscaling satellite soil moisture products.

Publications

1. Yin Jifu, Xiwu Zhan, Youfei Zheng, Christopher R. Hain, Michael Ek, Jun Wen, Li Fang, and Jicheng Liu, 2016, Improving Noah land surface model performance using near real time surface albedo and green vegetation fraction, Agric. For. Meteor., 219, 171–183.
2. Yin Jifu, Xiwu Zhan, Christopher R. Hain, Jicheng Liu, and Martha C. Anderson, 2017, Blending Drought Indices via Objective Integration of Satellite Observations and Model Simulations of Soil Moisture, Remote Sensing of Environment, Under Review.
3. Yin Jifu, Christopher R. Hain, Xiwu Zhan, Michael Ek, and Jiarui Dong, 2017, Improvements in the Forecasts of Near-surface Variables in the Global Forecast System (GFS) via Assimilating Soil Moisture Retrievals, submitted to Journal of Hydrology.

Presentations

1. Yin Jifu, Xiwu. Zhan, Christopher R. Hain, Jicheng Liu and Martha C. Anderson. A global blended drought Index (BDI) from merging satellite observations and land surface model simulations. Provided a presentation. North American Land Data Assimilation System (NLDAS) Telecon. College Park, MD, USA. May 19th, 2016.

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

This project assessed the improvements of using near real time (NRT) surface types, GVF and albedo on Noah model performance, and developed a new blended drought index (BDI) with objectively merging the retrievals from thermal remote sensing land surface temperature-based evapotranspiration along with the remotely sensed and land surface modeling soil moisture (SM). The techniques submitted to NOAA for consideration in future operational use include (1) real time surface types and GVF insertion component in NCEP numerical weather forecast models and (2) development of drought monitoring objective integration indicators. We provided one presentation and had a peer-review paper published; and there are additional 2 papers have been submitted.

Enhancing NCEP-NAM Weather Forecasts via Assimilating Real-time GOES-R Observations of Land Surface Temperature and Green Vegetation Fraction

Task Leader	Mitchell Schull & Christopher Hain
Task Code	CHCH_NCEP_ 15 Year 2
NOAA Sponsor	Xiwu Zhan
NOAA Office	NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 10%; Theme 3: 40%
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 65%; Goal 2 :35%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: Based on the land data assimilation framework and evaluation tool implemented in previ-ous funding cycles, we accomplished two major tasks in the current funding cycle, 1) con-ducted data assimilation of both directly GOES/GOES-R LST observations and LST-based ALEXI SM data into weather forecast model; 2) evaluate the effectiveness and efficiency of the two assimilation approaches and reported data assimilation evaluation statistics.

Background

With enhanced observations from the GOES-R, the goal of this project is to assimilate real-time GOES-R observations of land surface temperature, a GOES-R based thermal infrared soil moisture proxy retrieved using the Atmosphere-Land Exchange Inversion model (ALEXI), and GOES-R vegetation dynamics into the NCEP NAM in order to improve NAM weather forecasts.

Accomplishments

A semi-coupled LIS/WRF framework is designed to test the impact of either direct LST or LST-based SM assimilation on WRF weather forecast. The framework is designed in a flexible way that can be relatively easily applied to semi-coupling NCEP NAM system and LIS to assimilate land surface variables. In the coupling workflow, WRF provides atmospheric forcing data to LIS and LIS sets up the simulation domain on the same grid (spatial resolution and projection) with the same terrestrial data and land surface physics (identical versions of the Noah LSM) as WRF run. All land data assimilations (e.g. LST DA and SM DA) are conducted within LIS using EnKF method. LIS then generates updated initializations daily and returns updated initial land surface data (e.g. SM, soil temperature, fluxes, albedo, etc) to WRF for next day forecasts. Figure 1 shows a schematic of the semi-coupled LIS/WRF system.

Our first milestone is to evaluate the effectiveness and efficiency of the two assimilation approaches and report data assimilation evaluation statistics.

1. Differences of WRF Forecasts with and without Assimilations

The differences of four surface forecast variables (soil moisture layer 1, T-2m, soil temperature layer 1 and surface skin temperature) between ALEXI SM DA run and free run are shown in Figure 2. Shown in Figure 3 are the same as those in Figure 2 but for the differences between direct LST data assimilation run and free run.

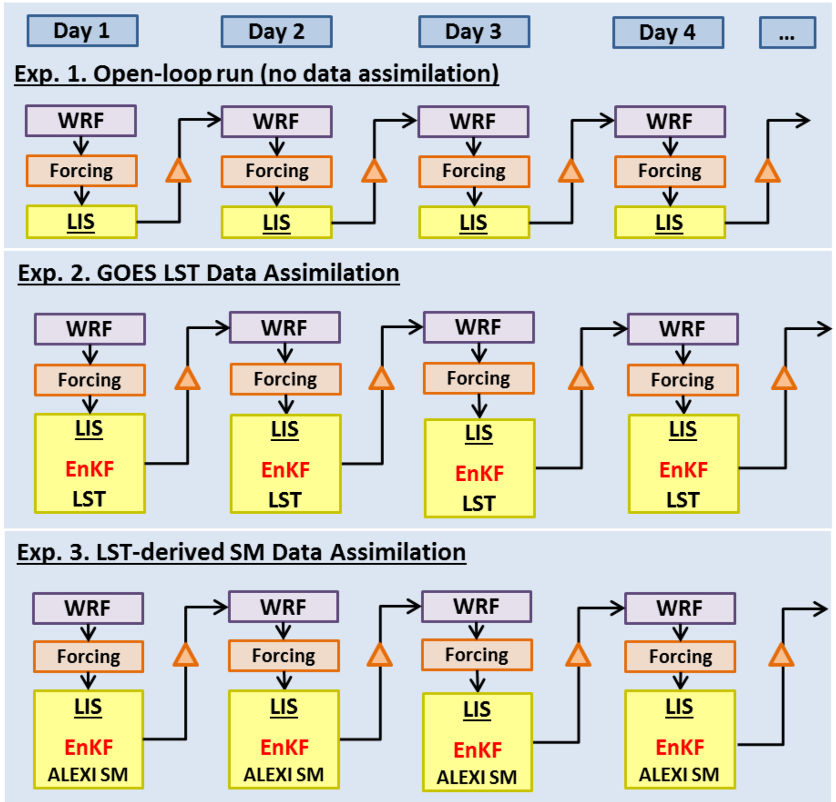


Figure 1. Schematic description of the semi-coupled LIS-WRF system for the three data assimilation experiments

2. Evaluation of the WRF Forecasts against Ground Observations

a. T2m: 2 meter air temperature

Figure 4 shows the comparison of 2-m temperature forecasts from ALEXI SM DA run and LST DA run along with the in-situ observation at a sample validation site (34.64N, 106.83W) in New Mexico over the period of June 8th to 16th, 2012. WRF open-loop run predicted 2-m temperature forecast of presents with an obvious warm bias during the daytime and cold bias over nighttime throughout the validation period. The bias reaches 2.28 degrees at daytime and 4.8 degree at nighttime on average. Evidently, the assimilation of satellite LST information either direct LST assimilation or LST-based SM assimilation corrects the warm bias. The warm bias is reduced by 1.5K on average with direct assimilation of LST, while the assimilation of LST-based SM data can further correct the warm bias by 0.5K on top of the direct LST assimilation.

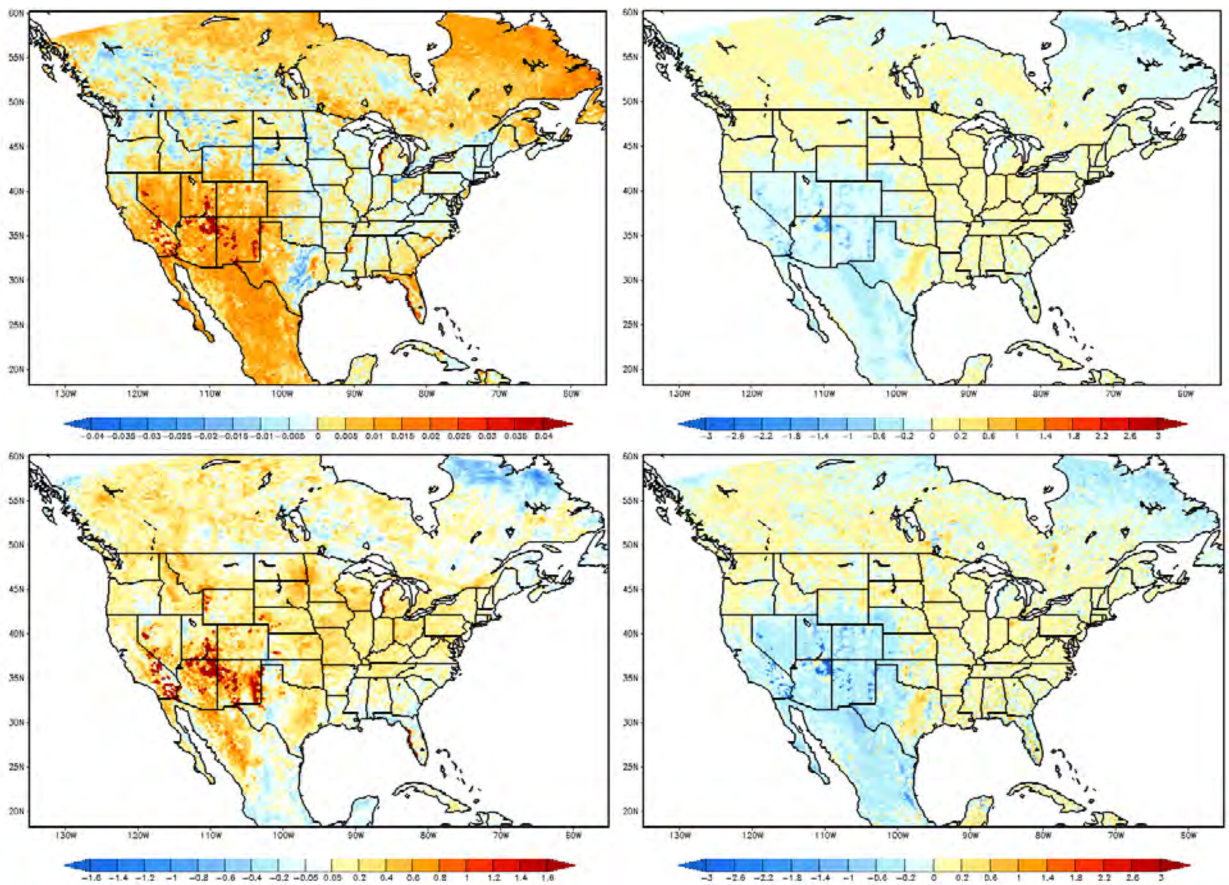


Figure 2. Comparison between LST-based ALEXI SM DA run and free run; Average difference of top layer soil moisture, T-2m, Soil temperature layer 1 and surface skin temperature at UTC19, over the period of June 8th – June 15th, 2012 (ALEXI SM DA run minus Free run)

b. RH: 2 meter relative humidity

The results illustrated in Figure 5 show a comparison of relative humidity (RH) forecasts from WRF open-loop run and two assimilation runs, along with the observations from a ground validation site in New Mexico (-106.83W, 34.64N) over the period of June 8th to 12nd, 2016. The open-loop run presents a consistently positive bias compared to the in-situ measurements. The time-series comparison suggests that the assimilation of LST information (both direct LST and LST-based SM) is able to reduce the positive bias. Compared to the mean bias from the open-loop run (3.07%), the direct LST assimilation can reduce bias to 2.62%, while the LST-based ALEXI SM assimilation run lowers the bias to 2.53%. The largest impact occurred on June 12nd, when the bias of open-loop run was reduced by 4.85% by directly assimilating LST and an extra 9.10% reduction by assimilating LST information into WRF model via converted to SM signals (ALEXI SM).

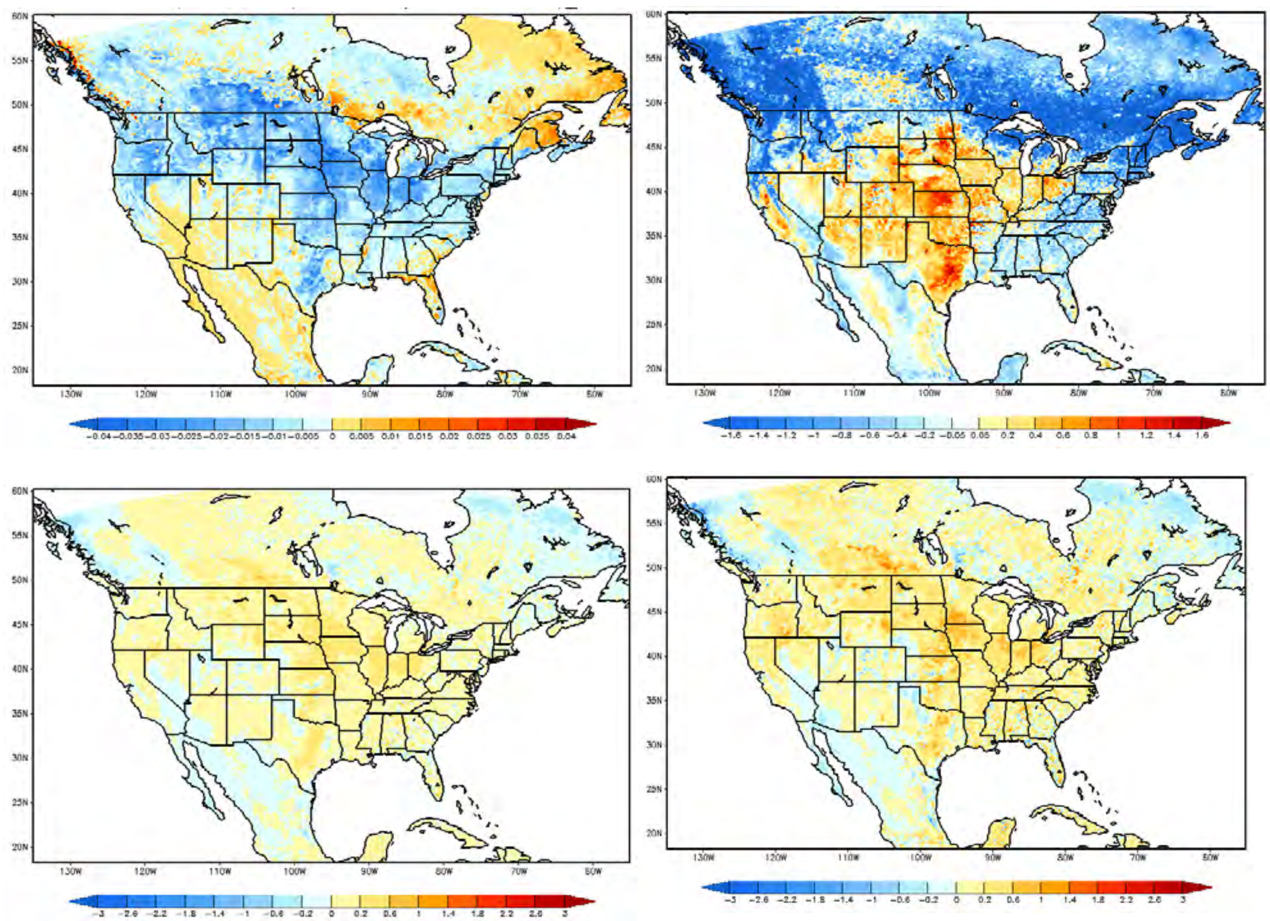
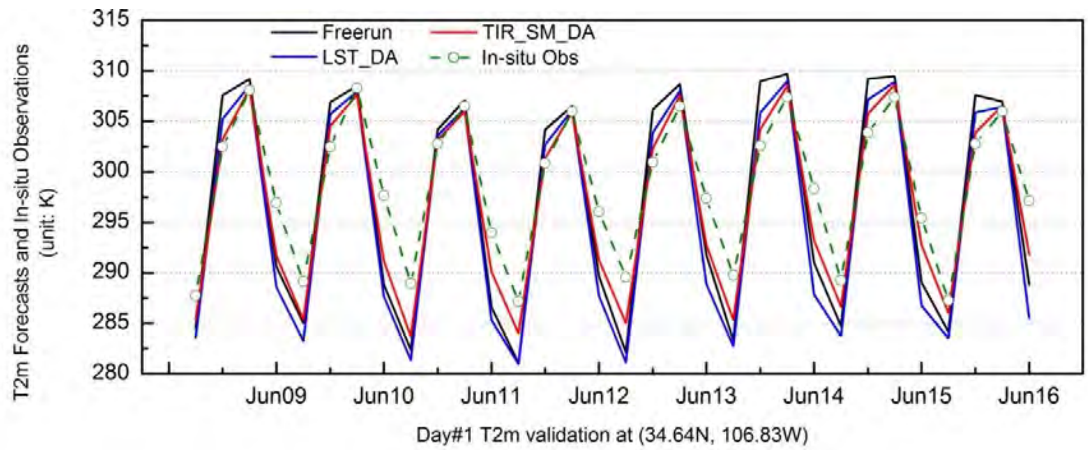


Figure 3. Comparison between LST DA run and free run; Average difference of top layer soil moisture, T-2m, Soil temperature layer 1 and surface skin temperature at UTC19, over the period of June 8th – June 15th, 2012 (LST DA run minus Free run)

c. P: Daily precipitation

The Impact of the assimilation of LST information on precipitation is examined by comparing WRF runs with NCEP National Stage IV Precipitation data set. The percentage of matched pairs of 24-hour accumulated precipitation between the Stage IV precipitation data set and WRF forecasts of are shown in Figure 11. First of all, the impact on precipitation by assimilation of land surface temperature is not as strong as the above-analyzed near surface forecasts (e.g. temperature or humidity). However, validation results still illustrate subtle improvement in precipitation forecast from LST assimilation runs by showing higher percentage of matched pairs of forecasts and ground observations, averaged over CONUS domain. Better agreement with ground observations can be detected throughout the validation period, with the exception of June 13rd when direct LST assimilation shows a slight degradation.



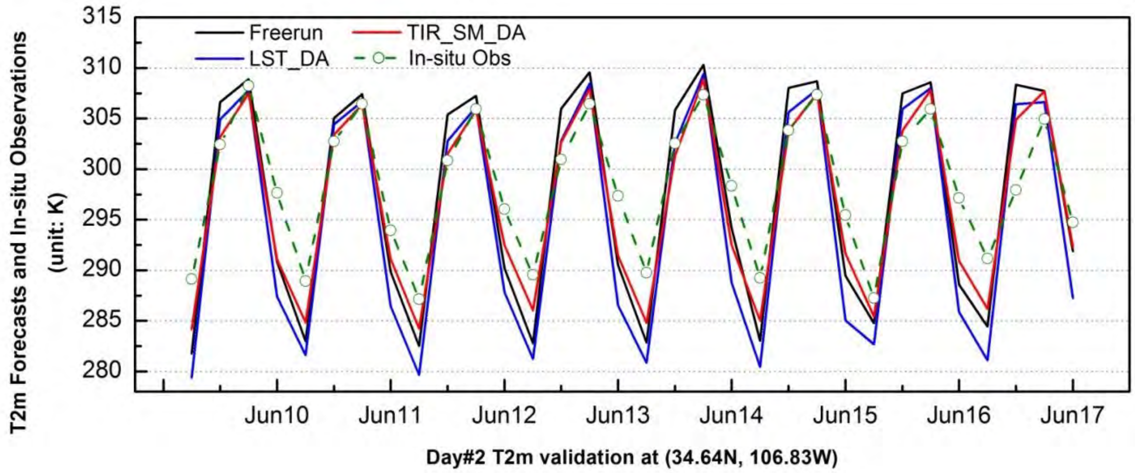


Figure 4. Comparison of 2-m temperature between forecasts and in-situ observations at the validation site at (34.64N, 106.83W) in New Mexico for Day 1 forecast (top) and Day 2 forecast (bottom)

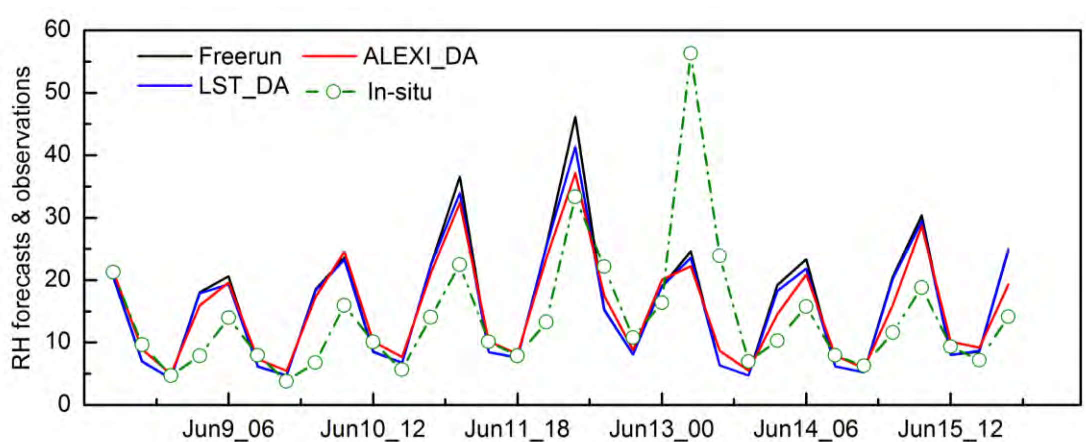


Figure 5. Comparison of 2-m temperature between forecasts and in-situ observations at a sample site at the validation site in New Mexico (34.64N, 106.83W) for Day 1 forecast

We then focus on a rainfall event over the northeast coast region on June 10th, 2012. The RMSE differences between DA runs and open-loop run (open-loop run minus DA runs) are plotted and shown in Figure 7 to illustrate the added or degraded value by data assimilation. It is found that both assimilation approaches improve the precipitation forecasts as can be seen in a lower RMSE over the majority of the rainfall region. Furthermore, LST-based SM DA outperforms direct LST method presenting added value to precipitation forecasts over larger areas and to larger extend.

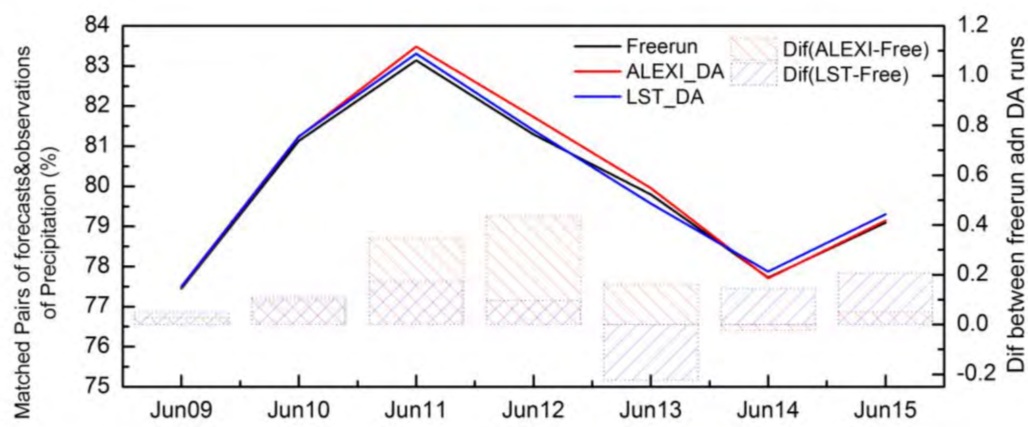


Figure 6. Percentage of matched pairs of Stage IV precipitation data set and WRF forecasts (free run, LST DA run and direct LST DA run)

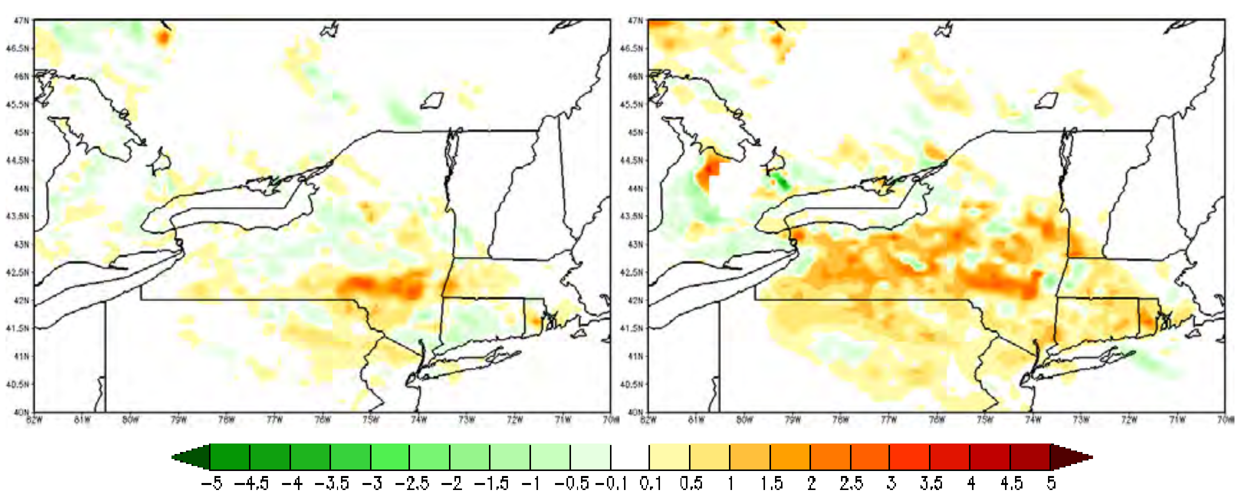


Figure 7. RMSE difference of precipitation forecasts between WRF free run and direct LST DA run (LST-based SM DA run) on the left (right); Free run minus DA run; warm (cool) color means added (degraded) value

Planned work

1) Demonstrate NCEP NAM data assimilation utility for parallel real time operational assimilation of GOES/GOES-R LST and/or LST-based ALEXI soil moisture;
2) Documents and reports of the findings of the whole project.

Publications

Fang, L., C. R. Hain and X. Zhan, 2014, An Assessment of Land Thermal Infrared Observation Impact on Regional Weather Forecasts with Two Different Data Assimilation Approaches, In internal review. *To be submitted to J. Hydrometeor.*

Products

- Products of GOES based input data sets (GOES/GOES-R proxy GVF, GOES/GOES-R LST, and ALEXI SM derived from GOES/GOES-R TIR observations); and
- Documentation for the fully/semi coupled LIS and NAM system.

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

This project accesses the impact of near-real time GOES-R LST and GVF observations on NCEP NAM forecasts. The techniques submitted to NOAA for consideration in future operational use include (1) real time GVF insertion component in NCEP NAM and (2) land satellite data assimilation utility in NAM. There are total of 1 journal papers have been prepared and ready to submit.

Improve HYSPLIT Mercury Code

Task Leader:	Chris Loughner
Task Code:	TCTC_HYSP_15 Year 2 & CLCL_HYSP_16
NOAA Sponsor:	Mark Cohen and Ariel Stein
NOAA Office:	ARL
Contribution to CICS Research Themes (%):	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic:	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%):	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: Implemented Parallelization, improved model precision, developed Regional Eulerian Model within HYSPLIT-Hg; and created a new set of HYSPLIT meteorological input fields

Link to a research web page: http://www.arl.noaa.gov/Mercury_modeling.php **and** http://www.arl.noaa.gov/HYSPLIT_info.php

Background

This purpose of this task is to improve our understanding of mercury (Hg) transport and chemical conversion in the atmosphere and deposition into aquatic and terrestrial ecosystems. In addition, a climatology of meteorological fields for input into the HYSPLIT model are being developed with the use of the Weather Research and Forecasting (WRF) model.

Mercury, a well-known neurotoxin, is not only harmful to wildlife but is also particularly dangerous to children in early stages of development and may impact cognitive thinking, memory, attention, language, and fine motor and visual spatial skills. It is emitted from a variety of anthropogenic sources with power plants being one of the leading sources that contribute to elevated levels of mercury in the Great Lakes Basin (GLB). The Great Lakes Restoration Initiative (GLRI) was launched in 2010 to accelerate the protection and restoration of the GLB. As part of these efforts, the GLRI is funding studies that elucidate the sources and transport of atmospheric mercury.

The HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model calculates the trajectories and dispersion of air masses. The HYSPLIT-Hg model has special features added to simulate atmospheric mercury. This version of HYSPLIT can be used to evaluate the atmospheric transport and deposition of mercury into each of the Great Lakes and their watersheds. Unlike many air quality models, HYSPLIT has the ability to quantify the source attribution of the deposited mercury. By determining the relative importance of different source regions and source type stakeholders and policy makers will be more effective in evaluating and prioritizing control measures that seek to reduce mercury contamination in the GLB.

This task aims to improve the operation and capabilities of HYSPLIT-Hg with the goal of creating a better representation of mercury transport and deposition within the model framework. This code has been parallelized to decrease run times. Model precision has been increased to improve the robustness of results across different computer systems, configurations, and compilers. In addition, a Regional Eulerian Model was developed within HYSPLIT-Hg to allow for higher resolution Eulerian mode simulations over a region of interest utilizing nested domains.

In addition, this task continued building a new climatology of HYSPLIT meteorological input fields with the WRF model. The WRF model has previously been run covering the continental U.S. spanning 1980-1990. This task continued running WRF onward through 2016 to create a 37 year climatology of WRF fields. WRF output were converted to HYSPLIT meteorological input files and evaluated with ground observations. The new HYSPLIT meteorological input files have been made publically available. This new product is now being used with HYSPLIT to calculate ash resuspension and atmospheric concentrations near a Waste Treatment and Immobilization Plant (WTP) located downwind of Mt. St. Helens. This work will help determine design requirements for a natural phenomena hazards assessment for the WTP.

Accomplishments

Parallelization has been implemented into the HYSPLIT-Hg model running in the Lagrangian, Eulerian, and hybrid Lagrangian / Eulerian modes. The Lagrangian mode utilizes puffs. This was accomplished using the Message Passing Interface (MPI). This update allows the model to use multiple computer processors on a distributed processing system and results in a decrease in model run time.

While testing the updated parallelized HYSPLIT-Hg code, it was discovered that the precision of numerous variables was not adequate. Model simulations run with 1 CPU versus multiple CPUs resulted in different results. Through a series of sensitivity simulations, the variables that caused this problem were identified and the precision of these variables was increased. New tests were made to ensure that both the puff and Eulerian modes run serially (with 1 CPU) obtained identical results with simulations run with multiple CPUs using MPI.

In addition, a Regional Eulerian Model (REM) has been developed within HYSPLIT-Hg. This update allows for HYSPLIT-Hg to be run at higher resolutions in a Eulerian framework over a region of interest utilizing nested domains. This new code allows for output from the HYSPLIT-Hg Global Eulerian Model (GEM) to be input into the REM for initial and boundary conditions. In addition, REM outputs can be used for initial and boundary conditions for higher resolution REM simulations. This update allows for the model to better represent spatial variability within an Eulerian framework. Like the GEM, the REM can be utilized within a hybrid Lagrangian / Eulerian mode.

Finally, a new set of HYSPLIT meteorological input files have been created. The WRF model was run covering the continental U.S. from 1980 through 2016. WRF model output files have been converted to HYSPLIT meteorological input files and made publically available on the ARL Gridded Meteorological Data Archive (https://ready.arl.noaa.gov/archives.php). This new meteorological product is currently being used to calculate ash resuspension from hypothetical volcanic eruptions near a WTP downwind of Mt. St. Helens. The first 30 years of this new product and the North American Regional Reanalysis have been evaluated with ground observations near the WTP to determine the effectiveness of using these meteorological fields in simulating ash resuspension with HYSPLIT. A depiction of wind roses highlights that WRF simulated wind direction is in better agreement with the observations than a comparison of NARR with observations (Figure 1). In addition, WRF simulated wind speed and 6 hour precipitation totals agree better with ground observations near the WTP than NARR. Wind speed mean bias for WRF and NARR are -0.094 and -1.17 m/s, respectively, and 6 hour precipitation mean bias for WRF and NARR are

-0.10 and -0.13 mm, respectively. These results show that utilizing the new meteorological product in HYSPLIT will produce more robust results than using NARR fields.

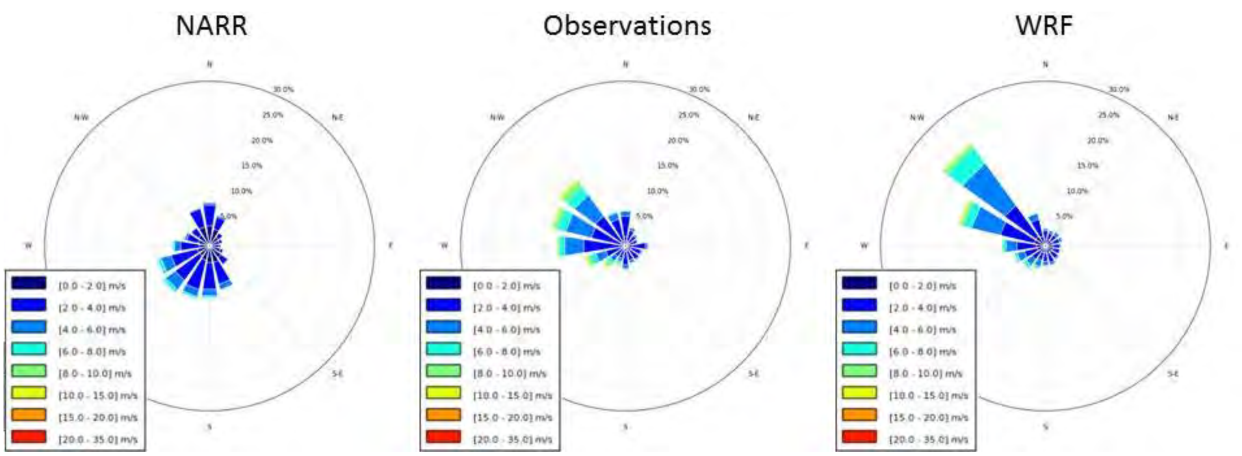


Figure 1. Windroses from the NARR (left) observations (center), and WRF (right) at the WTP.

Planned work

- Porting over the REM from the HYSPLIT-Hg code into the base HYSPLIT model.
  The REM will be beneficial to analyzing local and regional effects on long range transport by allowing for higher resolution simulations than a GEM simulation and without the computational expense of running a Lagrangian model over long distances.
- Add the capability to simulate particles in HYSPLIT-Hg.
  Particle simulations are a state-of-the-science approach of Lagrangian transport, but it is computationally expensive. With the recent implementation of MPI into HYSPLIT-Hg, it is now feasible to utilize particles in this model.
- Add the capability for HYSPLIT-Hg to ingest chemical fields from a regional and global model.
  This update will result in more realistic chemical input fields that vary spatially and temporally.
- Adding a sub-surface layer (or multiple layers) to the model.
  HYSPLIT does not currently have the capacity to consider mercury that is resident in sub-surface layers. Addition of this source to the model will improve the efficacy of the simulations.
- Improving the numerical finite-difference grid calculation within the Eulerian component of the model.
  The Eulerian component of the model is used to calculate Hg concentrations on a fixed grid and improvements will better represent the actual chemistry of the atmosphere.
- Follow Quality Assurance procedures for documenting the effectiveness of using the new WRF generated HYSPLIT meteorological fields for modeling ashfall resuspension with HYSPLIT.
  Reports will be developed and submitted as part of the ashfall resuspension project.

Publications

Cohen, M.D., R.R. Draxler, R.S. Artz, P. Blanchard, M.S. Gustin, Y.-J. Han, T.M. Holsen, D.A. Jaffe, P. Kelley, H. Lei, C.P. Loughner, W.T. Luke, S.N. Lyman, D. Niemi, J.M. Pacyna, M. Pilote, L. Poissant, D. Ratte, X. Ren, F. Steenhuisen, A. Steffen, R. Tordon, and S.J. Wilson (2016), Modeling the global atmospheric transport and deposition of mercury to the Great Lakes, Elementa Science of the Anthropocene, doi:10.12952/journal.elementa.000118.

Products

The following model improvements and products were produced:

1) parallelized HYSPLIT-Hg code that can be run in the puff, Eulerian, and hybrid modes;
2) improved HYSPLIT-Hg model by increasing the precision in the puff, Eulerian, and hybrid modes;
3) a Regional Eulerian Model (REM) within HYSPLIT-Hg to allow for higher resolution Eulerian mode simulations utilizing nested domains; and
4) a new set of HYSPLIT meteorological input files spanning 37 years that were developed with the WRF model.

Details of these four products are described above.

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

As discussed above, the following products were developed:

1) Parallelized HYSPLIT-Hg code that can be run in the puff, Eulerian, and hybrid modes;
2) Improved HYSPLIT-Hg model by increasing the precision in the puff, Eulerian, and hybrid modes;
3) A Regional Eulerian Model (REM) within HYSPLIT-Hg to allow for higher resolution Eulerian mode simulations utilizing nested domains; and
4) A new set of HYSPLIT meteorological input files spanning 37 years that were developed with the WRF model.

Student Support for NOAA's Climate Prediction Center	
Task Leader	E. Hugo Berbery (Student: Katherine Lukens)
Task Code	EBEB_CPC_14 Year 3 & EBEB_CPC_16
NOAA Sponsor	Mike Halpert
NOAA Office	NWS/NCEP/CPC
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: %100
Main CICS Research Topic:	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 25%; Goal 3:25 %
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

This report summarizes the research conducted from April 2016 to March 2017 by Katherine E. Lukens, Ph.D. Candidate and GRA III. Her dissertation has the working title, "The Relation and Predictability of Severe Storm Tracks and High Impact Winter Weather in North America."

Katherine examined the behavior of winter storm tracks using data from the Climate Forecast System Reanalysis (CFSR; Saha et al. 2010). Storm trajectories were identified as isentropic potential vorticity (IPV) maxima larger than a chosen threshold within a Lagrangian framework, which provides the optimal combination of variable and methodology to illustrate storm track behavior and allows for the straight-forward identification of small-scale cyclogenesis and cyclolysis regions associated with the storm tracks. IPV is an ideal dynamical tracer because of its conservation properties in an adiabatic, frictionless flow (Holton 2004). Because IPV considers both absolute vorticity and static stability, it encapsulates many of the dynamic and thermodynamic properties of atmospheric circulation. In the Northern Hemisphere (NH), a positive (i.e., cyclonic) IPV anomaly, which generally corresponds to an upper-tropospheric pressure trough, induces a vortex with positive circulation (i.e., a cyclone) (Hoskins et al. 1985; Hoskins and Hodges 2002).

The storm tracks defined in IPV correspond with those described in previous studies: three storm tracks are identified over the North Pacific and North Atlantic Oceans as well as over the Mediterranean Sea. The cyclogenesis pattern shows that severe storms generally develop along the storm tracks. The cyclolysis pattern reveals that many storms dissipate in the eastern North Pacific and western North Atlantic Oceans, and in the central and northeastern United States.

Accomplishments

Under the advisement of Dr. E. Hugo Berbery, Katherine has investigated the relationship between severe storm tracks and high impact winter weather in North America. She has found that severe storms in the Northern Hemisphere (NH) winter make up about 18% of all winter storms, and they are primarily associated with deep convection (Fig. 1a). Across the NH large increases in diabatic heating occur where the storm tracks are most intense, e.g., over the oceans. High impact weather is represented by strong low-level winds and intense precipitation. In general, the low-level winds shift southeastward during severe storm activity and are strongest in deep convective areas over the oceans and leeward of the Rocky Mountains (Fig. 1b). Moreover, the largest increases in the wind speeds are found where many storms tend to develop and intensify, e.g., poleward of the low-level wind speed maxima in the oceans and leeward of the Rocky Mountains. Precipitation intensity related to the severe storm tracks over the Pacific and Atlantic Oceans is largest where they are strongest (i.e., in deep convective areas in the eastern North Pacific and western North Atlantic, respectively), as well as along the west coast of North America due to orographic effects (Fig. 1c). In the majority of North America, the mean precipitation during severe storm activity is more intense than the mean precipitation during all storm activity. Specifically in the United States, the severe storms contribute over 50% of the precipitation associated with all winter storms. Katherine's findings indicate that severe storm tracks leave a significant imprint on high impact winter weather in North America, despite making up a small fraction of all storms that develop.

Katherine has found similar relationships between severe storm tracks and high impact winter weather in the Southern Hemisphere. The subtropical and subpolar storm tracks identified from IPV minima are consistent with previous studies (e.g., Hoskins and Hodges 2005). Severe storms make up a small percentage of all storms in winter, and still they leave significant imprints on high impact winter weather, particularly in deep convective areas.

Katherine has also begun the final phase of her research. This phase concerns the 1983-2010 cold season (i.e., December-January-Februrary; DJF) in the NH, with a focus on North America. The main objective is to evaluate the ability of NCEP's Climate Forecast System version 2 (CFSv2) model to forecast severe storm track behavior and related high impact winter weather in North America relative to the reanalysis, which is taken as "ground truth" for the purpose of this investigation. The results from this work will be used to address any gaps or areas of improvement in the forecasting capability of the CFSv2 model in the sub-seasonal (i.e., weeks 3-4) to seasonal time frame.

Currently, Katherine is evaluating any systematic biases in the NH storm track behavior using CFSv2 reforecasts made 15-45 days prior to each month in the DJF season. Statistical bias computations help clarify the magnitude of the bias between CFSv2 storm track characteristics (i.e., storm track density, mean intensity, genesis density, lysis density) and those from the reanalysis. Preliminary results suggest that biases in the density statistics for all storms are statistically significant with the largest biases in the higher latitudes over land (e.g., cyclogenesis for all storms in Fig. 2a). Additionally, the biases in the density statistics are reduced over the majority of the NH when considering only severe storms (e.g., cyclogenesis for severe storms in Fig. 2b).

She continues to use the NCAR Command Language (NCL) along with shell scripting, and she is also learning Python. Katherine continues to expand her knowledge of these languages and sharpen her programming skills.

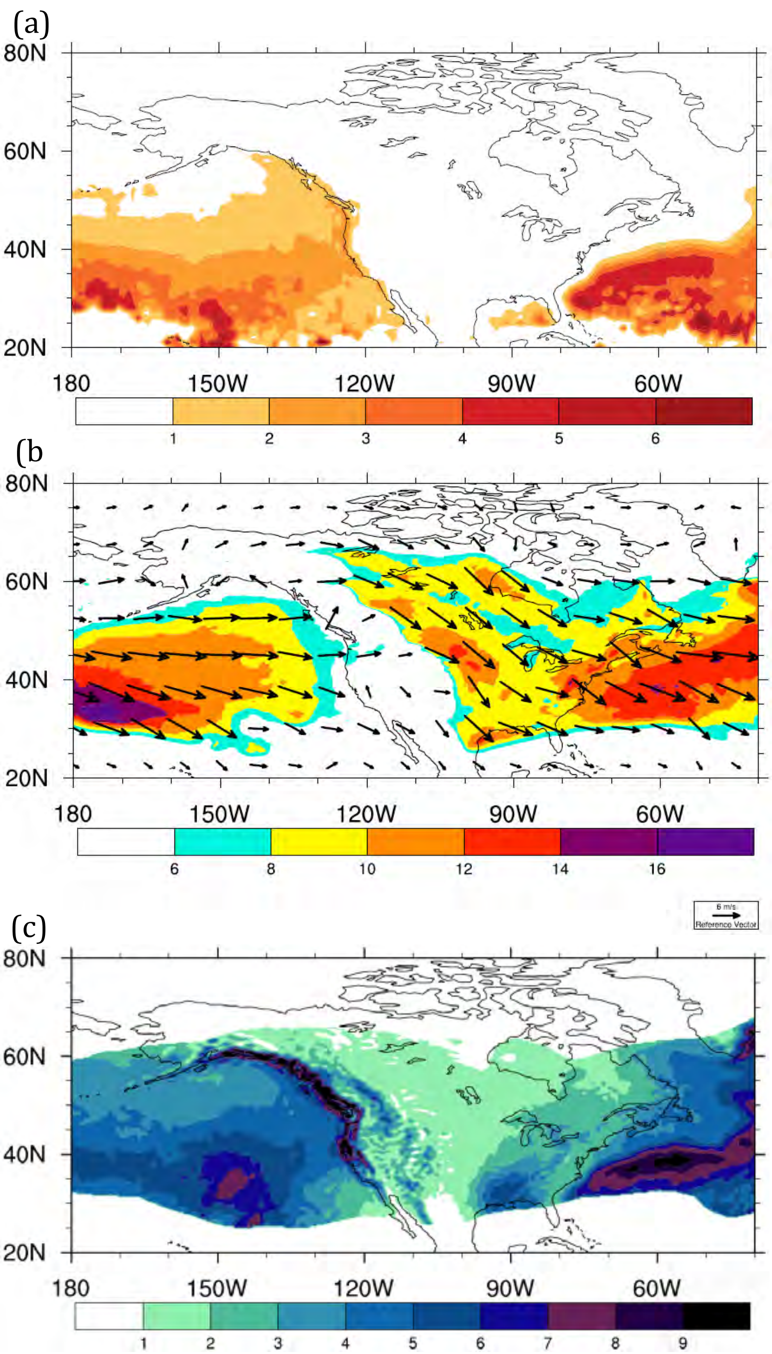


Figure 1. Deep convection and high impact weather related to the severe storm tracks from CFSR for the North American 1980-2010 winter season.

(a) Deep convection during severe storm activity with a contour interval of 1.0 K day^{-1}.
(b) Winds at 850mb associated with severe storms. Directionality is shown in vectors and wind speed is shown in colors with a contour interval of 2.0 m s^{-1}.
(c) Precipitation associated with severe storms with a contour interval of 1.0 mm day^{-1}.

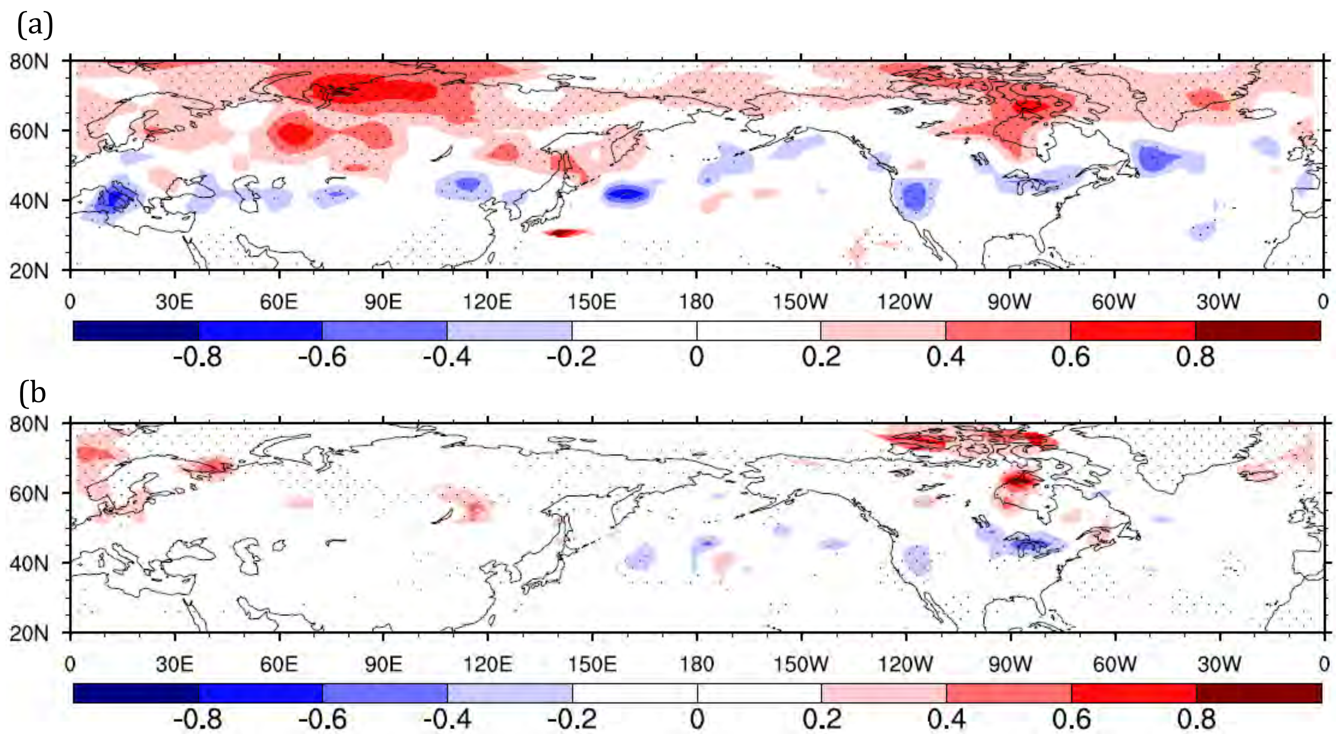


Figure 2. Genesis density biases (CFSv2 – CFSR) in the Northern Hemisphere DJF season for 1983-2010. 15-45day reforecasts from CFSv2 are used in the computations. Contour interval is 0.2 storms per area per month. Stippling indicates 95% significance using the t-test. (a) Bias for all storms. (b) Bias for severe storms.

Planned work

The planned work is expected to take up to 12 months to complete, with the publication processes likely extending beyond the 12 months.

Katherine intends to:

- Submit and publish a manuscript titled, "The imprint of severe storm tracks on high impact winter weather in North America" in the Journal of the Atmospheric Sciences or a similar journal.
- Submit and publish a manuscript on severe storm tracks and related high impact weather in the Southern Hemisphere in the Geophysical Research Letters or a similar journal.
- Determine the low-level wind and surface precipitation distributions associated with severe storm tracks using 15-45 day reforecast data from CFSv2.
- Assess seasonal and systematic biases in high impact weather related to the severe storm tracks using the 15-45 day CFSv2 data relative to the reanalysis.
- Analyze storm track behavior and related high impact weather using 30-60 day reforecast data from CFSv2 and determine any biases relative to the reanalysis.
- Analyze storm track behavior and related high impact weather using 60-90 day reforecast data from CFSv2 and determine any biases relative to the reanalysis.

- Determine the longest lead time that CFSv2 is able to forecast severe storm tracks and related high impact winter weather with *relative confidence*. It is expected that the reliability of the CFSv2 to accurately predict storm track-related high impact weather will decrease with increasing lead times.
- Document, submit, and publish the results in a relevant and established journal.
- Document the findings in her doctoral dissertation.

Publications

- *Peer reviewed*
  - *To be submitted to J. Atmos. Sci*:
    Lukens, K. E., and E. H. Berbery, 2017: The imprint of severe storm tracks on high impact winter weather in North America.

Presentations

Lukens, K. E., and E. H. Berbery: *Storm Tracks and their Influence on High Impact Weather in the Southern Hemisphere Winter.* (oral)

(1) 97[h] AMS Annual Meeting, Seattle, WA, 22-26 January 2017.
(2) CICS Science Conference, College Park, MD, 29-30 November and 1 December 2016.
(3) 41st Annual Climate Diagnostics & Prediction Workshop, Orono, ME, 3-6 October 2016.

Lukens, K. E., and E. H. Berbery: *Storm Tracks and their Influence on North American Precipitation in the Boreal Winter.* (oral)

1. 2016 CoRP Symposium, Ft. Collins, CO, 18-19 July 2016.

Other

Katherine volunteered at the USA Science & Engineering Festival as a representative of the University of Maryland's Department of Atmospheric & Oceanic Science in Washington, D.C. (15 April 2016).

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

Exploring Pathways to Improve MJO Predictions

Task Leader	Jieshun Zhu
Task Code	EBEB_PDOC_16
NOAA Sponsor	Arun Kumar
NOAA Office	Climate Prediction Center
Contribution to CICS Research Themes (%)	Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight : The Task Leader conducted a series of coupled simulations using the NCEP CFSv2 to explore the impacts of SST feedback and convection parameterization on the propagation simulations. The critical role of SST feedback was first identified in maintaining MJO propagation. Analyses of two simulations with different convection parameterization schemes further indicated that including air-sea coupling alone does not result in realistic maintenance of the MJO eastward propagation without the development of favorable SST conditions in the western Pacific. Diagnostics suggested that the pre-conditioning of SSTs is strongly affected by surface latent heat fluxes that are modulated by surface wind anomalies in both zonal and meridional directions.

Background

The Madden-Julian Oscillation (MJO) is the dominant mode of tropical convection variability on the intraseasonal time scale. Over the recent years, significant improvements have been made in MJO prediction skill in operational forecasts. However, the MJO prediction performance still differs greatly among the operational systems and efforts are continually underway to seek further improvements. furthermore, a general guidance on what would be most beneficial developmental pathways to improve MJO simulation and prediction skill remains unclear. Addressing the issues for improving MJO forecasts requires quantifying the sensitivity of MJO predictions to different factors that affect the prediction, and quantifying the relative importance of individual factors.

Accomplishments

The observed Madden-Julian oscillation (MJO) tends to propagate eastward across the Maritime Continent from the eastern equatorial Indian Ocean to the western Pacific. However, numerical simulations present different levels of fidelity in representing the propagation, especially for the tropical convection associated with the MJO. This study conducts a series of coupled simulations using the NCEP CFSv2 to explore the impacts of SST feedback and convection parameterization on the propagation simulations.

Firstly, two simulations differing in the model horizontal resolutions are conducted. The MJO propagation in these two simulations is found generally insensitive to the resolution change (Fig. 1). Further, based on the CFSv2 with a lower resolution, two additional experiments are performed with model SSTs nudged to climatologies with different time scales representing different air-sea coupling strength. It is demonstrated that weakening the air-sea coupling strength significantly degrades the MJO propagation simulation (Fig. 1), suggesting the critical role of SST feedback in maintaining MJO propagation.

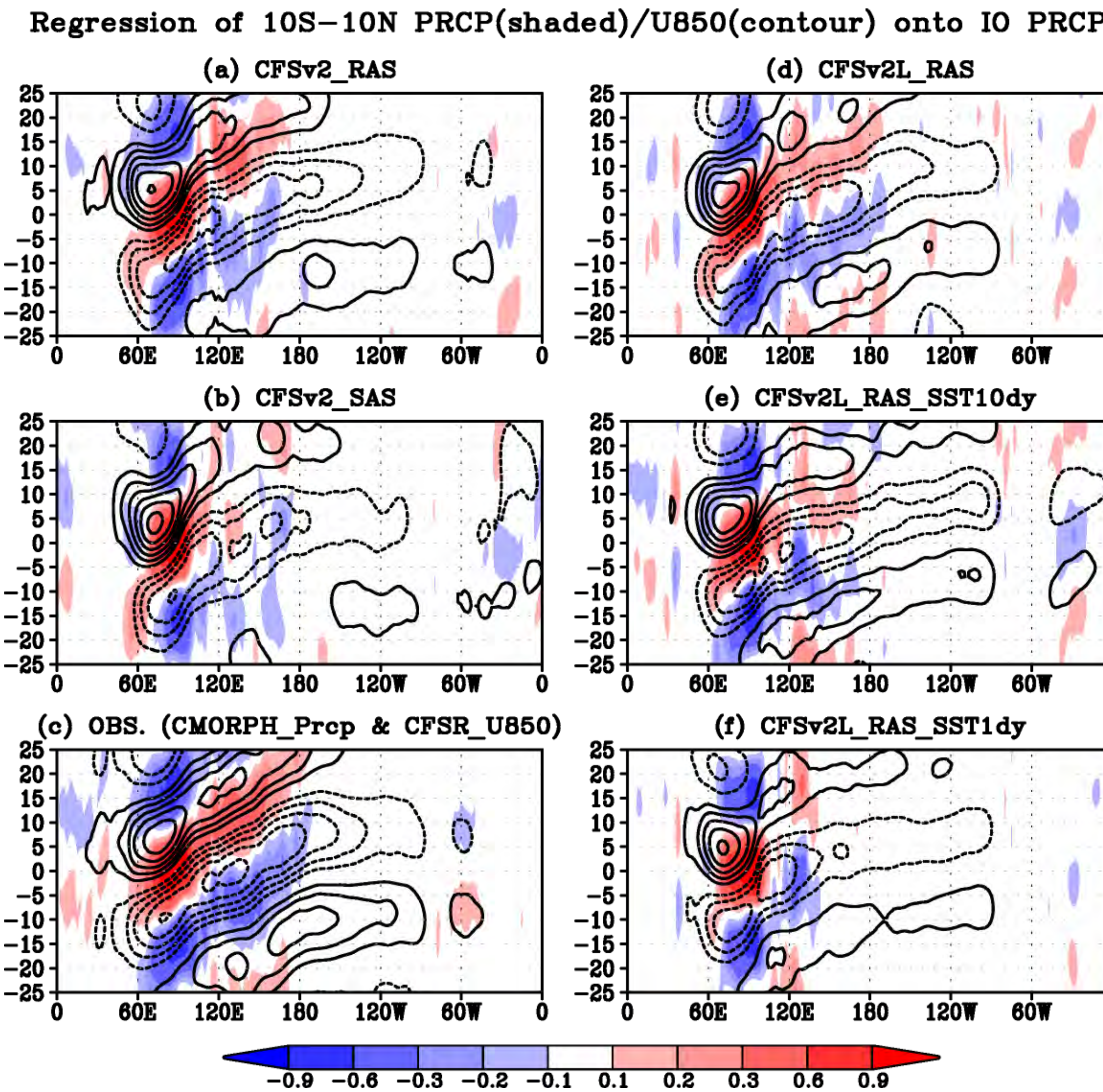


Figure 1. November-April lag-longitude diagram of 10ºS–10ºN averaged intrasesonal (20–100-day filtered) precipitation anomalies (colors) and 850-hPa zonal wind anomalies [contours; (m/s)/(mm/day)] regressed against the Indian Ocean precipitation (70-100ºE, 10ºS-10ºN) for (a) CFSv2_RAS, (b) CFSv2_SAS, (c) observation (CMORPH precipitation and CFSR wind), (d) CFSv2L_RAS, (e) CFSv2L_RAS_SST10dy and (f) CFSv2L_RAS_SST1dy. Contour interval is 0.1 (m/s)/(mm/day) with the zero contour omitted.

Lastly, the sensitivity to convection parameterization is explored by comparing two simulations with different convection parameterization schemes. Analyses of these simulations indicate that including air-sea coupling alone in a dynamical model does not result in realistic maintenance of the MJO eastward propagation (Fig. 1) without the development of favorable SST conditions in the western Pacific. In both observations and one simulation with realistic MJO propagations, the pre-conditioning of SSTs is strongly affected by surface latent heat fluxes that are modulated by surface wind anomalies in both zonal and meridional directions (Fig. 2). The diagnostics highlight the critical contribution from meridional winds in wind speed variations, which has been neglected in most MJO studies.

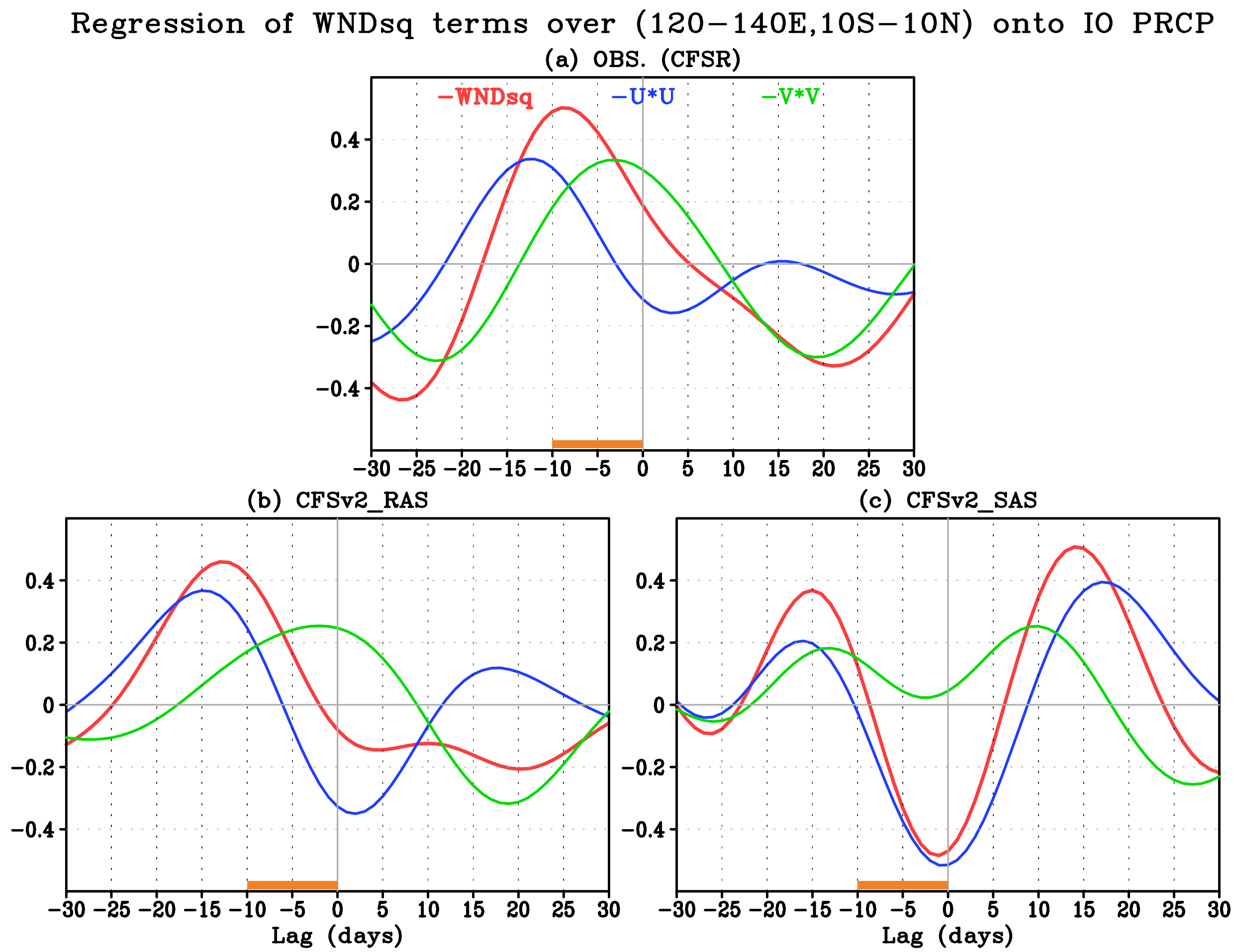


Figure 2. November-April lead-lag regressions of the intraseasonal w^2, u^2 and v^2 anomalies [averaged over (120-140ºE, 10ºS-10ºN)] against the Indian Ocean precipitation (70-100ºE, 10ºS-10ºN) for (a) observation (CFSR), (b) CFSv2_RAS, and (c) CFSv2_SAS. The red curves are for $-w^2$ (corresponding to red curves in Fig. 6), and the blue (green) curves are for $-u^2$ ($-v^2$). Unit is $(m/s)^2/(mm/day)$. Note that regressions are calculated for the opposite of w^2, u^2 and v^2, which is to coincide with the sign of surface heat flux into the ocean.

Planned work

- Based on a set of long-term control simulations with different model configurations (e.g., *the atmospheric resolution, convection, and ocean component*), a control configuration that produces the most realistic MJO simulation will be selected;
- Potential predictability of the MJO will be assessed for the selected *control configuration* based on prediction runs with slight perturbations to atmospheric initial conditions taken from its long-term simulation;

- The most important factors governing MJO prediction performance will be isolated by a suite of forecast experiments that will be done with changes to various aspects to the control configuration (e.g., *model resolution, convective parameterization, and representation of air-sea coupling*).

Publications

Peer reviewed:

Zhu, J., W. Wang and A. Kumar, 2017: Simulations of MJO Propagation across the Maritime Continent: Impacts of SST Feedback. *J. Clim.*, **30**: 1689-1704. DOI: 10.1175/JCLI-D-16-0367.1.

Zhu, J., A. Kumar, H.-C. Lee, and H. Wang, 2017: Seasonal Predictions using a Simple Ocean Initialization Scheme. *Clim. Dyn. (published online)*. DOI: 10.1007/s00382-017-3556-6

Zhu, J., and A. Kumar, 2017: Influence of surface nudging on climatological mean and ENSO feedbacks in a coupled model. *Clim. Dyn.* (accepted).

Hu, Z.-Z., A. Kumar, B. Huang, **J. Zhu,** R.-H. Zhang and F.-F. Jin, 2016: Asymmetric evolution of El Niño and La Niña: The recharge/discharge processes and role of the off-equatorial sea surface height anomaly. *Clim. Dyn. (published online)*. DOI: 10.1007/s00382-016-3498-4.

Hu, Z.-Z., A. Kumar, B. Huang, **J. Zhu** and H.-L. Ren, 2017: Interdecadal variations of ENSO around 1999/2000. *J. Meteor. Res.*, **31**: 73-81. DOI: 10.1007/s13351-017-6074-x.

Zhu, J., A. Kumar, W. Wang, Z.-Z. Hu, B. Huang, and M. A. Balmaseda, 2017: Importance of Convective Parameterization in ENSO Predictions. *Geophys. Res. Lett.* (under revision).

Hu, Z.-Z., A. Kumar, **J. Zhu**, B. Huang, Y.-h. Tseng, and X. Wang, 2017: Why Has the Lead Time of Ocean Warm Water Volume to ENSO SST Shortened Since 2000? *Sci. Repts.* (revised)

Presentations

Zhu, J., W. Wang and A. Kumar, 2016: Simulations of MJO Propagation across the Maritime Continent: Impacts of SST Feedback. CLIVAR Open Science Conference, Qingdao, China, 18-25 September 2016.

Zhu, J., 2016: The role of off-equatorial surface temperature anomalies in the 2014 El Niño prediction. CICS Science Conference, College Park, MD, USA, 29-30 November and 1 December, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	7
# of NOAA technical reports	
# of presentations	2
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Science Support for Mesoscale Data Assimilation at EMC & JCSDA

Task Leader	Xiaoyan Zhang
Task Code	EBXZ_MDA2_14 Year 3 & EBXZ_MDA2_16
NOAA Sponsor	Steven Goodman
NOAA Office	GOES-R Program Office
Contribution to CICS Research Themes (%)	Theme 1: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: Work has been completed to verify high-resolution model forecasts of storm and cloud fields over Lake Victoria with SEVIRI all-sky brightness temperatures in the GSI (Grid-point Statistical Interpolation) system. SEVIRI infrared brightness temperatures for the water vapor and window channels have been simulated using the experimental, hourly-updated North American Mesocale forecast system – Rapid Refresh (NAMRR) forecast system and the Community Radiative Transfer Model (CRTM) implemented in the NCEP GSI data assimilation system. With this verification method, three Lake Victoria storm cases were investigated and validated with and without assimilating SEVIRI cloudy radiances. Work has also been done to further study the GSI cloud detection scheme in radiance space instead of brightness temperature space. The corrected cloud detection code directly improved the cloud top height and cloud fraction estimates, which are two crucial factors to assimilate SEVIRI cloudy radiance.

Background

After three years, many works have been done to assimilate radiance data from Meteosat Second Generation (MSG) SEVIR, as a proxy of GOES-R, in NCEP's mesoscale data assimilation systems. We investigated the potential of high resolution geostationary satellite radiance data to improve the numerical prediction of high impact weather. However, we found it is very challenge to obtain the positive impact from assimilating cloudy SEVIRI radiance under overcast condition on the forecast of Lake Victoria storm for the limited understand of cloud. Therefore, in this year we spent many efforts to check the GSI code and understand the theory of cloud for further improving the performance of assimilating all-sky satellite radiance from both geostationary imager instrument and high spectral polar orbit instrument. Cloud detection algorithm is the basic important step to ensure that the overcast radiance is assimilated at the correct level and with the correct cloud amount. The cloud detection scheme impacts the ability to define and accuracy of the cloud fraction and cloud top height for infrared radiances. The other challenge is how to verify the Lake Victoria storm with the lack of suitable data for verifying model forecasts (e.g. rain gauge and radar data). So we developed a radiance based verification tool to verify model forecast storm and cloud forecasts for the Lake Victoria area.

Accomplishments

1. Storm forecast impact

Two major components of the project have been completed to evaluate the impact of assimilating SEVIRI overcast radiances on Lake Victoria storm forecasts. The assimilation studies were performed with the NCEP hybrid 3D-ensemble-variational data assimilation system (hybrid 3DEnVar) and the experimental NAMRR forecast system and the model forecasts were validated by a newly developed, SEVIRI-based verification tool.

Storm cases

March–May and October–December are the long and short rainy seasons respectively every year over the entire Lake Victoria basin. Strong nocturnal thunderstorms over Lake Victoria typically happened in the following two periods. During the most recent research, two storm cases from November 2015 and one from March 2016 were investigated to evaluate the impact of assimilating overcast SEVIRI radiances.

- Case study 1: 0600 UTC, 7 November 2015

  Satellite images showed that storm began to grow south east of Lake Victoria at approximately 0300 UTC (0600 LT) and then moved eastward towards the center of lake at 0600 UTC, disappearing three hours later.
- Case study 2: 0600 UTC, 19 November 2015

  Satellite images showed a storm developing north of Lake Victoria around 2100 UTC 18 November 2015. It later moved into Lake Victoria at 0000 UTC 19 November 2015, and was well developed and propagating westwards at 0300 and 0600 UTC. It appeared to dissipate by 0900UTC.
- Case study 3: 0600 UTC, 9 March 2016

  Satellite images showed this storm developing over Lake Victoria from the north with the larger scale cloud system covering all of the lake from 0000 UTC, 9 March 2016. It appeared to dissipate by 0900 UTC.

Experiment design

The exact same model domain configurations were used for the Lake Victoria storm forecasts as for all experiments presented in the previous status report, except for the data assimilation system, which has been updated to hybrid 3DEnVar from the older 3DVar which was used to test March 2012 Lake Victoria storm case. Therefore, the description about GSI and NAMRR will not be repeated in this report. The results presented in this section were derived from experiments with the NAMRR hourly cycle with both 12-km parent and 4-km nest domains for all three storm cases listed above. The control run experiment (clear) assimilated conventional observations and SEVIRI clear-sky radiances (from the EUMETSAT SEVIRI ASR product, see Table 1) every hour. The cloudy experiment also assimilated the overcast cloudy radiance observations from the ASR product. Both experiments did not assimilate other satellite radiances data in order to facilitate a clear examination of the impact of assimilating the SEVIRI overcast cloudy radiance data. Figure 1 shows the example of assimilating clear-sky radiances and overcast cloudy radiances from the 6.2 µm water vapor channel for these case studies. It was found that cloudy observations add much more data over the Atlantic Ocean (circled area) and a few more observations in equatorial-Africa (oval area).

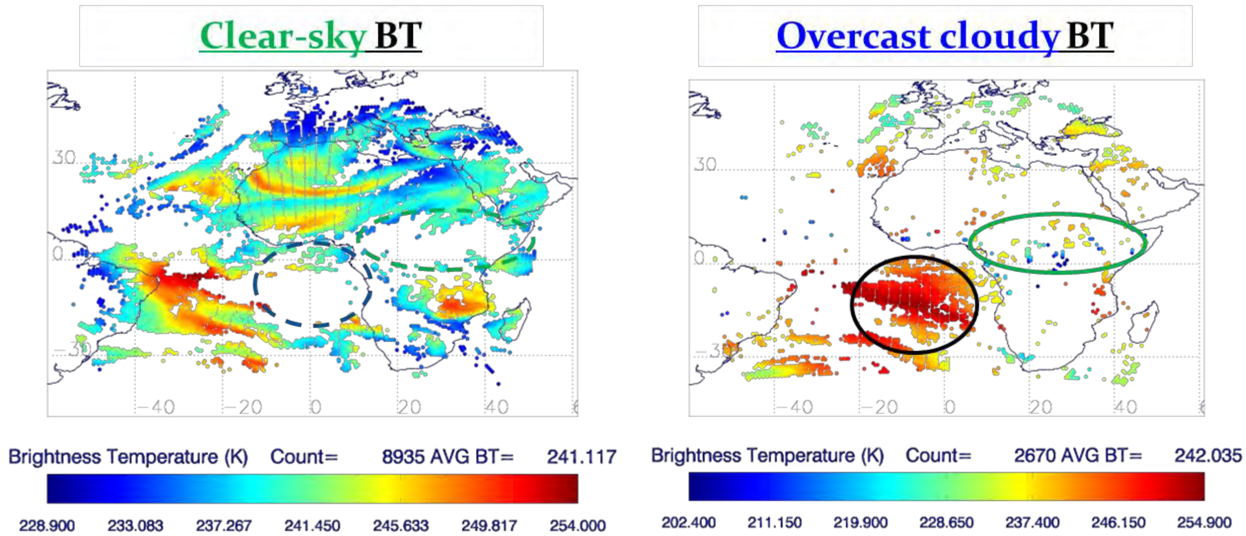


Figure 1: The distribution of clear-sky scenes (left side) and overcast cloudy scenes (right side) from SEVIRI water vapor channel at 6.2 µm brightness temperature in K for the first 1-hour analysis cycle 00 UTC on 7 November 2015.

<u>SEVIRI all-sky based verification tools</u>

The challenge of forecasting Lake Victoria storms is twofold: 1) poor coverage of suitable conventional observations for data assimilation and 2) the lack of suitable data for verifying model forecasts (e.g. rain gauge and radar data). In the past three years of this project, we developed a verification package for the Lake Victoria region by transitioning the NCEP operational forecast verification fit-to-obs, and grid-to-grid packages to the Lake Victoria domain. However, those methods can only evaluate the entire domain forecast skill, and are unable to identify storm features. Furthermore, the fit-to-obs package relies on conventional observations, such as rawinsondes, as the truth to verify model forecasts. But the poor coverage of conventional data over Africa, especially around and over Lake Victoria dramatically reduced the reliability of verification results for this area. Additionally, there is no rawinsonde data that are available near the lake to enable temperature, humidity and wind comparisons with forecast sounding profiles. In contrast, the grid-to-grid method uses the analysis from the Global Forecast System (GFS) as the truth to validate high resolution regional model forecast, but the global analysis resolution is too coarse to identify the convective scale temperature and moisture structures associated with the Lake Victoria storms, thus providing primarily synoptic information. An attempt was also made to use satellite retrieved CMORPH precipitation data to verify model precipitation forecasts, but the accuracy of the retrieval data was too uncertain to be considered reliable, therefore this effort was not pursued any further. Thus, recently, a SEVIRI all-sky radiance based verification tool was developed within GSI to verify model forecast storm and cloud forecasts for the Lake Victoria area. The EUMETSAT SEVIRI ASR product provides six categories of radiance products (Table.1), which allowed us to use all-sky radiance to validate the forecast model in addition to assimilating the cloudy and clear sky radiance data. In order to use this verification tool the GSI must be run to compute the all-sky radiances for every model forecast at any time frequency (e.g. 1-hour, 3-hour) via the use of the CRTM. The inputs for the CRTM to calculate the all-sky radiance are cloud liquid water, cloud ice water, rain water, and snow/graupel in addition to temperature and specific humidity profiles (Fig. 2). Cloud fraction was not yet used as an extra input for the CRTM because this capability with the various cloud overlap schemes is still under development in the CRTM. This verification tool is executed at the SEVIRI pixel location instead of on the model grid (i.e. in observation space), which is a very useful diagnostic of the model forecast in data sparse areas. It is also helpful in diagnosing the model cloud properties in order to improve the model microphysics scheme.

Table 1. ECMETSAT ASR products introduction

Category	uses...
ASR-all	all pixels within a segment (16x16)
ASR-clear	all clear pixels within a segment(16x16)
ASR-cloudy	all cloudy pixels within a segment(16x16)
ASR-low	all low-level cloud pixels within a segment(16x16)
ASR-mid	all mid-level cloud pixels within a segment(16x16)
ASR-high	all high-level cloud pixels within a segment(16x16)

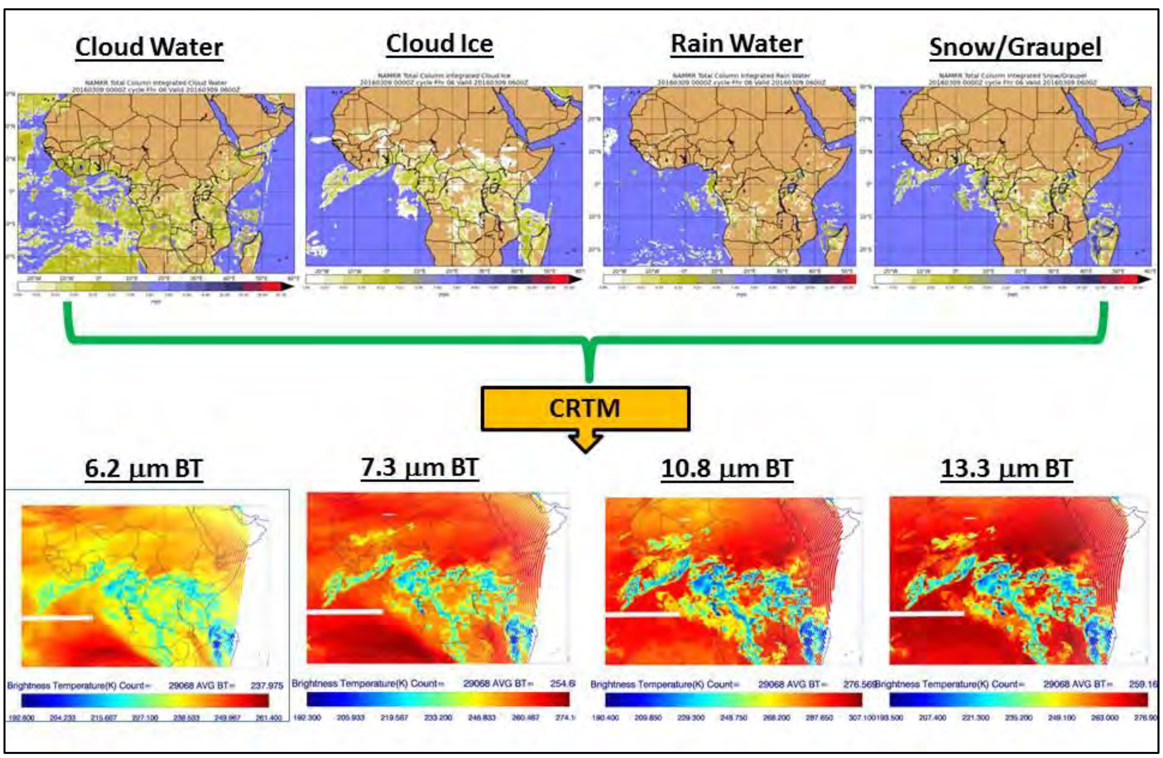


Figure 2: The example of simulated SEVIRI radiance (bottom) from model forecast with CRTM showing the cloud pattern is consistent with the model forecast of cloud water, cloud ice, rain water and snow/graupel at top panel.

Experiment results
The differences between temperature, humidity and wind analysis increments in the SEVIRI overcast cloud experiment and the clear-sky experiment have been examined for the first 6-h analysis cycle. The increment differences at 700 hPa are shown in Figure 3 for temperature (increments for humidity and winds are omitted for brevity). The assimilation of overcast SEVIRI radiances affects temperatures, humidity and winds in areas where overcast observations are assimilated, showing a good correspondence between the location where the observations occur in Figure 1. It is also worth noting that the magnitude of the analysis increment differences between the control and experiment simulations increased along with the hourly catch-up time (Fig. 3).

Figure 4 shows the simulated SEVIRI brightness temperature from a 6-hour forecast (0600 UTC 7 March 2016) compared to observed brightness temperatures at 6.2, 7.3, 10.8, and 13.3 µm band from SEVIRI. It appears that both the clear and the cloudy experiments have similar colder brightness temperatures over Lake Victoria (solid black oval) as observed brightness temperatures seen in the top panel of Fig. 4. This means the model forecast has captured the convective cloud system over the lake but with weaker intensity. Within the entire domain, the NAMRR 6-hour forecast failed to get the middle-west Africa convective cloud system (white solid oval), and over forecasted cloud coverage west of Madagascar (black dashed oval) when compared to SEVIRI. Figure 5 is the root-mean-square error (RMSE) between the models forecast simulated brightness temperature and observed brightness temperature for the entire 4-km domain associated with the first 6 hours of the forecast period. The cloud experiment (red line) has the slightly lower RMSE than clear sky experiment, which means assimilation of overcast radiance did have a small positive impact overall, but did not translate to a direct, highly local improvement in the forecast of storms over Lake Victoria.

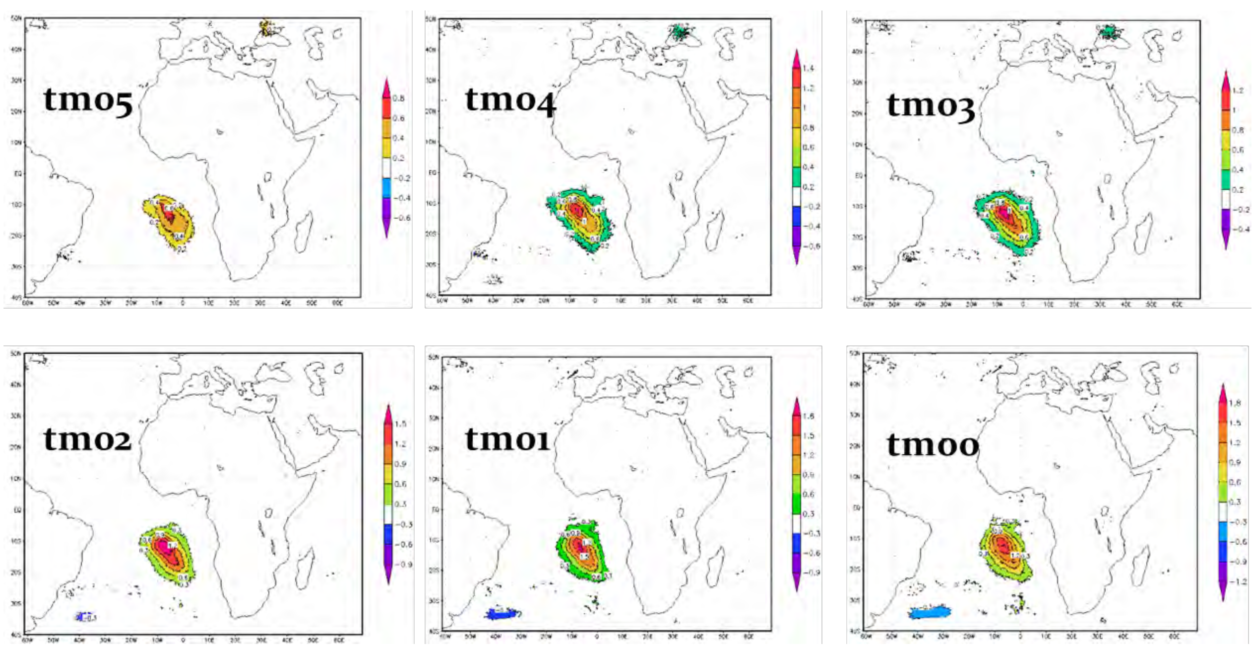


Figure 3. For the first 6-hour analysis cycle (00 UTC on 7 November 2015), temperature increment differences (cloudy experiment minus clear experiment) in K, produced by the overcast SEVIRI observations at 700 hPa. The location of overcast scenes is corresponding to Figure 1.

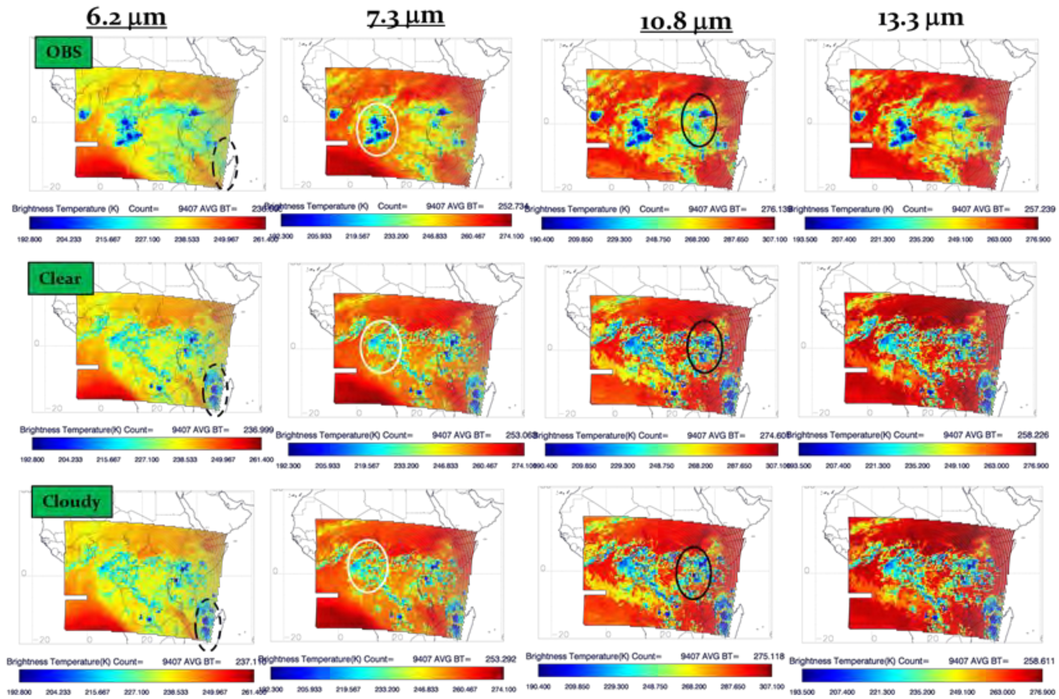


Figure 4. SEVIRI all-sky radiances from observations (top panel), simulated from the clear experiment 6-hour forecast at 06 UTC on 9 March 2016 (middle panel), and simulated from cloudy experiment (bottom panel) at two WV channels (6.2 and 7.3 µm) and two window channels (10.8 and 13.4 µm). The solid black oval circled is the Lake Victoria storm.

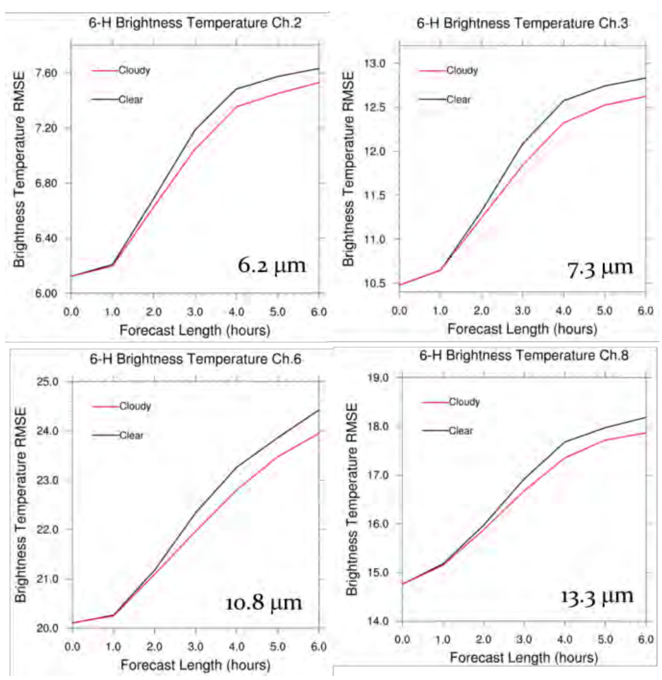


Figure 5. 0-6 hours forecast RMSE profiles against Brightness Temperature. 'Clear' with black line represents the experiment with SEVIRI clear-sky radiance assimilation; 'Cloudy' along with red line represents the experiment with overcast SEVIRI radiance assimilation.

2. Impact of cloud detection

The cloud detection scheme impacts the ability to define and accuracy of the cloud fraction and cloud top height for infrared radiances. It is the most important step to ensure that the overcast radiance is assimilated at the correct level and with the correct cloud amount. Thus, we spent more effort to revisit the modification of the cloud detection algorithm in the GSI from brightness temperature space to radiance space. This technique was developed and tested in the second year of this project but with an unsatisfactory result of large differences between GSI detected cloud fraction and EUMETSAT provided SEVIRI cloud fraction. The reason for the modification is that the current cloud detection in GSI is correct for monochromatic radiances in radiance space, but uses brightness temperatures for channels, thus a discrepancy exists. In recent research, we found the departure of model background and observed radiance with/without bias correction can lead to large differences in cloud top height and cloud fraction which then leads to a different cloudy radiance value, especially for the window channels that are largely affected by cloud. The warm model bias would lead to smaller cloud fraction and to higher estimates of cloud top than truth. This might cause sharp temperature Jacobians at the wrong height and with the wrong amplitude. Thus, it is necessary to correct as many biases in the models and measurements as possible before estimating the cloud top height and cloud fraction. Furthermore these efforts have resulted in improved fits between observation and background for window channels.

A series of experiments were performed to test the radiance space cloud detection scheme in global system for general assimilation of IR instrument and SEVIRI overcast radiance. Figure 6 displays the statistics of 45-day experiments from control run (brightness temperature space cloud detection) and radiance space cloud detection. It shows the total number of clear-sky IASI from Metop-B is reduced after the radiance space cloud detection replaced the original brightness temperature cloud detection in GSI. It also means more cloud was detected by radiance space cloud detection than the GSI original brightness temperature space cloud detection. However, there is no big difference from the departure of background and analysis (O-B) between two experiments. The 5-day forecast anomaly correlation shows neutral impact for both north and south hemisphere too (Figure 7). Therefore, this work will be considered to use in NCEP operations. The improved performance of the GSI cloud detection scheme will be highly beneficial for the implementation of GOES-R radiance assimilation in NCEP data assimilation systems and has the potential to improve its impact on weather forecasts once the data become available.

Planned work

If sufficient resources are available, this work would provide the basis for the implementation of GOES-R radiances in the NCEP data assimilation system with water vapor channels for clear-sky conditions. A proposal for an SEVIRI ASR-like product to be provided for GOES-R has been submitted to the GOES-R product, as currently data volume precludes ingest of the full volume of GOES-R radiances at NCEP. Additionally directly assimilating all-sky radiance with hydrometer variables would be explored as is done with microwave all-sky assimilation in current NCEP operational data assimilation system, building on recent advances in the GSI and CRTM. Lessons learned and experience with SEVIRI and Lake Victoria storms also form a solid foundation to enable the investigation of the assimilation of GOES-R radiances for high impact weather events. The observation space radiance verification system with GOES-R will also be applied.

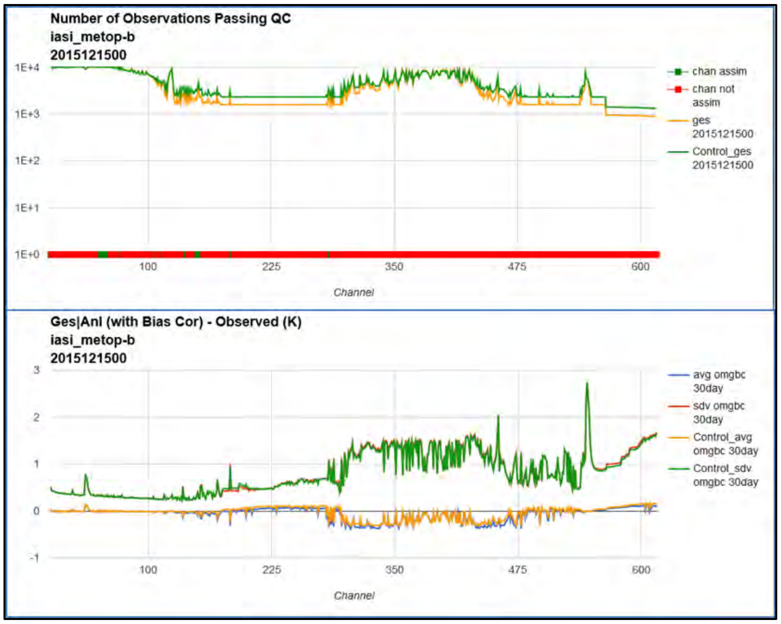


Figure 6. The assimilated IASI_metop-B clear-sky radiance data in NCEP global forecast system (top), and the departure of observation and background (bottom).

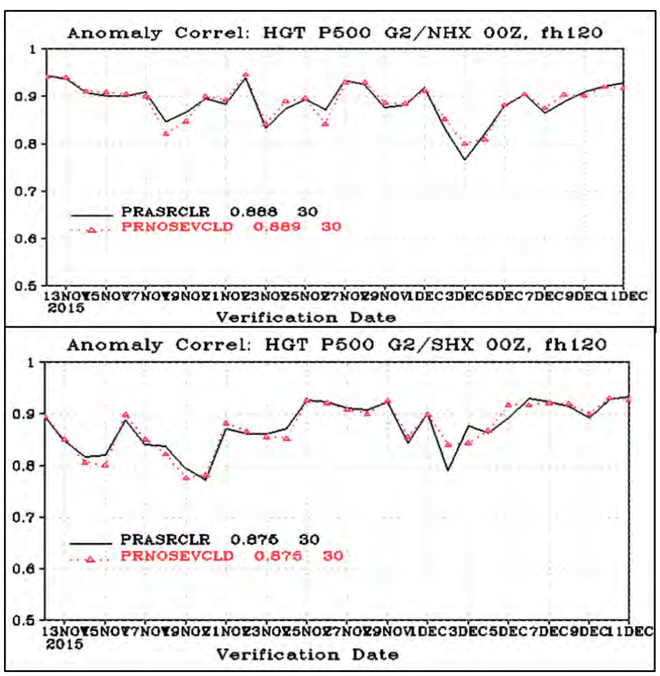


Figure 7. 500-hPa anomaly correlation for 5-day global forecast from 11 November -10 December 2015, top panel is for north hemisphere, and bottom is south hemisphere. 'PRASRCLR' represents the experiments with brightness temperature space cloud detection, and 'PRNOSEVCLD' represents the experiments with radiance space cloud detection.

Presentations

Xiaoyan Z., A. Collard and G. DiMego, 2016: **The Assimilation of Cloud-affected Satellite Infrared Radiance in NCEP 3D-Hybrid system, AGU fall meeting,** San Francisco, California, 11-16 December, 2016

Xiaoyan Z., A. Collard and G. DiMego, 2016: **Lessons Learned from the Assimilation of Cloud-affected SEVIRI Radiance Observations at NCEP, *CICS Science Conference,*** College Park, 29 November – 1 December, 2016

Xiaoyan Z., A. Collard and G. DiMego, 2016: **Validation of Regional Modeling Clouds in Lake Victoria Region with All-sky SEVIRI Radiance** , ***2016 EUMETSAT Conference,*** *Toulouse France, 26-30 September 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	1
# of peer reviewed papers	2
# of NOAA technical reports	1
# of presentations	1
# of graduate students supported by a CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

Advances and Operational Implementation of Proactive QC (PQC) and Ensemble Forecast Sensitivity to R (EFSR) in the Atmosphere and the Ocean

Task Leader:	Eugenia Kalnay
Task Code	EKEK_PQC_15 Year 2
NOAA Sponsor	Mitch Goldberg
NOAA Office	JPSSO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic:	g. Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Accomplishments

During this year we made major excellent progress on the Proactive Quality Control (PQC) project so that we expect to complete it this coming year:

1) We developed a PQC based on Ensemble Forecast Sensitivity to Observations (EFSO, Kalnay et al., 2012) that provides a very clear visual QC estimation for all the observations, indicating the observing systems that are frequently detrimental. Fig. 1 clearly shows that both MODIS winds and PROFILER winds are frequently detrimental.

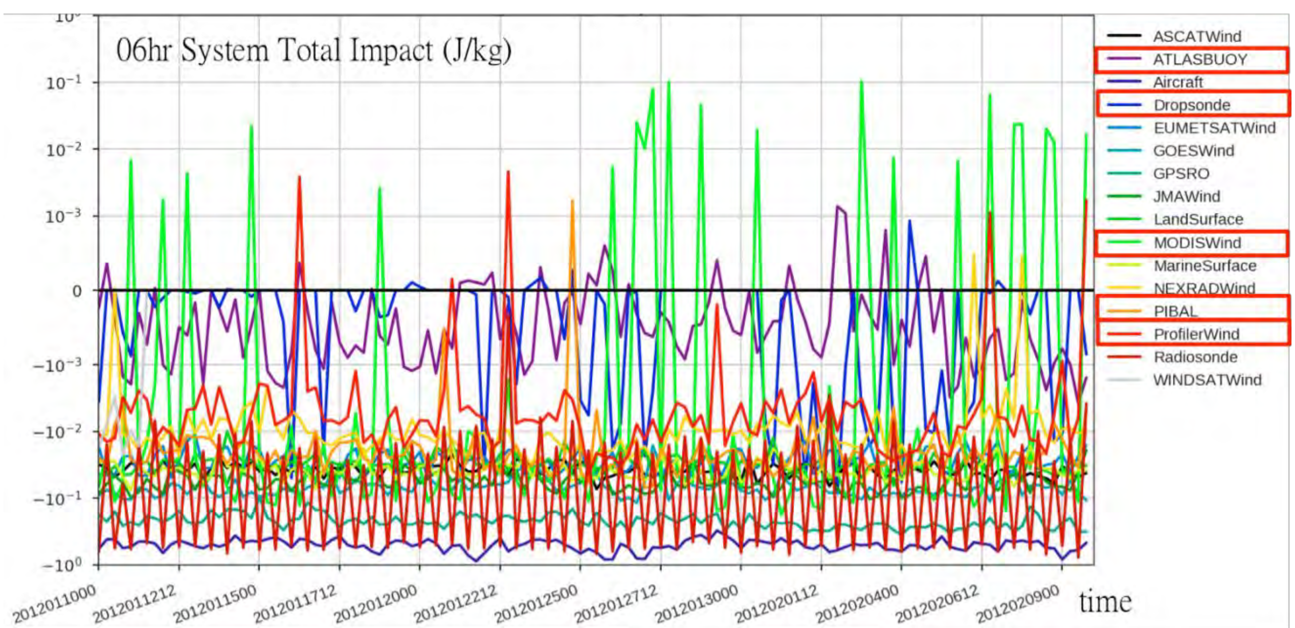
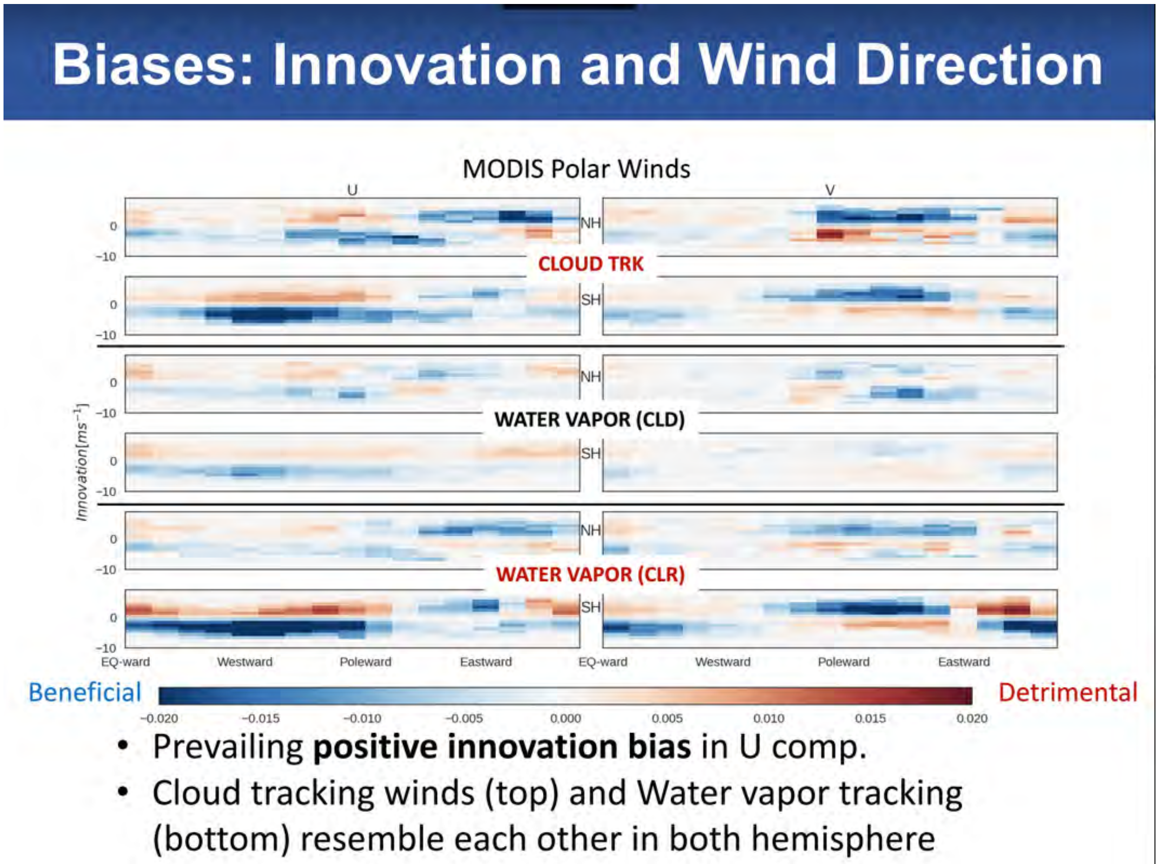


Figure 1: Example of a PQC track record of the total EFSO impact of all the observing systems. A negative EFSO represents an overall BENEFICIAL impact (a reduction of Total Moist Energy of the error), and a positive EFSO indicates that the total impact was DETRIMENTAL. Note that Profiler winds and especially MODIS winds are frequently detrimental. Such simple QC plot can be prepared both regionally and globally, and would provide QC estimates for both current and new instruments.



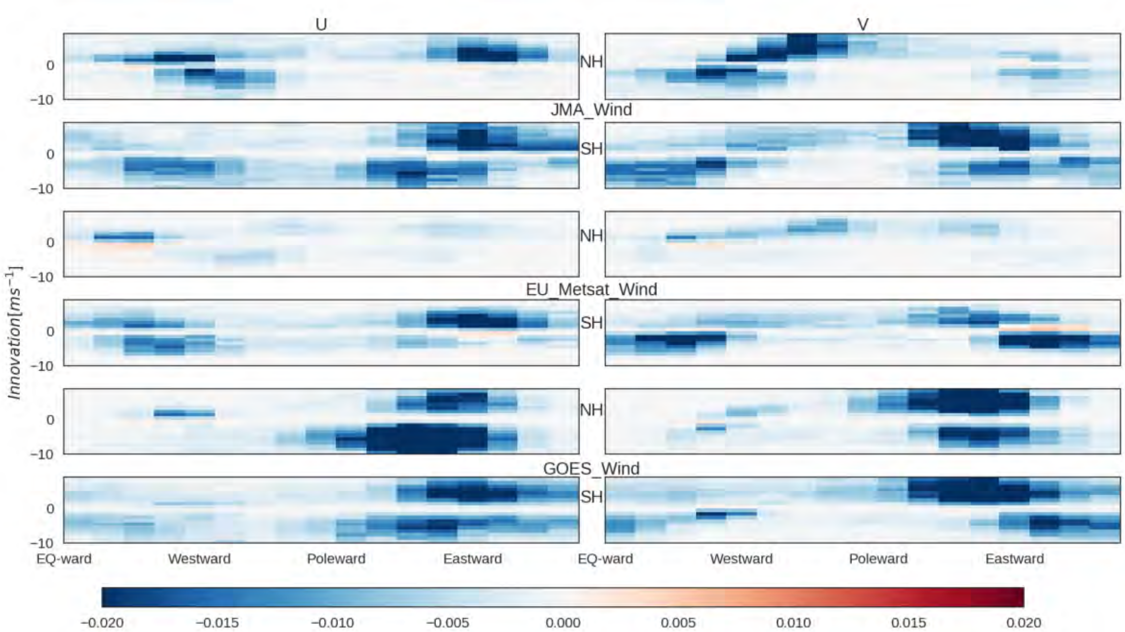


Figure 2. (Top): Characteristic bias of the MODIS WINDS: Positive U innovations (Ob-Fcst), and negative V innovations tend to be detrimental in both hemispheres.(Bottom): By contrast, essentially no biases are apparent in the Geostationary Satellite Winds (JMA, EU-Metsat and GOES winds).

2) We showed that the metadata provided by PQC can be used to identify the characteristics of the error bias, for example the MODIS WINDS classified by type and direction (Fig. 2a), which should provide enough guidance to the instrument algorithm developers to identify the origin of the error. By contrast, other Geostationary Tracked Winds do not show such bias (Fig. 2b).

3) We made a remarkable improvement on the use of the EFSO information. Whereas Ota et al (2013) and Hotta (2014) used "regional skill dropouts" as guidance to identify potential detrimental observations, Tse-Chun Chen developed a simple global threshold approach as well as a method inspired by Anna Trevisan's idea of "Analysis in the Unstable Space". The Hotta (2014) regional PQC method was quite successful, reducing the total global 5-day forecast error by about 0.5%, but the global PQC methods decreased the 5-day forecast errors by about a remarkable 2.5% and 5% respectively (Fig. 3).

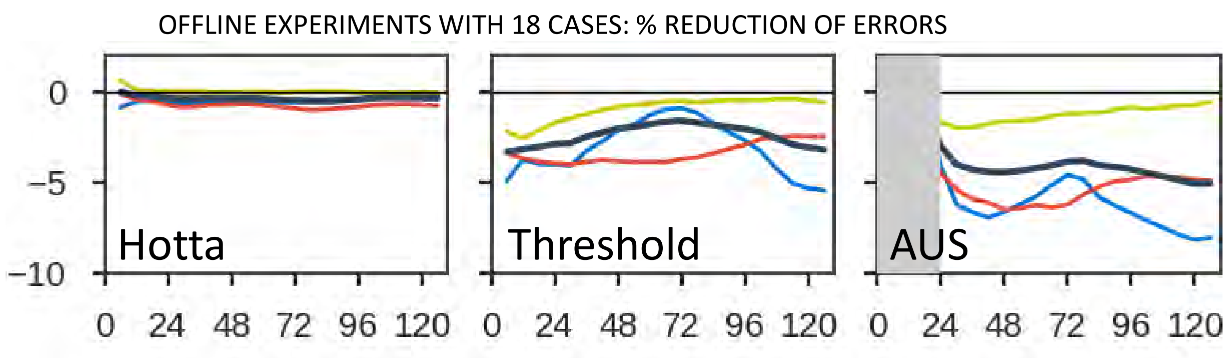


Figure 3: Percentage Reduction of Total Moist Energy of the 5-day forecast errors comparing: Left, the results obtained using the original method of Hotta (2014), Center: the Threshold method of Chen (2016), rejecting all observations with a positive (detrimental) EFSO impact larger than 10^{-5}J/kg, and Right: the method inspired by Anna Trevisan's Analysis in the Unstable Space (AUS) where an observations is accepted only if its 6hr TME is negative (beneficial) and the 24hr reduction of error is even more negative (beneficial). The AUS-like can only be used for reanalysis, since it requires observations and analyses valid after 24hrs.

4) We note that student Tse-Chun Chen made an oral presentation of his PQC research at the annual AMS meeting, and received the award for the best student presentation. We believe that this reflects the revolutionary impact that EFSO and PQC will have when implemented operationally, hopefully within the next year.

CPC Graduate Student Support: ENSO and the Related Precipitation in Recent Reanalyses and CMIP5 Models

Task Leader	Phillip Arkin/Fernando Miralles Wilhelm
Primary Scientist	Ni Dai
Task Code	PAND_BASE_16
NOAA Sponsor	N/A
NOAA Office	N/A
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight This year, we have distinguished the better and worse performing models from total 30 CMIP5 models, in an ENSO perspective, by comparing the models with recent reanalyses and observations. The better performing model group can simulate more realistic spatial patterns, mean magnitude and seasonal variability of ENSO-related precipitation, as well as ENSO-related SST, diabatic heating and circulation structures that resemble those of the reanalyses. We have also studied the connections between ENSO-related precipitation biases in the models and model biases in SST, atmospheric diabatic heating and circulations. The results show that models with stronger cold tongue bias in the SST have more severe negative bias of the equatorial precipitation anomalies over the Pacific, combined with less atmospheric diebatic heating and lower (upper) level convergence (divergence). The bias of double positive anomaly bands over the eastern Pacific in the ENSO-related precipitation is also related to the ENSO-related SST biases in the models.

Background

This task started from 2013 and is a major part of graduate student Ni Dai's Ph.D. research. The goal of this task is to investigate variabilities and biases of El Niño/Southern Oscillation (ENSO) and the related precipitation in recent reanalyses and the Coupled Model Intercomparison Project Phase 5 (CMIP5, Taylor et al. 2012) models. ENSO is the most significant interannual climate phenomenon, and is associated with large-scale changes in sea surface temperature (SST), surface pressure and atmospheric circulation. It is important to understand and predict ENSO and ENSO-related precipitation due to its association with environmental and societal problems in many populated regions. However, since ENSO is a complex atmosphere-ocean coupling phenomenon and has significant variations and nonlinearity in its pattern and strength, it is still difficult for models to accurately simulate the ENSO behavior and the related precipitation. The CMIP5 brings together the most state-of-the-art Coupled Global Climate Models (CGCMs) and provides excellent opportunities to compare inter-model diversity of ENSO and the related precipitation and to further understand ENSO variability. The objectives for this task include:

- To examine the ability of the CMIP5 models in simulating precipitation climatology and ENSO-related precipitation and distinguish better performing models from the others.
- To investigate how the ENSO-related precipitation biases in the CMIP5 models are affected by model biases of precipitation mean states, SST, atmospheric diabatic heating, upper ocean heating, atmospheric/oceanic circulations and air-sea fluxes.
- To study the multi-decadal variability of ENSO-related precipitation in the 20th and 21st century.

Accomplishments

From 2013 to early 2016, our research focused on comparing the precipitation climatology and ENSO-related precipitation in the CMIP5 models with recent developed long-term reanalyses datasets such as the 20th Century reanalysis (20CR) from NOAA (Compo et al. 2011) and statistically Reconstructed Precipitation (REC) from CICS-MD (Smith 2012) in a century-long perspective. The results show that CMIP5 models are able to simulate similar precipitation climatology and mean state of ENSO-related precipitation as the REC and the 20CR, though detailed patterns vary. The biases in the CMIP5 models precipitation climatology such as dry equator over the Pacific Ocean, double- Intertropical Convergence Zones and overly zonal Southern Pacific Convergence Zone exert major influences on simulating ENSO-like precipitation patterns. It is also very possible that the ENSO-related precipitation and drought extremes during the 2nd half of the 20th century are significantly larger than the 1st half. Part of those results above was published in Climate Dynamics journal in July 2016 (see Publications).

This year, we have distinguished the better and worse performing models from total 30 CMIP5 models, in an ENSO-related precipitation perspective, and compared the differences between these two model groups. We have also studied the connections between ENSO-related precipitation biases in the models and model biases in SST, atmospheric diabatic heating and circulations.

By comparing the 30 CMIP5 models with recent reanalyses and observations (20CR, REC, TRMM, ERA-interim, MERRA2 and CFSR), we found that 10 CMIP5 models (CNRM-CERFACS.CNRM-CM5, NCAR.CCSM4, NSF-DOE-NCAR.CESM1-CAM5, CMCC-CMCC-CMS, NSF-DOE-NCAR.CESM1-BGC, CCCma.CanESM2, MIROC.MIROC5, NSF-DOE-NCAR.CESM1-FASTCHEM, NCC.NorESM1-ME and NOAA-GFDL.GFDL-ESM2M) consistently simulate better precipitation climatology and ENSO-related precipitation, while another 10 models perform poorly. The better performing model group can simulate more realistic spatial patterns, mean magnitude and seasonal variability of ENSO-related precipitation, as well as ENSO-related SST, diabatic heating and circulation structures that resemble those of the reanalyses. On the other hand, the worse performing group has more biases, such as 1) overly dry equator over the Pacific Ocean and obvious double- Intertropical Convergence Zones in its precipitation climatology; 2) meridionally narrower and more westward extended center of ENSO-related precipitation over the central Pacific (Fig. 1 lower panel); 3) overly strong cold tongue and meridionally narrower and more westward extended ENSO SST pattern over the eastern to central Pacific (Fig. 1 upper panel); 4) stronger "Hadley-like" but weaker "Walker-like" atmospheric circulations; 5) weak diabatic heating center at 500hPa during ENSO events.

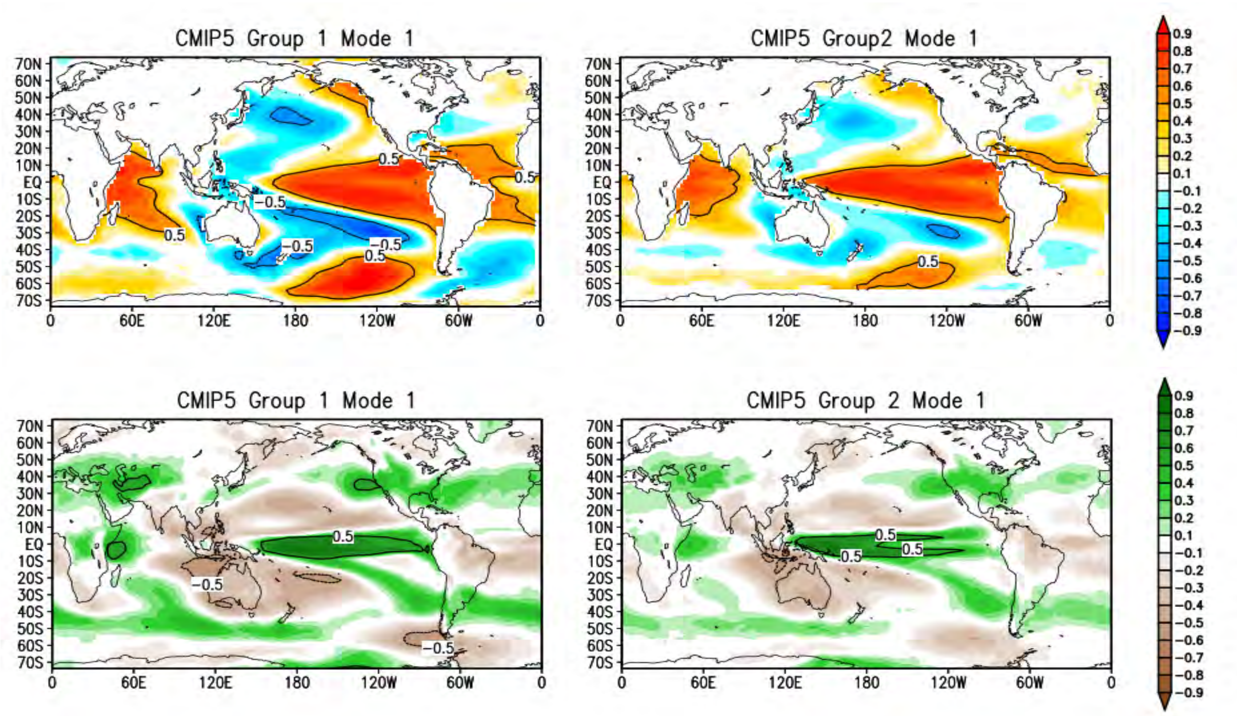


Figure 1. Annual-averaged SVD (Sigular Value Decomposition analysis) first mode the 2 CMIP5 groups. Group 1 is the better performing group and group 2 is the worse performing one. Upper panel: homogenous temporal correlation between the normalized SST field and the SVD first mode of SST time series; lower panel: heterogenous temporal correlation between the normalized precipitation field and the SVD first mode of SST time series.

Our research also reveals that the ENSO SST pattern and temporal variability exert influences on the ENSO-related precipitation in both of the reanalyses and the models. For example, the ENSO-related SST variability may affect the DJF La Niña-related precipitation extremes more than the El Niño ones. The SVD results (Fig. 1) show that the meridional width and zonal length of the ENSO-related positive precipitation anomaly pattern over the tropical Pacific are corresponded with the ones of the ENSO positive SST anomaly pattern. Models with stronger cold tongue bias in the SST have more severe negative bias of the equatorial anomalies over the Pacific, combined with less atmospheric diabetic heating and lower (upper) level convergence (divergence). The bias of double positive anomaly bands over the eastern Pacific in the ENSO-related precipitation is also related to the ENSO-related SST biases in the models.

Planned work

- Continue to study the ENSO diabatic heating distribution and vertical structures in recent reanalyses and CMIP5 models.
- Investigate the biases of ENSO-related air-sea fluxes and upper ocean heating structures in the CMIP5 models.
- Analyze the effects of global warming and multi-decadal variability on the ENSO-related precipitation during the 20^{th} and 21^{st} century.

Publications

Peer reviewed:

Dai, N., and Arkin, P. A. (2016). Twentieth century ENSO-related precipitation mean states in twentieth century reanalysis, reconstructed precipitation and CMIP5 models. *Climate Dynamics*, 1-23.

Non-peer reviewed:

Ni Dai, Sumant Nigam and Phillip A. Arkin. Diabatic heating Differences in ERA-Interim and MERRA-2 Atmospheric Reanalyses, and Intercomparison of the Reanalysis and CMIP5 ENSO Heating Distribution (in preparation)

Products

- Monthly diabatic heating for ERA-interim (0.75° ×0.75°, 37 vertical levels) and MERRA2 (0.625° ×0.5°, 42 vertical levels) from January 1980 to December 2016.
- 2.5° ×2.5° re-gridded CMIP5 historical monthly precipitation rate, sea surface temperature and diabatic heating (17-33 vertical levels) outputs from January 1901 to December 2005.

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

GMU Support of ARL Air Quality Work

Task Leader	Daniel Tong
Task Code	QTQT_GMU_16
NOAA Sponsor	Rick Artz
NOAA Office	OAR/ARL
Percent contribution to CICS Themes	Theme 3, 100%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Percent contribution to NOAA Goals	Goal 3, 100%
Strategic Research Guidance Memo:	1. Integrated Earth System Processes and Predictions

Highlight: 1) GMU scientist helped develop the NOAA unified dust forecasting system; 2) GMU scientist developed a new emission data assimilation algorithm to assess the impact of the 2008 economic recession on US air quality.

Background

This work is part of the collaboration between NOAA Air Resources Laboratory (ARL) and George Mason University to advance atmospheric modeling and satellite data assimilation. The specific tasks are: 1) to improve windblown dust emissions; and 2) to implement NO_x emission data assimilation (EDA) algorithm in NAQFC.

Accomplishments

In the past year, GMU has completed the following tasks:

1. **Implementation of the FENGSHA dust module within HRRR:**

This work focuses on the development of a unified dust modeling capability towards a verified NOAA dust model that can be used within all modeling systems. NOAA has developed and is currently operating the U.S. Dust Forecasting Capability (DFC) in concert with one of its core missions to build a “Weather Ready Nation”. The current DFC is based on the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT, forecast available at http://airquality.weather.gov) model (Draxler et al., 2010). The NOAA DFC has been in operations since November 2011. DFC gives dust forecast in the form of hourly surface fine particulate concentration out to 48 h servicing the continental United States (CONUS). NOAA also now uses a version of a dust module from the Goddard Chemistry Aerosol Radiation and Transport (**GOCART**) model within a version of the Global Forecast System (GFS). In addition, the Rapid Refresh (RR), and the High Resolution Rapid Refresh (HRRR) meteorological model, which are run operationally at NCEP are using an aerosol aware microphysics scheme that currently uses climatological dust fields.

This report summarizes the effort to unify several popular dust-emission modules in various readiness levels for operational implementations and considerations, such as various in-line modules developed for HRRR and the modularized FENGSHA-CMAQ code in the operational NAQFC. As the wind-blown dust storms are prevalent in the Western U.S., we focused on the May 11 2014 storm outbreak in UT, AZ, and CA as a test case for the study. All dust modules exhibit shortcomings that include over predictions, false alarms, and missed events. All modules do “know” that this period is an extreme event for dust emissions. Without better availability of data sets for comparisons, it would be difficult to favor one scheme over the other for global applications. In spite of the shortcomings, for our regional CONUS applications, a version of FENGSHA and one of AFWA are favorable, although the GOCART approach is not far behind (without tuning). Much more evaluation work would be needed to identify a clear "winner". Our preference for further development, testing, and evaluation would be to continue work with the dust emission models that are constantly being developed in the US. These are FENGSHA and GOCART/AFWA. *The most important outcome of this study is that at this point all modules would be ready with minimal effort for inline coupling with an NGGPS core*.

2. Impact of economic recession on US air quality

Satellite and ground observations detected large variability in nitrogen oxides (NO_x) during the 2008 economic recession, but the impact of the recession on air quality has not been quantified. This study combines observed NO_x trends and a regional chemical transport model to quantify the impact of the recession on surface ozone (O_3) levels over the continental United States. The impact is quantified by simulating O_3 concentrations under two emission scenarios: business-as-usual (BAU) and recession. In the BAU case, the emission projection from the Cross-State Air Pollution Rule (CSAPR) is used to estimate the "would-be" NO_x emission level in 2011. In the recession case, the actual NO_2 trends observed from Air Quality System (AQS) ground monitors and the Ozone Monitoring Instrument (OMI) on the Aura satellite are used to obtain "realistic" changes in NO_x emissions. The model prediction with the recession effect agrees better with ground O_3 observations over time and space than the prediction with the BAU emission. The results show that the recession caused a 1-2 ppbv decrease in surface O_3 concentration over the eastern United States, a slight increase (0.5-1 ppbv) over the Rocky Mountain region, and mixed changes in the Pacific West. The gain in air quality benefits during the recession, however, could be quickly offset by the much slower emission reduction rate during the post-recession period.

Planned work

None

Publications

5. Tong, D.Q., L. Pan, W. Chen, L. Lamsal, P. Lee, Y. Tang, H. Kim, S. Kondragunta, I. Stajner, 2016. Impact of the 2008 Global Recession on air quality over the United States: Implications for surface ozone levels from changes in NO_x emissions. Geophysical Research Letter, 43(17), 9280-9288, doi: 10.1002/2016GL069885.
6. Shepherd, Gemma, Enric Terradellas, Alexander Baklanov , Utchang Kang , William A. Sprigg , Slobodan Nickovic , Ali Darvishi Boloorani , Ali Al-Dousari , Sara Basart , Angela Benedetti, Andrea Sealy, Daniel Tong, Xiaoye Zhang, Joy Shumake-Guillemot , Zhang Kebin, Peter Knippertz, Abdulkareem A. A. Mohammed, Moutaz Al-Dabbas, Leilei Cheng, Shinji Otani, Feng Wang, Chengyi Zhang, Sang Boom Ryoo, and Joowan Cha, Gemma Shepherd, editor (2016). Global Assessment of Sand and Dust Storms. United Nations Environment Programme, Nairobi. Retrieved from uneplive.unep.org.
7. Dong, X., Fu, J. S., Huang, K., Tong, D. and G. Zhuang: Model development of dust emission and heterogeneous chemistry within the Community Multiscale Air Quality modeling system and its application over East Asia, Atmos. Chem. Phys., 16, 8157–8180, 2016.
8. 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.

Presentations

Daniel gave ten presentations at national and international conferences.

Other

Community Services

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

Water Quality Monitoring of Coastal Urban Waters Using In-Situ Chemical Measurements and Satellite Remote Sensing Data

Task Leader	Sujay Kaushal
Task Code	SKSK_CWQM_16
NOAA Sponsor	Paul DiGiacomo
NOAA Office	NESDIS/STAR/SOCD
Contribution to CICS Research Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%.
Main CICS Research Topic	Climate Research, Data Assimilation & Modeling
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: Distinct patterns in carbon, nitrogen, and greenhouse gases extending along the urban watershed continuum to coastal zones. Both dissolved organic and inorganic carbon concentrations increase from land to coast whereas nitrogen concentrations show the opposite pattern. Carbon dioxide concentrations also increased along the urban watershed continuum, which suggests that it can be an important transformer of carbon and nutrients to gaseous forms via river metabolism. More rapid changes occur along different river reaches of the urban watershed continuum, which suggests the importance of targeting restoration and management decisions based on position and location. However, higher frequency data from remote sensing is necessary to fill in the gaps when sampling cannot occur to fully understand these spatial patterns.

Background

Large cities can be located in close proximity to coastal waters and therefore directly impact coastal carbon, nitrogen, and phosphorus. In addition to carbon and nutrient sources, urban areas export a large amount of labile organic carbon which can affect coastal water quality such as increased biochemical oxygen demand (BOD) (Kaushal et al. 2014). Thus, a fundamental question is how sources and transformations of carbon and nutrients change across the watershed-coastal interface and how does the "water quality footprint" of urbanization evolve across space and time in coastal waters. The ability to answer this question is critical for guiding and prioritizing river and coastal restoration efforts, which have already cost billions of US dollars.

Traditional *in situ* approaches for carbon and nutrient source tracking are very useful in understanding inputs and transformations of nutrients and organic carbon. However, they are very time consuming and there is generally limited temporal and spatial resolution. Satellite remote sensing is an invaluable tool for improving the understanding and management of coastal regions (DiGiacomo and McManus, 2006). Satellites provide frequent, synoptic observations for a number of key geophysical, biological and biogeochemical parameters (e.g., chlorophyll-a, sea-surface temperature, ocean surface vector winds). A number of recent efforts (e.g., DiGiacomo et al., 2004; Wang et al. 2009; Song et al. 2012) have specifically focused on use of satellite remote sensing data (satellite ocean color radiometry (OCR) observations) to improve understanding and monitoring of water quality in coastal and inland waters. In many cases, however, remote sensing data are used indirectly, *i.e.*, as a proxy or indicator for contaminants contained in freshwater terrestrial runoff that cannot be measured remotely and it is highly necessary that both *in-situ* chemical measurements and satellite remote sensing data are used to monitoring coastal water quality changes with high temporal and spatial resolution.

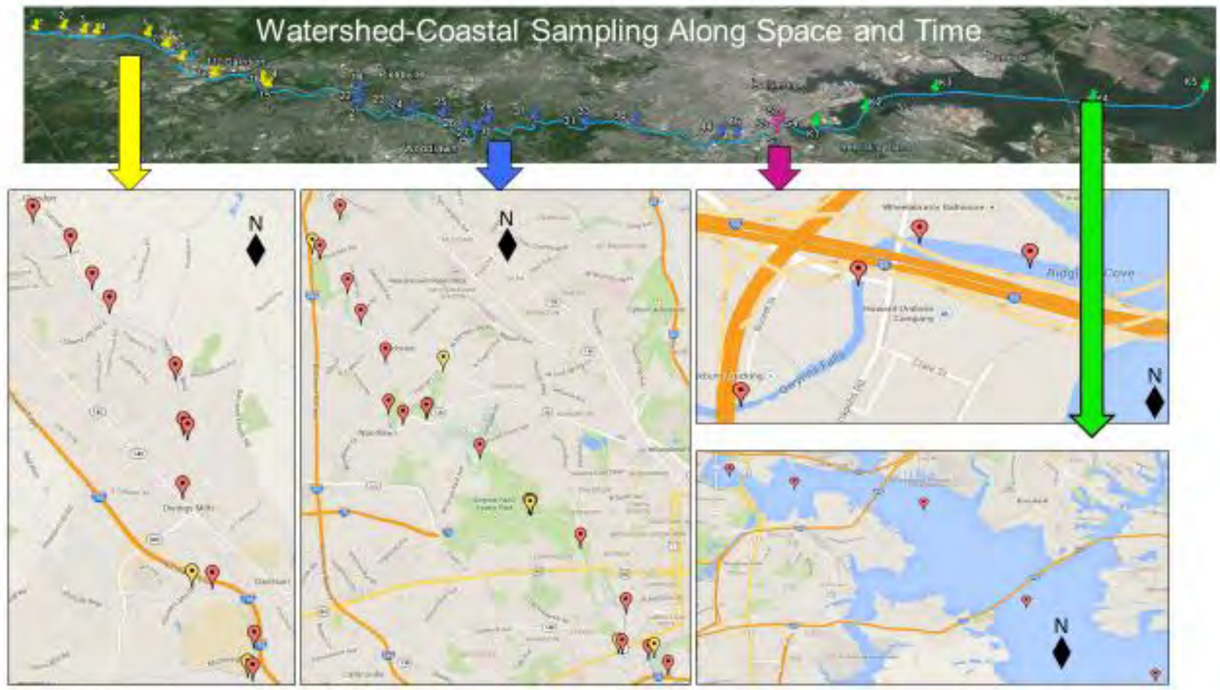


Figure 1: Example of longitudinal sampling across the land-coastal interface. We have worked on multiple sampling campaigns analyzing greenhouse gases, carbon, nutrients, base cations, dissolved inorganic carbon, and other parameters.

Accomplishments

We have collected *in situ* water quality samples along seasonal transects from the Gwynns Falls watershed to the Baltimore Harbor. These transects were chosen because Baltimore is one of the major cities in Chesapeake Bay watershed, which has experienced water quality problems receiving recent national attention. Furthermore, we can leverage data collected from the NSF supported Baltimore Long-Term Ecological Research (LTER) program (www.beslter.org).

Specifically, seasonal synoptic sampling campaigns were conducted along the Gwynns Falls and Baltimore Harbor, from the mouth of the Gwynns Falls (a NSF-funded Long-Term Ecological Research site) to the mainstem of the Chesapeake Bay. Coordinated sampling along land and coastal waters can provide a holistic view of how does the "water quality footprint" of urbanization propagate and dissipate across space and time in urban coastal waters.

Lab chemical analyses at UMD include chl-a, TSS, nutrients and carbon, carbon stable isotopes, greenhouse gases, 3D fluorescence of or dissolved organic matter (DOM). 3D fluorescence and isotopic composition will be used for tracking the source of nutrients and organic matter and the occurrence of transformation to greenhouse gases. Other in situ measurements include CTD and other water quality measurements: water temperature, salinity, chl-a fluorescence, light absorption and attenuation coefficients, turbidity, dissolved oxygen, and pH. In order to study the dynamics of various water quality parameters across the transects, our collaborators of NOAA will also utilize the tool of satellite radiometric remote sensing. Depending on what water quality products are developed with remote sensing proxies, we can characterize the continuum of coastal water quality conditions from upstream headwaters to downstream coastal zones. We expect that such a study can provide us insights into the evolution of nutrients and carbon on the coastal end of the watershed-coastal interface.

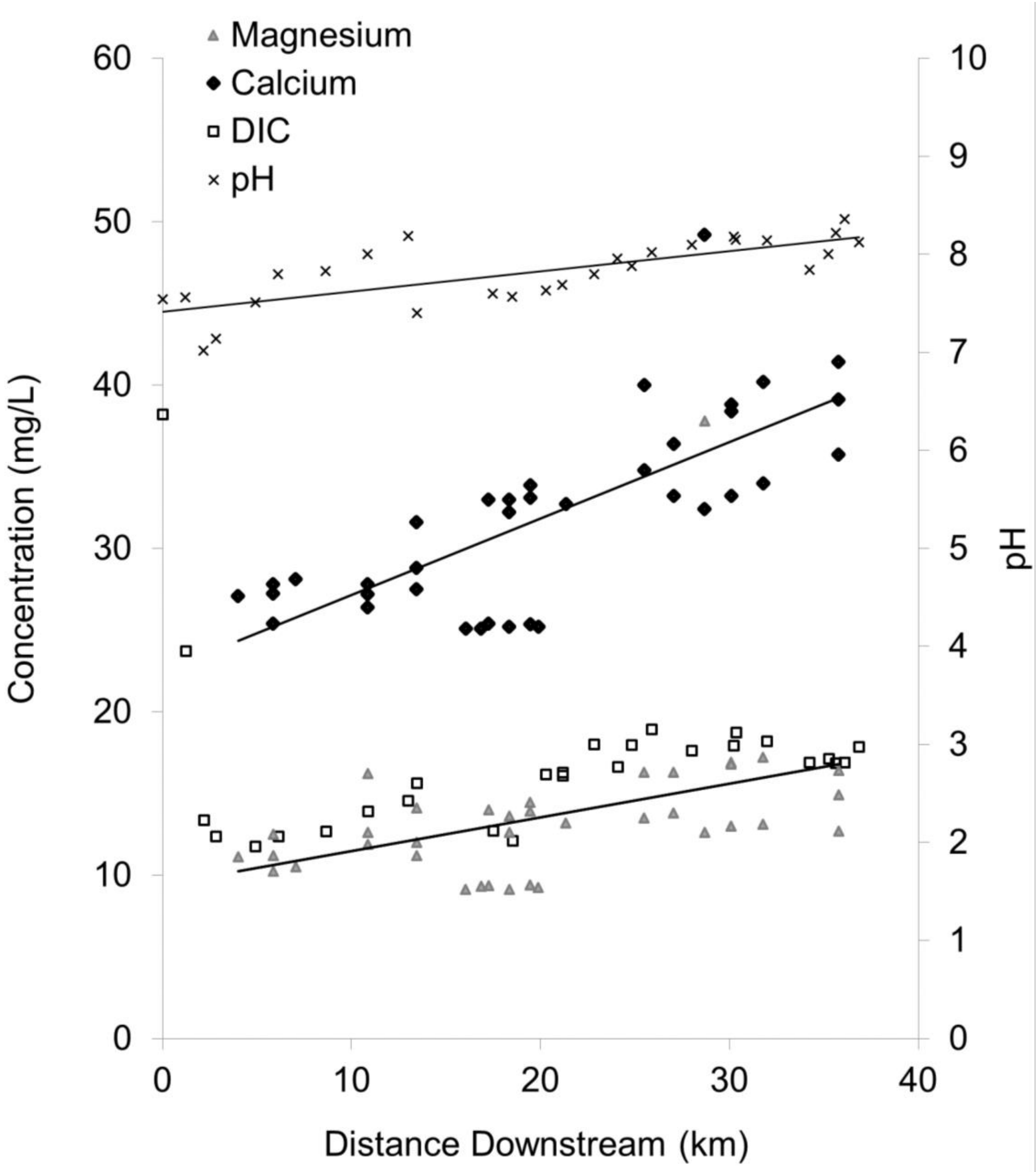


Figure 2: Example of observed longitudinal trends in base cations and dissolved inorganic carbon (alkalinity) that can influence buffering of coastal ocean acidification from urban watersheds. We recently completed a sampling campaign where we can analyze these types of data related to coastal ocean acidification further and will present at an upcoming CLIVAR meeting.

Field work and chemical analyses have been conducted by a technician of the Biogeochemistry Lab at the University of Maryland, Shahan Haq. *Shahan is now enrolled as a graduate student in the Department of Geology at UMD under the supervision of Dr. Sujay Kaushal.* Dr. Kaushal will continue help to advise and monitor the research associated with water quality data analysis and publications.

Planned work

This is a continuing project over multiple years. We will continue analyses of carbon, nutrients, and greenhouse gases, and work on papers from the project. Our results will also be presented at an upcoming CLIVAR meeting as an invited keynote talk.

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

Incorporation of Near-Real-Time Suomi NPP Land Surface Temperature Data into the NCEP Land Modeling Suite

Task Leader	Zhen Song
Task Code	SLZS_NLMS_15 Year 2
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 40%; Theme 3: 60%.
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal1:60%; Goal 2: 40%; Goal 3: 0%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

This report summarizes the ongoing project "Incorporation of Near-Real-Time Suomi NPP Land Surface Temperature (LST) Data into the NCEP Land Modeling Suite".
The VIIRS LST environmental data record (EDR) generated by the JPSS Interface Data Processing Segment (IDPS) provides effective land surface skin temperature value at the time of overpass with spatial resolution of 750m at nadir, which is a unique data source of obtaining LST information at regional and global scales. However, due to the complexity of land-atmosphere interactions as well as unavailability of high quality, real-time products, satellite-derived land surface temperature is not well incorporated in improving numerical weather forecast.

The goal of this project is to accelerate the use of VIIRS LST in a suite of operational numerical prediction models at NOAA's National Centers for Environmental Prediction, including NCEP NAM, NCEP GFS and NLDAS, with two steps: (1) Produce Global Gridded VIIRS LST data at 0.036° and hourly resolution for NCEP NAM, GFS, and NLDAS;(2) Apply gridded VIIRS LST data to evaluate the model performance of NAM, GFS, and NLDAS.

Accomplishments

During this funding cycle we mainly made following accomplishments: produce the gridded VIIRS LST in routine mode at STAR server; develop the diurnal temperature model based on GOES LST datasets and apply the models to VIIRS hourly LST interpolation; produce the hourly interpolated LST data for EMC people. In detail, the accomplishments include:

1) Produce the gridded VIIRS LST in routine mode at STAR server

2) Develop the diurnal temperature model based on GOES LST datasets for CONUS region
   Build monthly diurnal temperature model (DTM) by geostationary LST (GOES):
   - Collect monthly diurnal LST from GOES in different groups divided by longitude, latitude, land cover and elevation for CONUS
   - Build the diurnal temperature model according to *Gottsche and Olesen* semi-physical model by non-linear least square fit

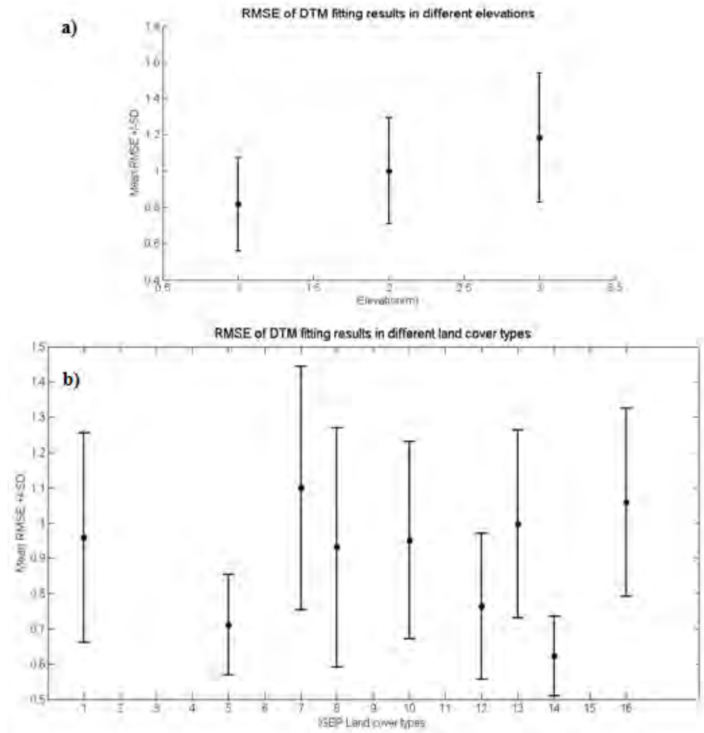


Figure 1. Diurnal temperature model fitting accuracy in (a) different elevations and (b) different land cover types

3) Apply the diurnal temperature model to produce VIIRS hourly interpolated LST
   Based on the diurnal temperature model, instantaneous VIIRS LST is interpolated to the nearest hourly LST. First, the observed daytime and nighttime VIIRS LST are involved to correct the monthly DTM for a specific day; second, the hourly interpolated LST is calculated based on the corrected DTM. The hourly interpolated LST has been validated by SURFRAD ground measurements and the overall accuracy is suitable for model evaluation.

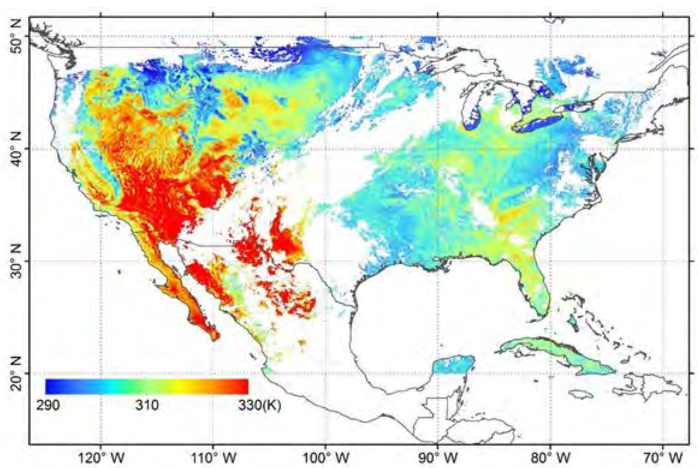


Figure 2. VIIRS Interpolated LST for 19Z and 20Z, June, 25, 2016

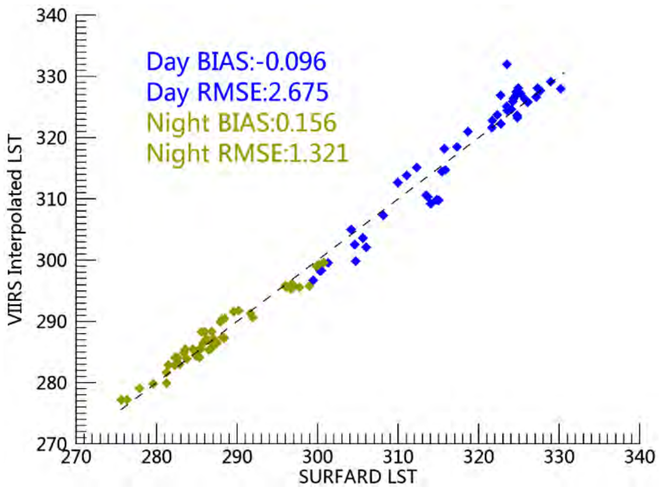


Figure 3. VIIRS interpolated LST validation by SURFRAD ground measurements for Aug.2015

4) Produce the hourly interpolated LST data for EMC people for model LST evaluation

Planned work

- Develop the software package for VIIRS hourly LST producing.
- Evaluate the model LST by gridded hourly VIIRS LST.

Products

- VIIRS Hourly LST

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

New products developed: VIIRS Hourly LST

Improving Hurricane and Coastal QPFs through Direct Assimilation of GOES-R ABI Radiances in Regional Models

Task Leader:	Xiaolei Zou
Task Code:	XZXZ_ABIR_16
NOAA Sponsor:	Steve Goodman
NOAA Office:	NESDIS/STAR
Contribution to CICS Research Themes (%):	Theme 1: 100%
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%):	Goal 1: 100%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: A new infrared-only cloud mask algorithm was developed for AHI/ABI data assimilation, which is critical when visible and near-infrared channels are not inputted to NWP systems.

Background

Direct assimilation of radiance observations from GOES imagers on board Geostationary Operational Environmental Satellites (GOES) lagged behind the assimilation of radiances from POES. Since the GOES data are unique for capturing fast evolving weather systems such as tropical cyclones convections. In order to get ready for direct assimilation of GOES-R Advanced Baseline Imager (ABI) radiance measurements, which becomes available only recently. Some test runs could be conducted to assimilate the radiance data from a similar instrument —— the Advanced Himawari Imager (AHI). Specifically, the AHI infrared channels are assimilated into the Hurricane Weather Research and Forecasting (HWRF) system and Advance WRF (ARW) models. Both HWRF and ARW employ the National Centers for Environmental Prediction (NCEP) Gridpoint Statistical Interpolation (GSI) system for data assimilation. ABI and AHI have a total of three visible channels (AHI channels 1-3), three near infrared channels (AHI channels 4-6) and 10 infrared channels (AHI channels 7-16), while the previous and current GOES-11 to -15 have only one visible channel (GOES channel 1), one near infrared channel (GOES channel 2) and three infrared channels. Although a capability of GOES-11/-12 and GOES-13/-15 imager radiance assimilation were added to ARW/GSI [Zou et al., 2011; Qin et al., 2013] and HWRF/GSI [Zou et al., 2015] respectively, assimilation of ABI and AHI requires a new set of schemes related to bias estimate, cloud detection and quality control (QC) of AHI data.

Accomplishments

Assimilation of infrared channel radiances provided by geostationary imagers requires an infrared only cloud mask (CM) algorithm that could identify cloud-contaminated pixels without involving any visible or near-infrared channels. Such an infrared-only CM algorithm is developed using the Advanced Himawari Imager (AHI) radiance observations in this paper. It consists of a new CM test for optically thin clouds, two modified Advanced Baseline Imager (ABI) CM tests and seven other ABI CM tests. These ten CM tests are used to generate composite CMs for AHI data, which are validated by using the Moderate Resolution Imaging Spectroradiometer (MODIS) CMs. It is shown that the Probability of Correct Typing (PCT) of the new CM algorithm over ocean and land is 89.59% and 90.96%, respectively, and the corresponding Leakage Rate (LR) is 6.18% and 4.85%, respectively, The new infrared only CM algorithm achieves a higher PCT and a lower false alarm rate over ocean than the *Clouds from the AVHRR Extended*

System (CLAVR-x) that makes not only the infrared channels, but also visible and near-infrared channels. However, a slightly higher LR of 7.54% occurred over land during daytime in the presence of low stratus clouds, which requires further investigation. Positive impacts are obtained on quantitative precipitation forecasts (QPFs) associated with a typical summer precipitation case over eastern China in both setups, i.e., one assimilating all ten AHI infrared channels (AHIA) and the other assimilating only four GOES-like AHI channels (AHIG).

Planned work up to 250 words

- Complete updates of CRTM fast transmittance model using updated post-launch updated SRF
- Complete assessments of new CRTM cloud scattering LUTs for ABI cloudy-scene simulation
- Fine-tune AHI IR-only cloud mask algorithm in GSI for ABI applications
- Complete ABI bias estimate in clear-sky conditions
- Complete a comparison of data assimilation and forecast results with and without AHI and/or ABI radiance assimilations
- Publish the work on AHI/ABI data assimilation in refereed journals

Publications

Zhuge, X. and X. Zou, 2016: Test of a modified infrared only ABI cloud mask algorithm for AHI radiance observations. *J. App. Meteor. Climatol.*, **55**, 2529-2546. doi: 10.1175/JAMC-D-16-0254.1.

Qin, Z., X. Zou and F. Weng, 2017: Impacts of assimilating all or GOES-like AHI infrared channels radiances on quantitative precipitation forecasts over Land. *Quart. J. Roy. Meteor. Soc.,* (submitted)

Presentations

The 97th Annual Meeting of America Meteorology Society, 22-26 January 2017, Seattle, Washington. A poster presentation entitled "Assimilation of AHI Infrared Radiance Measurements for Improved Typhoon Track and Intensity Forecasts Using HWRF" by Zou, Qin, Zhuge, and Weng at the Fifth AMS Symposium on the Joint Center for Satellite Data Assimilation.

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

Advance CrIS Radiance Assimilation in GSI to Improve Forecasts of High-Impact Weather Events

Task Leader:	Xiaolei Zou
Task Code:	XZXZ_CRIS_16
NOAA Sponsor:	Mitch Goldberg
NOAA Office:	NESDIS/STAR
Contribution to CICS Research Themes (%):	Theme 1: 100%
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%):	Goal 1: 100%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: An innovative double CO2 cloud detection algorithm was developed for improving CrIS data assimilation.

Background

Cloud detection is an important step that remains to be the largest source of uncertainty for satellite infrared data assimilation in numerical weather prediction (NWP). If clouds-affected radiances are treated as clear-sky measurements and then assimilated into NWP models, then the analysis fields would be biased and the NWP forecast skills could be significantly degraded. The optically thin cirrus clouds (e.g., optical depths less than 1) are more difficult to detect than thick clouds. Cirrus clouds regularly cover about 20% of the globe. They are optically thin due to a low concentration of ice particles, not lack of a significant amount of large, non-spherical ice crystals. McNally and Watts (2003) developed a cloud detection algorithm for high-spectral-resolution infrared sounders by comparing the difference spectrum between the observations and cloud-free model simulations (i.e., $O\text{-}B^{clear}$). In the presence of cloud, the $O\text{-}B^{clear}$ difference spectrum would be closest to the $B^{cloud}\text{-}B^{clear}$ difference spectrum assuming that the simulated clear and cloudy spectra were free of error. However, errors in the simulations of the background clear and cloudy spectra and in the background atmospheric state itself can enter the minimum residual estimate. The infrared semi-transparent clouds (e.g. thin cirrus) are poorly detected from the current GSI quality control process and thus the cloud-affected CrIS radiances could be treated as clear-sky radiances and assimilated wrongly into the operational systems. In contrast to the model-based cloud detection in the GSI system, an observation-based algorithm need to be developed.

Accomplishments

Detection of clouds within certain vertical layers of the atmospheric from satellite infrared instruments is challenging, especially of those optically thin clouds due to their small thermal contrasts to the background. We developed a new method for cloud detection using the Cross-track Infrared Sounder (CrIS) hyperspectral radiances at shortwave (~4.3 m) and longwave (~15 m) CO2 bands. Specifically, CrIS longwave channels are firstly paired with shortwave channels based on weighting function altitudes and sensitivity to clouds. A linear relationship of brightness temperatures between each paired channel is then derived for predicting the shortwave channel from the longwave channel in clear-sky conditions. A cloud emission and scattering index (CESI) can finally be defined as the difference of the shortwave channel between the clear-sky, regression model predicted and the observed brightness temperatures. Spatial distributions of such derived CESI for several paired channels in the troposphere are examined for a winter storm that occurred in the eastern part of the United States during 22-24 January 2016. It is shown that the CESI values over the storm regions with optically thin cirrus, fog and supercooled water clouds are positively larger than those over optically thick opaque ice and overshooting clouds or in clear-sky conditions. Of particular interest is that an area of fog and water clouds over Gulf of Mexico, which are indicated by the Visible Infrared Imaging Radiometer Suite (VIIRS) day and night band (DNB) observations, is identified by the CESI. The global distributions of CESIs derived from CrIS double CO2 bands with weighting functions peaks located at about 280 hPa and 231 hPa agree well with the distributions of ice cloud optical thickness contained in the AIRS Version 6 data set (Fig. 1).

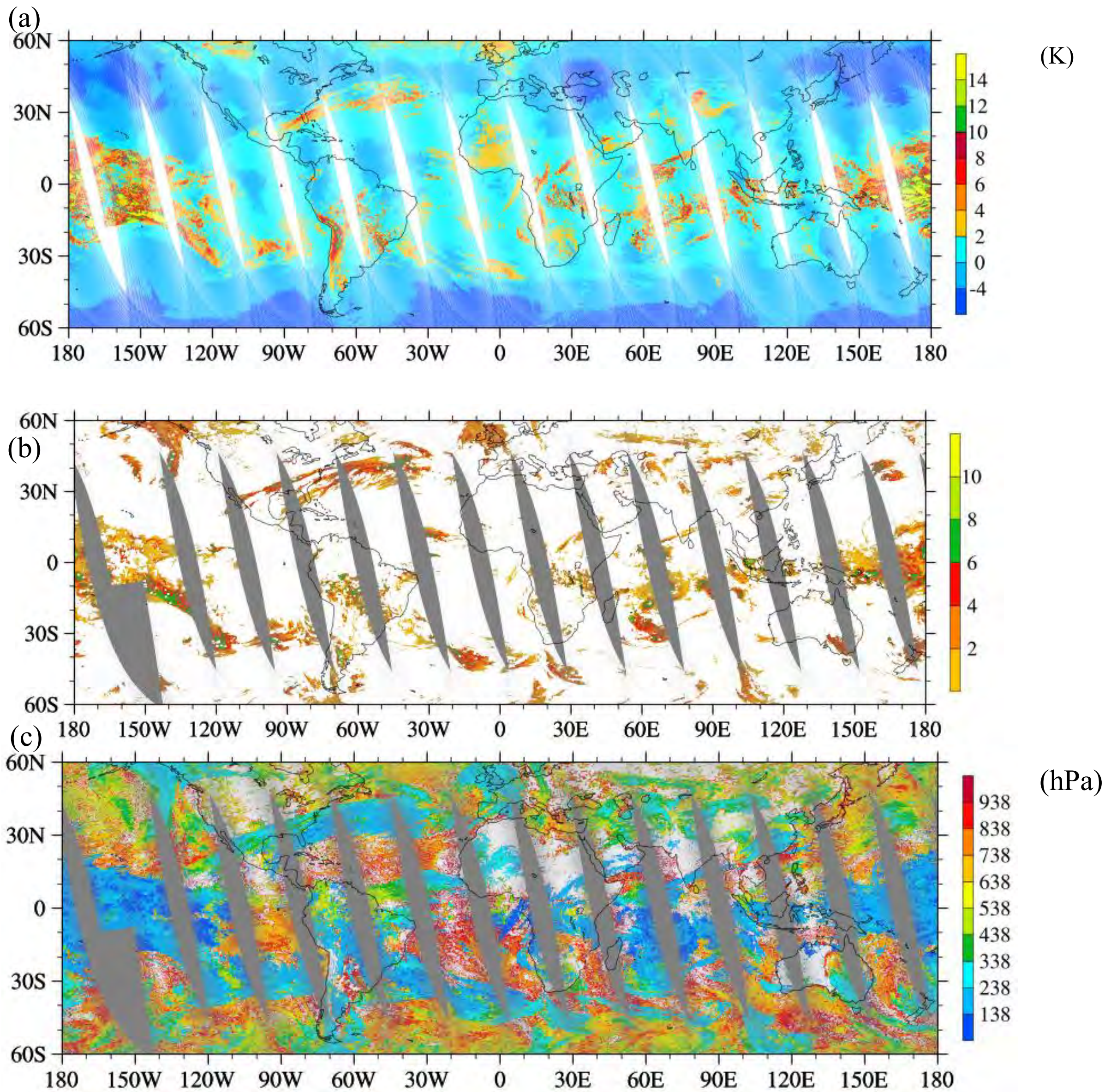


Figure 1: Spatial distributions of (a) CESI of pair 3 (~321 hPa), (b) AIRS ice cloud optical depth and (c) AIRS cloud toppressure at CrIS ascending node on 1 January 2016.

Planned work

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

Publications

Lin, L., X. Zou and F. Weng, 2017: Combining CrIS double CO2 bands for detecting clouds located in different vertical layers of the atmosphere. *J. Geophy. Res.*, doi: 10.1002/2016JD025505.

Presentations

The 97th Annual Meeting of America Meteorology Society, 22-26 January 2017, Seattle, Washington. An oral presentation entitled "Impacts of a New Bias Estimate and a New Cloud Detection Algorithm on CrIS Data Assimilation" by Zou, Weng, Lin and Li at the 13th Annual Symposium on New Generation Operational Environmental Satellite Systems (Post Launch Activities for GOES-R and JPSS)

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

CRTM Upgrades and Applications for GOES-R Program

Task Leader:	Xiaolei Zou
Task Code:	XZXZ_CRTM_16
NOAA Sponsor:	Jaime Daniels
NOAA Office:	NESDIS/STAR
Contribution to CICS Research Themes (%):	Theme 1: 100%
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%):	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: An action was taken to correct a mistake found in CRTM that it failed to incorporate the new spectral response functions of AHI after the launch of Himawari-8.

Background

In preparing for the incoming launch of the GOES-R, we will update the current CRTM to accommodate for both the scientific and operational needs for the future applications of GOES-R ABI data. Work related to GOES-R algorithm developments includes updating the CRTM capability for simulating AHI and ABI visible channel reflectance for aerosols and clouds; updating and refining look-up-tables (LUT) for clouds, aerosols and precipitations; and updating surface emissivity datasets for surface-sensitive AHI/ABI channels. In order to enhance the calibration and validation (CalVal) science activities for GOES-R, CRTM will also be extended from the current scalar radiative transfer model to a new vector radiative transfer model. The vector 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). An implementation of the new surface emissivity models to the vector CRTM will also play a key role to the instrument CalVal process. Work related to GOES-R Algorithm Working Group (AWG) applications in numerical weather prediction (NWP) include cloud detection, bias estimation, and data thinning, which are works that require careful investigation and be completed before any AHI/ABI data can be effectively assimilated in NWP models.

Accomplishments

Starting 2014, the new generation of Japanese geostationary meteorological satellite carries an Advanced Himawari Imager (AHI) to provide the observations of visible, near-infrared and infrared with much improved spatial and temporal resolutions. For applications of the AHI measurements in numerical weather prediction (NWP) data assimilation systems, the biases of the AHI brightness temperatures at channels 7-16 from the model simulations are firstly characterized and evaluated using both Community Radiative Transfer Model (CRTM) and Radiative Transfer for TIROS Operational Vertical Sounder (RTTOV). It is found that AHI biases under clear atmospheres are independent of satellite zenith angle except for channel 7. The biases of three water vapor channels increase with scene brightness temperatures and the rest of infrared channels are nearly constant except at high brightness temperatures. The AHI biases at all the infrared channels over ocean and land are less than 0.6 K and 1.2 K, respectively. The bias differences between CRTM and RTTOV are small except for the two upper tropospheric water vapor channels 8-9 and the low tropospheric carbon dioxide channel 16. Since the inputs used for simulations are the same for CRTM and RTTOV, the differential biases at the water vapor channels may be associated with the subtle difference in forward models. Figure 1 shows the SRFs and the center frequencies of AHI channel 16 with and without using the updated SRFs. The center frequency of channel 6 shifted from a larger value (753.37 cm^{-1}) to a smaller value (754.13 cm^{-1}).

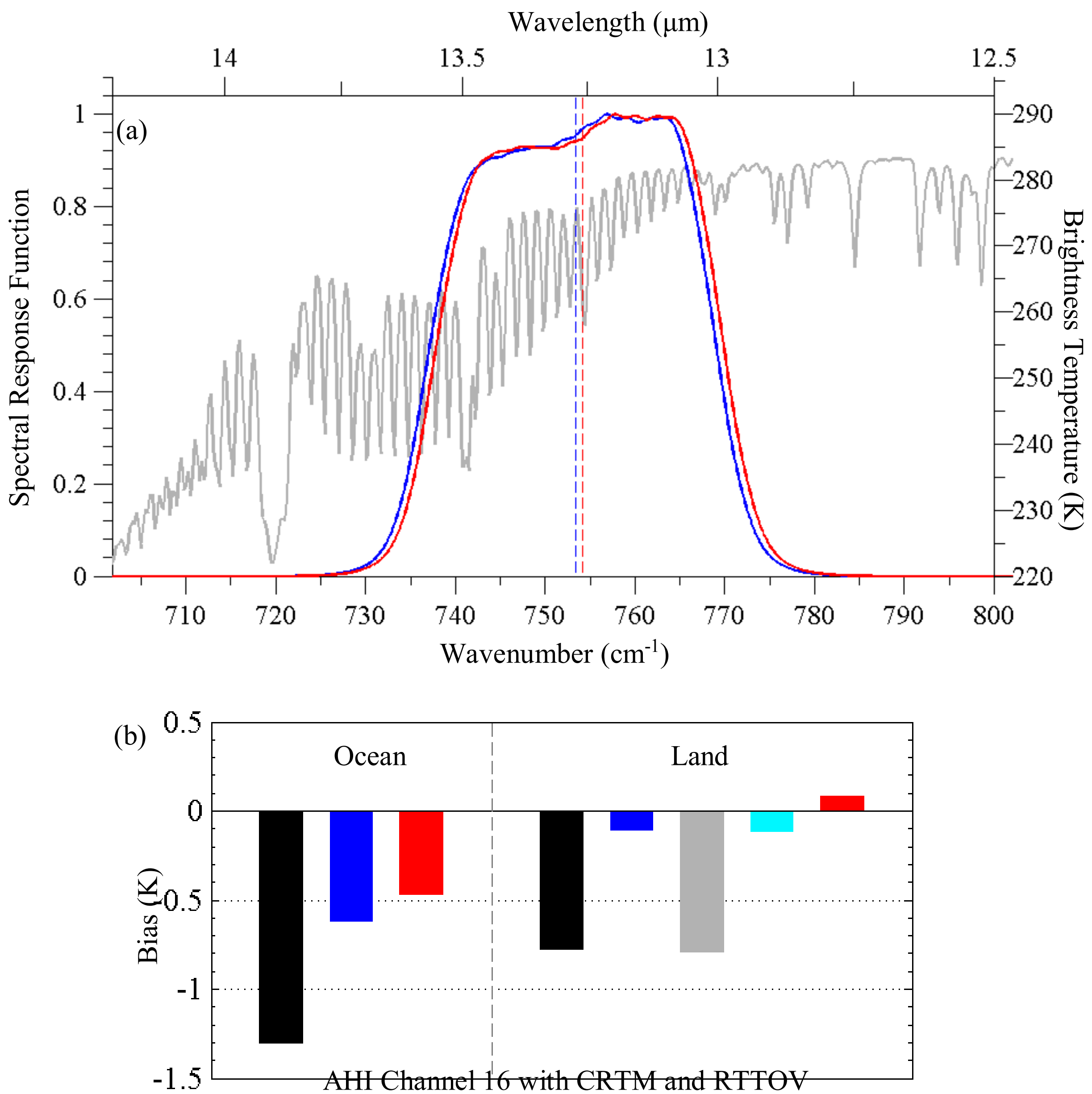


Figure 1. (a) Spectral response functions (curves) and the center frequencies of AHI channel 16 with (blue) and without (red) using the updated SRFs, as well as a typical IASI brightness temperatures simulated with CRTM (grey). (b) Biases of AHI channel 16 with model simulations generated by CRTM with old SRF (black), CRTM with new SRF (blue), RTTOV with new SRF (red), CRTM with old SRF and RTTOV emissivity (grey), and CRTM with the new SRF and RTTOV emissivity (cyan).

Because the spectral radiances in channel 16 have strong slope, the SRF shift can cause a large difference between CRTM and RTTOV. In fact, the bias of AHI channel 16 calculated by $O\text{-}B^{CRTM}$ with the updated AHI SRFs reduces to -0.52 K, which is comparable to that of RTTOV. In other words, a 0.24 cm^{-1} center frequency and SRF shift doubled the bias magnitude of channel 16.

Planned work

- Compare CRTM and RTTOV simulations and performance over various surface conditions and document the findings on the discrepancy between the two models
- Characterize the ABI O-B bias with respect to scan angles and under different surface types and find out further improvements needed for CRTM
- Develop a set of cloud mask tests that can be used for cloud detection of ABI data assimilation for NWP
- Propose a resolution-dependent "optimal" AHI/ABI data thinning scheme for AHI/ABI data assimilation in NWP models at different horizontal and vertical resolutions

Publications

Zou, X., X. Zhuge and F. Weng, 2016: Characterization of bias of Advanced Himawari Imager infrared observations from NWP background simulations using CRTM and RTTOV. *J. Atmos. Oceanic Technol.*, **33**, 2553-2567. doi: 10.1175/JTECH-D-16-0105.1.

Presentations

"Assimilation of AHI Infrared Radiance Measurements for Improved Typhoon Track and Intensity Forecasts Using HWRF" by Zou, Qin, Zhuge, and Weng at the Fifth AMS Symposium on the Joint Center for Satellite Data Assimilation.

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

Development and Improvement of Satellite Data Applications for Global and Regional Weather Monitoring and Forecasting

Task Leader:	Xiaolei Zou
Task Code:	XZXZ_DATA_16
NOAA Sponsor:	Fuzhong Weng
NOAA Office:	NESDIS/STAR
Contribution to CICS Research Themes (%):	Theme 1: 100%
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%):	Goal 1: 100%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Highlight: A new convective initiation (CI) algorithm was developed and delivered to NOAA for AHI data.

Background

AMSU-A and MHS are currently on board NOAA-18, -19 and two European Meterological Satellites (e.g., MetOp-A and –B). NOAA-19, MetOp-A, -B, were launched on 6 February 2009, 19 October 2006, and 17 September 2012, respectively. MetOp-A and –B satellites are configured in the mid-morning orbits with the local equator crossing times (LECT) around 0930 local time (LT), whereas NOAA-18 and -19 are the afternoon orbits with the LECT around 1400 LT. With these constellations, AMSU-A and MHS measurements are provided at least four times a day at any location of the globe for profiling the atmospheric temperature and humidity. The 20 microwave channels from AMSU-A and MHS had played and will continue to play a key role for numerical weather prediction (NWP) through radiance assimilation. Since MHS is more sensitive to both water vapor and clouds than AMSU-A, it is more challenging to use the MHS data in NWP systems due to the highest uncertainty in the forward operators and cloud forecasts (Karbou et al., 2010; Bouchard et al., 2010; Bormann et al., 2010). Recently, it was shown that impacts of MHS data assimilation on short-term quantitative precipitation forecasts (QPFs) could be significantly improved by modifying the quality control (QC) schemes (Qin et al., 2013; Zou et al., 2013; Qin et al., 2016). The current approach of using MHS-only data for cloud quality control could misclassify the cloud-affected radiances as clear. Unlike the ATMS data implemented in Gridpoint Statistical Interpolation (GSI) system (Zou et al., 2013), AMSU-A and MHS radiance data are digested in the NCEP NWP data assimilation systems in two separate Binary Universal Form for the Representation of meteorological data (BUFR) files. Thus, the QC scheme for MHS only data assimilation must be done with its own radiances without information on the lower frequency measurements from AMSU-A.

Accomplishments

Since the launch of NOAA-15 satellite in 1998, the observations from microwave temperature and humidity sounders have been routinely disseminated to user communities through two separate data streams. In the Advanced Microwave Sounding Unit-A (AMSU-A) data stream, brightness temperatures at 15 channels are available primarily for profiling atmospheric temperature from the earth surface to low stratosphere. In the Advanced Microwave Sounding Unit-B (AMSU-B) or Microwave Humidly Sounder (MHS) data stream, the brightness temperatures at five channels are included for sounding water vapor in the low troposphere. Assimilation of microwave radiance data in numerical weather prediction systems has also been carried out with AMSU-A and AMSU-B (MHS) data in two separate data streams.

A new approach is to combine AMSU-A and MHS radiances into one data stream for their assimilation. The National Centers for Environmental Prediction Gridpoint Statistical Interpolation analysis system and the Advanced Research Weather Research and Forecast model are employed for testing the impacts of the combined datasets. It is shown that the spatial collocation between MHS and AMSU-A field of views in the one data stream experiment allows for an improved quality control of MHS data, especially over the conditions where the liquid-phase clouds are dominate. As a result, a closer fit of analyses to AMSU-A and MHS observations is obtained, especially for AMSU-A surface-sensitive channels. The quantitative precipitation forecast skill is improved over a 10-day period when Hurricane Isaac made landfall. Figure 1 provides the ETSs of the model-predicted 3-h accumulative rainfall amounts at 1-mm, 5-mm, 10-mm and 15-mm thresholds from 0600 UTC to 1500 UTC 30 August 2012. The skill of QPFs associated with the landfall Hurricane Isaac is significantly improved by combining AMSU-A and MHS data from the same polar-orbiting satellite into the same BUFR file for the GSI analysis system.

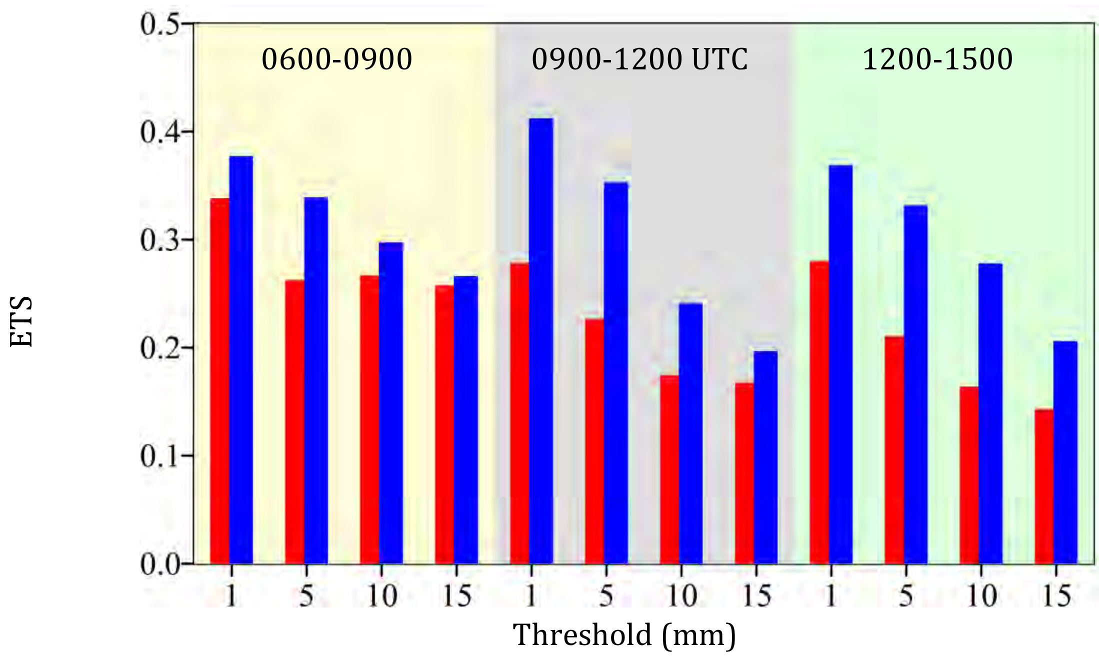


Figure 1. ETS scores of 3-h accumulative precipitation during 0600-0900, 0900-1200, 1200-1500 for the previous two data streams (red bars) and the new one data stream (blue bars) experiments initialized at 0000 UTC 30 August 2012.

The launch of the Japanese Advanced Himawari Imager (AHI) on October 7, 2014 represents a new era of geostationary operational environmental satellite (GOES) imagers, providing many more channels than any previously launched GOES imagers for the first time. A convective initiation algorithm was developed and tested over China using AHI data.

Planned work

- Use Advanced Himawari Imager (AHI) data for detecting the convective initiation (CI)
- Complete a journal paper on AHI CI over Taiwan and China

Publications

Zou, X., Z. Qin and F. Weng, 2016: Impacts from assimilation of one data stream of AMSU-A and MHS radiances on quantitative precipitation forecasts. *Quart. J. Roy. Meteor. Soc.*, doi:10.1002/qj.2960.

Presentations

The 97th Annual Meeting of America Meteorology Society, 22-26 January 2017, Seattle, Washington. A poster presentation entitled "Impacts from Assimilation of One Data Stream of AMSU-A and MHS Radiances on Quantitative Precipitation Forecasts" by Qin, Zou and Weng at the 21st Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface.

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

2.6 Climate Data & Information Records/Scientific Data Stewardship

World Ocean Database Updates and Seasonal Estimates of Ocean Temperature, Salinity, Heat Content, and Steric Sea Level

Task Leader:	Alexey Mishonov
Task Code:	AMAM_WOD_16
NOAA Sponsor:	Dr. Krisa Arzayus, Dr. Rost Parsons, Mr. Tim Boyer
NOAA Office:	National Centers for Environmental Information
Contribution to CICS Research Themes (%):	Theme 1: 0% Theme 2: 50% Theme 3: 50%
Main CICS Research Topic:	Climate Data & Information Records/Scientific Data Stewardship
Contribution to NOAA goals (%):	Goal 1: 100% Goal 2: 0% Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: From April 2016 through March 2017 the World Ocean Database (largest publicly available quality controlled ocean profile database) was updated four times, with over 200,000 profiles added by CICS staff. Additionally, the Northwest Atlantic Regional Climatology (high-resolution decadal climatology of the Northwest Atlantic) was released in the summer of 2016.
Link to a research web page: https://www.nodc.noaa.gov/OC5/indprod.html

Dr. Alexey Mishonov (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons, Tim Boyer)
James Reagan (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons, Tim Boyer)

Background

NOAA's National Centers for Environmental Information (formerly National Oceanographic Data Center) (NCEI) is an organization (http://www.ncei.noaa.gov/) that provides scientific and public stewardship for national and international marine, environmental, and ecosystem data and information. With its regional branch assets and divisions (http://www.nodc.noaa.gov/General/NODC-About/orgchart.html), NCEI is integrated to provide access to the world's most comprehensive sources of marine environmental data and information. NCEI maintains and updates a national ocean archive with environmental data acquired from domestic and foreign activities and produces products and research from these data which help monitor global environmental changes.

The World Ocean Database (WOD) is one of the most requested products from the NCEI (http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html). It is a vast hydrographic database that includes over 15.1 million profiles dating back to Captain Cook's second voyage in 1772. In order for the WOD to keep growing, and to keep being used by the public for a multitude of different ocean and climate studies, data from the NCEI archive must be continually processed and merged into the WOD. This requires that the data be converted into a common format, checked for uniqueness and quality, and merged into the WOD. CICS staff is heavily involved in WOD's continual maintenance and expansion.

The WOD is also used to calculate gridded climatologies of the ocean. The World Ocean Atlas as well as a multitude of regional climatologies (http://www.nodc.noaa.gov/OC5/indprod.html) have been created from the WOD. The climatologies require extensive amounts of quality control (QC) to ensure an accurate product. The World Ocean Atlas offers global climatologies of temperature, salinity, dissolved oxygen, apparent oxygen utilization, oxygen saturation, silicate, phosphate, and nitrate. The WOD is further used to calculate pentadal (5-year), annual, seasonal, and monthly temperature and salinity anomalies, which for some compositing periods (e.g., pentadal) date back to 1955. These anomaly products are used to calculate ocean heat content for multiple depth layers, and sea level changes arising from temperature (thermosteric) and salinity (halosteric) changes. The anomalies and associated products can be found at: https://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/. The regional climatologies are created based on the public's need and additionally constrained by the regional hydrographic data distribution. Because regional climatologies are only calculated in regions of high data distribution, vertical resolutions of 102 standard levels and horizontal resolutions up to 1/10th degree are attainable. CICS staff is involved in the creation and QC of these products.

Accomplishments

1. World Ocean Database

The WOD was updated four times (quarterly) over the past year. Constant data updates to WOD are needed to maintain and enhance the database. CICS staff's responsibility is to populate WOD on a quarterly basis with bottle and CTD data from the CLIVAR & Carbon Hydrographic Data Office (CCHDO) and the International Council for the Exploration of the Sea (ICES). Temperature and salinity data collected by various gliders all around the world and submitted by the Integrated Ocean Observing System (IOOS), Integrated Marine Observing System (IMOS), the University of Washington, and other providers were also added to WOD on a quarterly basis. We also processed the annual update of CTD data from the Northeast Fisheries Science Center (NEFSC) and other miscellaneous datasets for inclusion in WOD. Figure 1a-b shows all data CICS staff added/updated (~233,000) in WOD over the past year.

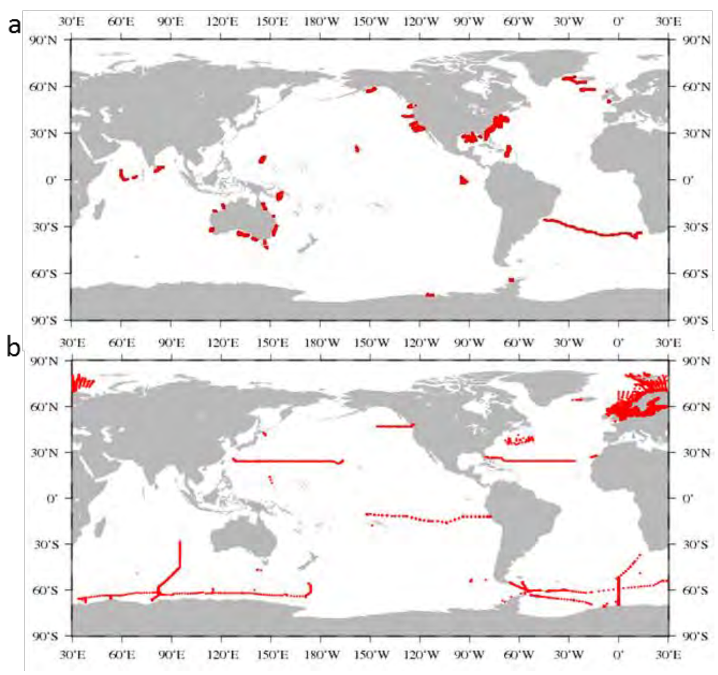

Figure 1. Geographical distribution of a) glider and b) bottle and CTD (Conductivity-Temperature-Depth) profiles added to WOD by CICS staff during 2016/17. There were a total of ~222,000 glider profiles and ~11,000 bottle and CTD profiles.

2. Ocean Heat and Salt Content

CICS staff assisted in the creation and QC of the 2016 globally gridded seasonal temperature and salinity anomaly products, which were released four times (quarterly) over the past year. Additionally, during January 2017 CICS staff quality controlled the 2012-2016 (pentad) and the 2016 annual temperature and salinity anomalies along with the 2016 monthly salinity anomalies. The January 2017 updates are especially important and time sensitive due to these products being extensively used in both the "Salinity" section, in which CICS staff co-authors, and the "Ocean Heat Content" section of the "State of the Climate in 2016" report in the Bulletin of the American Meteorological Society (BAMS).

The pentadal salinity anomalies were extensively used in a manuscript currently under revision lead by CICS staff. The manuscript investigates global salinity pattern amplifications (i.e., salty regions becoming saltier and fresh regions fresher) over varying time periods from 10-60 years. Salinity pattern amplifications have been shown to be directly related to amplifications in the global hydrological cycle, and with historically unreliable estimates of evaporation and precipitation over the ocean, global salinity patterns provide us with a way of monitoring the changes in the hydrological cycle over the past 60 years.

The World Ocean Atlas 2013 and the pentadal temperature anomalies were used extensively in a manuscript currently under review. The manuscript analyzes changes in ocean heat content (OHC) over the North Atlantic Ocean over the past six decades.
CICS staff are co-authors on this work.

3. Regional Climatologies

Some CICS staff are members of the Regional Climatology Team at NCEI. The Regional Climatology Team is responsible for creating and performing QC on high-resolution climatologies of temperature and salinity in data-dense regions of the global ocean that are of particular interest to the broader scientific community. During 2016 the Regional Climatology Team completed the regional climatology of the Northwest Atlantic. The Northwest Atlantic Regional Climatology composes of six decadal climatologies from 1955-1964 through 2005-2012. The climatology horizontal resolution ranges from 1-degree to 1/10th-degree and contains 102 standard vertical levels. For each decade, annual, seasonal, and monthly fields are available. Figure 2 is an example of the 1/10th-degree sea surface temperature field of the six decade average.

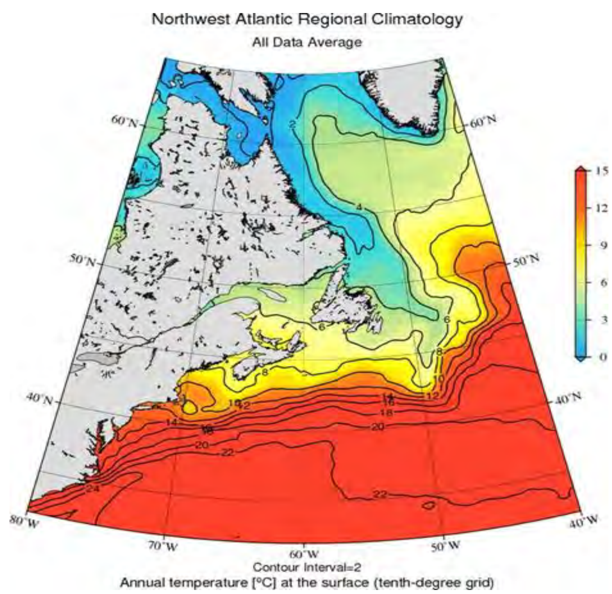

Figure 2. The Northwest Atlantic Regional Climatology six decade average of the 1/10th-degree field of sea surface temperature. The six decades include 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, and 2005-2012.

Planned work

- Continue to discover, assess, acquire and archive the wide array of new ocean data as they become available.
- Continue to process data for inclusion in WOD. This includes CCHDO, ICES, NEFSC, and glider data, as well as other data sets received by NCEI.
- Continue to QC monthly, seasonal, annual, and pentadal temperature and salinity anomaly fields derived from the WOD.
- Develop climatological (and anomalous) mixed layer depth (MLD) fields using multiple MLD criteria.

- Continue to analyze salinity variability through satellite and in situ data.
  - Continue to analyze the relationship between salinity and evaporation/precipitation
- Continue to participate in the Regional Climatology Team activities
  - QC of decadal-scale climatological fields for the Greenland, Iceland, and Norwegian Seas (GINS) including recalculation of fields after different stages of QC
  - Create updated version of maps for the different oceanographic variables
- Analyze long-term changes in temperature and salinity in the Gulf of Maine and GINS
- Continue to participate in OHC research
- Begin preparing for the next release of the World Ocean Atlas (World Ocean Atlas 2017)
  - QC of World Ocean Atlas 2017 temperature and salinity fields
  - Update documentation
- Begin preparing for the next release of the World Ocean Database (World Ocean Database 2017)
  - Update documentation
- Creation and quality control of global ocean in situ derived sea surface density fields.

Publications

Peer-reviewed (published):

1. **Reagan, J.**, T. Boyer, C. Schmid, and R. Locarnini, 2016: Subsurface salinity [subsection in "State of the Climate in 2015"]. *Bull. Amer. Meteor. Soc*., **97** (8), S72–S73.

Peer-reviewed (in review):

2. **Reagan, J.**, T. Boyer, C. Schmid, and R. Locarnini, 2017: Subsurface salinity [subsection in "State of the Climate in 2016"]. *Bull. Amer. Meteor. Soc*..
3. Seidov, D., **A. Mishonov**, **J. Reagan**, A. Parsons, 2017: Multidecadal variability and climate shift in the North Atlantic Ocean*. Geophysical Research Letters.*

Peer-reviewed (under revision):

4. **Reagan, J.**, D. Seidov, T. Boyer, and M. Zweng, 2017: The time-evolution of climatically significant salinity trends in the World Ocean. *Geophysical Research Letters.*
5. Tyler, R., T. Boyer, M. Takuto, **J. Reagan**, and M. Zweng, 2017: Electrical conductivity of the global ocean. *Earth, Planets and Space.*

Not peer-reviewed (published data atlas):

1. Seidov, D., O.K. Baranova, T. Boyer, S.L. Cross, **A.V. Mishonov**, and A.R. Parsons, 2016, *Northwest Atlantic Regional Ocean Climatology*. NOAA Atlas NESDIS 80, Tech. Ed.: **A.V. Mishonov**. Silver Spring, MD, 56 pp.; doi:10.7289/V5/ATLAS-NESDIS-80.

Products

1. World Ocean Database – Quarterly Updates/Releases
2. Most recent release of pentadal (2012-2016), annual (2016), seasonal (2016), and monthly (2016) temperature and salinity anomaly gridded products
3. Seidov, D., O.K. Baranova, D.R. Johnson, T.P. Boyer, **A.V. Mishonov** and A.R. Parsons (2016), *Northwest Atlantic Regional Climatolog*y, Regional Climatology Team, NOAA/NCEI (www.nodc.noaa.gov/OC5/regional_climate/nwa-climate), dataset doi:10.7289/V5RF5S2Q.

4. Seidov, D., O.K. Baranova, T.P. Boyer, **A.V. Mishonov** and A.R. Parsons (2016), *Northern North Pacific Regional Climatology*, Regional Climatology Team, NOAA/NCEI, (www.nodc.noaa.gov/OC5/regional_climate/nnp-climate), dataset doi:10.7289/V5KK98TQ.
5. **Mishonov, A**. & NCAR Staff (Eds). "*The Climate Data Guide: World Ocean Atlas 2013 (WOA13).*" https://climatedataguide.ucar.edu/climate-data/world-ocean-atlas-2013-woa13 .

Presentations

A. NOAA/NESDIS CoRP Science Symposium (18-19 July 2016; Fort Collins, CO)
   1. **Reagan, J.**, T. Boyer, and M. Zweng. The World Ocean Database: Connecting Ocean Observing Systems since 1994.

B. CICS Science Conference (29-1 November/December 2016; College Park, MD)
   1. **Reagan, J.**, D. Seidov, T. Boyer, and M. Zweng. The time-evolution of climatically significant salinity trends in the World Ocean.

C. 2016 Fall AGU Meeting (11-16 December 2016; San Francisco, CA)
   1. **Reagan, J.**, D. Seidov, T. Boyer, and M. Zweng. Long-term (> 40 years) monitoring of near-surface salinity needed to detect global changes in the hydrological cycle.
   2. Gardner, W.D., M.J. Richardson, and **A.V. Mishonov**. Particle Mass in Deep-water Benthic Nepheloid Layers: A Global Synthesis.
   3. Seidov, D., **A. Mishonov**, J. Reagan, T. Boyer, A. Parsons, and S. Cross. Ocean Climate Shift Derived from Northwest Atlantic Regional Climatology.
   4. **Mishonov, A.V.**, M.J. Richardson, W.D. Gardner, and T. Boyer. Historical and Modern Deep-Sea Transmissometry Data in World Ocean Database – its Status, Challenges, and Utilization.

Other

1. **Awards**
   - **i.** "***Global Transmissometer Database***" project by Wilford D. Gardner (TAMU), **Alexey Mishonov (CICS-MD)** and Mary Jo Richardson (TAMU) received an **Honorary Mention** at *'The 2016 International Data Rescue Award in the Geosciences'* competition (https://www.elsevier.com/physical-sciences/earth-and-planetary-sciences/the-2016-international-data-rescue-award-in-the-geosciences).
2. **Mentoring/Advising**
   - **i. J. Reagan** is co-advising (with Dr. James Carton) an undergraduate's senior research project in the Department of Atmospheric and Oceanic Science (AOSC) that is focused on salinity and AMOC variability. Student is expected to graduate in fall of 2017 after presenting a poster on her research.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	4
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	1
# of NOAA technical reports	1
# of presentations	6
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	1

New/Updated Products:

1. World Ocean Database - Quarterly Updates/Releases
2. Release of pentadal (5-year), annual, seasonal, and monthly temperature and salinity anomalies for 2016
3. Release of Northwest Atlantic Regional Climatology
4. Release of Northern North Pacific Regional Climatology

Improving the Inventory, Discoverability, and Delivery of Oceanographic Data at the National Centers for Environmental Information

Task Leader:	Alexey Mishonov/James Reagan
Task Code:	AMJR_BEDI_16
NOAA Sponsor:	Dr. Rost Parsons and Mr. Tim Boyer
NOAA Office:	National Centers for Environmental Information (NCEI)
Contribution to CICS Research Themes (%):	Theme 1: 70%, Theme 2: 10%, Theme 3: 20%
Main CICS Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%):	Goal 1: 100%, Goal 2: 0%, Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: Through this project, we have greatly improved ocean profile datasets (WOD, ARGO, GTSPP, GOCD, led by James Beauchamp) and an ocean surface dataset's (ICOADS, led by Zhankun Wang) discoverability and delivery through the National Centers for Environmental Information (NCEI) geoportal and THREDDS server. Z. Wang also developed the THREDDS access to the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) modelling data archived at NCEI-NC.
Link to a research web page: https://www.nodc.noaa.gov/

Background

The goal of BEDI is to improve the discoverability and delivery of datasets developed or archived at the National Centers for Environmental Information (NCEI) through NCEI's geoportal and THREDDS server. These include (1) ocean profile datasets, (2) ocean surface datasets and (3) ocean model datasets.

1. **Ocean profile datasets:**

The NCEI maintains the World Ocean Database (WOD) which is the most comprehensive, quality controlled database of ocean profile data. Two other important ocean profile datasets, available at NCEI, are Global Temperature and Salinity Profile Program (GTSPP) and the Argo data program. The GTSPP data are near real-time data and the Argo program uses autonomous profiling floats and is recognized for its excellent quality control and delivery system. One of the important goals of the Big Earth Data Initiative (BEDI) project is to generate International Organization for Standardization (ISO) metadata files for all three datasets – thereby making these data more discoverable and accessible for researchers. In time, it is hoped that this will make these data easier to aggregate. In an attempt to expand to other data types, ISO metadata files will also be created for Global Ocean Current Data (GOCD), also an NCEI product.

2. **Ocean surface dataset**:

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS) is a foundational dataset of in situ marine meteorological and ocean surface variables spanning more than 300 years from the 1600s to the present. ICOADS is vital to research into global climate change. Among many other uses, it is the base dataset for the Extended Reconstruction of Sea Surface Temperature (ERSST) which is used to estimate historical changes in SST and monitor current SST trends. ICOADS data in IMMA format is served from an online system at the National Center for Atmospheric Research (NCAR). However, IMMA is an ASCII format which does not readily lend itself to machine-to-machine transfer, nor to the National Centers for Environmental Information (NCEI) granule discovery tools. Data needed to be converted to NetCDF format, archived at NCEI and then severed through the NCEI geoportal and THREDDS server.

3. **Ocean model datasets:**

CO-OPS Operational Forecast Systems (OFS) provide NOAA's capability to produce operational guidance on water levels and currents in the coastal ocean and Great Lakes in support of maritime navigation. The heart of each OFS is a state-of-the-art hydrodynamic model, run every 6 hours to provide up-to-date guidance. OFS are currently implemented in 13 geographic domains (see https://tidesandcurrents.noaa.gov/models.html), with plans to expand to 15 within 3 years and full CONUS coverage within 7 years. In aggregate, the current 13 systems produce approximately 150 gigabytes of output daily. CO-OPS currently retains the model output for one to two years and makes it available via THREDDS Data Server (TDS), after which it is overwritten and lost to future use. At this time no OFS output is archived; however CO-OPS has submitted a request to NCEI for basic archival services (file-level access, tape storage). While this is an encouraging step forward in terms of preserving these important data, accessibility of the archived data will be cumbersome. The proposed work builds upon the commitment to archive the data already in progress.

Accomplishments

1. **Ocean profile datasets:**

Since coming aboard the BEDI project in October 2016, Beauchamp initially familiarized himself with the World Ocean Database (WOD), completed the NOAA IT Security Awareness course, and enrolled in an overview of Metadata Basics seminar taught by Kathy Martinolich from NOAA/NCEI. After becoming familiar with the WOD, he began to utilize an updated isolite metadata template and existing WOD software to create metadata files for WOD ragged-array format NetCDF files. Several iterations of template files and some minor tweaking of the software were necessary in order to make the metadata files valid. These files were then made available to another team member, Yuanjie Li, so that they could be indexed for the NCEI granule geoportal.

An existing script to process GTSPP profiles was adapted and a significant number of metadata files (from years 1985 – 2008) were generated. As these files are successfully indexed by Yuanjie Li, the remainder of the GTSPP metadata files will be processed. As both the WOD and GTSPP metadata files were being indexed, Beauchamp confirmed that they could be discovered via the granule geoportal and provided feedback to Yuanjie Li whenever issues arose. The indexing for WOD and GTSPP is ongoing. Argo profile data are archived as single cast NetCDF files. FORTRAN code and a script were developed to extract the necessary information from the NetCDF files and insert it into a template file to generate Argo metadata files, which will be eventually indexed. These Argo metadata are not in their final form and some minor revisions are still necessary.

2. **Ocean surface dataset**:

Wang has created ISO metadata for ICOADS observational data and has developed a CF compliant netCDF format for same. This will allow for discovery and delivery of ICOADS data through the NCEI granule discovery tools and THREDDS server either independently or in conjunction with WOD data. This delivery of two foundational datasets together will allow researchers to access the entire array of marine meteorological, ocean surface, and subsurface ocean data through one mechanism. It should be noted that ICOADS Release 3.0 (available ~June 2016) has more than 455 million "granules" (i.e. individual "marine reports" in ICOADS terminology) compared to 13.9 million for WOD, so the work will entail scaling up the WOD system one order of magnitude. Wang is working with the NCEI data ingest team (John Relph) to set up automation of ingest and archive the ICOADS netCDF format into the NCEI Archive Management System. The ISO metadata template for ICOADS data has also been developed and he will work with Li to finalize the metadata files

3. **Ocean model datasets:**

Wang has set up a test THREDDS website on the THREDDS server at NCEI-NC to provide access and service to the CO-OPS OFS Modeling data at NCEI. He also set up catalogs for THREDDS time aggregation for both structured and un-structured models. This will provide advanced web-service access to the CO-OPS OFS model data over the long term.

Planned work

1. **Ocean profile datasets:**

- Continue working with Yuanjie Li, generating and making available WOD and GTSPP metadata for indexing and confirming that the indexing is complete and successful.
- Completing the procedure (FORTRAN code, template, and script) for generating Argo metadata files. Upon generating these files we will make them available for indexing.
- Develop a procedure for creating metadata files for Global Ocean Current Data (GOCD) and generate and make these files available for indexing.
- Explore the use of elasticsearch for granule search as well as using ERRDAP as an aggregation tools.

2. **Ocean surface dataset:**
- Complete the ICOADS NetCDF automation setup
- Finalize the ICOADS ISO metadata template and create ISO metadata file for each granule in ICOADS
- Testing and implementation of granule geoportal searches, THREDDS server and NCEI Data Access and OneStop data delivery
- Maintain the ICOADS data automation and solve any issues encountered

3. **Ocean model datasets:**
- Apply the THREDDS catalogs to production when COOPS OFS data are available at NCEI-NC
- Apply the time aggregation to the data

Products

(1) The International Comprehensive Ocean-Atmosphere Data Set netCDF format
(2) THREDDS server for the COOPS OFS modeling data with time aggregation capability
(3) ISO metadata for GTSPP data (years 1985 – 2008)
(4) ISO metadata for WOD (9 of 11 instrument types completed)
(5) Preliminary method developed to generate ISO metadata from Argo profiles

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

New or improved products developed that became operational
(1) The International Comprehensive Ocean-Atmosphere Data Set netCDF format

NCEI Data Management in support of the Coral Reef Conservation Program

Task Leader	Brian Beck
Task Code	EBBB_CORAL_15 Year 2
NOAA Sponsor	Dr. Krisa Arzayus
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 2: 50% Goal 3: 50%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

In June of 2015, Dr. Brian Beck joined CICS-MD and is the NESDIS representative on Coral Reef Conservation Program (CRCP) Strategic Evaluation and Assessment (SEA) Team. The SEA Team is responsible for developing an annual spend plan for the CRCP. They are also tasked with ensuring the CRCP is compliant across all line offices with various NOAA policies and administrative orders. Brian is also the Data Management Coordinator for the CRCP and coordinates all data management efforts through the NCEI Maryland office. He is the CRCP representative on the *Acropora* Recovery Team, in order to help coordinate research across the country to assure the recovery of the 2 ESA listed *Acropora* corals in the Caribbean. He is the NESDIS executive secretariat on the NOAA Ocean and Coastal Council (The NOAA Ocean and Coastal Council serves as the principal advisory body to the Under Secretary and the focal point for the agency's activities and interests in the open ocean, near shore, coastal and estuarine areas, and the Great Lakes) and the NESDIS representative for the NOAA Caribbean strategy.

Accomplishments

Dr. Brian Beck fulfills a number of roles with the CRCP. The primary is representing NESDIS on the Staff Evaluation and Assessment (SEA) Team. The SEA Team (one member for each of the four line offices participating in the CRCP) is tasked with reviewing internal work plans for funding and drafting a recommended annual spend plan for the CRCP’s $26 million dollar budget. The SEA Team is also responsible for assuring the CRCP funded work within their line offices are compliant with certain NOAA wide policies (eg. NEPA). He will also be coordinating with American Samoa and the US Virgin Islands to better coordinate the jurisdictional needs for coral reef management with internally funded projects.

He also fulfills the role of Data Management Coordinator for the CRCP. This involves assuring that all CRCP funded projects (across all line offices and external grants) are compliant with all NOAA and federal data management requirements, most notably the White House memorandum on Public Access to Research Results (PARR). This work included the development of a program wide data management plan. In the 6 months, over 80 coral reef monitoring data sets were made publicly available due to these efforts. This is by far the largest collection of NOAA coral data to be released to date. Brian coordinates the upkeep and further development of the NOAA Coral Project Database with the NOS’s Office of Coastal Management, which is used to track all funding and deliverables of CRCP projects. Finally, he also serves as Data Content Manager within NCEI for incoming CRCP funded data to be archived.

Planned work

- Continue to discover, assess, acquire and archive the wide array of new ocean data as they become available.
- Continue roles supporting the CRCP. This includes representation on a number of teams and councils and releasing a third version of the NOAA Coral Project Database.
- Secured funding to work on the next tier of data management for the CRCP and created automated products from the archived monitoring data. These products will be directed at resource managers in the U.S. states and territories that manage coral reefs.

Products

- Improved the NOAA Coral Project Database to version 2.0 improving on the initial release.

Presentations

- **Beck, B**. Will your data be useful after you are gone? U.S. federal data management policies as recommendations for all scientists 2016 International Coral Reef Symposium. Honolulu, HI. 19-24 June 2016.
- **Beck, B.** Data Management: If it's good enough for the government, it's good enough for you. CICS Science Conference. College Park, MD. Nov. 29, 30 and Dec 1.
- **Beck, B.** Coral Reef Conservation Program: an overview of the program and NCEI involvement. NCEI Seminar Series. Silver Spring, MD. 7 February 2017.

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

Ocean Data Stewardship: Development of a Global Thermosalinograph (TSG) Database

Task Leader	Zhankun Wang
Task Code	EBEB_NODC_ 14 Year 3
NOAA Sponsor	Rost Parson
NOAA Office	NESDIS/NCEI & STAR
Contribution to CICS Research Themes (%)	Theme 1: 70%, Theme 2: 10%, Theme 3: 20%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%, Goal 2: 0%, Goal 3: 0%
Strategic Research Guidance Memorandum*:*	2. Environmental Observations

Highlight : I have constructed a Global Thermosalinograph Database (NCEI-TSG) to facilitate access to the *in situ* sea surface salinity and temperature measurements. This database provides a comprehensive set of quality-controlled *in situ* sea surface salinity (SSS) and temperature (SST) measurements collected from over 200 vessels during the period 1989 to the present. I also worked with NCEI personnel to develop a NCEI Thermosalinograph Portal to improve the discoverability of the database.

Background

Ocean surface is the location of strong exchanges with the atmosphere but also with ice and continents. Ship-based thermosalinograph measurements can make a significant contribution to the observation of this very active layer if the quality of the datasets produced is in accordance with current research standards. The sea surface salinity and temperature from thermosalinograph can be used to validate and calibrate the remote sensing data from satellites or other devices. They can also be used for global water cycle studies.

One of the motivations of developing this global thermosalinograph database is to conduct an in-situ/satellite matchup research of Sea Surface Salinity observations. This database will be one of the fundamental in-situ components for the Satellite SSS Quality Monitor (4SQM) project. Data are from different data assemble centers including GOSUD (IODE), SAMOS and AOML. NCEI Archive Management System has large amount of raw TSG data that are not included in any of the TSG data assembly centers. The goal of this project is to provide a well-organized, uniformly quality-controlled TSG database for the user community with granule search capability.

Data sources for the TSG database:

- NCEI Archiving Management System, over 1300 accessions
- International Oceanographic Data and Information Exchange (IODE) Global Ocean Surface Underway Data (GOSUD), LEGOS (Laboratoire d'Etudes en Géophysique et Océanographie Spatiales) data has been included in the GOSUD.
- Atlantic Oceanographic & Meteorological Laboratory (AOML) TSG
- Shipboard Automated Meteorological and Oceanographic System (SAMOS), Florida State University
- Other data could be included:
    - Wave glider data
    - Unmanned Surface Vehicle (USV) data

- Ferrybox data
- Surface bucket data

Accomplishments

I have constructed a Global Thermosalinograph Database (NCEI-TSG) to facilitate access to the *in situ* sea-surface salinity and temperature measurements. This database provides a comprehensive set of quality-controlled in situ sea-surface salinity (SSS) and temperature (SST) measurements collected from over 200 vessels during the period 1989 to the present. Figure 1 shows the spatial distribution of the NCEI-TSG with color-coded data sources.

Compared to other TSG datasets, these data have several advantages:

1. The NCEI-TSG is the world's most complete TSG dataset, containing all data from the different TSG data assembly centers, e.g. Shipboard Automated Meteorological and Oceanographic System (SAMOS), Global Ocean Surface Underway Data (GOSUD) and Atlantic Oceanographic and Meteorological Laboratory (AOML), with more historical data from NCEI's archive to be added.
2. When different versions of a dataset are available, the dataset with the highest resolution is always chosen.
3. All data are converted to a common NetCDF format, employing enhanced metadata, following Attribute Convention for Dataset Discovery (ACDD) and Climate and Forecast (CF) conventions, to increase the overall quality and searchability of both the data and metadata.
4. All data are processed using the same 11-step quality control procedures and criteria and flagged using a two-level flag system to provide a well-organized, uniformly quality-controlled TSG dataset for the user community.

The NCEI-TSG, a unique dataset for in situ sea-surface observations, serves as a significant resource for establishing match-ups with satellite SST and SSS observations for validation and comparisons. The NCEI-TSG database will significantly contribute to the in situ component of the NOAA Satellite SSS Quality Monitor (4SQM) project (under development). This dataset facilitates assessments of global SST and SSS variability and the analysis of patterns and trends at various regional and temporal scales, enabling new insights in climate change, the global water cycle, air-sea interaction, etc. The NCEI-TSG database is freely accessible via the NCEI website (https://archive.nodc.noaa.gov/archive/ingest/0156189/) and will be maintained with newly received TSG data, as well as further expanded with more historical data from NCEI's archive.

I have developed several python modules to manage and provide quality controls to this large datasets. The python modules process different formats of raw data and convert them to the same NCEI netCDF format. Uniformly quality controls are applied to all the data. I am working with the NCEi ingest team to set up automations for the entire process. Fig 2 shows the flow-chart of the NCEI-TSG database from data sources to data users.

A NCEI geo-portal based search portal has also been developed to improve the discoverability and access of the NCEI-TSG database. The portal is now under NCEI security review and will become publicly available when it passed all the codes and security reviews.

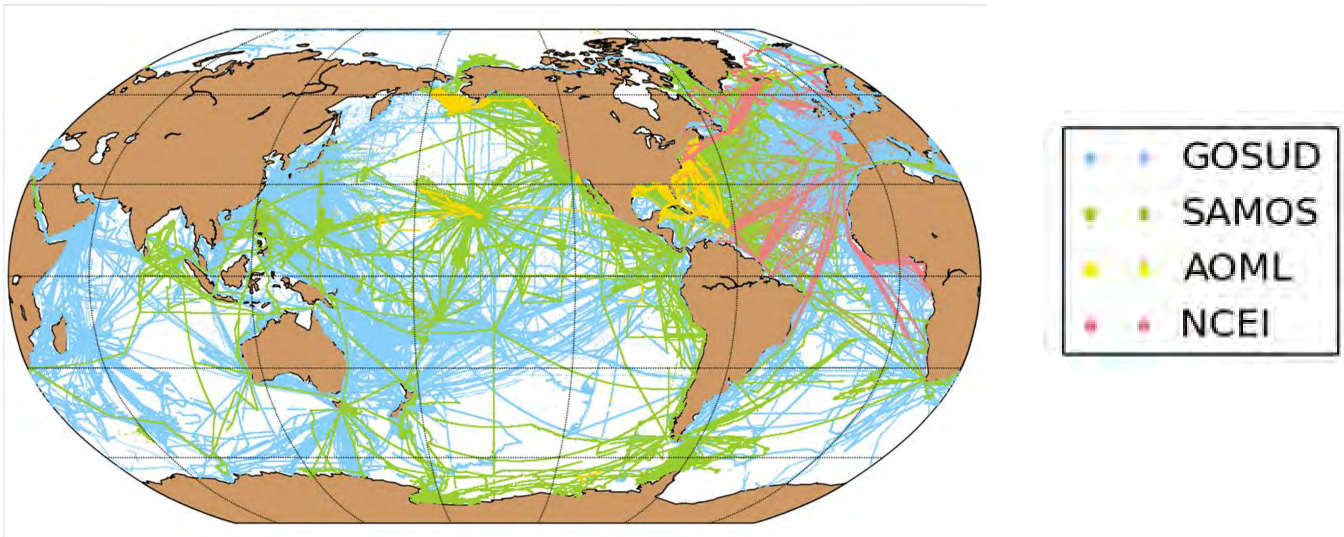

Figure 1. Spatial distribution of the NCEI-TSG dataset. The data are color-coded with data sources.

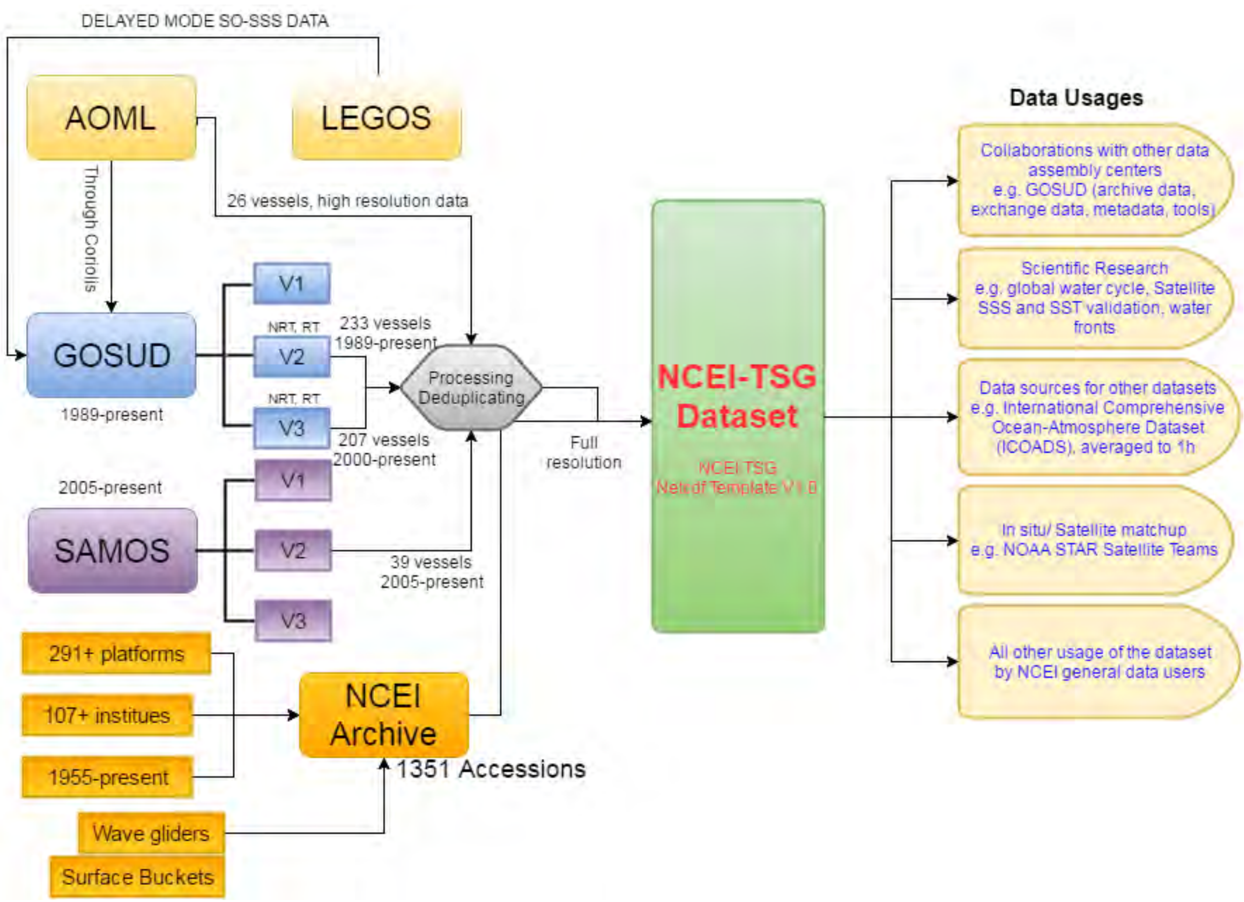

Figure 2. Flowchart of the NCEI-TSG dataset from data sources, data processing, data product and data usages.

Planned work

- Database daily updates/maintenance
- Expand the database
  - with more historical data from NCEI archive (1300+ accessions)
  - Adding atmospheric and biochemical data concurrently collected, e.g. Chl a, Dissolved Oxygen, air tem etc.
  - Replacing averaged low-resolution data with raw high resolution data
  - Adding surface data from other instruments/platforms
  - Wave glider data
  - Unmanned surface vehicle (USV) data
  - Ferrybox data
  - Surface bucket data
- Metadata enhancement, e.g. water intake depth, instr. setup etc.
- QC updates/improvements
- Scientific Research, e.g. in-situ/satellite match-up, water-front, global water cycle etc.

Products

- NCEI-TSG database
- NCEI Thermosalinograph Portal

Presentations

- **Wang, Z.** (2016), Potential NCEI contributions to GOSUD project, 6th Session of the IODE Steering Group for the GOSUD Project. November 2016, Oostende, Belgium (invited).
- **Wang, Z.** (2016), NCEI-TSG: A Global in situ Sea-surface Salinity and Temperature Database of Thermosalinograph (TSG) Observations, 2016 CICS Science Conference, November 2016, College Park, MD.
- **Wang, Z.**, T. Boyer, H. Zhang, E. J. Bayler, M. Biddle, S. Baker-Yeboah, Y. Zhang (2016)., NCEI-TSG: A Global in situ Sea-surface Salinity and Temperature Database of Thermosalinograph, December 2016, 2016 AGU Fall Meeting, San Francisco, CA.

Other

I became a member of the Global Ocean Surface Underway Data (GOSUD) Project steering group to represent NOAA NCEI. Global Ocean Surface Underway Data (GOSUD) is an initiative of the International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC) programme.

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

New or improved products developed that became operational:
(1) NCEI-TSG database

Outgoing Longwave Radiation – Monthly CDR – Software Rejuvenation

Task Leader	Hai-Tien Lee
Task Code	HLHL_CDR_16
NOAA Sponsor/Office	NESDIS/NCEI
Percent contribution to CICS Themes	Theme 1: 10%; Theme 2: 90%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to NOAA Goals	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: NOAA/NCEI CDR Program is in the process of migrating the Monthly OLR CDR production towards the Full Operational Capability (FOC). Software package rejuvenation efforts reviewed and revised the production code system for meeting the standards in computer program language, system maintenance and efficiency. Industry compliant procedures for software development are employed to ensure the comprehensive examination and documentation of the production system.

Background

During Research to Operational transition, the production codes are under critical reviews so that they can meet the established standards for computer language and maintenance. Codes and scripts have been significantly revised for better organization and execution efficiency.

Accomplishments

Refactored Monthly OLR CDR production package has been completed and delivered.
Implementation and testing at NCEI towards Full Operational Capability has been initiated.

Planned work

- Update of C-ATBD for OLR-Monthly v02r07 revisions
- Update Code documentation for refactored code package
- Deliver documentations and testing packages
- Provide assistance to CDR Program for software system implementation and product verification

Deliverables

1. OLR-Monthly CDR v02r07 production code package (upgraded and refactored) (delivered)
2. Testing packages (sample input/output) for System Acceptance Test (delivered)
3. Documentations: including Code Static Analysis report, Implementation Plan, Code Design Diagrams, Data Flow Chart, Unit Level Test Package, Operational Algorithm Description, System Acceptance Test Plan, and C-ATBD.

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

O&M for OLR-Monthly and OLR-Daily Climate Data Records

Task Leader	Hai-Tien Lee
Task Code	HLHL_OLR_16
NOAA Sponsor/Office	NESDIS/NCEI
Percent contribution to CICS Themes	Theme 1: 10%; Theme 2: 90%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to NOAA Goals	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: CICS is responsible for the development, sustainment, maintenance and operational production of the OLR CDR products for NCEI Climate Data Record Program, including the Monthly OLR CDR product (v02r02a and v02r07) and the Daily OLR CDR product (v01r02-final and v01r02-interim).

Background

This is a continuing project for OLR CDR products. Being in the Initial Operational Capability (IOC) phase of both the OLR-Monthly and OLR-Daily CDR products, CICS is responsible for the continued development and maintenance of these products before Full Operational Capability (FOC) is attained. Both the Monthly and Daily OLR CDR data are operationally generated and delivered to NCEI as well published on CICS OLR CDR web site for public access in near real-time. Quality assurance and quality control mechanisms have been developed and applied.

Accomplishments

Operational OLR CDR Production, Data Access Portal and Monitoring

OLR CDR Daily and Monthly Products data access portal –

http://olr.umd.edu/index.html for 2-day lag
http://olr.umd.edu/index_alt.html for 1-day lag (experimental)

OLR CDR Production Monitoring –

HIRS data ingest and geo/leo blending: http://olr.umd.edu/CDR/Daily/HIRS
GSIP data ingest and global OLR composite: http://olr.umd.edu/CDR/Daily/GSIP

Products

1. Monthly production and delivery of OLR-Monthly CDR v02r02a and v02r07 products.
2. Daily production and delivery of OLR-Daily CDR v01r02-Interim product.
3. Annual delivery of v01r02 Final product for year 2015.
4. Quality Assurance Procedure document (delivered)
5. QA results/summary

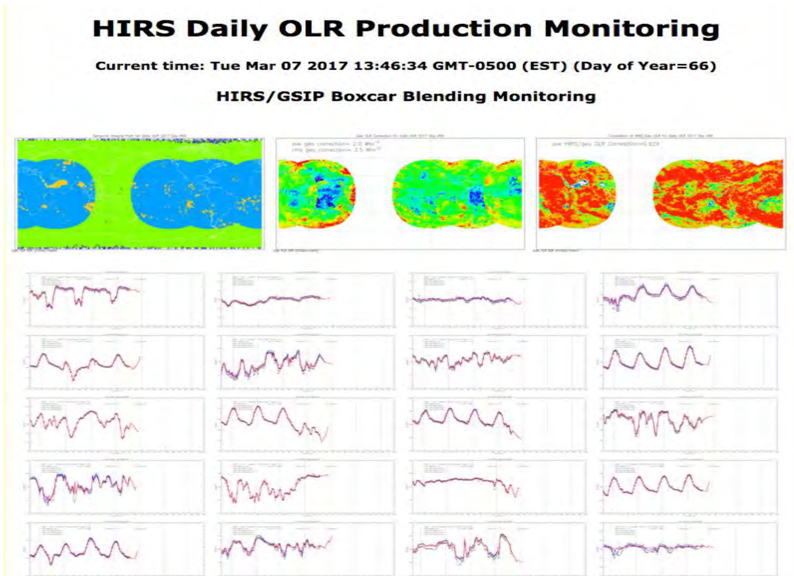

Figure 1. Snapshot of OLR temporal integration process monitoring webpage, dated on March 7, 2017 for the Daily OLR CDR v01r02a-preliminary product. It is one of the OLR CDR QA tools.

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

Ocean Acidification Data Stewardship (OADS) Project

Task Leader:	Liqing Jiang, PhD
Task Code:	LJLJ_OADS_16
NOAA Sponsor:	A. Rost Parsons, PhD
NOAA Office:	NESDIS/NCEI
Contribution to CICS Research Themes (%):	Theme 3: 100%.
Main CICS Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%):	Goal 1: 0%; Goal 2: 50%; Goal 3: 50%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: New study on the global distribution of pH, mechanisms and regressions.
Link to a research web page: www.nodc.noaa.gov/oceanacidification

Background

The National Centers for Environmental Information (NCEI) developed and implemented a program for data management of global observations surrounding the acidification of the world's oceans. Partial funding for this effort has been provided by NOAA's Ocean Acidification Program (OAP). The goal is to ensure all data collected from OAP investment are properly archived and made accessible towards improved assessments of marine ecosystem vulnerability, and better forecasting capabilities, in accordance with the NOAA Plan for Public Access to Research Results (PARR) and the White House executive order on making data open and machine readable. This include dedicated support for data acquisition, quality assurance, management of rich metadata, application of controlled vocabularies, long-term archival, stable data citation, as well as online data discovery and access services. Under this funding effort, Dr. Liqing Jiang, CICS-MD, worked to develop standard data sharing guidelines, rich metadata using international standards to support human and machine data discovery and readability, and value-added scientific data sets for the ocean acidification research community.

Accomplishments

- Published all of the submitted data sets over the last year into NCEI's long-term archives, created rich metadata for these data sets and made sure they are discoverable and searchable: https://www.nodc.noaa.gov/oceanacidification/stewardship/oap_data.html

- Revised the Ocean Acidification data search portal to enable link based search. Now a user can copy the link of some search results and get the same results in another browser.

- Create new data management forms for PIs to use, so that they do not need to write lengthy data management plans: https://www.nodc.noaa.gov/oceanacidification/downloads.html
- We published a peer-reviewed paper about how to document ocean acidification data.

- We published a peer-reviewed paper about the how CO2 affects coral reef and human society in the coming century.

Planned work

The following areas will be addressed through this project:

- Long-term preservation of future NOAA OAP data streams (i.e. scientific oversight of ocean acidification data submitted to NCEI);

- Continual interaction with OA scientific community on data management requirements including implementation of data standards, rich metadata and data discovery.

- Continue to improve the project data management infrastructure, including the website, display format, etc.

Publications

- Pendleton, L., A. Comte, C. Langdon, J. Ekstrom, S. Cooley, L. Suatoni, M. Beck, L. Brander, L. Burke, J. Cinner, C. Doherty, P. Edwards, D. Gledhill, **L.-Q. Jiang**, R. Portela, R. van Hooidonk, L. Teh, G. Waldbusser. 2016. Coral reefs and people in a high CO2 world. *PLoS ONE*, 11(11): e0164699. doi:10.1371/journal.pone.0164699.

- **Jiang, L.-Q.**, K. M. Arzayus, J.-P. Gattuso, H. E. Garcia, C. Chandler, A. Kozyr, Y. Yang, R. Thomas, B. Beck, and T. Spears. 2016. How to document ocean acidification data. Limnology and Oceanography e-Lectures, doi:10.1002/loe2.10004.

Products

pH distributions, mechanisms and regressions in the global Ocean. We describe both surface and subsurface pH distributions in the global ocean based on the recently released Global Ocean Data Analysis Project Version 2 (GLODAPv2) database, and discuss the mechanisms that control them. Gridded surface ocean pH in the year of 2002 ranged between 7.77 and 8.35 globally, with an area-averaged surface pH of 8.08. Surface pH is mainly controlled by water temperature and the subsequent ratio of total alkalinity and dissolved inorganic carbon (TA/DIC). Vertically, pH is highest in the surface mixed layer, but unlike calcium carbonate saturation state, minimum pH is often found in mid-water depths ranging from 200 to 2000 m. Subsurface pH shows large differences among the major ocean basins. Aerobic respiration within the global thermohaline circulation plays a major role in shaping the subsurface pH distribution. In addition, subsurface pH is strongly controlled by temperature and pressure. Decreasing temperature with depth increases pH and increasing pressure lowers pH. Multi-Linear regression analyses in the subsurface data at 160 nodes show that temperature, salinity, pressure and dissolved oxygen account for the majority of the pH variations in the global subsurface ocean.

Presentations

- Jiang, L.-Q., R. A. Feely, S. Lauvset, B. Carter, A. Olsen. 2017. pH distributions, mechanisms, and regressions in the global ocean, 2017 Aquatic Sciences Meeting, February 26 - March 3, 2017, in Honolulu, HI.

- Jiang, L.-Q., K. M. Arzayus, H. Garcia, and J. Relph. 2016. NOAA Ocean Acidification Data Stewardship (OADS) Project, the 3rd Global Ocean Acidification Observing Network (GOA-ON) Science Workshop, May 8-10, 2016, Hobart, Tasmania, Australia.

- Jiang, L.-Q., R. A. Feely, B. Carter, R. Wanninkhof, D. Gledhill, R. Key, and K. M. Arzayus. 2016. Climatological distribution of aragonite and calcite saturation states in the global oceans, 4th International Symposium on the Ocean in a High-CO2 World, May 3-6, 2016, Hobart, Tasmania, Australia.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
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# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

NOAA Video Data Management System Modernization

Task Leader:	Dr. Ernesto Hugo Berbery.
Task Codes:	SBFK_VDMS_16.
NOAA Sponsor:	Dr. Krisa Arzayus.
NOAA Office:	NESDIS/NCEI.
Contribution to CICS Research Themes (%):	Theme 1: 60% Theme 2: 30% Theme 3: 10%.
Main CICS Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%):	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlights: In 2016, CICS played a significant role developing improved ocean data products, working with the ocean science community to provide global and regional ocean data, and validating new ocean-based observing technologies.
CICS researchers enhanced NOAA's abilities to understand, predict and communicate climate variability by data dissemination and public education, through web based *in-situ* data, and by detailed descriptions of these data.
CICS team actively participated in the continued development, maintenance, and enhancement of the OER Video Portal, the NCEI Collection Level and Granule Level Geoportals, the World Ocean Database, the World Ocean Atlas, and Regional Climatology Projects.
Link to a research web page: www.nodc.noaa.gov

Background

NOAA's National Centers for Environmental Information (NCEI) is an integration of NOAA/NESDIS National Data Centers in Asheville, NC; Boulder, CO; Stennis, MS; and Silver Spring, MD to provide access to the world's most comprehensive environmental data. The Silver Spring, MD location was formerly known as the National Oceanographic Data Center (NODC). NCEI is composed of two main centers: the Center for Weather and Climate; and the Center for Coasts, Oceans, and Geophysics (http://www.ncei.noaa.gov/). NCEI hosts and provides public access to over 20 petabytes of comprehensive atmospheric, coastal, oceanic, and geophysical data. NCEI provides scientific and public stewardship for the nation's environmental data, maintains and updates archives of these data, and contributes scientific research and produce products from these data that help monitor global environmental changes.

Since January of 2015, **Fred Katz** has been part of CICS-MD and has been working on the Video Data Management Modernization Initiative (VDMMI) team at NCEI. The VDDMI is an ongoing, multi-year project jointly supported by OER, NCEI, and NOAA/CLASS. The VDMMI team is responsible for standardizing and optimizing documentation, discovery and access to environmental data collected on video media.

Accomplishments

- Developed video data discovery geoportal for OER video archived in CLASS
- Led project to transfer technology from the OER Video Data Management Model for archiving physical video tape data to the Bureau of Ocean Energy Management (BOEM) Hydrocarbon Seep Video collection

- Directed usability and access improvements to OER video geoportal website
- Archived legacy video data originally captured on physical video tape from Islands in the Stream 2001 and Florida Coast Deep Corals 2005 expeditions
- Developed software tools for inventorying and monitoring growth in OEDV holdings in Central Library
- Supported migration of OEDV video from Central Library to NCEI servers

Planned work

- Document VDMMI history and process as a case study/model for Big Earth Data Initiative (BEDI)
- Continue to develop OER video geoportal
- Continue to oversee technology transfer for the BOEM Hydrocarbon Seep Video collection
- Develop automated workflows to more efficiently transfer high volume video data and associated metadata from submersible-based monitoring cameras to be archived in CLASS and make discoverable though NOAA Geoportals
- Develop user-focused documentation for the Advanced Tracking and Resource tool for Archive Collections (ATRAC), an online interface for the science community to archive and track high-volume datasets

Products

OER Video Portal (https://www.nodc.noaa.gov/oer/video/)

Presentations

Katz F., Blythe, J. "Legacy Video - A Practical Application in Video Rescue and Management," 2017. NOAA Environmental Data Management Workshop. Bethesda, MD. Jan 2017 (talk). https://nosc.noaa.gov/EDMW_2017/2017-EDMW-presentations/5D/5D.3 Katz_BOEM_Seep_Video_2016_0110.pptx

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

CICS Support for the management of Ocean and Climate Data originating from member Regional Associations of the US Integrated Ocean Observing System (IOOS)

Task Leader:	Sheekela Baker-Yeboah
Task Code:	SBSB_IOOS_15 Year 2
NOAA Sponsor:	Dr. Krisa Arzayus
NOAA Office:	NESDIS/NCEI
Contribution to CICS Research Themes (%):	Theme 1: 10% Theme 2: 50% Theme 3: 40%.
Main CICS Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: In 2016, CICS played a significant role working with the ocean science community to provide regional ocean data to the NCEI archive. CICS researchers enhanced NOAA's abilities to understand, predict and communicate climate variability by data dissemination and public education. CICS researchers provided resources to the community, which has assisted numerous data providers throughout the oceanographic environment.
Link to a research web page: https://www.nodc.noaa.gov/ioos/

CICS-UMD NOAA/NESDIS/NCEI Staff: **Mathew Biddle** (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons, Dr. Huai-min Zhang);

Background

NOAA's National Centers for Environmental Information (NCEI) is an integration of NOAA/NESDIS National Data Centers in Asheville, NC; Boulder, CO; Stennis, MS; and Silver Spring, MD to provide access to the world's most comprehensive environmental data. The Silver Spring, MD location was formerly known as the National Oceanographic Data Center (NODC). NCEI is composed of two main centers: the Center for Weather and Climate; and the Center for Coasts, Oceans, and Geophysics (http://www.ncei.noaa.gov/). NCEI hosts and provides public access to over 20 petabytes of comprehensive atmospheric, coastal, oceanic, and geophysical data. NCEI provides scientific and public stewardship for the nation's environmental data, maintains and updates archives of these data, and contributes scientific research and produce products from these data that help monitor global environmental changes.

NCEI has been funded by the Integrated Ocean Observing System (IOOS) Program Office which then funds CICS-MD to perform various data management tasks. IOOS is comprised of eleven Regional Associations (RAs), which serve the nation's coastal communities, including the Great Lakes, the Caribbean and the Pacific Islands. IOOS is a national-regional partnership network working to provide new tools and forecasts to improve safety, enhance the economy, and protect our environment. CICS staff plays an important integral role in fostering the relationship between the various IOOS RAs and NCEI by acting as a liaison for IOOS RA archival at NCEI. CICS staff provides input on the certification of Regional Information Coordination Entities (RICEs). The certification formally establishes the role of the RICE in the U.S. IOOS and ensures that the data collected and distributed by the RICE are managed according to the best practices, as identified by NOAA.

Accomplishments

Archive and Scientific Stewardship of *In Situ* Data by Fostering relationships with IOOS Regional Associations. CICS staff archived numerous archival information packages at NCEI. For example, CICS Research Assistant **M. Biddle** developed automations for three different data streams (1) IOOS RA SCCOOS, (2) IOOS RA NANOOS, and (3) IOOS RA PacIOOS over the FY15/16 time period. Together, these three automations consist of 31 Archival Information Packages and total to ~4+GB of data which get updated on a monthly basis. Acting as the IOOS-related data processing lead, **M. Biddle** continues to maintain the automated archival processes for the Southeast Coastal Ocean Observing System (SECOORA) and Great Lakes Observing System (GLOS) *in-situ* data. Both of these automated archival processes account for 98 archival packages, contributing 1+GB of *in-situ* observational data to the NCEI archive (Figure 1). Together, we now have 129 Archival Information Packages at NCEI that are being updated monthly with new data from five IOOS RAs, contributing to 5+GB of in-situ observational data (Figure 2). While the three new data streams were built upon the already established pathways for GLOS and SECOORA into the archive, NCEI fostered relationships with 6 other RAs to follow a similar paradigm in automated archiving.

Figure 1. Distribution of the Integrated Ocean Observing System (IOOS) Regional Association (RA) data currently archived at NCEI through the IOOS project effort.

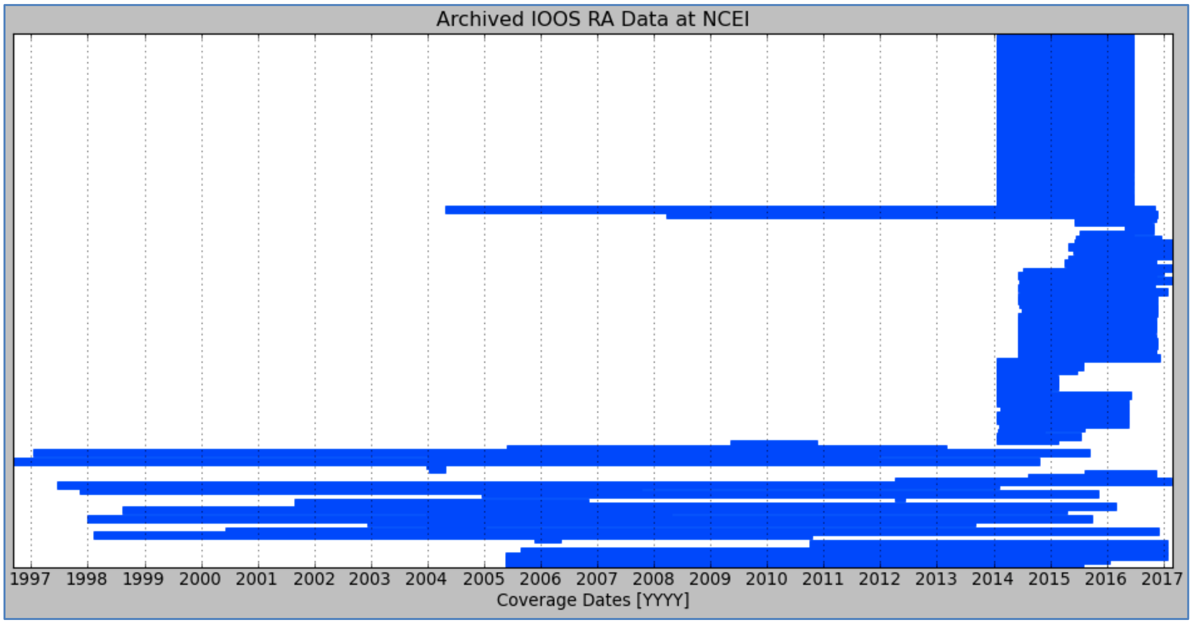

Figure 2. Time-series plot of the currently archived Integrated Ocean Observing System (IOOS) Regional Association (RA) data at NCEI. This time-series only uses the start and end dates from the metadata extracted from each archival information package. Each bar on the time-series represents one archival information package.

Last year, CICS staff developed and delivered a cookbook on how to archive in-situ observational data at NCEI (Figure 3), "Archiving your data at NCEI: A Guide for IOOS Regional Association Data Managers". Which webpage provides a step-by-step procedure on how to develop an automated archival process with NCEI. The information provided therein has been propagated to other user communities, outside of the IOOS RAs, who are learning know how to better manage their data. This year, large portions of the oceanographic data management community, outside of IOOS, requested access and referenced to the NCEI-IOOS Goolge Site for archive discussions. The community response to this resource has indicated that this was a much-needed gap that has finally been filled.

CICS staff has developed a process to move information from an NCEI metadata management system to an NCEI standard operating procedure for automated archive, to facilitate timely archiving of consistent data sets coming from IOOS RAs. Previously, NCEI staff were required to manually transfer information from the metadata management system ATRAC into a standard operating procedure for NCEI IT staff to implement. Through the development of automated archival processes for IOOS RAs, CICS staff has developed an automated pathway for information to be transferred from the ATRAC system to an NCEI standard operating procedure. Thus significantly reducing the amount of effort required for NCEI personnel to establish a procedure for automatically archiving oceanographic data. This new paradigm is also a significant step forward in the recent merger and formation of NCEI. Since the ATRAC system was developed specifically at the National Climatic Data Center (NCDC) and will now be an integral part in the archival process at NCEI, and will be of significant importance in the new NCEI governance structure.

In addition, CICS staff consolidated NCEI wide feedback on the IOOS certification applications. The certification applications ensure that the data collected and distributed by the RAs are managed according to the best practices, as identified by NOAA. CICS staff have reviewed and consolidated responses from NCEI for two applications for certification.

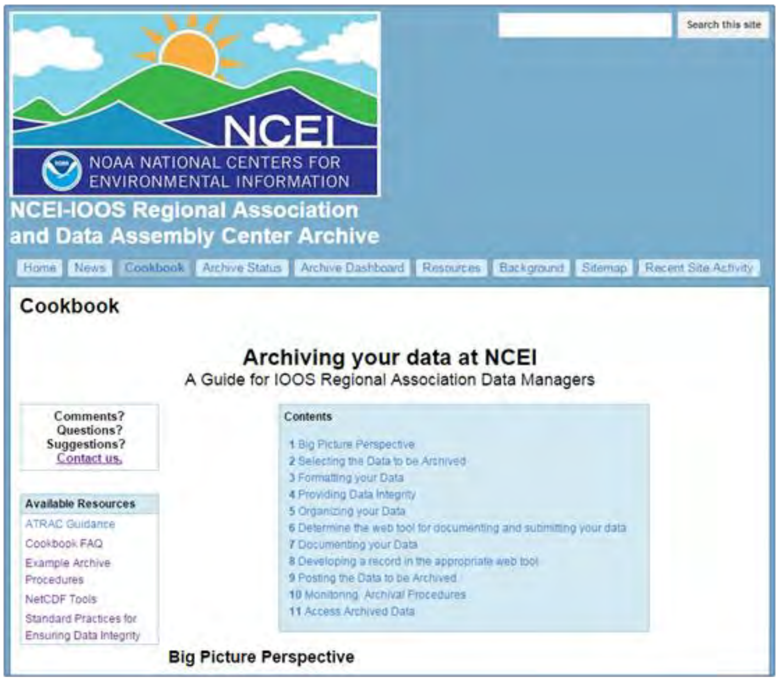

Figure 3. A screen capture of the NCEI-IOOS Google Site cookbook page where Integrated Ocean Observing System Regional Association (IOOS RA) data managers can find information about archive activities at NCEI and how to format and archive their data through an automated process.

In an attempt to assist IOOS RA data providers in formatting their data following current best practices, CICS staff developed a set of “gold standard” example netCDF files. These “gold standard” netCDF examples are examples of how to format a netCDF file following the current discrete sampling geometries as identified by Unidata, Climate and Forecast (CF), and Attribute Conventions for Dataset Discovery (ACDD) netCDF metadata conventions. As data providers are generating new netCDF files for submission to the NCEI archive, they have been using these gold standard examples as a resource for compiling their data files. In addition to the example files, CICS staff have also compiled numerous documents which detail out using the netCDF gold standard example files on various compliance checkers, software tools, and web services. The results of this work can be viewed at the NCEI netCDF templates web page for template versions 1.1 (https://www.nodc.noaa.gov/data/formats/netcdf/v1.1/) and 2 (https://www.nodc.noaa.gov/data/formats/netcdf/v2.0/) in the Feature Type Templates and Examples table.

Planned work

No future work is planned due to the lack of funding for the IOOS Project. However, below is a list of the future work if we were funded:

- Continue to act as the liaison for NCEI to work with the IOOS Program Office and interact with all eleven Regional Associations to enable smooth transfer of data into the archives and respond to any operational problems.
- Archive other IOOS related data sources, like ecosystem projects and animal telemetry data.
- Provide documentation for using NCEI services for IOOS RA archived data.

Products

1. **NCEI netCDF Gold Standard Example Files**
   ("Gold Standard Example" column at https://www.nodc.noaa.gov/data/formats/netcdf/v2.0/#templatesexamples and https://www.nodc.noaa.gov/data/formats/netcdf/v1.1/#templatesexamples)
2. **NCEI netCDF Gold Standard Example File Documentation**
   ("Gold Standard File Testing Report" column at https://www.nodc.noaa.gov/data/formats/netcdf/v2.0/#templatesexamples and https://www.nodc.noaa.gov/data/formats/netcdf/v1.1/#templatesexamples)

Presentations

Biddle, M., NCEI-IOOS Regional Archiving. 2017 IOOS Data Management and Communication Meeting. Silver Spring, MD. March 2017.
Biddle, M., NetCDF Gold Standard Examples: A Walkthrough of the NCEI Templates. 2017 NOAA Environmental Data Management Workshop. Bethesda, MD. Jan 2017.
Biddle, M., NetCDF Overview to the National Institute of Fisheries Science (NIFS). NCEI NIFS face-to-face workshop. Silver Spring, MD. Oct 2016

Other

Nomination for NCEI Innovative Product Award for developing documentation for and data examples promoting the use of NCEI netCDF templates. As quoted from a colleague: "His goal is our goal: to make data more usable, more interoperable, and more relevant."

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
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# of undergraduate students mentored during the year	

New or improved products developed: NCEI netCDF template Gold Standard Examples and documentation.

Products or techniques submitted to NOAA for consideration in operations use: A conversion process which takes data provider information about a data set and translates into NCEI common infrastructure.

Invited presentations: See "Presentations" section above.

CICS Support for the National Centers for Environmental Information (NCEI): Pathfinder Sea Surface Temperature (PFSST), Ocean Surface Salinity Investigation (OSSI), Ocean Color Reprocessed Data (OCRD), and Jason 3 Stewardship Archive

Task Leader Dr. Sheekela Baker-Yeboah.
Task Code SBSB_OCRD_16, SBSB_ODAT_16, SBSB_OPPA_16, SBSB_OSSD_16
NOAA Sponsor Dr. Krisa Arzayus
NOAA Office NESDIS/NCEI
Contribution to CICS Research Themes (%) Theme 1: 45%; Theme 2: 40%; Theme 3: 15%
Main CICS Research Topic: Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%) Goal 1: 0%; Goal 2: 100%; Goal 3: 0%
Strategic Research Guidance Memorandum: 2. Environmental Observations

Highlight: In 2016 CICS played a significant role developing improved satellite data products, working with the ocean science community to provide global and regional ocean data, and contributing to the validating new space-based ocean observing technologies. CICS researchers enhanced NOAA's abilities to understand, predict and communicate climate variability by data dissemination and public education, through web based in-situ and satellite data, and by detailed descriptions of these data.
Link to a research web page: www.nodc.noaa.gov

CICS-UMD NOAA/NESDIS/NCEI Staff: **Dr. Sheekela Baker-Yeboah, PI/Co-PI for Satellite Team Projects** and Team Lead (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Paul DiGiacomo, Dr. Eric Bayler, Dr. Eileen Maturi, Dr. Alexander Ignatov, Dr. Robert Evans, Dr. Eric Leuliette, Dr. Kenneth S. Casey, Dr. Huia-min Zhang, Dr. Laury Miller, Dr. Menghua Wang, Dr. David Donahue); **Dr. Korak Saha** (NOAA Collaborators: Dr. Kenneth S. Casey, John Relph, Thomas Ryan, John Sapper, Dr. Alexander Ignatov, Dr. Frank Monaldo, Christopher Jackson, Dr. Gang Liu, Dexin Zhang); **Dr. Yongsheng Zhang** (NOAA Collaborators: Dr. Eric Bayler, Dr. Banghua Yan, David Donahue, John Lillibridge).

Background

NOAA's National Centers for Environmental Information (NCEI) is an integration of NOAA/NESDIS National Data Centers in Asheville, NC; Boulder, CO; Stennis, MS; and Silver Spring, MD to provide access to the world's most comprehensive environmental data. The Silver Spring, MD location was formerly known as the National Oceanographic Data Center (NODC). NCEI is composed of two main centers: the Center for Weather and Climate; and the Center for Coasts, Oceans, and Geophysics (http://www.ncei.noaa.gov/). NCEI hosts and provides public access to over 20 petabytes of comprehensive atmospheric, coastal, oceanic, and geophysical data. NCEI provides scientific and public stewardship for the nation's environmental data, maintains and updates archives of these data, and contributes scientific research and produce products from these data that help monitor global environmental changes. In January 2017, **Dr. Xiaoyan Li** joined the CICS-MD team at NCEI to work with Dr. Sheekela Baker-Yeboah, Dr. Krisa Arzayus, and Dr. Kenneth Casey on the NSF Arctic Data Center Project.

The NCEI Ocean Satellite Team consists of CICS members **Dr. Sheekela Baker-Yeboah** (Team Lead), **Dr. Korak Saha**, and **Dr. Yongsheng Zhang**, and are responsible for the product development and scientific stewardship of ocean satellite data into the archive. The Satellite Team work on product generation and closely with the NOAA/NESDIS Center for Satellite Applications and Research (STAR) to archive satellite data. These include Jason altimetry, Satellite Sea Surface Salinity, Sea Surface Temperature, Synthetic Aperture Radar, VIIRS (Visible Infrared Imager Radiometer) Ocean Color products, and Satellite Ocean Heat Content Suite, all derived from the variety of satellite platforms.

NCEI serves as the authoritative source within the US for the near real-time and delayed-mode Ocean Surface Topography Mission (OSTM) Jason-2 and Jason-3 products, distributing them to the scientific community as well as the public at large. In addition to providing rigorous long-term archival services, NCEI provides high-level data stewardship with development of custom and routine satellite data products and data visualizations.

CICS-NCEI Satellite Team Members also develop products for scientific applications. Example products include Coral Reef Temperature Anomaly Databased (CoRTAD) and Pathfinder 4km Sea Surface Temperature Climate Data Record. The satellite team works collaboratively with the NCEI Data Stewardship Division to make these data discoverable, perform quality assurance, and provide scientific and technical support to users of these data (http://www.nodc.noaa.gov/SatelliteData/). The ongoing satellite data products are all automatically ingested and placed in the NCEI public data archive. Here they are made available to the public with an array of access mechanisms including ftp, http, OPeNDAP, THREDDS and our geoportal.

The CICS-NCEI Satellite Team produces the Pathfinder Sea Surface Temperature Climate Data Record. Global sea surface temperature (SST) fields are important in understanding ocean and climate variability. The NOAA National Centers for Environmental Information (NCEI) develops and maintains this high-resolution, long-term, climate data record (CDR) of global satellite SST. These SST values are generated at approximately 4 km resolution using Advanced Very High Resolution Radiometer (AVHRR) instruments aboard NOAA polar-orbiting satellites going back to 1981. The Pathfinder SST CDR is recognized and utilized by users as an authoritative source of SST and contributes to the international effort on quality controlled SST field through GHRSST. This CDR is a primary source of information for numerous regional and global marine resource efforts (e.g., local habitat characterization, coral reef stress monitoring by Coral Reef Temperature Anomaly Database).

Another product produced by the Satellite Team is the Coral Reef Temperature Anomaly Database (CoRTAD) designed to quantify global-scale stressors that are widely deemed responsible for the decline of coral reefs. A likely candidate is rising sea surface temperature (SST) in much of the tropics. CoRTAD, funded in part by the NOAA Coral Reef Conservation Program, uses SST from NOAA's Pathfinder program to develop weekly SST averages, thermal stress metrics, SST anomalies (SSTA), SSTA frequencies, SST Degree heating weeks and climatologies (http://www.nodc.noaa.gov/SatelliteData/Cortad/).

Accomplishments

The University of Maryland CICS Researchers continue to enhanced NOAA's abilities to understand, predict and communicate climate variability by data dissemination, public education and product development. Product development and scientific archival stewardship of Satellite Data are summarized by projects: SBSB_OSSD_16 - Ocean Satellite and Surface Data Stewardship, SBSB_ODAT_16 - Ocean Data Stewardship, SBSB_OPPA_16 - NOAA Jason 3 Stewardship Archive, SBSB_OCRD_16 - VIIRS Ocean Color Reprocessed Data Stewardship.

Ocean Satellite and Surface Data Stewardship

1. **Pathfinder Sea Surface Temperature (SST) development and stewardship**

   a. CICS Research Scientist **Dr. S. Baker-Yeboah** and CICS Postdoctoral Research Associate **Dr. K. Saha** continue to maintain ongoing updates to this suite of products. Version 5.3 recent updates to the L2P and L3U products (version 5.3.1). Ongoing efforts are to port these data onto Amazon Web Services for long term access and discovery. **Dr. Baker-Yeboah** is the project PI who worked collaboratively with team members **Dr. Saha** and Mr. Dexin Zhang to generate and steward these products. They are working on the manuscript (Baker-Yeboah, S., K. Saha, D. Zhang, K. S. Casey, K. A. Kilpatrick, R. Evans, and Thomas Ryan. "Pathfinder Version 5.3 AVHRR Sea Surface Temperature Climate Data Record''). **Dr. Baker-Yeboah** gave a poster presentation on PFSST at the AGU 2016 Meeting San Francisco, California.

   b. Pathfinder version 5.3.1 for L2P and L3U data was updated from the version 5.3 after some minor codes changes were applied. These code changes were made to account for swath drops and avoid missing navigational files. The L2P and L3U data is regenerated and is being quality monitored for archiving. The quality monitoring includes generating images (Figure 1) for each swath using the Python code and visually inspect them.

   c. Coefficient updates for the next version of Pathfinder - A match-up database (MDB) is generated between L2P SST and iquam-2 in-situ SST for one sample year (2014). Work is undergoing to develop, maintain and use codes to generate the coefficients going forward.

   d. Automation process for archival of Pathfinder 5.3 L3C data was developed, in September 2016 the 33 years (1981-2014) of data was archived and collection and granule level metadata are developed.

   e. Pathfinder version 5.3 L3C Archival process started with data quality monitoring and validation against the in-situ observations (Figure 2). **Dr. Korak Saha** generated the codes in IDL to develop a matchup database (MDB) using L3C pathfinder data against the iQuam2 insitu SSTs. Daily global statistics as well their monthly and yearly counterparts are also generated. These global statistics were part of the L3C validation process.

2. **Synthetic Aperture Radar (SAR) Wind archive implementation**

   a. New SAR data for Sea Surface Wind from Sentinel-1A and Sentinel-1B produced by NOAA STAR is getting archived using an automation process that was developed with the help of DSD and SEB branches of NCEI. **Dr. Baker-Yeboah** worked collaboratively between NCEI and STAR with **Dr. Saha** on this project to champion these data into the NCEI archive.

   b. **Dr. Baker-Yeboah** provides subject matter expertise as a Physical Oceanographer and manages the project.

   c. Figure 3 (a-b) shows an archived image of wind data from Sentinel-1A and Sentinel-1B.

   d. **Dr. Korak Saha** worked with DSD to generation granule metadata and discovery through NCEI Geoportal, collection metadata is ready but is not yet indexed with the granule metadata.

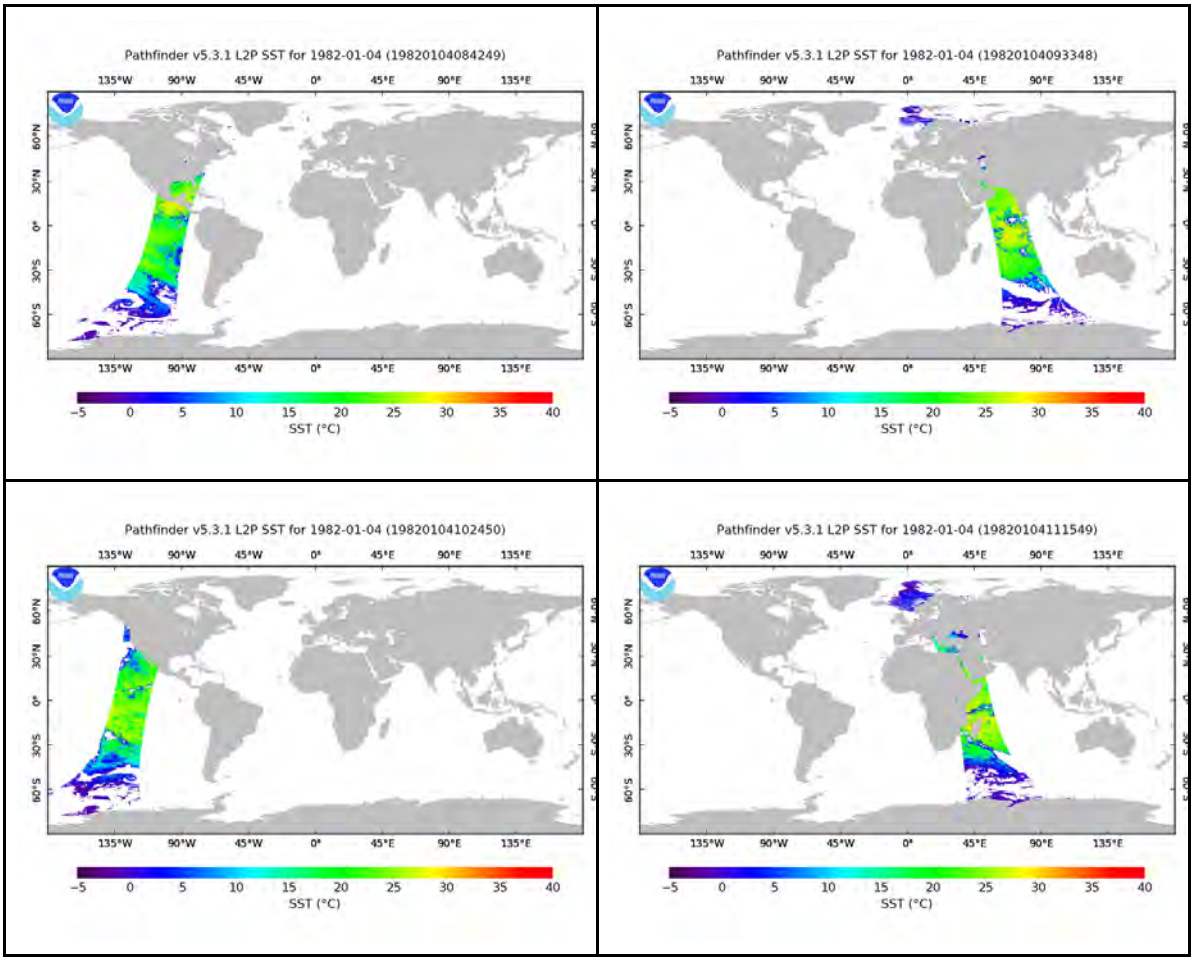


Figure 1. Pathfinder Sea Surface Temperature level 2 processed (L2P) data to be published to the public via the NOAA archive for the first time.

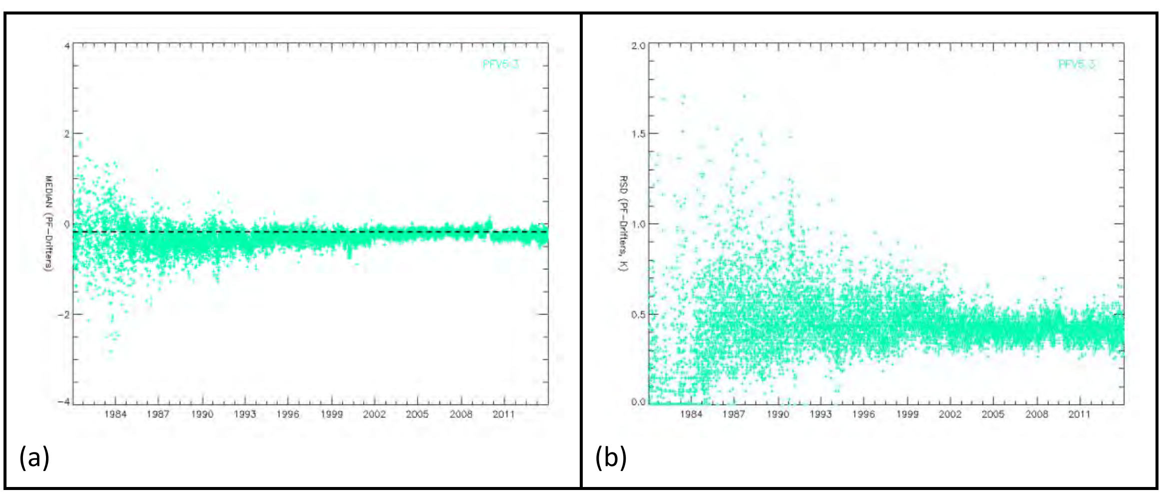


Figure 2. Pathfinder 5.3 L3C Match-up database with in-situ SSTs are used to generate global median (a) and robust standard deviation (b) statistics on the difference field.

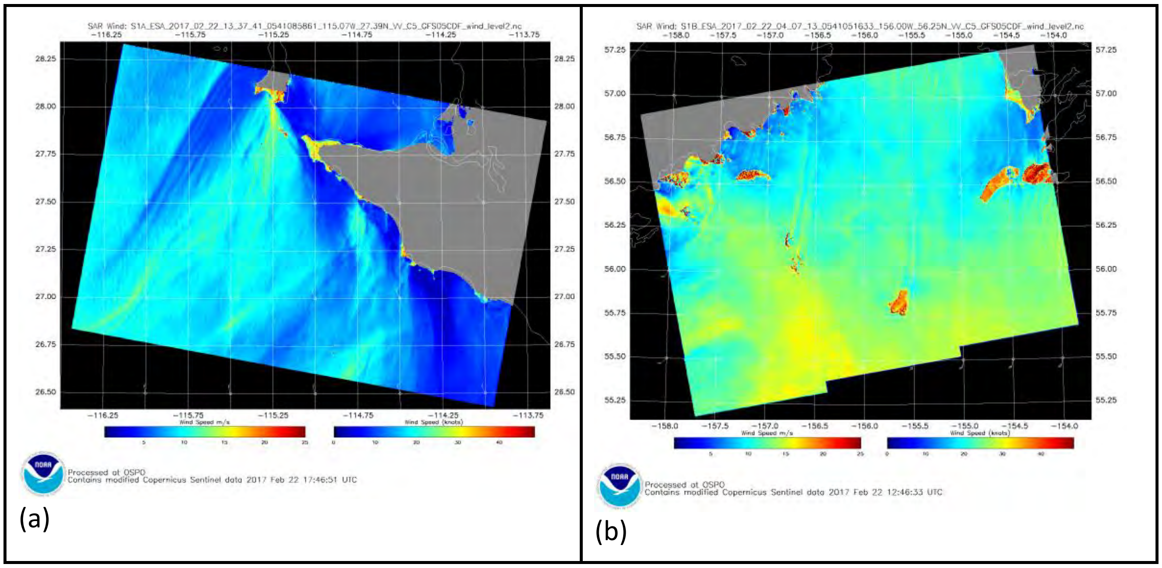


Figure 3. Archived images of SAR wind data obtained from Sentinel-1A (a) and Sentinel-1B (b).

3. **Coral Reef Watch Daily 5 km Satellite Coral Bleaching Thermal Stress Monitoring Product**

   a. **Dr. Korak Saha provided scientific stewardship for the STAR** Coral Reef Watch (CRW) 5 km data. Data samples was checked for netCDF compliance and necessary suggestions were made to the producer for changes in the metadata.

   b. CRW automation procedure is started by developing a archive documentation and finalizing the directory structure and archival procedure.

4. **GHRSST Stewardship**

NCEI has a Long Term Stewardship and Reanalysis Facility (LTSRF) for the Sea Surface Temperature Products as part of the Group for High Resolution Sea Surface Temperature (GHRSST). GHRSST is one of the dataset chosen to be served using NOAA’s OneStop Data Discovery and Access Framework Project, initialized in FY15 and is now working rapidly to improve discovery and access to NOAA's data.

   a. **CICS team members Dr. Baker-Yeboah and Dr. Saha** contribute to the international effort on sea surface temperature call the Group for High Resolution Sea Surface Temperature (GHRSST: https://www.ghrsst.org).

   b. **Dr. Baker-Yeboah** is a Co-PI on the NCEI GHRSST project and worked collaboratively with NCEI staff and **Dr. Saha** on this project. **Dr. Baker-Yeboah** presented a talk and posters at the GHRSST June 2016 meeting on the NCEI GHRSST data sets, Pathfinder SST GHRSST products and the Scientific Stewardship of GHRSST Products. **Dr. Saha** presented a poster on the level 3C product validation for the Pathfinder SST GHRSST products.

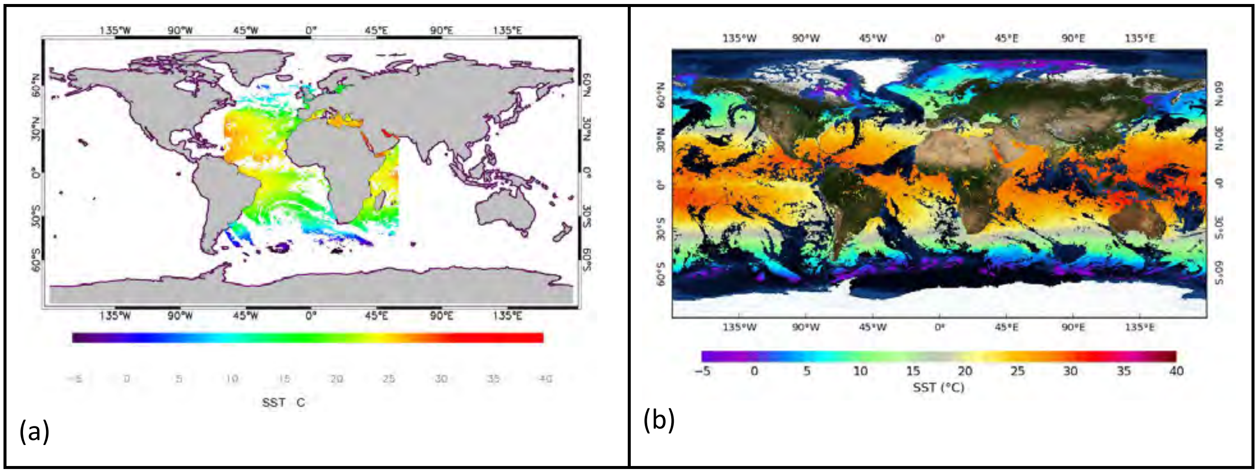


Figure 4. Two of the newly added GHRSST products in LTSRF; (OSI SAF) L3C SST data from SEVIRI on MSG-3 (a) and NOAA L3U SST product from VIIRS_NPP (b)

c. **Dr. Korak Saha** worked with the DSD to generate granule level metadata for some of the GHRSST products archived last year. These data include Ocean and Sea Ice Satellite Application Facility (OSI SAF) L3C SST data from SEVIRI on MSG-3(Figure 8a), NOAA Office of Satellite and Product Operations (OSPO) L2P (Figure 8b) and L3U SST products from VIIRS_NPP.

d. Regular maintenance of GHRSST archived data. Annual GHRSST archive updates on provider information and other metadata updates performed for the GHRSST science team meeting. Troubleshoot related with daily automatic archival of all the products is regularly done, along with that helping out users of the GHRSST data by providing them information on the data.

e. Direct Archival of SST data from the producers (NCEI as GHRSST RDAC)

i. As a part of preparation for the multi-GDAC idea that is being proposed in last GHRSST meeting, the NOAA/STAR generated ACSPO AVHRR GAC SST data is served directly to NCEI. NOAA CoastWatch is the data provider (RDAC) and NCEI will be the GDAC and will also archive this retrospective data set (2002-current).

ii. After request was received to archive this data, an ATRAC appraisal request form was generated for NCEI. The satellite members are involved in getting this data archived starting from generating the ATRAC form to develop automation process to archive and/or access this data for the public usage.

Ocean Data Stewardship

1. Sea Surface Salinity (SSS) product development and stewardship

a. CICS Research Scientists **Dr. Baker-Yeboah** and **Dr. Zhang** work collaboratively on the Sea Surface Salinity investigation in collaboration with Dr. Eric Bayler of STAR. They are working on a manuscript (Zhang, Yongsheng, Eric Bayler and Sheekela Baker-Yeboah, 2016: NCEI Binned level-3 Aquarius and SMOS sea surface salinity datasets; in preparation and to be submitted to *Data Science Journal*). **Dr. Baker-Yeboah** provides subject matter expertise as a Physical Oceanographer and manages the project.

b. **Dr. Zhang** worked to development of NCEI-binned level-3 sea surface salinity data. He generated gridded level-3 SSS data from Soil Moisture Active Passive (SMAP) satellite level-2 granules by applying data quality flags and simple interpolation method. The outputs cover various time scales from swath to 8-day and monthly means.

c. **Dr. Zhang** gave a poster presentation on satellite sea-surface salinity data validation using NCEI real-time and delay-mode in situ observations at the December 2016 AGU meeting in San Francisco, CA.

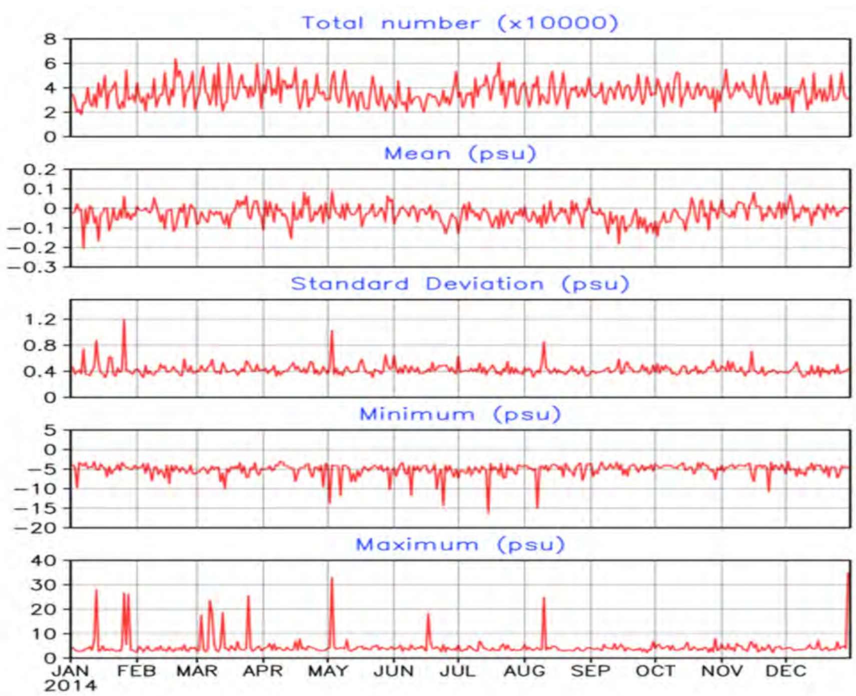


Figure 5. Daily statistical time series of SSS difference (SMOS roughness Model #1 minus co-located in situ GTSPP). From top to bottom: a) number of observations; b) global average; c) standard deviation; d) minimum and e) maximum. The data is matched within a 50-km footprint, centered at the SMOS Level-2 (swath) observation longitude and latitude values, and within a 3-day time window from -1 to +1 day.

d. **Dr. Zhang** worked to development of NCEI data quality monitoring systems (DQMS) on the level-2 sea surface salinity (SSS) swath data from the ESA's Soil Moisture Active Passive (SMOS), NASA's Aquarius and SMAP satellites. An important component of NCEI's data stewardship for SSS satellite products is to develop the DQMS based on NCEI's Rich Inventory conception in order to monitor and track the data assurance statistics and metadata attributes in each granule. In the last year, **Dr. Zhang** worked to establish and operationally implement of data quality monitoring on the latest version of level-2 SSS products from SMOS and Aquarius satellites, as well as those from SMAP satellite. The results are published on the NCEI SSS data quality monitoring homepage: http://www.nodc.noaa.gov/SatelliteData/sss/.

e. **Dr. Zhang** validates the NCEI-created binned SMOS V3.0 3-day and monthly mean, Aquarius (ADPS V4.0 and CAP V4.0) 7-day and monthly SSS products.

f. **Dr. Zhang** also worked on development of NCEI scientific data validation system on the satellite SSS data by using NCEI-collected conventional ship observations. This includes development of the satellite-*in situ* SSS matchup datasets and to establish the web-based satellite SSS validation system. **Dr. Zhang** applied the SSS observations from NCEI-collected Global Temperature and Salinity Profile Programme (GTSPP) and Global Thermosalinograph (TSG) Database to generate the satellite-in situ matchup datasets, and initiated to investigate the results.

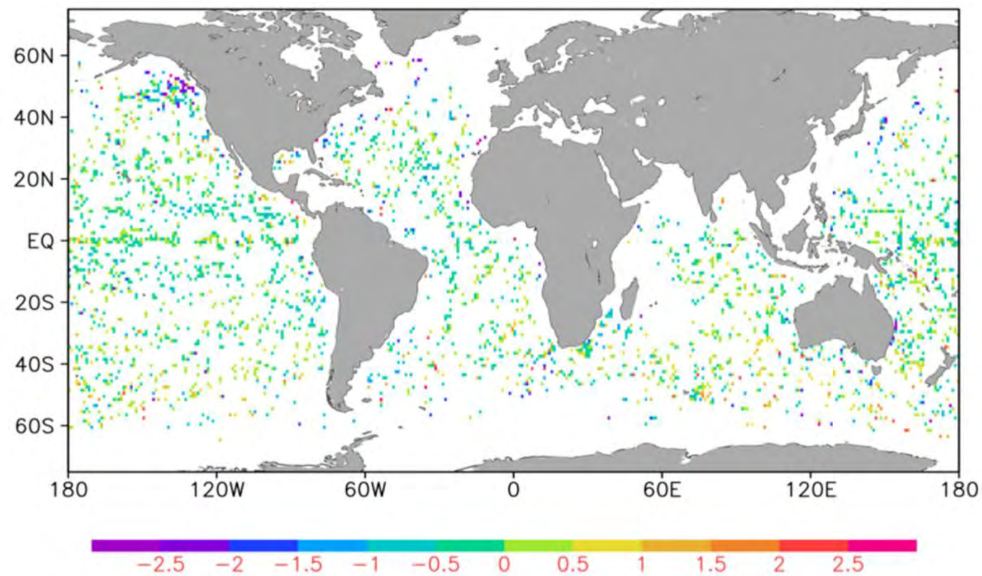


Figure 6. Global map of monthly mean SSS difference between SMOS (roughness Model 1) and co-located GTSPP in situ observations for March 2014. The data are matched within a 50-km footprint and within a 3-day time window. The matchup SSS differences are binned into a global 1-degree grid for determining monthly means.

NOAA Jason 3 Stewardship Archive

1. **Dr. Baker-Yeboah** provides subject matter expertise as a Physical Oceanographer and manages the project. **Dr. Zhang** is the Science Steward of the NCEI Jason Stewardship project. **Dr. Baker-Yeboah** participated in the Ocean Surface Topography Science Team (OSTST) meetings during the early launch period and planning of the Jason mission, presented on the combined effort of NCEI to support the Jason mission at the OSTST meeting in La Rochelle France and on decomposing the Sea Surface Height signal at the NASA Sea Level Change Team (N-SLCT) Meeting in Norfolk, Virginia. **Dr. Zhang** is also a member of the OSTST and has continued to work with NCEI staff to keep the Jason stewardship efforts going smoothly.

2. **Implemented routine data archive, access and distribution tasks for Jason-2 and Jason-3 products.** The CICS-NCEI Satellite Team members, **Dr. Baker-Yeboah** and **Dr. Zhang,** works collaboratively with the Jason-3 Team to provide public access to the Jason-3 level-2 X-GDR datasets and work with CLASS to archive the new data and work with STAR on providing more us-

er products.

3. **Dr. Zhang** generated the data quality monitoring on the Jason-3 level-2 final and Interim Geophysical Data Record (GDR/IGDR) data files in order to monitor and track the data quality assurance and metadata attributes in each granule and made them available as part of a data discovery system. He also generated quick-look gridded datasets GDR/IGDR (cycle mean, 0.25x0.25 and 3.0x1.0 longitude/latitude degree) for public users in near real-time. **Dr. Zhang** also coordinated NCEI's archival work with NOAA and CNES data centers and perform monthly and annual reconciliation of Jason2/3 products archive between the two data centers.

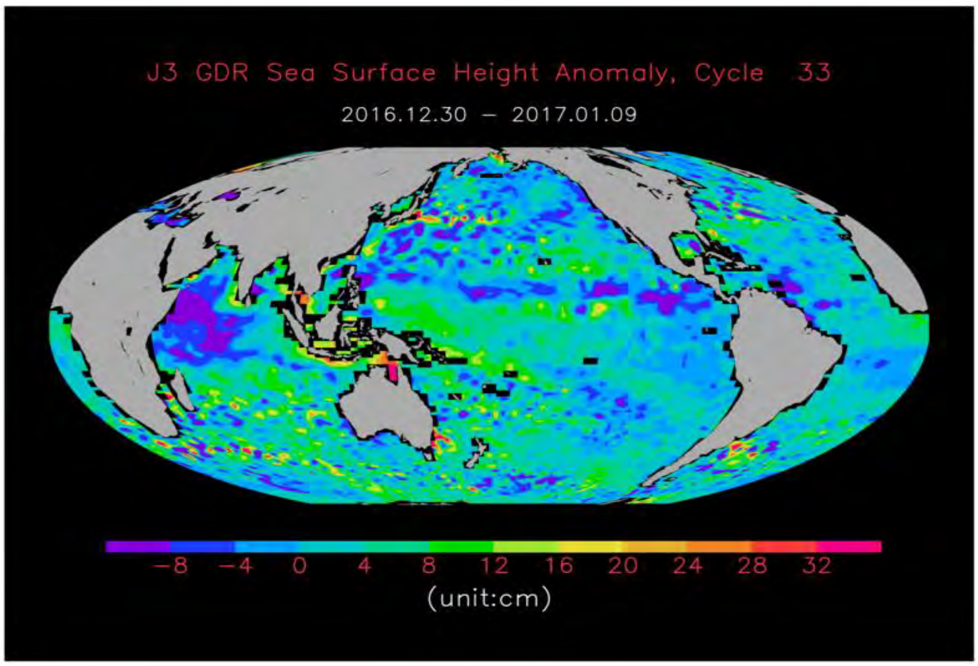


Figure 7. Cycle mean Sea surface height anomaly (in unit of) cm from NCEI-produced quick-look level-3 data from Jason-3 final Geophysical Data Record (GDR).

VIIRS Ocean Color Reprocessed Data Stewardship

1. **Development of a new NCEI VIIRS Ocean Color science quality data access system**
   a. CICS Research Scientists **Dr. Baker-Yeboah** worked with NOAA data producer and NCEI Data Stewardship Division (DSD) in collaboration with the NOAA Complex Large Array-Data Stewardship System (CLASS) to develop a new NCEI VIIRS Ocean Color science quality data access system in connection with new enterprise efforts within NCEI. **Dr. Baker-Yeboah** and **Dr. Zhang** have helped to complete necessary archival documents between NCEI, STAR/CoastWatch (the data producer) and CLASS.
   b. **Dr. Baker-Yeboah** continues to work with NCEI staff to move forward the repurpose of an OpenStack Cloud hardware system in connection with new enterprise efforts within NCEI and the development of collection.

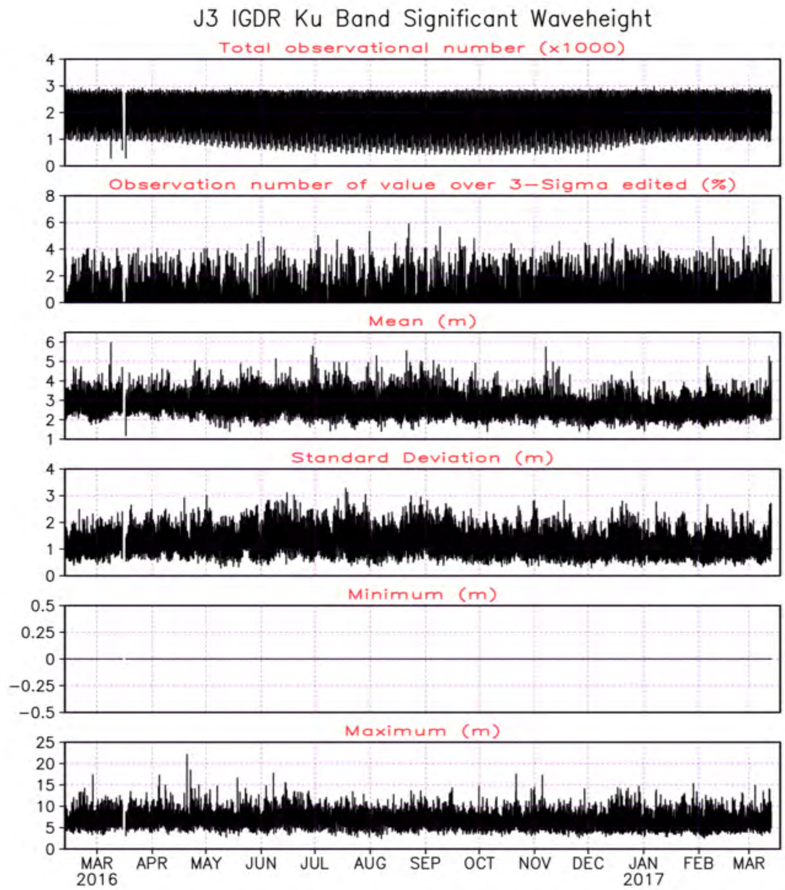


Figure 8. Jason-3 data quality assurance statistics in each granule (pass) for significant wave height of Jason-3 Interim Geophysical Data Record (IGDR)

c. **Dr. Zhang** will work with NCEI staff on the granule-level metadata to improve the data search and discovery of ocean color environmental data records.

d. **Dr. Baker-Yeboah** provides subject matter expertise as a Physical Oceanographer and manages the project.

Planned Work

University of Maryland CICS Researchers plan to continue contributing to the NOAA mission for long-term access and discovery of Oceanographic Satellite Environmental information to support our Nation. Future efforts are summarized below.

1. **Pathfinder SST product development and archive**
   a. Working towards validation statistics for the L2P and L3U products
   b. Development of process to generate the SST Coefficients for future pathfinder versions

c. Work on a Amazon Web Services (AWS) Project to serve PFSST data (L2P, L3U, L3C)

2. **Synthetic Aperture Radar (SAR) wind data archival stewardship**
    a. Scientific stewardship of Sentinel SAR-wind data
    b. Stewardship of upcoming data from newer satellites
3. **GHRSST Stewardship (pending NOAA funding)**
    a. Ongoing Data Stewardship for the GHRSST data set
    b. Continue working as a Subject Matter Expert (SME) for the GHRSST products in NOAA OneStop
    c. Complete and support archival of ACSPO AVHRR GAC L2P SST retrospective products.
    d. Continue work on including and stewarding new GHRSST products that is added to the GHRSST LTSRF.
    e. Prepare for the multi-GDAC idea that is being proposed in last GHRSST meeting
    f. Develop metadata (granule level) for 8 new products under GHRSST
4. **Jason Altimeter data archival stewardship**
    a. Work with NCEI staffs from Data Steward Divison on development of Jason-3 level-2 granule metadata to improve the data search and discovery at NCEI Geoportal Server.
    b. Continue to coordinate NCEI's archival work with NOAA and CNES data centers and perform monthly and annual reconciliation of Jason2/3 products archive between the two data centers, and re-ingest the missing data into CLASS.
    c. Generate the data quality monitoring system based on Rich Inventory conception for Jason-3 GDR granules and 1-degree cycle mean quick-look datasets.
    d. Work to set up daily file monitoring system on the Jason-3 level-2 data flowing into NCEI spin-disk from NESDIS operational data distribution system(DDS).
5. **Sea Surface Salinity product development and stewardship.**
    a. Generate the data quality monitoring system based on Rich Inventory conception for new version Aquarius, SMOS and SMAP level-2 SSS granules.
    b. Continue to produce level-3 binned satellite SSS products from SMAP and SMOS level-2 products.
    c. Continue to develop the satellite and in situ SSS matchup datasets, including SMOS and SMAP satellites with best-copy and real-time NCEI GTSPP and TSG in situ datasets, and initiate the web-based scientific data quality monitoring and validation on the SMOS and SMAP satellite SSS data.
    d. Investigate in the methods and create processing codes which lead to produce value-added satellite-in situ-blended level-4 SSS products.
6. **VIIRS Ocean Color Reprocessed Data** (pending NOAA funding)
    a. Work with the NOAA data producer (STAR/CoastWatch), CLASS and NCEI Data Stewardship Division on establishment the long-term preservation in CLASS and online ftp, http, OPeNDAP, THREDDS access services through replicating the L2 and L3 data from CLASS into NCEI-operated spinning-disk.

b. Work with NCEI staffs from NCEI Data Steward Division on development of collection and granule-level metadata for above-mentioned datasets to improve the data search and discovery at NCEI Geoportal Server.

7. **Additional Ocean Satellite Data Stewardship pending NOAA funding**.
   a. Continue working to extend and improve NOAA dataset by providing ongoing scientific data stewardship to fulfill the NOAA mission, e.g., Coral Reef Watch, Satellite Ocean Heat Content Suite, VIIRS Ocean Color Near Real Time Stewardship and other new products introduced throughout the year.
   b. Continue contributing efforts to the development of the NOAA/NCEI Archive Management System (AMS) for the oceanographic satellite products.

Publications

Baker-Yeboah, S. K. Arzayus, K. S. Casey, and M. B. Jones: National Centers for Environmental Information Arctic Data Integration with the NSF Arctic Data Center. 2016 Arctic Research Consortium of the United States, Fall Issue 6. https://www.arcus.org/witness-the-arctic/2016/3/article/26070
Baker-Yeboah, S., K. S. Casey, and V. Banzon: Report: GHRSST RDAC Update: NOAA/NESDIS/NCEI. GHRSST XVII - Science Team Meeting, June 6-10, 2016. https://www.ghrsst.org/agenda/ghrsst-xvii/

Products

1. NCEI Pathfinder Sea Surface Temperature Climate Data Record Version 5.3.1 Level L2P.
2. NCEI Pathfinder Sea Surface Temperature Climate Data Record Version 5.3.1 Level L3U.
3. Coral Reef Temperature Anomaly Data Base (CoRTAD). This is a level 4 suite of products used for coral reef ecosystem applications.
4. NCEI-binned level-3 V3.0 8-day and monthly mean sea surface salinity derived from the level-2B V3.0 swath data produced by the JPL SMAP project.

Presentations

1. **Baker-Yeboah,** S., K. Arzayus, K. S. Casey. NOAA Seminar: The NSF Arctic Data Center Collaborates with NOAA's National Centers for Environmental Information. NOAA/NESDIS Silver Spring, January 2017 (Talk).
2. **Baker-Yeboah,** D. Byrne, and R. Watts: Decomposing the Sea Surface Height Signal of Mesoscale Variability. NASA Sea Level Change Team (N-SLCT) Meeting in Norfolk, Virginia. September 7-9, 2016 (Poster).
3. **Baker-Yeboah, S.,** Kenneth S. Casey**, Korak Saha,** Yuanjie Li, and John Relph: Scientific Stewardship of GHRSST Products. GHRSST XVII - Science Team Meeting, June 6-10, 2016 (Poster).
4. **Baker-Yeboah, S.**, K. S. Casey, and **V. Banzon**: GHRSST RDAC Update: NOAA/NESDIS/NCEI. GHRSST XVII - Science Team Meeting, June 6-10, 2016 (Talk).
5. **Baker-Yeboah, S.** and K. S. Casey, NCEI and South Korean National Institute of Fisheries Science (NIFS) workshop October 24-25, 2016, Silver Spring, Maryland. October 2016 (Talk).
6. **Baker-Yeboah, S., K. Saha,** D. Zhang, K. S. Casey, R. Evans, and K. Kilpatrick. Pathfinder

Version 5.3 AVHRR Sea Surface Temperature Climate Data Record, AGU 2016 Meeting San Francisco, California. December 2016 (Poster).

7. **Baker-Yeboah, S., K. Saha,** D. Zhang, and Kenneth S. Casey. Pathfinder AVHRR Sea Surface Temperature 4 km Climate Data Record. Annual GHRSST Science Team Meeting, 06 - 10 June 2016. (Poster)
8. **Baker-Yeboah, S., K. Saha,** D. Zhang, and Kenneth S. Casey. Pathfinder AVHRR Sea Surface Temperature 4 km Climate Data Record. Annual GHRSST Science Team Meeting, 06 - 10 June 2016. (Poster)
9. **Baker-Yeboah, S., Korak Saha, Yongsheng Zhang**, and Dexin Zhang: Scientific Stewardship of Ocean Satellite Data, NOAA 2016 Environmental Data Management Workshop, Washington DC (Talk, January 2017).
10. **Baker-Yeboah, S. and Y. Zhang**: Scientific Stewardship for Jason-2/3 products: NOAA Archive and Access Services, 2016 Ocean Surface Topography Science Team (OSTST) Meeting, 31 October – 01 November 2016, La Rochelle France. (Talk)
11. Casey, K. S., **K. Saha**, A. Krishnan, Y. Li, J. Relph, **Y. Zhang**, and **S. Baker-Yeboah**. G17 LTSRF updates, Annual GHRSST Science Team Meeting, 06 - 10 June 2016.
12. **Saha, K., S. Baker-Yeboah,** Kenneth S. Casey, John Relph, Yuanjie Li and Ajay Krishnan. "Scientific Stewardship of Group for High Resolution SST products"; CICS Science Conference, 29 Nov - 01 Dec 2016. (Poster)
13. **Saha K., S. Baker-Yeboah,** and Kenneth S. Casey**.** Validation of the Pathfinder version 5.3 L3C Sea Surface Temperature with global drifter data, Annual GHRSST Science Team Meeting, 06 - 10 June 2016. (Poster)
14. **Wang, Z.**, T. Boyer, H. Zhang, E. J. Bayler, **M. Biddle, S. Baker-Yeboah, Y. Zhang** (2016)., NCEI-TSG: A Global in situ Sea-surface Salinity and Temperature Database of Thermosalinograph, December 2016, 2016 AGU Fall Meeting, San Francisco, CA.
15. **Zhang, Yongsheng**, Eric Bayler and **Sheekela Baker-Yeboah**, 2016: Toward satellite sea-surface salinity data validation using NCEI real-time and delay-mode in situ observations. 12-16 December, San Francisco, USA.

Other

Proposals

Dr. S. Baker-Yeboah CICS funded proposals and collaboration proposals

- SBSB_OCIA_16: Ocean Color In Situ Analysis
- NSF Arctic Data Center (ongoing proposal)

Outreach/Advising/Science Reviewer

1. **Dr. Korak Saha** served as reviewer Panelist for GRFP graduate students NSF funding 2017.
2. **Dr. Korak Saha** served as reviewer for applications for the Class of 2017 Ernest F. Hollings and Educational Partnership Program (EPP) Undergraduate Scholarships.
3. **Dr. S. Baker-Yeboah** served at AGU Science Judge.
4. **Dr. S. Baker-Yeboah** served as a panelist on the NCEI Grants Forum Panel February 1, 2017.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	4
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of NOAA technical reports	2
# of presentations	15
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

A description of all products can be found in the "Products" section.

2.7 Land and Hydrology

CICS Support for Hydroclimatological Activities at Climate Prediction Center	
Task Leader	Li-Chuan Chen
Task Code	EBLC_HACP_15 Year 2
NOAA Sponsor	David DeWitt and Huug van den Dool
NOAA Office	NWS/NCEP/CPC
Contribution to CICS Themes (%)	Theme 2: 25%; Theme 3: 75%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%
Strategic Research Guidance Memorandum: 4. Integrated Water Prediction	

Highlight: CICS researcher developed a new weighting system to objectively combine multiple seasonal probabilistic forecasts in the North American Multi-Model Ensemble (NMME). The new system improves prediction skill of precipitation and temperature from baseline, equally weighted forecasts.

Background

This work is to support NOAA/NCEP Climate Prediction Center's (CPC's) efforts on North American Multi-Model Ensemble (NMME) forecasts and evaluations. NMME is a multi-model forecasting system consisting of coupled climate models from U.S. modeling centers (including NCEP, GFDL, NASA, and NCAR) and Canadian Meteorological Centre (CMC), aimed at improving intraseasonal to interannual prediction capability. Tasks include (1) developing algorithms and techniques for multi-model ensemble forecasts and evaluations, (2) working on research to advance the science and technology necessary for subseasonal to seasonal prediction, and (3) assisting in NMME system upgrades/transition/maintenance, including pre-processing and post-processing hindcasts and real-time forecasts, migrating the codes for running at alternative platforms, and updating hindcast archive (originally 1982-2010) with real-time forecasts.

Accomplishments

In 2016, my colleagues at CPC and I developed a new weighting system to objectively combine multiple seasonal probabilistic forecasts in the NMME. The new system is applied to predict temperature (T) and precipitation (P) over the North American continent, and the analysis is conducted using the 1982-2010 hindcasts from eight NMME models, including the CFSv2, CanCM3, CanCM4, CM2.1, FLOR, GEOS5, CCSM4, and CESM models, with weights determined by minimizing Brier Score (BS) using ridge regression. Calculation of weights for models in a multi-model ensemble framework has been attempted before, but nearly always for forecasts in terms of physical units — in contrast we work directly with forecasts expressed as probabilities. Strategies to improve the performance of ridge regression are explored, such as excluding more years for cross validation, eliminating a-priori models with negative skill, and increasing the effective sample size by pooling information from neighboring grids. A set of constraints is placed to confine the weights within a reasonable range or restrict the weights departing wildly from equal weights, which is the fall-back. So when the predictor-predictand (model forecast-verifying observation) relationships are weak, the multi-model ensemble forecasts return to equal-weight combination.

Figure 1 shows an example of the cross-validated BS of equally weighted forecasts (left column) for FMA T probabilistic forecasts initialized on January 1. The top, middle, and bottom rows are for above-, near-, and below-normal (AN, NN, and BN) categories, respectively. The spatial variations of the predictive skill can be clearly seen in the plots, and the T forecast skill of the NN category is lower than that of the AN and BN categories. The middle column presents the differences in BS between the consolidated and equally weighted forecasts for the three categories. Colors (greens and blues) indicate improvements in T forecast skill with weighting scheme. The areas within the red contours are tested to be statistically significant at 5% level using the method described in DelSole et al. (2013). Comparing to their results, there is an increase in the fraction of North American area tested to be statistically significant in our study. For the AN and BN categories, there are large improvements in skill with weighted forecasts in the central U.S. These areas coincide with areas that have large model elimination percentages (shown in the right column), suggesting that the strategy of removing a-priori models with negative skill is a main factor contributing to the improved skill of the consolidation forecasts.

Overall, the new system is able to optimally select skillful models based on hindcast performance and assign weights accordingly. All models contribute to the weighted forecasts differently based upon location and forecast start and lead time. The system shows improved skill from baseline, equally weighted forecasts. Because of the elimination and fall-back, there is no loss (in respect to equal weight) when model skill is poor. The amount of improvements varies across space and corresponds to the average model elimination percentage. Area with higher elimination rate tends to have larger improvement in cross-validated verification scores. Pooling information from neighboring grids also improves forecast skill. Some local improvements can be as large as 0.6 in cross-validated probability anomaly correlation (PAC). On average, about 0.02-0.05 in PAC for T probabilistic forecasts and 0.03-0.05 for P probabilistic forecasts over North American continent. Skill improvement, on average, is greater for P probabilistic forecasts than T probabilistic forecasts. The fraction of North American land area for which the equal weighting hypothesis is rejected is about 4-26% and 6-17% at the 5% significance level for T and P forecasts, respectively, increased from past studies (e.g., DelSole et al. 2013). The results of this research were presented in 2016 AGU Fall Meeting and NMME Work Group meetings in October 2016 and February 2017.

In addition to the development of NMME weighting system, I have conducted an evaluation of the candidate NCAR CESM model, including its systematic errors, forecast skill of precipitation, temperature, and sea surface temperature (SST), and potential impacts on NMME if included. The assessment was carried out using the 1982-2010 hindcast and the results were compared to other NMME models. Among the eight models, CESM has larger systematic errors and its forecast skill of P, T, and SST generally is lower than that in most NMME models. However, CESM outperforms other NMME models in some areas and months. Because of the number of participant models in NMME (i.e., eight), the impact is small by adding CESM into NMME. These results were presented in

NMME teleconference on 5 May 2016, and CESM was added in NMME and started to produce real-time forecasts since July 2016.

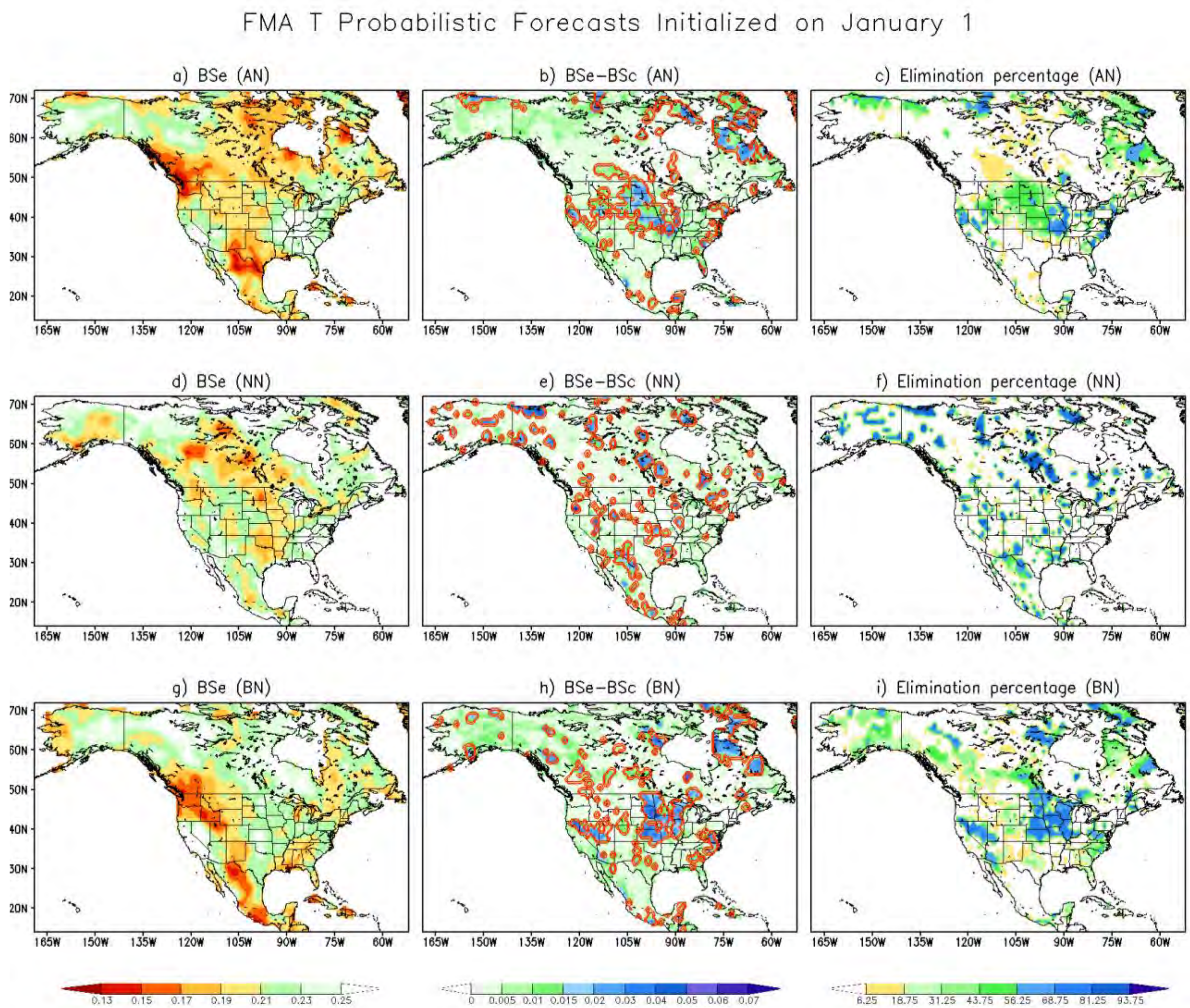


Figure 1. For FMA T probabilistic forecasts initialized on January 1: left column: cross-validated BS of equally weighted forecasts for (a) above-, (d) near-, and (g) below-normal categories; middle column: difference in BS between the consolidated and equally weighted forecasts for (b) above-, (e) near-, and (h) below-normal categories; right column: average elimination percentage of consolidated forecasts for (c) above-, (f) near-, and (i) below-normal categories.

Beside these research and development activities, I participate in NMME's planning, research to operation (R2O), and maintenance activities as well. I assist in data processing, hindcast update, and planning for subseasonal forecast system and new NMME Work Group projects. I also attend monthly NMME teleconferences and Work Group meetings. NMME, aimed at improving intraseasonal to interannual prediction capability with increased ensemble size and model diversity, has provided a unique research platform for predictability and prediction research and become a valuable resource to support CPC's operational forecasts.

Planned work

- Analysis of choice, request, or opportunity (such as NAO performance, model produced ENSO composites, global change trends in each model, drought, initial soil moisture anomaly etc.)
- Basic evaluation of a candidate new model (climatological analysis, skill assessment etc.)
- Development of additional real-time verification products and assessment of real-time forecast skill of current events.
- Design of different approaches to accomplish systematic error correction, both in the mean and higher moments.
- Development of weighting scheme of N models to optimize skill in a consolidation, both deterministically and probabilistically.

Publications

Refereed Journal Articles:

Chen, Li-Chuan, Huug van den Dool, Emily Becker, and Qin Zhang (2017): ENSO Precipitation and Temperature Forecasts in the North American Multimodel Ensemble: Composite Analysis and Validation. *J. Climate*, **30**, 1103–1125, doi: 10.1175/JCLI-D-15-0903.1.

Van den Dool, Huug, Emily Becker, Li-Chuan Chen, and Qin Zhang (2017): The Probability Anomaly Correlation and Calibration of Probabilistic Forecasts. *Wea. Forecasting*, **32**, 199–206, doi: 10.1175/WAF-D-16-0115.1.

Chen, Li-Chuan, and Huug van den Dool (2017): Combination of Multi-Model Probabilistic Forecasts Using Objectively Determined Weights. In preparation.

Book Chapters:

Pena, Malaquias, Li-Chuan Chen, and Huug van den Dool (2017): Intra-Seasonal to Inter-Annual Climate Variability and Prediction in *Handbook of Hydrometeorological Ensemble Forecasting*, edited by Qingyun Duan, Hannah Cloke, John C. Schaake, Jutta Thielen-del Pozo, Andy Wood, and Florian Pappenberger, Springer. Submitted.

Products

A new weighting system to objectively combine NMME seasonal probabilistic precipitation and temperature forecasts.

Presentations

Chen, Li-Chuan, Huug van den Dool, Emily Becker, and Qin Zhang (2016): ENSO Precipitation and Temperature Forecasts in the North American Multi-Model Ensemble: Composite Analysis and Validation. World Environmental & Water Resources Congress 2016, West Palm Beach, FL.

Chen, Li-Chuan, and Huug van den Dool (2016): Combination of Multi-Model Probabilistic Forecasts Using Objectively Determined Weights. AGU Fall Meeting, San Francisco, CA.

Van den Dool, Huug, Emily Becker, Li-Chuan Chen, and Qin Zhang (2016): Some Ideas about Applying the Probability Anomaly Correlation to Improve Probability Scores. 7th NOAA Test Bed and Proving Ground (TBPG) Workshop, College Park, MD.

Van den Dool, Huug, Li-Chuan Chen, Qin Zhang, Joe Tribbia, and Julie Caron (2016): Adding CESM to NMME: What it Would Look Like. NMME Teleconference, March 10.

Chen, Li-Chuan, and Huug van den Dool (2016): CESM Skill Evaluation and More. NMME Teleconference, May 5.

Van den Dool, Huug, Emily Becker, Li-Chuan Chen, and Dan Collins (2016): Unequal Weights Project Update. NMME Work Group Meeting, August 30.

Chen, Li-Chuan, and Huug van den Dool (2016): NMME Weighting. NMME Work Group Meeting, October 26.

Chen, Li-Chuan, and Huug van den Dool (2017): NMME Weighting Report. NMME Work Group Meeting, February 8.

Other

Chen, Li-Chuan, Lifeng Luo, Hamid Moradkhani, and Shahrbanou Madadgar (Convenors and Chairs), Hydroclimatic Extremes: Drought, 2016 Fall Meeting, American Geophysical Union, San Francisco, CA, 12-16 Dec.

Chen, Li-Chuan, and Alfonso Mejia (Convenors and Chairs), Probabilistic Forecasting and Verification in Hydrometeorology, 2016 Environmental & Water Resources Institute Congress, West Palm Beach, FL, 22-26 May.

Chen, Li-Chuan (Chair), American Society of Civil Engineers/Environmental & Water Resources Institute/Risk, Uncertainty, and Probabilistic Approaches Technical Committee.

Chen, Li-Chuan (Reviewer), Journal of Hydrologic Engineering, Water Resources Research, Journal of Hydrology, Bulletin of the American Meteorological Society, Journal of Applied Meteorology and Climatology, Weather and Forecasting, Journal of Hydroinformatics, Atmospheric Science Letters, and Climatic Change.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	3
# of NOAA technical reports	
# of presentations	8
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

GOES-R Water Cycle Products & Services to Support the National Weather Service

Task Leader	E. Hugo Berbery/ Patrick Meyers
Task Code	EBPM_GOES_16
NOAA Sponsor	Ralph Ferraro
NOAA Office	NESDIS/STAR/CRPD/SCSB
Contribution to CICS Research Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA goals (%)	Goal 1: 75%; Goal 2: 25%; Goal 3: 0%;
Strategic Research Guidance Memorandum:	4. Integrated Water Predictio

Highlight: We held a workshop in October with National Weather Service (NWS) and National Ocean Services (NOS) stakeholders to learn about their current and future needs for satellite hydrology products. They set snowfall rate and evapotranspiration/soil moisture products as our first priorities.

Background

The Cooperative Institute for Climate and Satellites at the University of Maryland (CICS-MD), in conjunction with its NOAA/NESDIS/Center for Satellite Applications and Research (STAR)/Cooperative Research Programs (CoRP)/Satellite Climate Studies Branch (SCSB) partner, will support the Geostationary Operational Environmental Satellite - R Series (GOES-R) Risk Reduction Program (GOES-R3) through this proposal focused on research and development (R&D) of water cycle products that will serve multiple users at NOAA's National Weather Service (NWS). The primary topical areas include: precipitation, land surface hydrology, water quality and high impact weather. The R&D will exploit the new capabilities from baseline and future products of the GOES-R satellite, mainly measurements (or proxies of them) from the Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM). In particular, measurements from the Himawari-8, rapid scan operations of current GOES satellites and ground lightning networks will be exploited to advance water cycle products.

The targeted end users within NWS include the National Water Center (NWC), the Weather, Ocean and Tropical Prediction Centers (WPC, OPC and TPC) and the NWS Pacific Regions, where collaborations are already underway. Additionally, synergy and exploitation of Joint Polar Satellite System (JPSS) products will also be included in this project, in particular, direct broadcast (DB) data which will greatly reduce data latency and offer a greater potential of fusion with GOES-R data. The advantage of reduced latency from DB data has been demonstrated by the NESDIS Snowfall Rate product that was evaluated at NWS Weather Forecast Offices (WFOs) over the past few years. Finally, the SCSB/CICS-MD Satellite Proving Ground will be used to test the new products in a near-real time capability and form the basis for testbed activities with the NWS users.

Accomplishments

This new start project in FY16 (July 1) had just a few milestones that were started during the initial 6-month reporting period; these as well as the overall project milestones are noted in the table below. Some specific details on the project include:

1. Workshop with NWS and NOS stakeholders to define project priorities:
In order to determine project priorities as we move ahead in this multi-year project, we met with members of the NWS/Office of Water Prediction (OWP) on October 19, 2016, to describe to them the current project (as proposed) and potential new topics (as outlined in the proposal) to get their input as to their priorities. Brian Cosgrove represented the interests of NWS/OWP and was joined by Dave Kitzmiller and Yu Zhang from OWP; Cosgrove gave a nice overview of the current/future needs of satellite products at OWP. Topics presented by the project team included:

- ***Review of ongoing activities in support of NWS and of potential interest to NWS*** – Scott Rudlosky and Patrick Meyers
- ***Improved precipitation rates for the NWS Pacific Region*** – Nai-Yu Wang
- ***Advancement of LEO snowfall rate retrievals*** – Huan Meng
- ***Water quality*** – Christopher Brown
- ***Global flood estimate and forecasting using satellite precipitation and hydrological models*** – Bob Adler and Huan Wu
- ***High resolution remote sensing of evapotranspiration (ET) and soil moisture*** – Chris Hain
- ***Global snow depth and water equivalent estimations using satellite and in-situ data*** – Cezar Kongoli

The first two topics are tasks in progress; of the other activities presented, OWP had the most interest in the snowfall rate and the ET/soil moisture projects. Next of interest was the water quality and global flood activities. Because of the budget constraints in year 2 of the project, our plan will be to complete the first two tasks and work next on the snowfall rates. Water quality is a focus of the OWP starting in FY19, so that work will strongly be considered in year 3 of the project. (It should be noted that Chris Hain has departed CICS-MD so it would be unclear how that activity would be carried out).

2. OCONUS Rain Algorithm for NWS Pacific Region
This task is being carried out by CICS-MD research scientists Nai-Yu Wang and Yalei You. OCONUS rain algorithm for the Pacific region is under development. The preliminary algorithm development makes use of IR channels from Himawari-8 on board of the Japanese Meteorological Agency (JMA) and lightning observations (flash occurrence) from ground lightning network GLD360. Figure 1 top panel shows the brightness temperatures (TBs) from IR window channel 13 from Himawari-8 satellite.

The colder IR TBs signal higher cloud top height which implies higher vertical extent of the clouds and possible heavy rainfall. However, the correlations between IR TBs and surface rainfall are very weak. Methods of deriving surface rainfall using IR TBs through techniques of relating IR TBs and surface rainfall rate through linear or more complex regression methods have not yielded good results. A different methodology is used here and the initial assessment shows great promises. The bottom panel in Figure 1 shows the identification of convective clouds (in red) and other precipitating clouds (in blue) through a local minimum temperature and temperature gradient technique (on the left), and convective cloud identification from combined IR TBs and lightning flashes.

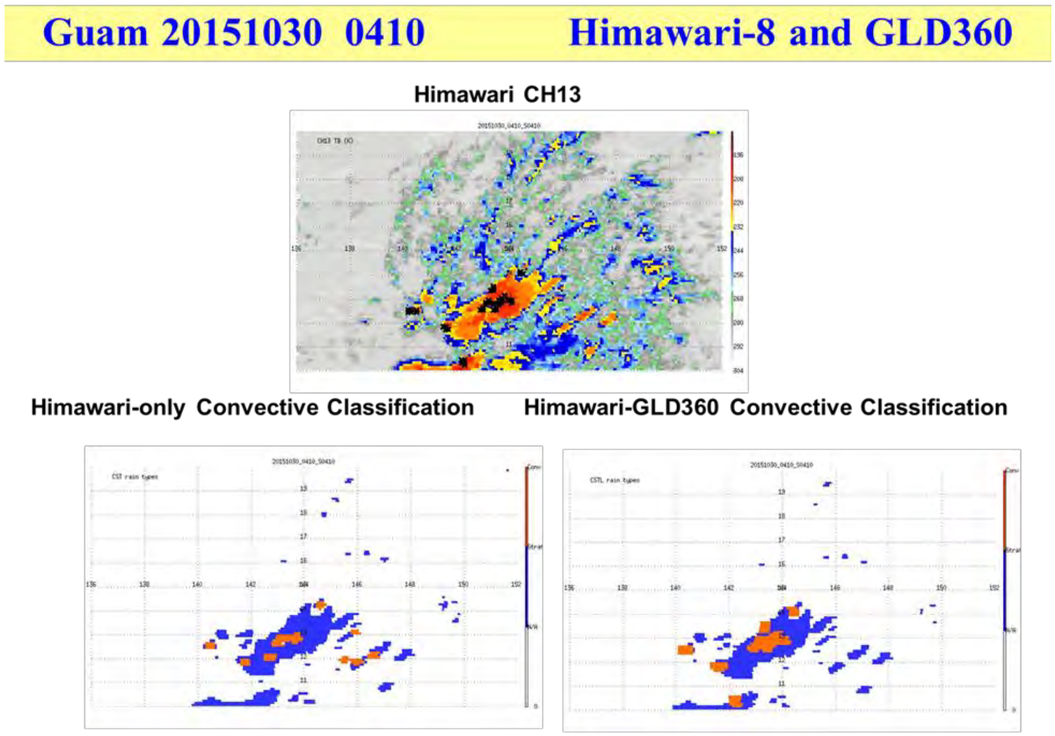


Figure 1. Himawari-8 Channel 13 IR imagery for 30 October 2015, 0410 UTC (top). The bottom panel shows the convective (red) and non-convective (blue) identified by the satellite QPE algorithm using IR only (on the left) and IR and lightning combination (on the right).

The rain storm pattern and amount between Quam radar and IR-lightning technique are highly comparable. Further algorithm refinements on the lightning information for oceanic convective rigor and rainfall rate relationships, and the evolution of convective cells using frequent GEO-IR observations will be the focus for next year. Coincident Guam and Hawaii islands ground radars, space-borne radar and radiometer from GPM, and Himawari-8 are being collected for algorithm development and validation. Algorithm validation effort will be a focus for this project as well.

3. ProbSevere for Ocean Regions

Two CICS-MD researchers and two UMD undergraduate students are contributing to this effort. This research is the senior theses research for the two undergraduate students. The senior thesis research is laying the ground work for more detailed analyses during summer 2017.

a) Complete development and testing of lightning advection rain rate algorithm over CONUS that also exploits LEO DB (Ground)

The shape and intensity of the precipitation field changes dramatically between consecutive LEO observations, requiring a transformation procedure to produce a realistic time-evolution of a storm system. Morphing of LEO precipitation features was tested using a basic optical flow technique. The method has only been applied to two consecutive LEO swaths, and not a full composite of all constellation members. Further testing and evaluation of the lightning-derived motion is required. Degrading the GLD360 lightning observations to the GLM 8 km horizontal resolution appears to reduce the precision of the advection technique. A downscaling technique may be needed to more accurately depict the storm motion field.

b) Develop ProbSevere training database over ocean; perform testing at OPC and NWS Pacific Region (Algorithm)

Doug Kahn is building a training database of offshore thunderstorms in the Atlantic Ocean and Gulf of Mexico. The selection of cases was aided by examination of turbulence reports from commercial aircraft. The turbulence reports were queried to identify those that could be attributed to nearby thunderstorms. Automated Warning Decision Support System – Integrated Information (WDSS-II) procedures have been developed to data mine the satellite and lightning datasets. User-defined information is extracted from storm clusters using WDSS-II. As shown in Figure 2, the storm clusters are then visualized in ArcMap (GIS) to view the progression of storms throughout entire days.

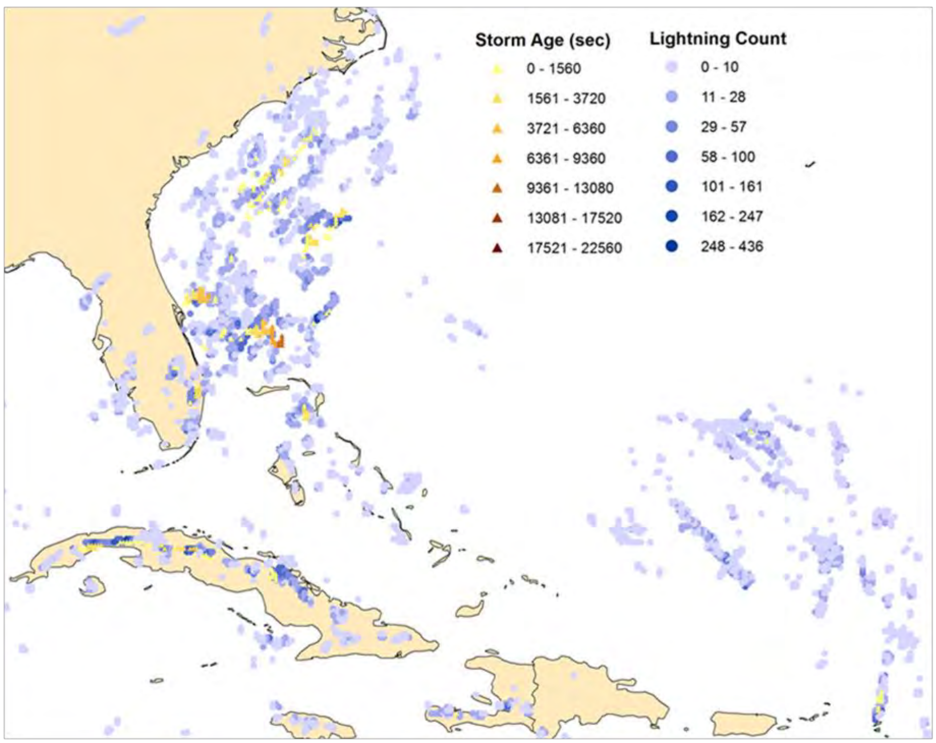


Figure 2. Depiction of the storm age and lightning count for all storms occurring on October 1, 2015. The storm age is for the larger storm features and the lightning count is for the smaller storm core features. Red shades indicate longer lived storms and the darker blues indicate larger lightning counts.

Smaller features are classified as Cores (Min. Size: 1280 km²), and Storms refer to larger convective regions (Min. Size: 6400 km²). Twelve of the planned twenty five cases have been processed, with each case expected to contain dozens of Storms and hundreds of Cores. With the automated procedures in place, the remaining case should be processed quickly before moving into the database analysis phase.

Planned work

The plans for the next six months include:

1. Rescope the project based on FY17 funding levels and the input received from NWS/OWP.

2. Continue to work on and test OCONUS rain algorithm by generalizing the relation between rainfall and IR temperatures plus lightning. Because of the sparsity of oceanic lightning, the utility of lightning in identifying deep convective cells and lightning-rainfall relationships need to be refined from the continental relationships previously developed. Additional development will be the examination of using high temporal information of the GEO-IR temperature variations to evaluate the evolution of the convective storm (is the storm growing or decaying).

3. Develop more advanced techniques will for the morphing of LEO precipitation features. Further testing and evaluation of the lightning-derived motion is required, and we plan to explore downscaling techniques in an attempt to more accurately depict the storm motion field. Results from the OCONUS Rain and Storm Tracking aspects of this project will provide important insights into the morphing of LEO precipitation features, and future efforts will work to incorporate this complementary information.

4. We will continue to process case studies that sample a variety of storm types in different seasons and regions to build the off-shore ProbSevere storm archive (training dataset). GIS software will be used to identify storms of interest on selected case study days. An important next step is to incorporate Global Forecast System (GFS) model data to augment the lightning and satellite information. The accuracy of the storm tracking and trending procedures will be characterized to provide recommendations for potential improvements in future versions. Statistics will be computed for all storms to document findings and aid in the development of an off-shore thunderstorm intensity tool.

Presentations

Nai-Yu Wang, “"Combining IR and Lightning For Enganced GOES-R Rain Estimates in the Pacific Region". *2016 GOES-R/JPSS OCONUS Satellite Proving Ground Technical Interchange Meeting, Honolulu, HI, June 30, 2016.*

Nai-Yu Wang and Yalei You – “Combining IR and Lightning for Enhanced Geostationary Satellite Rain Estimates”. *Eighth workshop of the International Precipitation Working Group (IPWG-8); Bologna, Italy, October 3-7, 2016*

Daniel Vitelli, D., and P. C. Meyers, 2017: Gale-forced storm prediction over the oceans. *16th Annual AMS Student Conference, Amer. Meteor. Soc., Seattle, WA, January 22, Poster S42.*

Kahn, D. T., S. D. Rudlosky, P. C. Meyers, and M. J. Pavolonis, 2017: Evaluating the ProbSevere Model Over the Atlantic Ocean Using WDSS-II, *7th Conference on Transition of Research to Operations, Amer. Meteor. Soc., Seattle, WA, January 23-26, Poster 880.*

Other

Interaction with operational partners –

- Met with the NWS/Office of Water Prediction to review project objectives and determine priorities
- A presentation at the AMS annual meeting included coauthors from the National Hurricane Center (NHC), Aviation Weather Center (AWC), Weather Prediction Center (WPC), and the Ocean Prediction Center (OPC).
- Side meetings were held at the 2017 AMS Annual Meeting between Scott Rudlosky and individuals from both the National Weather Service (NWS) and Federal Aviation Administration (FAA). Visits to several national centers and two WFOs have helped to guide our efforts.
- Nai-Yu Wang visited the National Weather Service Pacific Region Headquarters in Honolulu from June 20 to July 1, 2016 to demonstrate a new satellite QPE capability of combining infrared and lightning observations from the upcoming GOES-R using the current geostationary satellite Himawari-8 and ground lightning network GLD360 data.

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

CUNY-CREST An Enhanced Operational System for the Mapping of River Ice Using SNPP VIIRS for River Ice-Jam Modeling and Forecasting

Task Leader	Naira Chaouch (CUNY-CREST)
Task Code	NCNC_IJAM_16
NOAA Sponsor	Mitch Goldberg
NOAA Office	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1:70%; Theme 2:30%; Theme 3:0%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3:0%;
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight: Development of an enhanced operational river ice mapping system using VIIRS data to support NWS RFCs with timely information on river ice extent and concentration

Background

This project builds up on an expertise developed at the NOAA-Cooperative Remote Sensing Science and Technology (CREST) Center at the City College of the City University of New York (CCNY) in the application of remote sensing observation to study the cryosphere with an emphasis on river and lake ice in addition to freeze/thaw dynamics and snow cover. The heritage of the NOAA-CREST team in the field of river and lake ice detection and mapping was started with the use of: GOES-R Advance Baseline Imager for lake and sea-ice mapping (Temimi et al. 2011), MODIS imagery (Chaouch et al., 2014) to map ice on the Susquehanna River (http://water.ccny.cuny.edu/crios/) and continued with the integration of SNPP VIIRS imagery, an effort that led to the development of an operational River Ice mapping system that is displayed in NOAA National Weather Service's Advanced Weather Interactive Processing System (AWIPS) since 2014. This phase of the project proposes to enhance the operational river ice product by addressing the limitations that were noticed and reported by NWS experts in the first phase. The challenges that will be addressed in this phase of the project include a) cloud shadow, b) relief shade, c) narrow rivers, and d) low ice concentration cases where ice reflectance is very low and sensitive to atmospheric corrections that were faced during the first phase of the project especially in the Alaska RFC domain.

Accomplishments

1. **Expanding the geographic coverage of the product to include more rivers and upstream locations**

The original operational version of the VIIRS-based river ice mapping system covers the following river and some of their tributaries: Yukon River, Kuskokwim River, Missouri River, Mississippi River, Hudson and Mohawk Rivers. The current version includes in addition Tanana and Susitna rivers in Alaska and Sheepscot, Damariscotta, Androscoggin, Kennebec, Penobscot, Merrimack rivers, Piscataqua river and Great Bay in North east, figure 1. The first consideration when adding new rivers to the operational system is given to the generation of accurate rivers and lakes' masks which include all VIIRS pixels susceptible to be covered by ice in winter time. The masks identify and flag mixed land/water pixels. Our review of existing river and lake masks especially in remote watersheds revealed that they lack accuracy to determine particularly around lakes on rivers and along river banks curvature. Mixed pixels along rivers and lakes banks are included to account for the instrument navigation error which is less than 1 VIIRS pixel resolution.

2) **Developing a classification technique with adaptive thresholds that account for the seasonality of the reflectance and changes in sun angle**

This is very significant especially in Alaska: The technical approach consists of collecting water, ice, and mixed water/ice pixels' reflectance values in addition to observation geometry parameters within narrow rivers. The selection of the reflectance values sample is based on the analysis of high resolution data from Landsat corroborated with field surveys observations (from RFCs) or flyovers (from GINA in Alaska). The simulated ice and water reflectance values that are dependent on the sun angle are used as "tie-points" in a linear mixed model for the determination of ice concentration within each pixel.

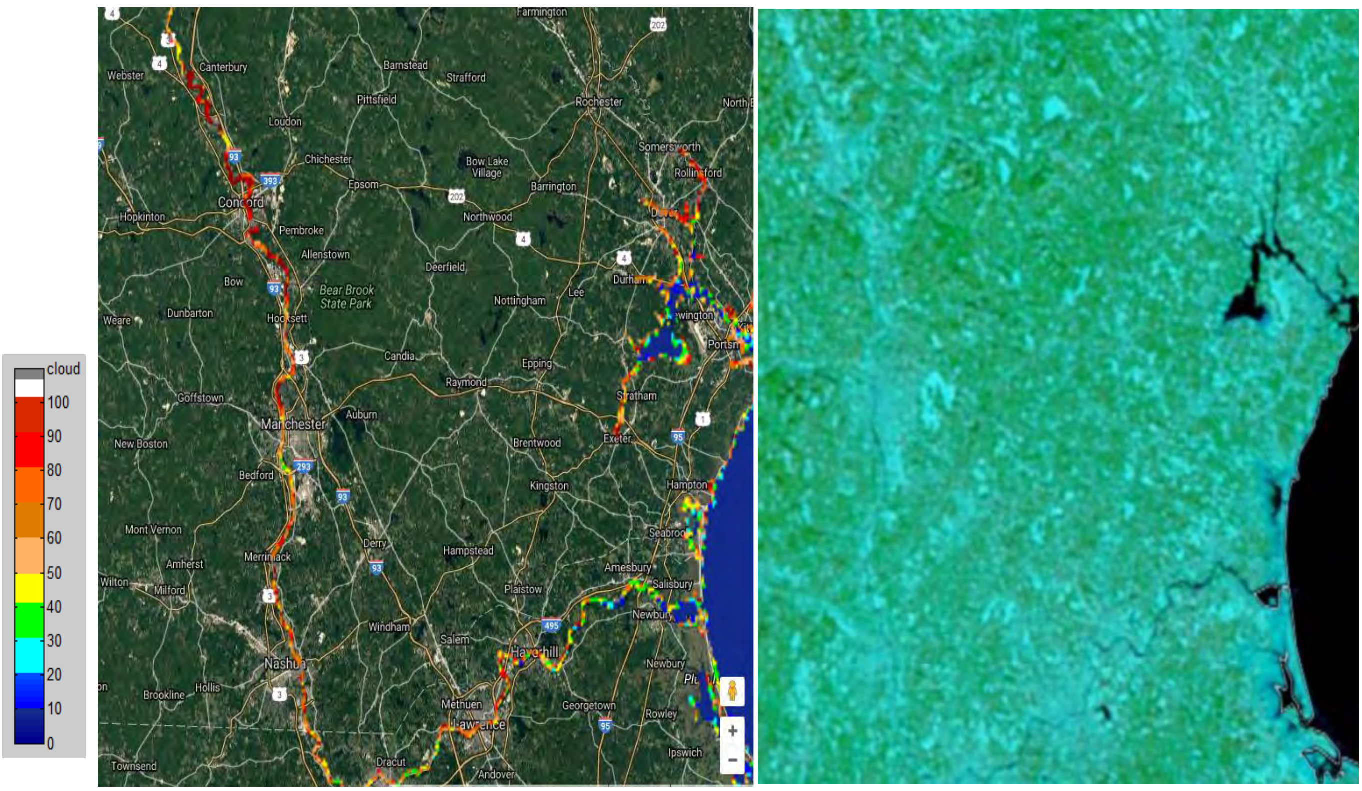


Figure 1. Ice concentration map over Piscataqua, Merrimack rivers and Great Bay (a) and MODIS RGB color composite (b), 01/08/2017

3) **Improving ice identification in presence of cloud shadow**:

The cloud shadow reduces the reflectance values of the pixel and fully ice covered pixels can be classified as mixed water/ice pixels or even ice free pixels. In order to reduce this misclassification problem, the detection of the cloud shadow was necessary. For this propose, the geometry based method are tested and used for cloud shadow detection, figure 2. The cloud top height is estimated using the cloud top temperature, the surface temperature which is assumed to be equal to the maximum temperature within 50x50 km, and a lapse rate of 6 k/km.

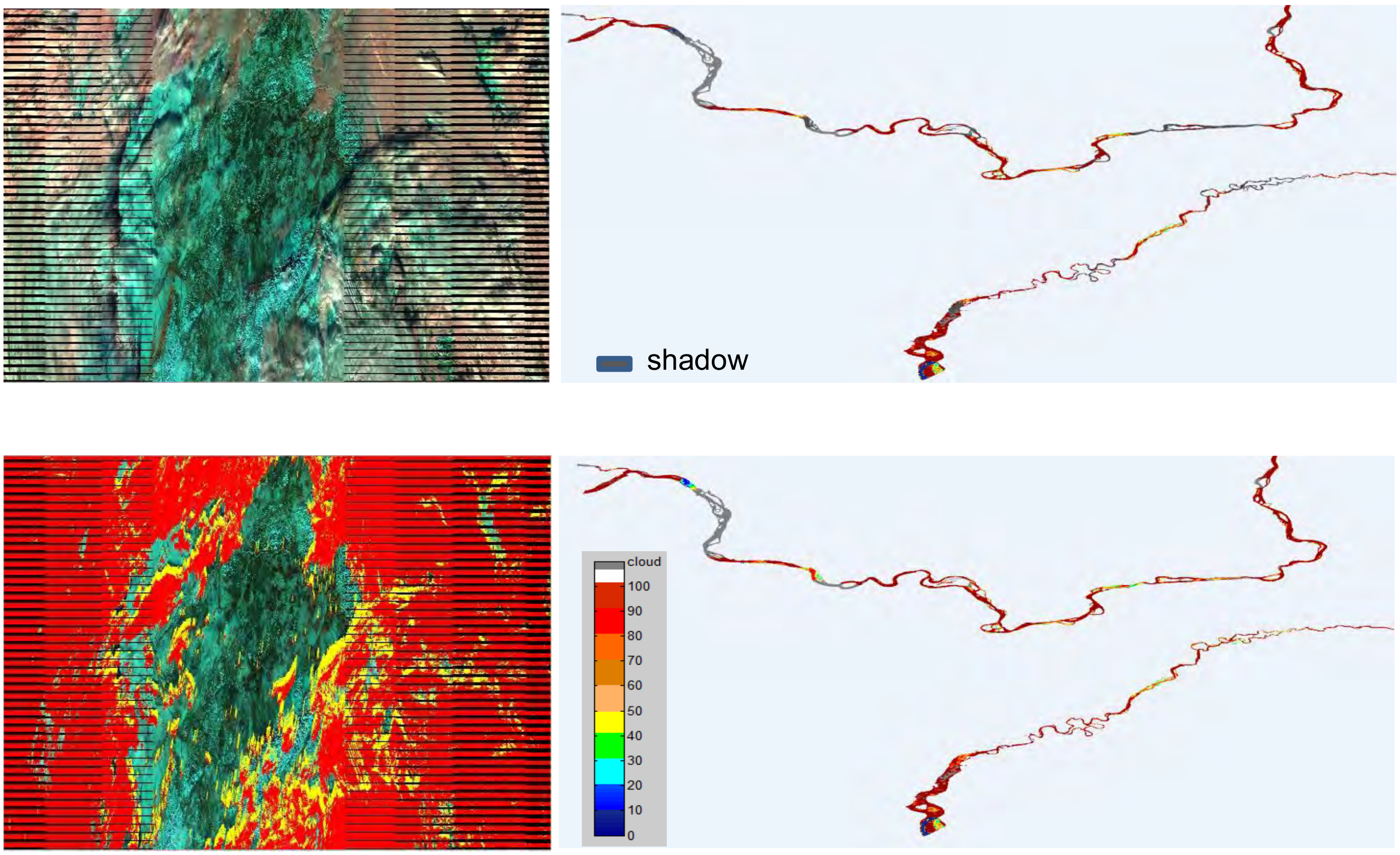


Figure 2. Cloud and cloud shadow detection, (top left) RGB SDR data, (bottom left) Red color: cloud, yellow: cloud shadow, (top right) ice concentration map over Yukon and Kuskokwim rivers using the cloud shadow, (bottom right) ice concentration map without cloud shadow detection, 02/14/2015

Planned work

During the next year of the project the following will be pursued:

- Ice detection over narrow river to be developed, tested, and implemented operationally
- Relief shade will be corrected automatically in the operational product. The method will be developed, tested, and deployed operationally.
- Ice jam/breakup likelihood will be assessed using information on river ice from VIIRS and additional auxiliary information
- A publication on VIIRS river ice detection over narrow river with cloud shadow correction will be prepared

Products

- Automated algorithm for the determination of ice concentration along selected rivers within four RFCs domains
- Daily River ice concentration maps over selected rivers.

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

Daily river ice concentration maps are generated over selected rivers and lakes within four RFCs domains: North central, North east, Missouri and Alaska (1). The river ice product is running operationally and it is displayed in NOAA National Weather Service's Advanced Weather Interactive Processing System (1).

Hampton University/CUNY Developing an Orographic Adjustment for the GOES-R Rain Rate Products and their Utilization in Hydrological Applications

Task Leader	Ismail Yucel
Task Code	RKIY_GOES_16
NOAA Sponsor	Jaime Daniels
NOAA Office	NESDIS
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA goals (%)	Goal 1: 100%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction

Highlight

- It is found that the developed orographic correction method for SCaMPR rainfall estimates consistently provided better performance than the previous correction techniques.
- The error reduction up to 5% is obtained in SCaMPR rainfall estimates when correction is applied.
- The 35 km fetch length of upwind effect for orographic correction is determined as optimum fetch length.
- It is foreseen that further improvement will be obtained when other meteorological variables (precipitable water, relative humidity) are added to the correction equation.

Background

The North American Monsoon Experiment (NAME) Event Rain gauge Network (NERN) in the Sierra Madre Occidental (SMO) Mountains in northwest Mexico is used as an important source of validation data. The NERN, consists of approximately 85 tipping bucket rain gauges arranged in 5 west-to-east transects through the SMO mountains, is used in this study to investigate the performance of the in Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) in depicting terrain-induced precipitation characteristics and the potential for improving the SCaMPR by incorporating an orographic correction based on the calibration of the algorithm against rain gauge transects in the topographically complex region of NAME. An orographic adjustment is developed for satellite-derived SCaMPR quantitative precipitation estimates, accompanied by robust error analyses. The event rain gauge data from the NERN is used to determine the errors in SCaMPR over this region of complex terrain, and these errors are compared to pertinent parameters such as elevation, slope, tropospheric wind direction and speed relative to terrain elevation gradient, moisture availability (total precipitable water), and thermodynamic stability (temperature). The relationships that are isolated during this analysis is used to create a more accurate terrain adjustment for SCaMPR that is applied to the SCaMPR fields.

Accomplishments

The methodology to develop an orographic correction technique in SCaMPR algorithm is being investigated. Raingauge data from NAME are used to develop a relationship between multiplicative errors of SCaMPR retrievals and updrafts (vertical wind) derived from North American Model (NAM). SCaMPR errors calculated from summer periods of 2002, 2003, and 2004 years are categorized into 0.25 m/s and 0.5 m/s updraft intervals, respectively. Rainfall multiplicative errors versus elevation are obtained for monthly rainfall for which both SCaMPR and gauge show rain values (Figure 1). In addition to summer time error analysis the same analysis is performed for winter time periods of 2002, 2003, 2004 and all years. In summer months for all analyses years, SCaMPR shows strong dry bias (low rainfall amount) towards high elevation. High uncertainty caused by summer convection is responsible for forming a weak trend in summer data. Developed correction method is evaluated by comparing the corrected results with the results from existing method used in operational NESDIS Hydro Estimator (HE) algorithm for summer and winter periods. It is found that the proposed method consistently provided better performance than the previous correction techniques for SCaMPR summer and winter precipitation. The error reduction up to 3% is obtained in SCaMPR rainfall estimates when correction is applied. The 35 km fetch length of upwind effect for orographic correction is determined as optimum fetch length.

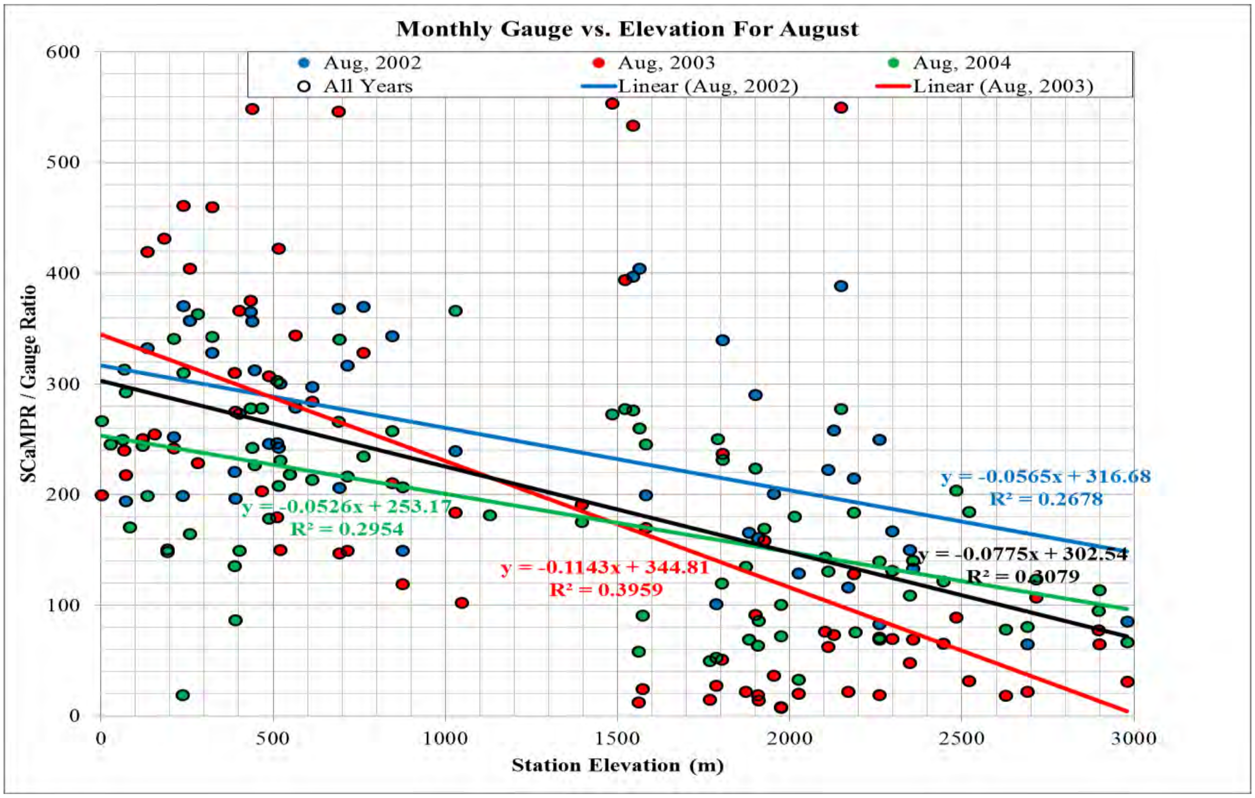


Figure 1. Multiplicative errors in SCaMPR rain is shown as function of elevation for August for all years.

Planned work

Our efforts are now focusing on further improvement of this technique by including other meteorological variables such as precipitable water, relative humidity, and temperature into the correction equation. It has been shown that these two variables release a valuable degree of association with multiplicative rainfall errors. We also obtained a new SCaMPR data to which humidity correction was already applied. For future analysis, we'll be using this new data for developing the orographic correction in SCaMPR. Apply developed orographic adjustment method using SCaMPR estimates to HE rainfall estimates to determine the potential of the correction method with respect to one used in HE algorithm. Two research papers will be submitted focusing on the development of orographic correction and its use in other operational algorithm such as the HE.

Other

A master student was already graduated from the CICS task performed. The student now continues for his PhD study with the same task.

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

One of my MS student was graduated with the support from CICS task.

CUNY-CREST Validation and Application of JPSS/GCOM-W Soil Moisture Data Product for Operational Flood Monitoring in Puerto Rico

Task Leaders	Tarendra Lakhankar & Jonathan Muñoz-Barreto
Task Code	TLTL_GCOM_16
NOAA Sponsor	Mitch Goldberg
NOAA Office	NESDIS/JPSSO
Contribution to CICS Research Themes (%)	Theme 1: 10%; Theme 2: 30%; Theme 3: 60%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%
Strategic Research Guidance Memorandum:	4. Integrated Water Prediction
Link to a research web page	http://www.uprm.edu/prsmart

Background

This project utilizes the CREST-owned L-band microwave radiometer to observe local scale soil moisture in Puerto Rico in order to provide ground validation data for GCOM-W soil moisture data (SMDP). During the performance period, the CREST L-band microwave observation is being use at one temporal site (Isabela) for the soil moisture monitoring. These observations are being collected on soils under variable conditions like bare soil and soil under a variation of crops. Throughout this period microwave brightness temperature and soil moisture were observed for different irrigation pattern and vegetation conditions including: bare soil, short grass, tall grass and agricultural fields which are representative of the study area. In parallel to the data collection, GCOM-W soil moisture data has validated and calibrated against the in-situ soil moisture measurements (12 NRSC scan sites and 3 UPRM-AES soil moisture test-beds).

Accomplishments

1. Downscaling GCOM-W1 Soil Moisture Products

The 25km resolution soil moisture product for GCOM-W1 was downscaled (Figure 1) using a methodology originally presented in a study by Ray et al. (2010). This methodology uses 1km MODIS data for Albedo, NDVI, and LST to produce a 1km resolution soil moisture estimate from the GCOM-W1 products. The following equation was used in the downscaling process:

$$\theta_s = \sum_{i=0}^{i=n}\sum_{j=0}^{j=n}\sum_{k=0}^{k=n} a_{ijk} V^i T^j A^k$$

For each individual pixel n the soil moisture is estimated as:

$$\theta_s = a_{000} + a_{001}A + a_{010}T + a_{100}V + a_{011}TA + a_{101}VA + a_{110}VT$$

Each MODIS parameter is upscaled to match the GCOM-W1 resolution using the following equations:

$$V_{25km} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} V_{ij}}{mn} \qquad T_{25km} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} T_{ij}}{mn} \qquad A_{25km} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} A_{ij}}{mn}$$

The upscaling is done by calculating an average value of all the 1km MODIS pixels that are inside each 25km soil moisture product of GCOM-W1. Once the upscaling is done, the regression coefficients $a_{\#\#\#}$ are calculated and proceeded to the downscaling. The downscaling was done by equation:

$$\theta_s = -1.2067 + 53.3466\,A + 0.0049\,T - 0.9109\,V - 0.1820\,TA + 1.676\,VA + 0.0027\,VT$$

By aggregating the 1km soil moisture to match the raw 25km GCOM-W1 product the RMSE and R^2 where calculated. This regression model proved to be of fair fit with the raw data having a RMSE of 0.0686 and R^2 of 0.6102. The following steps are to find the best fit regression model, validate the results with the SCAN-NRCS stations, and compare with the validation of the raw 25km resolution pixels. At the present an optimization scheme is being develop to minimize the RMSE and maximizes the R^2. Early/preliminary results shows promise; when compared against SCAN data. The new SMDP presents smaller bias with SM values more representative to local surface heterogeneity and meteorology.

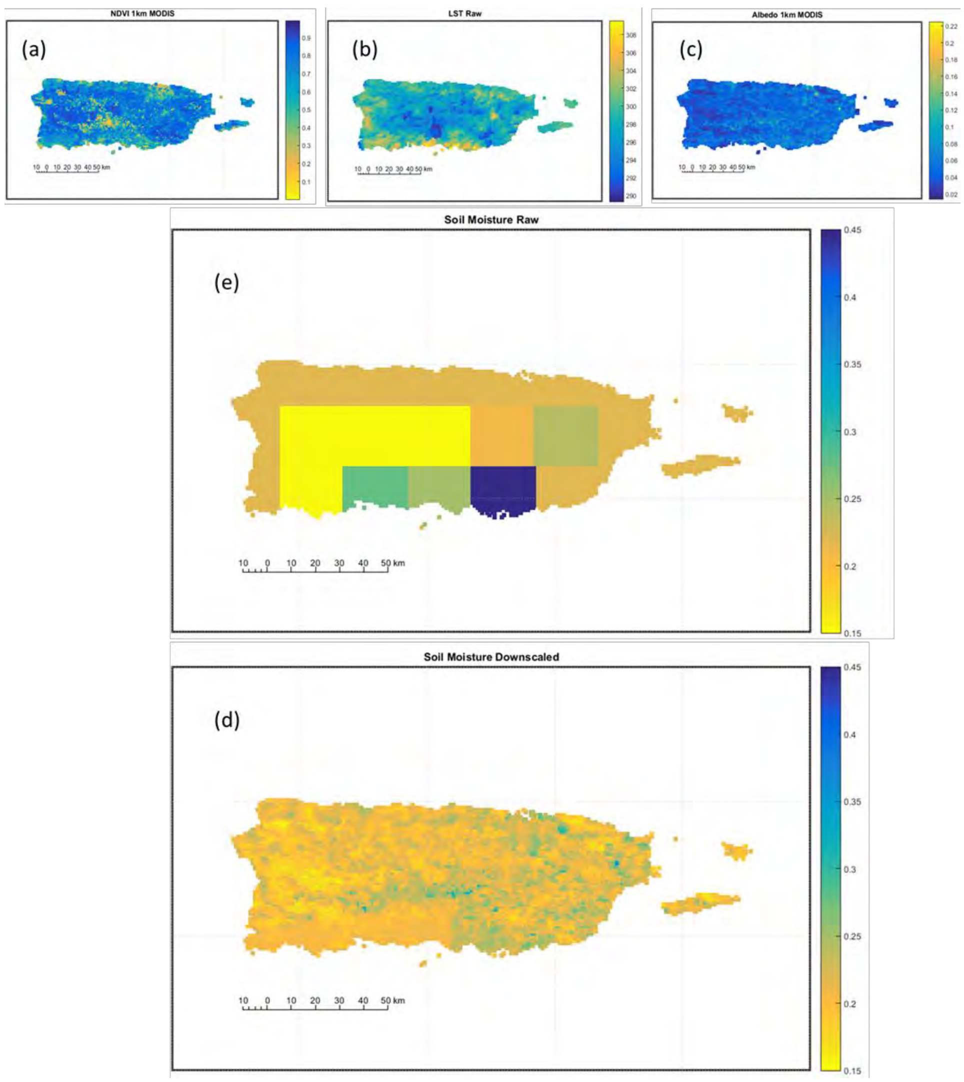


Figure 1. MODIS Downscaling parameters at 1Km resolution: (a) NDVI, (b) LST (c) Albedo, (d) GCOM-W soil moisture at 25 Km and (e) Downscaled GCOM-W soil moisture data at 1KM

2. Bias Correction of GCOM-W soil moisture data using CDF Matching:

Bias correction is a critical in pre-processing of GCOM-W before assimilation in hydrological modelling. In order to retrieve the GCOM-W data for the same coordinates as the in-situ data, the minimum distance between two points was calculated using the latitude and longitude of the ground station and the geographical coordinates included in the original satellite data. This was done through the use of the Euclidean Distance Method. The bias between the two sets of data was removed using a simple cumulative density function that utilized the mean and standard deviation of both the ground station data and the satellite data. The following CDF is used in order to make the calculations:

$$\Theta = \mu ground + (\sigma sat+\sigma ground)/2*[(sat-\mu sat)/ \sigma sat]$$

The corrected data was then plotted again the original in situ data and showed in Figure 2.

3. Simulation of hydrologic cycle using SWAT model

A physically based, distributed-parameter, Soil and Water Assessment Tool (SWAT) was used to validate satellite soil moisture data in parts of Puerto Rico. Sites with known flow discharge in Puerto Rico were considered as sub-basins to implement calibration and validation. The proposed calibration and validation approach were performed using the GCOM-W soil moisture data. The hydrologic cycle simulated by SWAT model is based on the water balance equation. A sub-basin was first divided into multiple Hydrological Response Units (HRUs) which are a unique combination of land use, soil, and slope. Each HRU of the sub-basin compute flow from Soil Conservation Services (SCS) Curve Number (CN) method. Daily inputs of weather data, such as precipitation and temperature were provided to model and relative humidity, solar radiation, and wind speed were simulated by the model. The monthly time step was used to calculate flow at the outlet. The GCOM-W soil moisture data (cm^3/cm^3) were converted into plant available water (depth unit mm) using μ-σ linear technique, which was used for the calibration and validation in SWAT.

Calibration and validation were carried out using Sequential Uncertainty Fitting (SUFI 2) method in SWAT CUP. Calibration of the flow was performed from the year 2008 to 2012 with two years of the warm-up period. The updated calibrated parameter, values then used to rerun the SWAT model. Further, the same ranges of values by replacing satellite soil moisture data in SWAT were used for the validation year 2013. The analysis involved a total of 13 parameters and a sensitivity analysis was undertaken by using the Latin Hypercube method. The model results of stream flow on a monthly basis is being compared with the observations in the preliminary assessment and even after calibration yielding a coefficient of determination (R2) greater than 0.50 reflecting satisfactory performance. Although GCOM-W and SWAT soil moisture values varied in range, other hydrological components such as stream flow in SWAT remains less affected. Preliminary model appraisal based on simulation was not given an adequate evaluation of model performance. The improved simulation results can be achieved by the use of detail and long-term soil moisture data.

Planned work

- Validation of Downscaling (4Km and 1Km) of GCOM-W soil moisture data.
- Quantify the effect of surface heterogeneity and meteorology in the satellite vs. point scale comparison.
- Identification of framework for GCOM-W soil moisture in Flash Flood Guidance System in Puerto Rico.

- Currently, discussing with NWS Puerto Rico and assessing current system for providing framework for GCOM-W soil moisture in distributed Flash Flood Guidance System in Puerto Rico

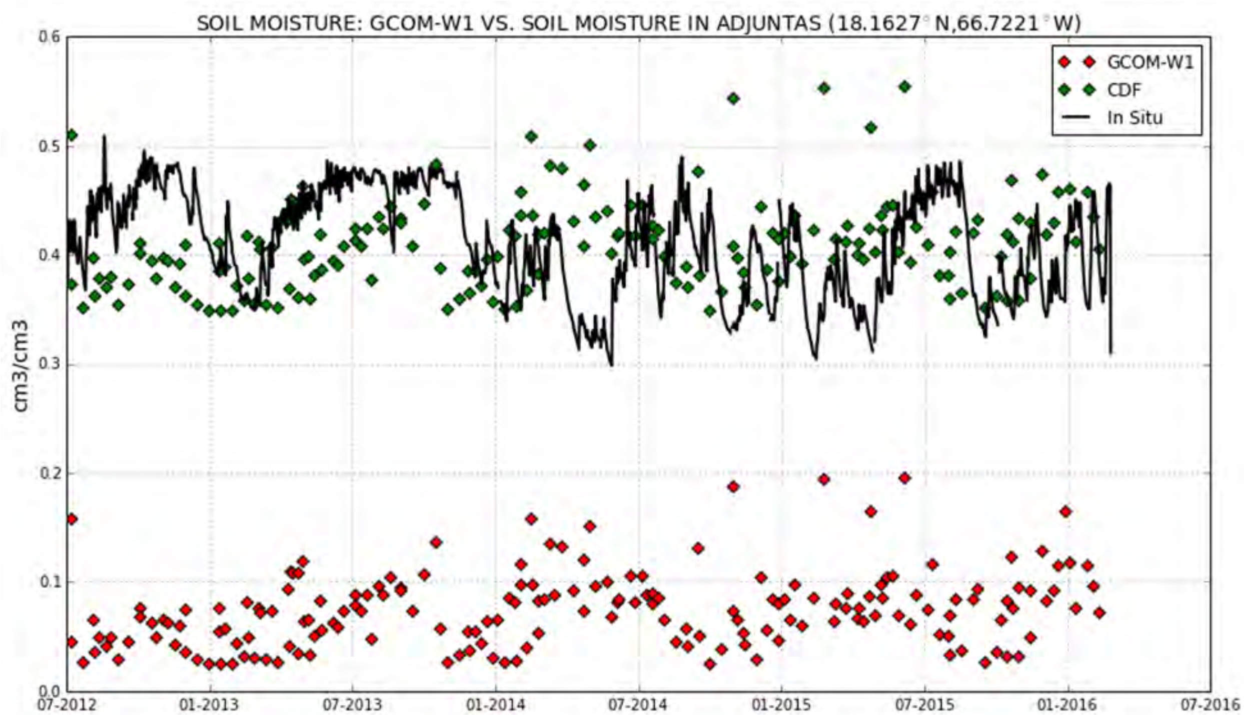


Figure 2. Comparison of Bias Corrected (using CDF Matching) GCOM-W soil moisture data with in-situ observations

Publications

Munoz J. & Lakhankar T., *Early Results of the Puerto Rico Satellite Soil Moisture Test-Bed*, in preparation to be submitted (*Spring 2017*) to Hydrology and Earth System Science (HESS) journal - ISSN 1027-5606.

Products

- Preliminary Downscaled GCOM-W SMDP (4KM & 1KM) for Puerto Rico.

Presentations

1. Title: Evaluation of the JPSS GCOM-W Soil Moisture Product in the Caribbean region: A Case Study for Puerto Rico
   Authors: Jonathan Muñoz-Barreto & Tarendra Lakhankar
   Event: Cooperative Institute for Climate and Satellites Science Conference
   Date: 29 Nov – 1 Dec, 2016

2. Title: Validation of SMAP and GCOM-W1 Soil Moisture Data using Field Measurements in New York and Puerto Rico
   Authors: Cassandra Calderella
   Event: CSC at NOAA Pacific Marine Environmental Laboratory
   Date: January 20, 2017.

3. Title: *Mapping Field-Scale Soil Moisture Using Ground-Based L-band Passive Microwave Observations in Western Puerto Rico*
   Authors: Jonathan Muñoz-Barreto & Tarendra Lakhankar
   Event: The 2016 Workshop at MOISST: The Growing Science of Soil Moisture Sensing
   Place: Oklahoma State University Stillwater, Oklahoma
   Date: May 17 – 18, 2016

4. Title: *Early Results of the Puerto Rico Advance Radiometric Test-bed (PR-SMART)*
   Authors: Jonathan Nuñez Olivieri, Jonathan Muñoz-Barreto & Tarendra Lakhankar
   Event: The 2016 Workshop at MOISST: The Growing Science of Soil Moisture Sensing
   Place: Oklahoma State University, Stillwater, Oklahoma
   Date: May 17 – 18, 2016

5. Title: *Mapping Field-Scale Soil Moisture Using Ground-Based L-band Passive Microwave Observations in Isabela Puerto Rico*
   Authors: Jonathan Nuñez Olivieri, Jonathan Muñoz-Barreto, & Tarendra Lakhankar
   Event: 2016 Southern Regional National Cooperative Soil Survey Conference
   Place: Rincón, Puerto Rico
   Date: June 23, 2016

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

2.8 Earth System Monitoring from Satellites

Development of SAR Altimeter Capability

Task Name:	Development of SAR Altimeter capability
Task Leader:	Alejandro Egido
Task Code:	EBEB_DSAC_14 Year 3 / AEAE_DSAC_16
NOAA Sponsor:	Walter HF. Smith
NOAA Office:	NESDIS/STAR/SOCD/OPB/LSA
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%
Main CICS Research Topic	Earth System Monitoring from Satellites
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 25%; Goal 3: 25%
Strategic Research Guidance Memorandum:	2. Environmental Observations
Link to a research web page	http://www.star.nesdis.noaa.gov/sod/lsa/SeaIce/index.php

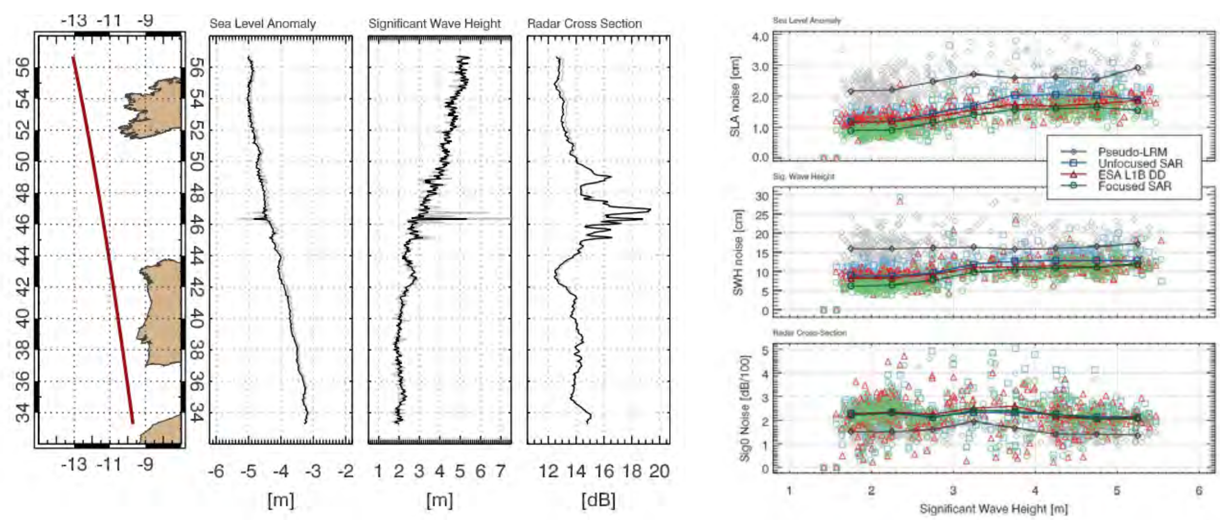
Background

From Geos-3 in 1975 until CryoSat in 2010, all satellite radar altimeters employed the same technology, called here “conventional” or “LRM” (Low Resolution Mode). This scheme employs radar pulses at low (~2 kHz) pulse repetition frequencies (PRFs) and simple, incoherent averaging (averaging power without regard to phase) to obtain estimates of elevation (sea level), surface roughness (wave height), and backscatter (related to wind speed) averaged over a circular patch of Earth’s surface a few km in diameter known as the pulse-limited footprint. CryoSat and Sentinel-3 operate in this fashion over much of the ocean but can also operate in two new, high-resolution modes. These modes employ a much higher (~18 kHz) PRF and coherent processing (meaning the phase of each complex radar echo is exploited) to narrow the measurement area in the along-track direction by the same Doppler beam sharpening as is used in side-looking imaging synthetic aperture radars (SAR). This technique is known as delay/Doppler (D/D) altimetry. One of the main benefits of delay/Doppler (D/D) altimetry is the improved resolution of the system along the satellite track. By means of an unfocused Synthetic Aperture Radar (SAR) processing technique, the altimeter footprint along the flight direction can be reduced by an order of magnitude with respect to conventional altimeters, i.e. around 300 meters. However, we are pushing even further the limits of this technology, as we have developed a processing technique that could improve the along-track resolution down to the meter level.

By accounting for the phase evolution of the targets in the scene, it is possible to counter-rotate the phase of the FBR I/Q complex echoes along the aperture, and perform inter-burst coherent averaging potentially as long as the target illumination time. This process, similar to SAR imaging systems, reduces the along-track resolution down to the theoretical limit equal to L/2, where L is the antenna length. We call this the fully focused SAR Altimetry processing. For the development of the technique we have used the CryoSat-2 SAR Mode data, but our methods could also be used with similar data from Sentinel-3 or Sentinel-6/Jason-CS.

The footprint of a fully focused SAR altimeter measurement is an elongated strip on the surface, which is pulse-limited across-track and SAR focused along-track. The technique has been demonstrated using transponder data, showing an achievable along-track resolution of 0.5 meters. Despite the asymmetry of the altimeter footprint, the fully focused technique may be useful for applications in which one needs to separate specific targets within highly heterogeneous scenes, such as in the case of sea-ice leads detection, hydrology, and coastal altimetry applications. Applying this technique on CryoSat-2 data over land and sea-ice, we can correctly measure the along-track extent of water bodies and ice-leads only a few meters long in the along-track dimension.

Over the open ocean, the fully-focused SAR technique can also provide significant improvements with respect to the other radar altimeter techniques. Fig. 1(a) shows the sea level anomaly (SLA), significant wave height (SWH) and radar cross section (RCS) obtained with the delay-Doppler processing (in grey), and with the fully-focused SAR technique. As can be observed, both estimates are mostly overlapping, showing that the fully-focused SAR technique can be used to obtain reliable estimations of ocean geophysical parameters. In addition, Fig.1 (b) shows the 1Hz noise estimations for these parameters for different processing approaches. The fully-focused SAR out-performs the delay/Doppler (unfocused SAR) processing technique by a factor of sqrt(2) in SLA and SWH, which could represent a significant improvement in a wide range of oceanographic applications.



(a) (b)

Figure 1: (a) CryoSat-2 SAR Mode track over the North-East Atlantic. The panels show the satellite track and the geophysical parameters retracking results for both PLRM (in gray) and fully-focused SAR data (in black) at 1 Hz. (b) Comparison of 1 Hz noise estimates for sea level anomaly, significant wave height, and radar cross section as a function of significant wave height, for the PLRM, unfocused SAR, and focused SAR processing approaches.

Accomplishments

Apart from the development of ocean applications, during this task we concentrated our effort in developing sea-ice applications. In this case, we compared CryoSat-2 observations to data from the Digital Mapping System (DMS) on board the IceBridge NASA mission. For this analysis, we selected a CryoSat-2 underflight performed on March 28, 2012. Within this track, we identified an area with recently formed sea ice leads. The FBR data of this track were processed by means of the FF-SAR processing technique, at an along-track resolution of 0.5 m. In order to compare our results directly to the official ESA products, we applied an along-track multilooking of 320 m, corresponding to a posting rate of roughly 20 Hz.

In Fig. 2(a), we show the power variations retrieved from the multilooked FF-SAR waveforms overlaid on the DMS geolocated and ortho-rectified images. For better visualization, the data were represented in polar-stereographic coordinates. The CryoSat and DMS data were acquired with a time difference under 1 h apart from each other; therefore, the ice drift is not significant for the type of analysis considered here. The along- track power variations are represented in color scale, setting in this case the 0-dB reference for the power measure from an extended ice surface (between 13 and 2 km south from the center of the image). After multilooking, the FF-SAR altimeter footprint is considered as a rectangle of 320 (along-track) × 1500 m (across-track), corresponding to the first waveform range gate projected on the ground. As observed from the image, as well as for the irrigation pond, the different features in the surface are clearly detected by the measured power variations, with a dynamic range of more than 30 dB.

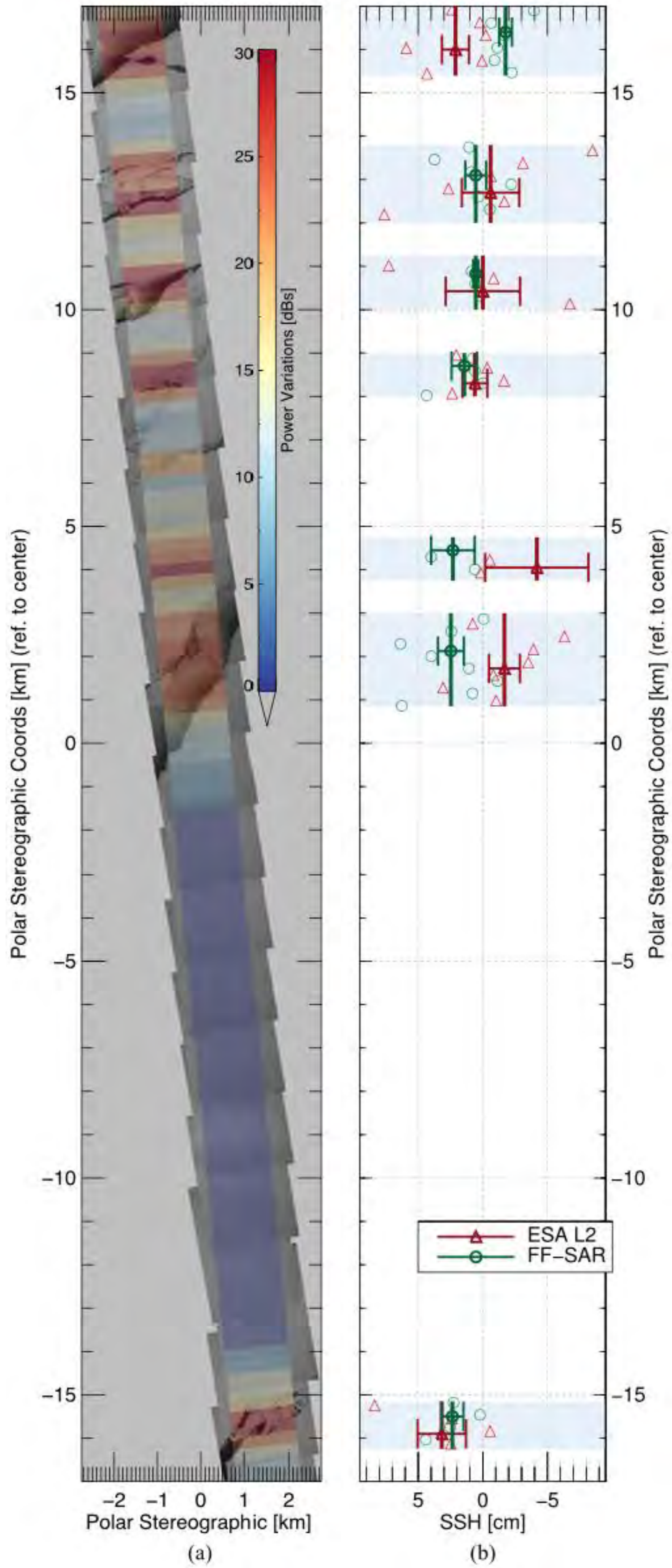
In this application example, we also estimated the sea surface height (SSH) from the FF-SAR multilooked waveforms retrieved over sea ice leads. The sea ice lead positions were determined according to a surface classification method which is based on the pulse peakiness, and the delay/ Doppler stack standard deviation. These two parameters were retrieved from the ESA L2 and L1 b products. For the estimation of SSH over leads, we implemented a simple waveform peak power parabolic retracker; as sea ice leads act, mostly, as specular scatterers, it suffices to determine accurately the position of the waveform peak in order to obtain a precise estimation of the range to the surface. In order to compare the FF-SAR and ESA L2 measurements, we removed the geoid variations and a constant bias between both data sets. Therefore, for the span of the observation area considered here, the mean sea surface is centered on 0.

The results are shown in Fig. 6(b). The sea ice lead positions are highlighted in light blue in the figure, corresponding very accurately to the sea ice leads observed in the DMS images. The individual SSH measurements in leads are shown for both the FF-SAR and ESA L2 products, as well as the mean SSH in the lead as determined by each measurement method, along with the 1σ uncertainty in the mean. The latter are computed as the standard deviation of the SSH measurements divided by the square root of the number of available measurements within each lead, which is, in all the cases, the same for both FF-SAR and ESA L2. It should be noted that the associated errors for the FF-SAR measurements are consistently lower than those for the ESA L2 product. In addition, the standard deviation of the SSH measurements for the whole observation area considered here is reduced by a factor of sqrt(2), from 4.4 cm, for the ESA L2 product, to 3 cm for the FF-SAR estimations. This improvement in the SSH retrieval is related to an increase in the effective number of looks of the surface.

Planned work

Despite the demonstrated resolution and performance improvement, the development of applications for this novel technique still remains to be done, and considerable theoretical and empirical research is needed in order to optimize the exploitation of this new measurement technology. The planned work will focus on the development of applications for two-key areas for NOAA, namely the open and polar oceans, specifically sea surface height and sea ice applications.

Figure 2. (a) Sigma-0 measurements from CryoSat-2 FF-SAR data, processed at full resolution, with an along-track multilooking of 30 m. The sigma-0 measurements, represented in color scale, are overimposed to NASA IceBridge DMS geolocated images. (b) Comparison of ESA L2 (dark red) product and FF-SAR (dark green) SSH estimations over sea ice leads. The sea ice lead positions are highlighted in light blue. The single ESA L2 and FF-SAR measurements are represented with triangles and circles, respectively. The solid lines with the associated error bars correspond to the mean and the uncertainty of the height measurements for each sea ice lead identified in the scene.



1) Sea Surface Height Applications

- Select an extended dataset in SAR mode with sufficiently diverse surface conditions to perform a statistically significant analysis of the performance of the FF-SAR technique vs other conventional altimetry methods.
- Process data in FF-SAR and delay/Doppler mode to determine waveform-to-waveform correlation in different sea state conditions.
- Develop a mode for waveform correlation as a function of sea state and coherent integration.
- Determine an optimum averaging strategy (coherent vs incoherent) of SAR altimeter radar returns.

2) Sea Ice Applications

- Determine best processing strategy in terms of final signal-to-noise ratio for D/D and FF-SAR mode observations over the open ocean. The parameters to be considered comprise: Hamming windowing (along-track and across-track), antenna pattern compensation, time dilation correction, etc…

Publications

(1) A. Egido, W. H. F. Smith, "Fully Focused SAR Altimetry: Theory and Applications", *IEEE Transactions on Geoscience and Remote Sensing, Jan. 2017*

Products

- Sea Surface Height experimental product.
- Sea-ice freeboard experimental product.

Presentations

(1) **Oral Presentations**:

(a) **A. Egido**, W. Smith, "Fully-focused SAR Altimetry: Theory and Applications", ESA Living Planet Symposium, Prague, Czech Republic, May 9-13, 2016

(b) W. Smith, **A. Egido**, "Fully focused coherent radar altimetry: precise datation, antenna motion, and transponder calibration", ESA Living Planet Symposium, Prague, Czech Republic, May 9-13, 2016

(c) **A. Egido**, W. Smith, "Scientific Applications of Fully-Focused SAR Altimetry", SAR Altimetry Workshop; La Rochelle, France, 31st Oct. 2016.

(d) W. Smith, **A. Egido**, "Some surprisingly wonderful aspects of fully focused SAR (FF-SAR) altimetry", SAR Altimetry Workshop; La Rochelle, France, 31st Oct. 2016

(e) **A. Egido**, W. Smith, "Focused SAR Altimetry for Oceanographic Applications", Ocean Surface Topography Science Team Meeting, La Rochelle, France, 1st – 4th Nov. 2016

(f) **A. Egido**, W. Smith, "Scientific Applications of Fully-Focused SAR Altimetry", CICS-MD Science Meeting, College Park, MD, USA; Nov 29-30 and Dec 1, 2016

(g) A. Egido, W. Smith, "Sea-Ice Applications of Fully-focused SAR Altimetry", North-American *CryoSat* Science Meeting 20-24 March *2017*. Banff, Alberta, Canada.

Other

2016 NOAA Center for Satellite Applications and Research (STAR) Innovation Award for the development of Fully Focused SAR Altimetry. Awarded on 23rd June 2016 to Dr. Alejandro Egido and Dr. Walter H.F. Smith, by STAR director Mike Kalb, and NOAA/NESDIS Director Dr. Stephen Volz.

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

CUNY-CREST: A new technique for VIIRS detection and delineation of *Karenia brevis* Harmful Algal Blooms (*KB* HABS) in the West Florida Shelf without the need for a fluorescence channel"

Task Leader	Sam Ahmed CREST CCNY
Task Code	SASA_HABS_16
NOAA Sponsor	Mitch Goldberg**,**
NOAA Office	JPSSO
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Earth System Monitoring from Satellites
Contribution to NOAA goals (%)	Goal 3: 100%
Strategic Research Guidance Memorandum:	1. Integrated Earth System Processes and Predictions

Background

Effective Karenia brevis harmful algal bloom (*KB* HAB) detection and tracking approaches in the West Florida Shelf (WFS) are needed for VIIRS, since, unlike MODIS, it does not have a 678 nm channel to detect chlorophyll fluorescence, which is used in a normalized fluorescence height (nFLH) algorithm technique that helps in detecting and tracking *KB* HABS from MODIS. The approach pursued here uses neural network (NN) algorithms which we have developed and trained, using a wide range of suitably parametrized synthetic data typical of coastal waters, to model the relationship between remote sensing reflectance (Rrs) values at the 486, 551 and 671nm bands that are available on VIIRS and phytoplankton absorption (a_{ph443}), and other IOPs at 443 nm. These relationships permit retrievals from VIIRS observations of (a_{ph443}) and from that the equivalent chlorophyll concentration [*Chla*] which is related (approximately linearly) to *KB* HAB cell counts. In conjunction with the NN VIIRS retrievals of a_{ph443} , we have developed an approach, based on known low backscatter characteristics of *KB* HABS in the WFS, to define and apply limiting criteria to NN retrievals and mask out all but *KB* compatible pixels, Analytical comparisons of the accuracy of VIIRS NN *KB* HABs and[*Chla*] retrievals, with these limiting criteria applied, against spatially coincident retrievals in-situ retrievals are compared with accuracies obtained using OCI, OC3, GIOP, QAA and RGCI retrievals. These comparisons have confirmed the viability, potential and advantages of the NN retrieval technique being pursued. They also confirm its ability to fill the void caused by the absence of a fluorescence channel on VIIRS.

Accomplishments

In the work reported here, NN algorithms using *Rrs* values from the 486, 551 and 671 nm VIIRS bands are used to retrieve an image of a_{ph443} values in the WFS. Then, these additional limiting constraints are applied, in two filter processes, F1 and F2 to eliminate from that image all a_{ph443} pixels which are not compatible with the existence of *KB* HABs. The residual image then shows only retrieved a_{ph443} values and their equivalent [*Chla*] values that are consistent with the existence of *KB* HABs.

NN retrievals of KB HABs in the WFS were obtained using the above filter processing approach. To evaluate the efficacy of these retrievals, they were matched against in-situ measurements. For meaningful quantitative comparisons of NN retrievals against in-situ measurements, it is important to have many data points. Accordingly, we sought all available match-ups between VIIRS NN a_{ph443} (and equivalent

[*Chla*] retrievals) and *in situ KB* cell count measurements for the period 2012–2016 for which there was available VIIRS data. These comparisons showed that for VIIRS observations, the NN technique appeared to offer good potential for effective retrievals of *KB* HABs cell counts in the WFS. More specifically, these comparisons showed that when the window between *in situ* observations and satellite overpass measurements was reduced from 100 minutes to 15 minutes, retrieval accuracies greatly improved with increased correlations and reduced errors. The comparisons against in-situ match-ups were also carried out for VIIRS retrievals using other algorithms: OCI/OC3, GIOP, QAA and RGCI.

The NN VIIRS retrievals accuracies against available in-situ measurements, over the 2012-2016 period, were then compared to retrieval accuracies obtained with OCI/OC3, GIOP and QAA algorithms, it was found that GIOP and QAA algorithms exhibited negative values or no retrievals in many instances. When these negative values are excluded, there remained 68 valid match-ups for the 100 minute overpass window. The retrieved [*Chla*] for these 68 match-ups is shown against in-situ cell counts in Fig. 1, for all retrieval techniques.

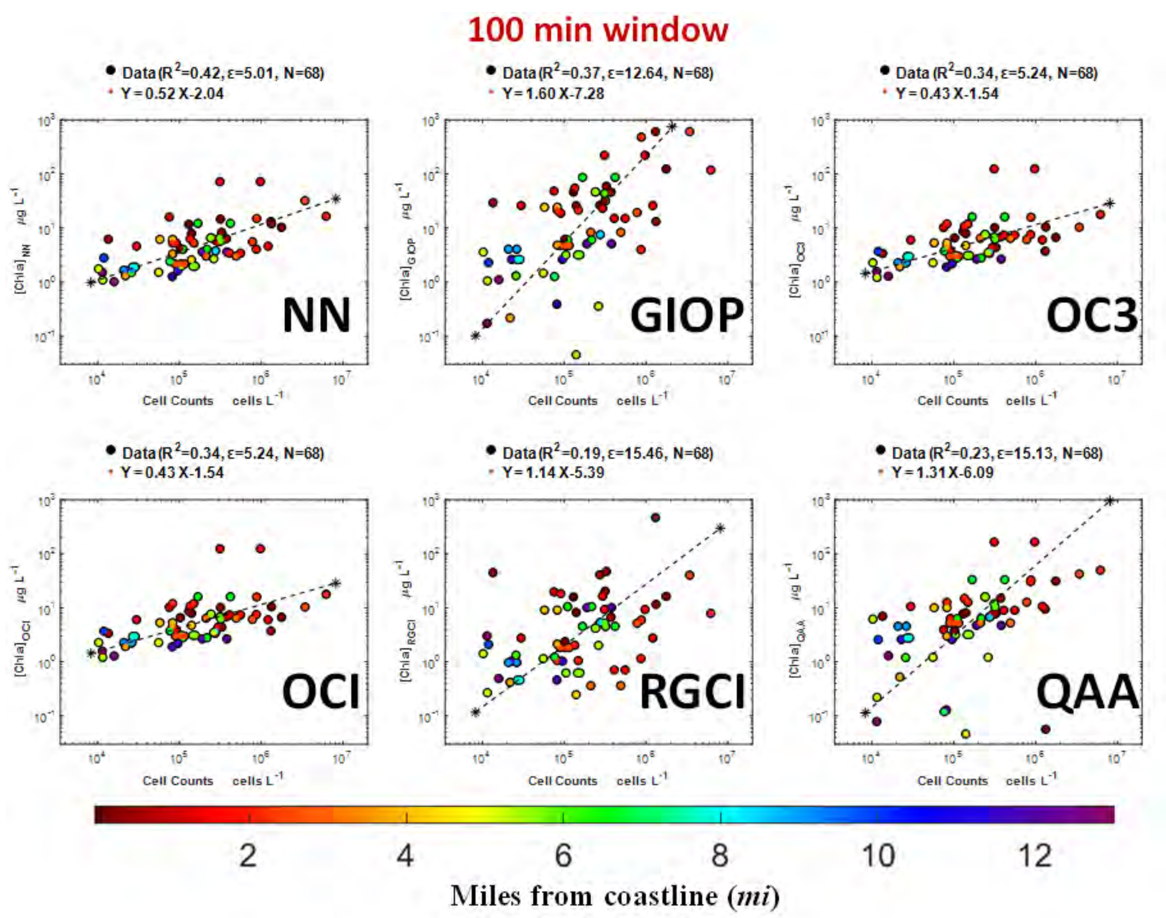


Figure 1. Results for 68 *in-situ* observations within 100 minutes of VIIRS overpass for the six algorithms showing retrieved [*Chla*] against *KB HABs* cell counts for NN, GIOP, OC3, OCI, RGCI, and QAA retrievals; Color coding of the dots denotes distance to shore, with red being the closest.

When the overlap observation window is reduced to 15 minutes, we have 18 valid match-ups remaining, after excluding negative values associated with GIOP and QAA. Results for these 18 match-ups are shown in Fig. 2 below. Again, as can be seen, correlations and errors greatly improve for the 15 minute window over those for the 100 minute window, Fig. 1.

These results support the conclusion, that, at least for these preliminary and somewhat limited data sets, the NN retrievals exhibit the best performances against the in-situ measurements, for both the

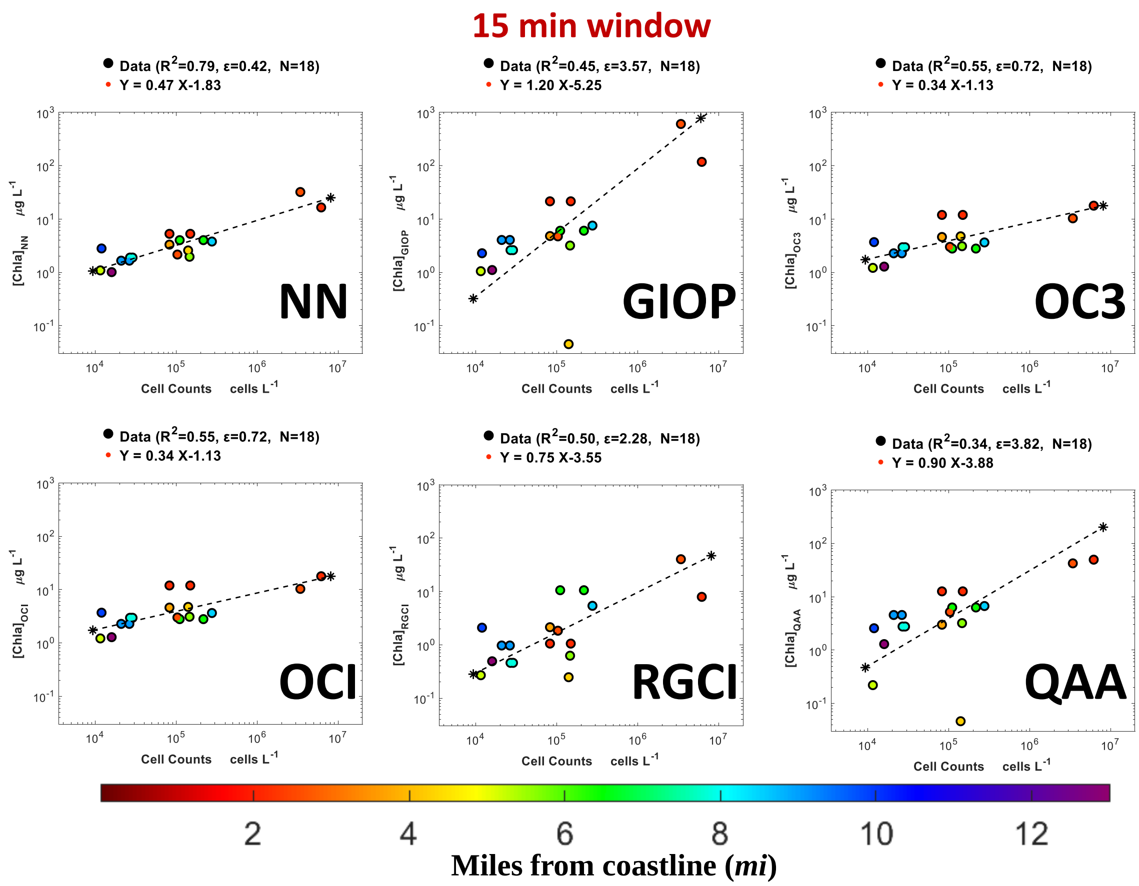


Figure 9. Results for 18 *in-situ* observations within 100 minutes of VIIRS overpass for the six algorithms showing retrieved [*Chla*] against *KB HABs* cell counts for NN, GIOP, OC3, OCI, RGCI, and QAA retrievals ; Color coding of the dots denotes distance to shore, with red being the closest.

longer (100 minute) and, more importantly, the shorter (15 minute) overlap time windows. This was observed both in terms of higher correlations and lower errors against the in-situ measurements. The improved accuracies for the shorter overlap window clearly reflect the impact of temporal variabilities in the KB HABs being observed. This has important implications for the accuracies of satellite retrievals.

Planned work

- Analysis of NN VIIRS retrievals will be done to examine the statistics of false positive and negative match ups against in-situ measurements. We will attempt to define the factors that contribute to incorrect match ups, if possible, including location.
- This anlysis will be extended to OC# retrievals and if warranted to other retrieval algorithms.
- Further in-sight into temporal variations will be pursued, as well as their impact on retrieval accuracies.
- This will be complemented by analysis of field measurements where available.
- The potential use of consecutive overlapping overflights of VIIRS and MODIS-A will be examined for the possibilities of obtaining information on temporal changes in Karennia brevis harmful algal bloom distributions min the West Florida Shelf. The consecutive overflights for the three satellites occur within an approximately 100 minute period. The use of sequential image comparisons should shed light on the potential of their use for studying temporal changes of KB HABs and their impact on satellite retrievals and their efficacy.
- We will continue with an ongoing investigation of the spectral characteristics of remote sensing relectance associated with KB bloom waters in the WFS with the objective of potentially establishing spectral signatures which would assist in their identification

Publications

A. El-habashi et al., "Satellite Retrievals of Karenia brevis Harmful Algal Blooms in the West Florida Shelf Using Neural Networks and Comparisons with Other Techniques," *Remote Sensing* **8**(5), 377

Presentations

2. An invited paper “Neural Network retrievals of *Karenia brevis* harmful algal blooms in the West Florida Shelf” Sam Ahmed and Ahmed El-habashi, was presented on the SPIE Remote Sensing International Conference, *Sept. 2016*.

2**.** A presentation was made at the JPSS Science Team meeting on 8/10/16, College Park, MD, entitled “VIIRS Retrievals of *Karenia brevis* Harmful Algal Blooms in the West Florida Shelf Using Neural Networks” by Sam Ahmed and Ahmed El-habashi (PhD candidate) CREST CCNY in Collaboration with Drs Rick Stumpf & Michelle Tomlinson NOAA National Ocean Services

3. A paper entitled *“A new technique for satellite retrievals of Karenia brevis harmful algal blooms in the West Florida Shelf using neural networks” was presented by* Ahmed El-habashi (CUNY) at the CoRP Science Symposium July 18-19, 2016 Connecting Observations Across Systems.

4.1.A paper entitled “Neural network retrievals of harmful algal blooms in the West Florida Shelf from satellite observations and comparisons with other techniques
” by Sam Ahmed, Ahmed El-habashi, Vince Lovko, Richard Stumpf, Michelle Tomlinson *was presented at the Ocean Optics XXIII Conference, Victoria, Canada, in October 2016*.

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

Towards Operational Arctic Snow and Sea Ice Thickness Products

Task Leader	Sinéad Louise Farrell
Task Code	SFSF_IOAS_14 Year 3
NOAA Sponsor	Laury Miller
NOAA Office	NOAA/NESDIS/STAR/SOCD/OPB/LSA
Contribution to CICS Research Themes (%)	Theme 1: 30%; Theme 2: 60%; Theme 3: 10%
Main CICS Research Topic	Earth System Monitoring from Satellites
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
Strategic Research Guidance Memorandum:	5. Arctic

Highlight Novel measurements of snow on Arctic sea ice now routinely available using FMCW Snow Radar system mounted on aircraft platform. Since Operation IceBridge measurements began in 2009, we find that snow depth on first-year sea ice is ~ 70 % of that on multi-year sea ice at the end of winter, with some inter-annual variability observed.

Link to a research web page http://ibis.grdl.noaa.gov/SAT/SeaIce/index.php

Background

Improving our knowledge of the nature, and variability, of the sea ice cover is critical in order to advance our capabilities to predict future Arctic state, on seasonal to decadal time-scales. The thickness and volume of the Arctic sea ice pack are key components of the polar climate system. Ongoing loss of the ice pack has serious implications for climate change, but also has ecological and socio-economic impacts on the Arctic region. Satellite altimetry observations from ICESat and CryoSat-2 indicate a decline in the thickness of the ice pack over the last decade. The latest results from NASA's IceBridge mission show that following the precipitous drop in multi-year ice in 2007-2008, the central Arctic remains dominated by multi-year ice just over 3 m thick, while ice thickness in the Beaufort and Chukchi Seas continues to decline. Extensive, and continued, monitoring of the Arctic sea ice pack using satellite altimetry is necessary to determine whether recent observations are part of a sustained negative trend, or a reflection of the natural variability of the system. Altimetry data from the Envisat, ICESat, CryoSat-2, Sentinel-3A, IceBridge and ICESat-2 missions provide almost two full decades of measurements of the Arctic ice pack. The goal of this investigation is to assess how well Arctic sea ice elevation, ice freeboard, snow depth, and ice thickness can be mapped using satellite and airborne altimeters. We validate the capabilities of the various altimeter systems, using independent aircraft and field measurements.

Accomplishments

During the reporting period (1 April 2016 - 31 March 2017), CICS-MD scientists, Dr. Sinéad L. Farrell, Dr. Thomas Newman, Mr. Kyle Duncan and Ms. Marissa Dattler, along with sea ice scientists at the NOAA Lab. for Satellite Altimetry (LSA), continued work to measure the inter-annual variability of key parameters describing the Arctic sea ice cover, including sea ice thickness, snow depth on sea ice, and the extent of multi-year sea ice. CICS-MD and NOAA-LSA sea ice scientists collaborated closely with the NASA OIB Science Team on flight planning during the 2016 Spring Campaign in the Arctic. The team designed a specific IceBridge flight to acquire temporally and spatially coincident data beneath the Sentinel-3A (S-3A) radar altimeter. This under-flight was conducted in the Beaufort Sea, north of Alaska (Figure 1) on 21 April 2016, during which critical calibration/validation data were collected. IceBridge quicklook data and

MODIS visible imagery provided details about sea ice conditions along the S-3A orbit, which comprised large first- and multi-year sea ice floes, interspersed with numerous leads. IceBridge Digital Mapping System (DMS) visible images were used for verification of sea ice lead and floe delineations in the S-3A radar altimeter waveform stack (Figure 1). The initial assessment demonstrated that lead locations delineated in DMS data agree with specular returns evident in the S-3A waveform stack.

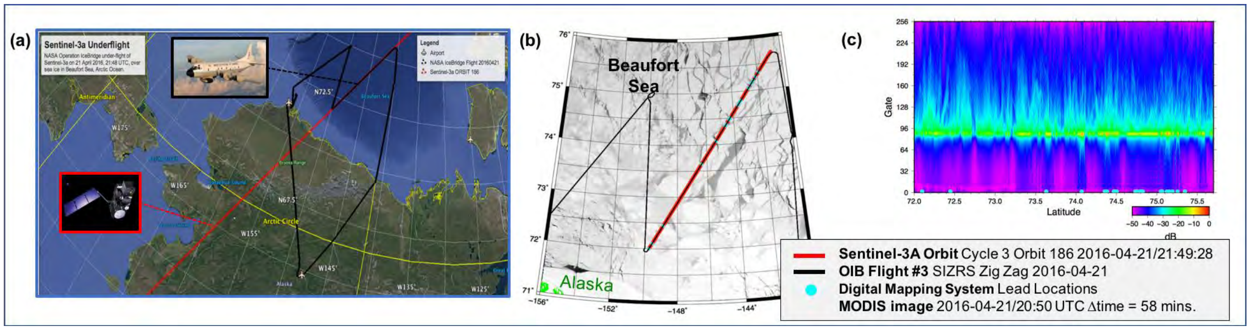


Figure 1: (a) Operation IceBridge under-flight of the Sentinel-3A spacecraft on 21 April 2016. (b) The study-area in Beaufort Sea, north of Alaska, comprised large sea ice floes interspersed with numerous leads. Lead locations (cyan dots) were derived using OIB Digital Mapping System (DMS) imagery. (c) Processed Sentinel-3A radar altimeter waveform stack, with sea ice lead locations delineated (cyan dots).

A snow depth retrieval technique to identify snow layer interfaces in NASA Operation IceBridge (OIB) snow radar echograms was developed and applied to the newly reprocessed (Dec. 2015) OIB / CReSIS snow radar echogram data set. Figure 2 shows estimates of snow depth on Arctic sea ice in March/April 2014, derived from snow radar data after the application of a wavelet-based snow depth retrieval algorithm (Newman et al., 2014). Snow on the oldest ice north of Greenland and the Canadian Arctic Archipelago was on average 0.35-0.5 m deep, while there was a strong gradient to thinner snow cover in the Canada Basin and the southern Beaufort Sea, where mean snow depth was 0.15-0.35 m at the end of winter 2014. The IceBridge snow radar data have now been successfully processed for the years 2009-2012, and 2014-2015, providing details of the inter-annual variability in the snow depth distribution over a seven-year period. Mean snow depth on first-year sea ice varied from 0.19-0.27 m over the observation period, and is on average 0.23 m. This is approximately 70 % of the mean snow depth on multi-year ice, which is 0.33 m, and varied from 0.28-0.35 m during the observation period. These results are currently being prepared for submission to the peer-reviewed literature.

The CICS-MD and NOAA-LSA sea ice team disseminated their scientific findings through seven articles in the peer-reviewed literature and presented their recent research in 21 presentations delivered at NOAA workshops, national and international meetings. The team continued to collaborate with Operation IceBridge and participated in the IceBridge Science Team Meeting, 25-26 Jan. 2017, held at the NASA Goddard Space Flight Center. CICS-MD Scientist Sinéad Farrell was selected to serve as the Project Scientist of PolarWatch, a new NOAA joint venture between STAR and the West Coast Regional Node (WCRN) of CoastWatch. The key goal of PolarWatch is to provide a user-driven information portal for accessing multi-sensor physical and biological ocean remote sensing data in support of a broad suite of applications and research in the Arctic and Antarctic (Figure 3). CICS-MD Scientist Dr. Farrell was also quoted in a NASA News article on March 15, 2017 regarding the upcoming NASA ICESat-2 mission. Dr. Farrell discussed the utility of ICESat-2 measurements for improved sea ice forecasting: https://www.nasa.gov/feature/goddard/2017/icesat-2-to-provide-more-depth-to-sea-ice-forecasts/.

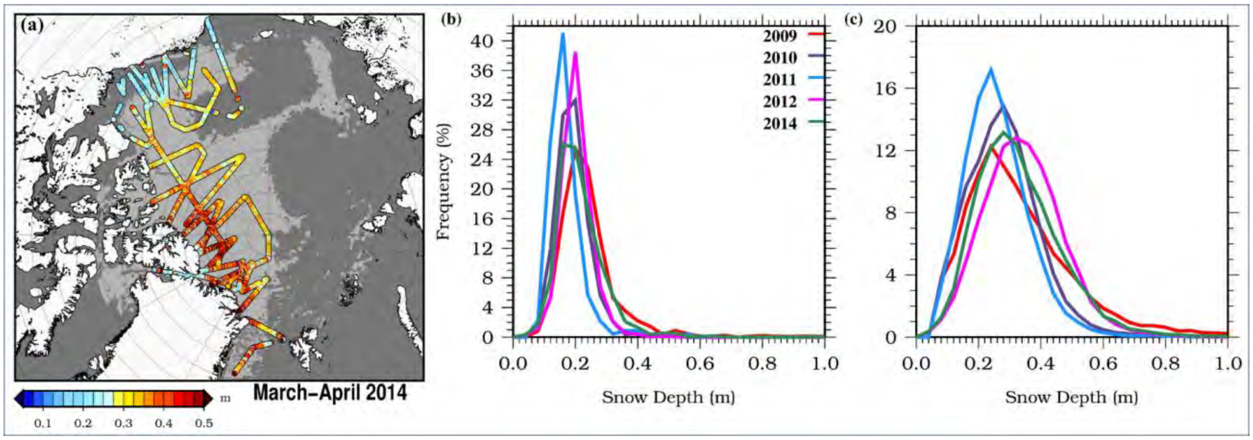


Figure 2: (a) Polarstereographic mapping of snow depth on Arctic sea ice, at the end of winter in 2014, overlaid on the ASCAT multi-year sea ice mask (light grey). Snow depth distributions (b) on first-year sea ice and (c) multi-year sea ice between 2009 and 2014.

Figure 3. The new PolarWatch initiative will provide NOAA and non-NOAA polar data sets through a new data portal, delivered to a broad set of stakeholders conducting research and operation activities in the polar regions.

Planned work

- Support planning, implementation and flight-line design for the NASA Operation IceBridge underflights of CryoSat-2, Sentinel-3A and ICESat-2 over Arctic and Southern Ocean sea ice.
- Support planning, implementation and flight-line design for the NOAA Global Archer Mission, during the first, high-altitude sea ice experiments in early 2018.
- Publish results of Arctic snow depth validation across all sea ice types include level sea ice and rough/ridged ice surfaces via comparison of airborne snow radar data with multiple validation data sets gathered in situ across a range of ice conditions between 2011 and 2015.
- Integrate Arctic snow depth estimates with the NOAA-LSA sea ice freeboard product for improved characterization of changes in Arctic sea ice thickness.
- Examine inter-annual variability in Arctic multi-year sea ice extent from 2009-present.

- Continue collaborations with the NOAA Laboratory for Satellite Altimetry, NASA GSFC, the Naval Research Laboratory (NRL), CRREL, Environment and Climate Change Canada, University of Washington, University of Alaska-Fairbanks, University of Leeds, and the European Space Agency on the assessment and inter-comparison of IceBridge and CryoSat-2 data products over Arctic sea ice.

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Haas, C., S. Baker, J. Beckers, S. L. Farrell, J. Gaudelli, S. Hendricks, J. King, R. Ricker, G. Spreen (2016), CryoSat Sea Ice Product Validation using CryoVex and IceBridge campaign data, *European Space Agency CryoVal – Sea Ice Technical Note 3*: Assessment of Different Sources of Uncertainty, CVSI-TN-WP3-3001, Issue 1.1. [*Non peer-reviewed*]

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Presentations

Farrell, S. L., F. Monaldo and E. Leuliette (2017), NOAA/NESDIS/STAR/SOCD Sea Ice Activities: Altimetry and SAR Ocean Products, Update on PolarWatch, JPSS/STAR/CPO Arctic Technical Interchange Meeting Part I, NOAA Center for Weather & Climate Prediction (NCWCP), College Park, MD, 29 Mar. 2017.

Farrell, S. L. (2017), NOAA/NESDIS/STAR/SOCD Sea Ice Activities, SOCD-EUMETSAT Operational Oceanography Meeting, NCWCP, College Park, MD, 27 March 2017.

Farrell, S. L. (2017), Understanding Interannual Variability and Long Term Trends in Polar Sea Ice using Satellite Laser and Radar Altimetry: Current Achievements and Future Prospects, North-American CryoSat Science Meeting, Banff, AB, Canada, 20 March 2017. [***Invited***]

Farrell, S. L., J. Richter-Menge, M. Dattler and T. Newman (2017), Novel Measurements of the Snow Depth Distribution on Sea Ice in Support of Polar Altimetry**,** North-American CryoSat Science Meeting, Banff, AB, Canada, 21 March 2017.

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Farrell, S.L. (2016), ICESat-2 Calibration/Validation over Sea Ice Surfaces, NASA ICESat-2 Science Definition Team Meeting, NASA GSFC, Greenbelt, MD, 27-29 Sept. 2016.

Farrell, S.L. (2016), Overview of Sea Ice Earth Observation - Altimetry, Extent, Concentration and Drift, *Guest Lecture*, 1st European Space Agency Advanced Training Course on Remote Sensing of the Cryosphere, University of Leeds, Leeds, UK, 12 - 16 September, 2016. [***Invited***]

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Other

ICESat-2 Science Definition Team Member

CICS-MD Scientist Sinéad Farrell serves as a member of the NASA ICESat-2 Science Team (2012 - present)

IceBridge Science Team Member

CICS-MD Scientist Sinéad Farrell served as a member of the NASA IceBridge Science Team (2009-2016)

European Space Agency (ESA) CryoSat Sea Ice Product Validation ("CryoVal-SI") Investigator

CICS-MD Scientist Sinéad Farrell is an International Investigator on the ESA CryoVal-SI project (2013-16)

NOAA/NESDIS/STAR/SOCD Sea Ice Team

Dr. Sinéad Farrell is the NOAA/NESDIS/STAR/SOCD Sea Ice Team lead and CICS-MD Scientists K. Duncan and M. Dattler currently serve as members of the SOCD Sea Ice Team.

COMMUNITY OUTREACH

CICS-MD Scientist S. L. Farrell serves on the Scientific Organizing Committee for the 3rd Blue Planet Symposium 2017.

CICS-MD Scientist S. L. Farrell co-organized the NOAA/NESDIS/STAR and NCEP/EMC Sea Ice Data Assimilation Workshop, NOAA Center for Weather and Climate Prediction, College Park, MD, 21 Feb. 2017,

CICS-MD Scientist S. L. Farrell convened the National Snow and Ice Data Center (NSIDC) – NOAA Laboratory for Satellite Altimetry Workshop: Accessing Operation IceBridge Data and the User Workflow Experience, NOAA Center for Weather and Climate Prediction, College Park, MD, 3 October 2016.

MENTORING, ADVISING, TEACHING

CICS-MD Scientist Sinéad Farrell mentored Post-Doctoral Associate Dr. Newman (2011-2016), and Faculty Specialists Mr. K. Duncan (2015 – present) and Ms. M. Dattler (2016 – present).

CICS-MD Scientist Farrell delivered a Guest Lecture entitled "Overview of Sea Ice Earth Observation - Altimetry, Extent, Concentration and Drift" at the 1st European Space Agency Advanced Training Course on Remote Sensing of the Cryosphere, University of Leeds, Leeds, UK, 12 - 16 September, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	1
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	5
# of NOAA technical reports	1
# of presentations	3
# of graduate students supported by your CICS task	
# of graduate students formally advised	
# of undergraduate students mentored during the year	

SDSU Global Biomass Burning Emissions (GBBEP) Product	
Task Leader	Xiaoyang Zhang (South Dakota State University)
Task Code	XZXZ_GBBE_16
NOAA Sponsor	Shobha Kondragunta
NOAA Office	NESDIS/STAR
Contribution to CICS Research Themes(%):	Theme 1: 20%; Theme 2: 40%; Theme 3: 40%.
Main CICS Research Topic	Earth System Monitoring from Satellites
Percent contribution to NOAA Goals	Goal 1: 60%; Goal 2: 40%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Background

NOAA/STAR developed a global biomass burning emissions product (GBBEPx) that combines fire detection and fire radiative power (FRP) from a network of geostationary satellites and polar-orbiting satellites. The polar-orbiting satellites used in the algorithm are Aqua and Terra MODIS. With the launch of Suomi NPP satellite and Himawari 8, FRP will be retrieved from both VIIRS (Visible Infrared Imaging Radiometer Suite) and Advanced Himawari Imager (AHI). Therefore, STAR is modifying the algorithm to incorporate VIIRS FRP and AHI FRP data for the estimates of biomass burning emissions.

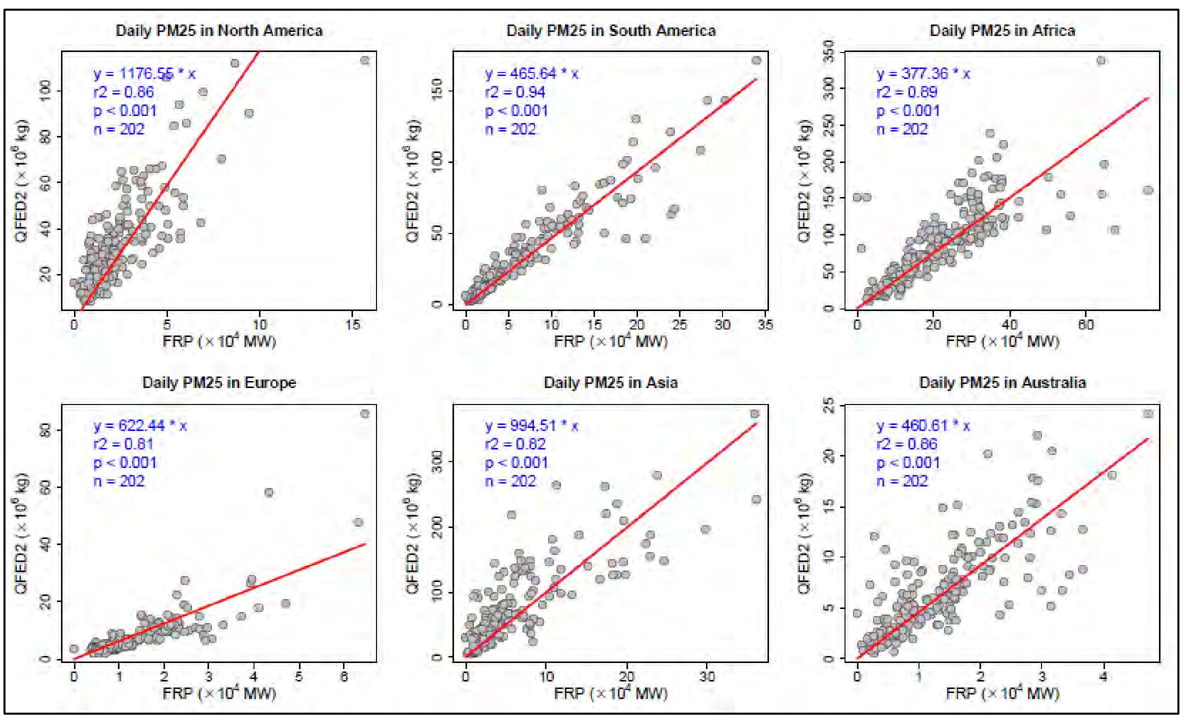

Figure 1. Coefficients between FRP with QFED PM2.5 (April-October 2016).

Accomplishments

- We prepared a pieces of computer code to process VIIRS HDF5 data, and compared VIIRS FRP with MODIS FRP.

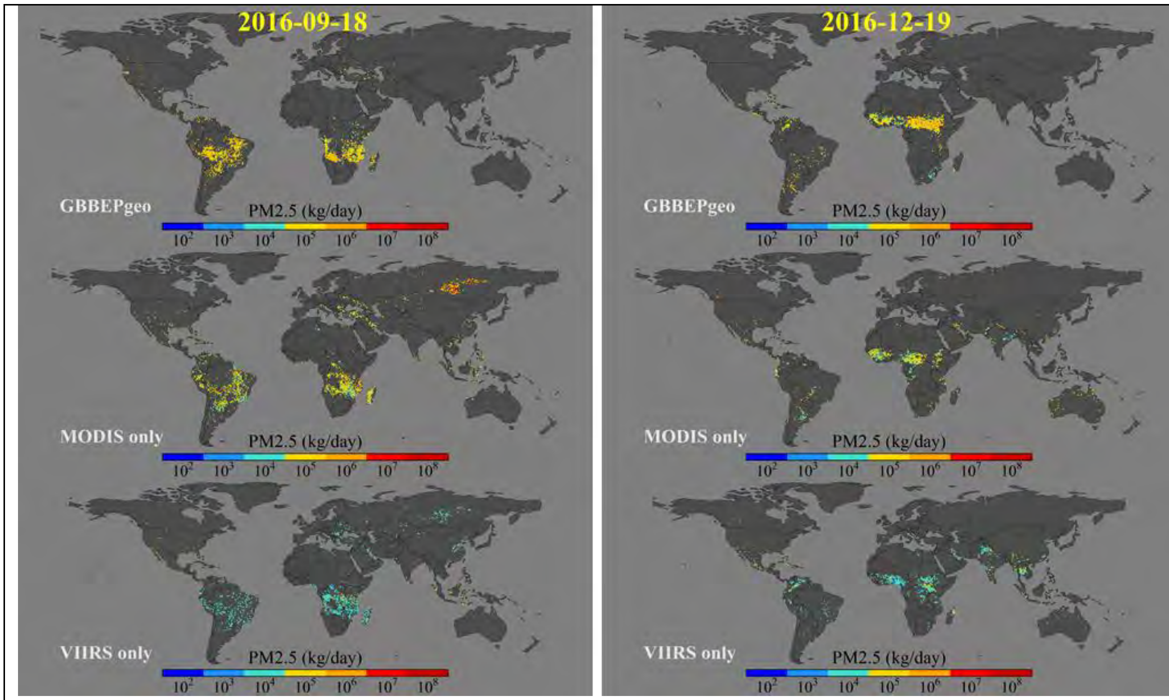

Figure 2. Comparison of biomass burning emissions from geostationary satellites, MODIS, and VIIRS FRP data.

- We collected and compared VIIRS FRP across the global and calculated fire emissions from VIIRS FRP for each 0.25-degree grid cell. Further, we compared VIIRS-FRP based emissions with QFED data for each individual continents across the globe. Finally, we obtained scaling factors to tune VIIRS-FRP emissions to QFED emissions (PM2.5, CO, CO2, BC, and OC) (Figure 1). This processing was conducted for two different periods (April-August and April-October). The resultant scaling factors were used to scale up the VIIRS FRP based emissions.
- We compared biomass burning emissions estimated from GBBEPx (MODIS and Geostationary satellites) during 2011-2015 with six global emissions products and two national (US) products (Figure 2). This comparison revealed the reliability of the emissions in the GBBEPx.
- We investigated the difference of biomass burning emissions derived from geostationary satellites, geostationary+MODIS satellites, and geostationary+MODIS+VIIRS satellites (Figure 3).
- We calculated and compared GOES FRP diurnal patterns for various ecosystems across the CONUS. These diurnal FRP patterns are expected to be used for improving the biomass burning emissions globally (Figure 4)
- We selected a set of Landsat-based burn scars over the western US and calculated biomass burned emissions using the traditional approach. In this approach, we obtained burned area and burn severity from USGS MTBS *(*Monitoring Trends in Burn Severity) product, fuel loading from

the Fuel Characteristic Classification System *(*FCCS*),* and biomass completeness from literature to calculate biomass consumption. Then we evaluated the biomass consumptions from FRP (MOIDS and GOES) with the estimates from the traditional approach (Figure 5).

- We completed critical design review for product of "*Global Biomass Burning Emissions Product from Geostationary and Polar Satellites (GBBEPx V2)*".
- We prepared documents of algorithm theory basis document (ATBD), user manual, system maintain manual for the "The Blended Global Biomass Burning Emissions Product From Modis And Geostationary Satellites (GBBEPx)".
- We delivered computer code for producing GBBEPx after adding fire emission estimates from VIIRS FRP data.

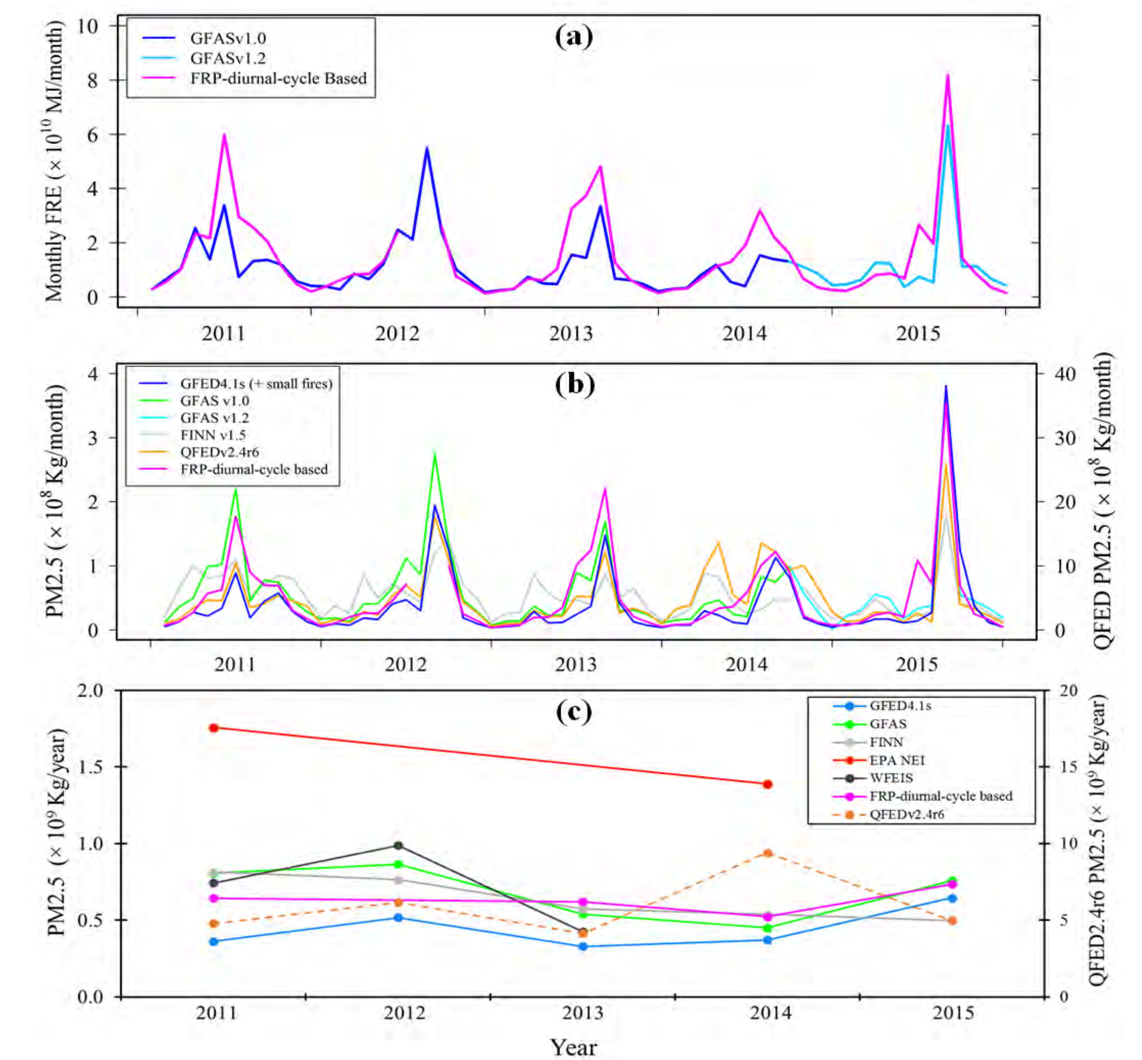

Figure 3. FRE and PM2.5 temporal patterns from 2013-2015 across the CONUS. **(a)** Monthly total FRE in this study and GFAS. **(b)** Monthly total PM2.5 in this study and other four inventories. **(c)** Annually total PM2.5 in this study and other six inventories. (Note: FRE and PM2.5 are unavailable from July to August 2012 due to missing GOES active fire products.)

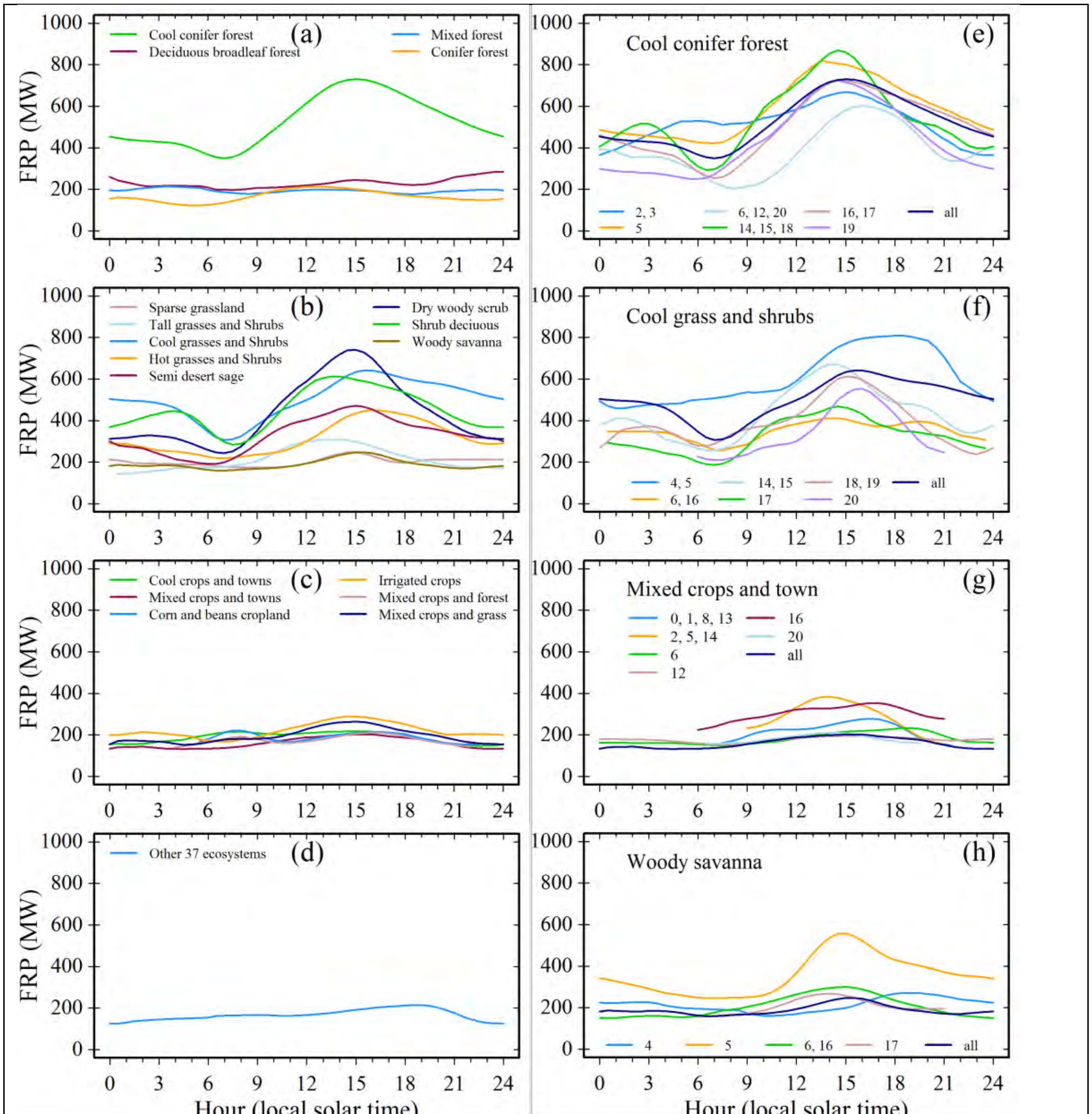

Figure 4. FRP diurnal climatologies at a 0.25˚°×0.3125° grid resolution. Ecosystem specific FPR diurnal climatologies across all the Bailey's ecoregions in the CONUS: (a) four forest related ecosystems, (b) eight grass, shrub, and savanna related ecosystems, (c) six crop related ecosystems, and (d) the other 37 ecosystems. (e-h) Examples of FRP diurnal climatologies in different Bailey's ecoregions: Cool conifer forest (e), Cool grass and shrubs (f), Mixed crops and town (g), and Woody savanna (h). In (e - h), the numbers in the legends are codes of the Bailey's ecoregions, and "all" represents all 25 ecoregions. Ecoregion codes: 0 - Hot Continental Division, 1 - Hot Continental Regime Mountains, 2 - Marine Division, 3 - Marine Regime Mountains, 4 - Mediterranean Division, 5 - Mediterranean Regime Mountains, 6 - Prairie Division, 8 - Savanna Division, 12 - Subtropical Division, 13 - Subtropical Regime Mountains, 14 - Temperate Desert Division, 15 - Temperate Desert Regime Mountains, 16 - Temperate Steppe Division, 17 - Temperate Steppe Regime Mountains, 18 - Tropical/Subtropical Desert Division, 19 - Tropical/Subtropical Regime Mountains, and 20 - Tropical/Subtropical Steppe Division.

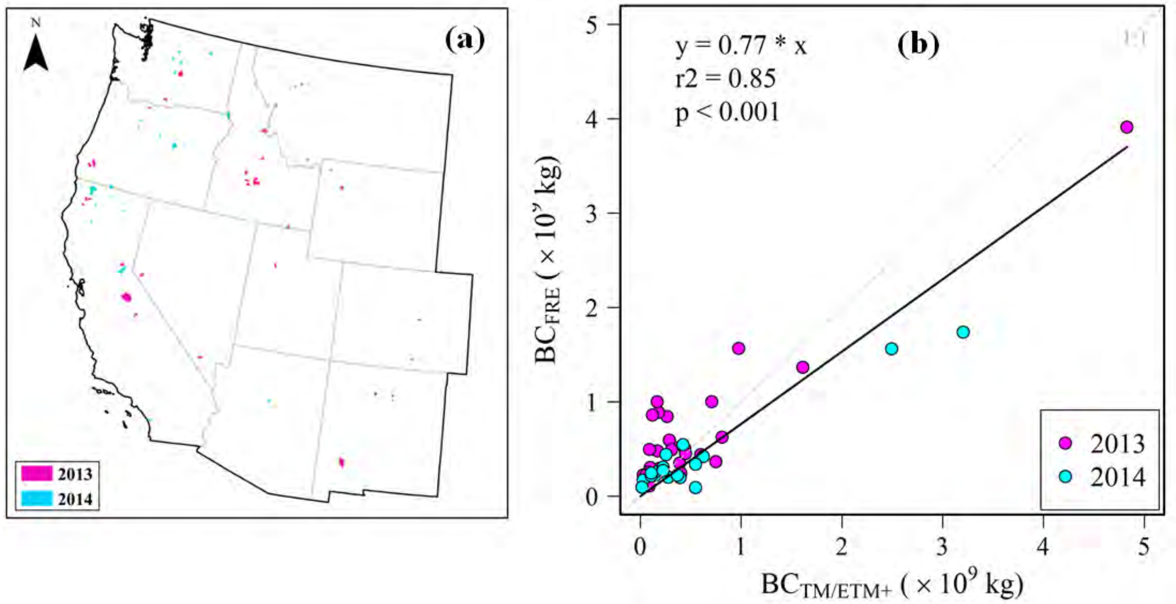

Figure 5. Comparison of total biomass consumption across the west CONUS between the satellite FRE based (this study) and the Landsat-burned-area-based estimates. (a) Distribution of 47 manually selected fire events across the west CONUS from 2013-2014. (b) Comparison between BC_{FRE} and $BC_{TM/ETM+}$.

Planned work

- Continuously investigate VIIRS FRP and related biomass burning emissions
- Investigate AHI and ABI fire data and estimate biomass burning emissions

Produts

- The Blended Global Biomass Burning Emissions Product From Modis And Geostationary Satellites (GBBEPx)

Presentations

1. Li, F., Zhang, X., Kondragunta, S., 2016, Estimation of Biomass Burning Emissions by Fusing Fire Radiative Power Observed from Polar-orbiting and Geostationary Satellites across the Continental United States, AGU Fall Meeting, 12–16 December, San Francisco, California, USA.

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

SDSU Real-Time Monitoring and Short-term Forecasting of Phenology from GOES-R ABI for the Use in Numerical Weather Prediction Models

Task Leader	Xiaoyang Zhang (South Dakota State University)
Task Code	XZXZ_GOES_15 Year 2
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR
Contribution to CICS Research Themes (%):	Theme 1: 20%; Theme 2: 40%; Theme 3: 40%.
Main CICS Research Topic	Earth System Monitoring from Satellites
Percent contribution to NOAA Goals	Goal 1: 60%; Goal 2: 40%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: We generated phenological datasets using SEVERI EVI2 from 2006-2013 and investigated the impacts from rainfall. Further, we conducted investigations of AHI time series observations for phenology detections. The AHI, SEVERI, and VIIRS data were used as proxy data of GOES-R for the real-time monitoring of phenology development. The results show that SEVERI EVI2 and AVHI significantly improves the data quality for tropical forest observations relative to MODIS data. Moreover, the investigation also shows that wildfire has limited impacts on green vegetation fraction (GVF) because fires generally occurs during dry seasons.

Background

This project is to use GOES-R ABI data to build an operational system for monitoring and forecasting the seasonality of the green vegetation fraction and phenology in order to *improve NWS Operational Numerical Weather Prediction (NWP)*. In this context, phenology at the spatial resolutions relevant to NWP quantifies the seasonal progression of green vegetation fraction (GVF), especially its timing, magnitude, and variation across the vegetated land surface. Real-time monitoring and short-term forecasting of green vegetation fraction could greatly benefit numerical weather modeling by incorporating a key determinant in albedo, surface energy balance, and evapotranspiration. However, the timing of critical phenological events is not explicitly defined and spatiotemporally consistent GVF is actually not produced in GOES-R ABI Option 2 GVF product. Therefore, we will use the high frequency of diurnal observations from GOES-R ABI to generate daily cloud-free trajectories of the vegetation index (VI) for real-time monitoring and short-term forecasting of phenological metrics, including the timing and GVF magnitude in vegetation growth. The specific goals of this project are: (1) to monitor in real time and forecast in the short term phenological metrics using simulated ABI vegetation greenness trajectories; (2) to produce a daily enhanced GVF dataset that is free of gaps in real time and a week ahead, respectively; (3) to evaluate and validate the stability, precision, and accuracy of the proposed GOES-R phenological metrics; (4) to demonstrate the influence of the enhanced phenological metrics on improving NWP systems.

Accomplishments

- We continued to make extensive comparison of temporal greenness trajectories derived from polar-orbit satellites and geostationary satellites. Specifically, we compared SEVERI data (a proxy of GOES-R) with MODIS data from arid desert to rainfall tropical forests, which are two extreme ecosystems. In tropical rainfall forests, geostationary satellite observations have demonstrated great advantages over MODIS in detecting greenness cycles (Figure 1). In central Congo basin, SEVERI data were able to retrieve canopy greenness cycles in 34% more pixels than MODIS. It is because SEVERI provides much higher chances to obtain cloud-free observations. Moreover, SEVERI time series reflects the multiple greenness cycles better than MODIS does. Further, time series of geostationary satellite data were used to extract the phenology development in the Sahara Desert, where vegetation was assumed to be unable to growth (Figure 2). This study is the first time to extract green vegetation development in the Sahara Desert.

- We investigated interannual variation of SEVERI phenology from 2006-2013 across the Congo basin and its response to rainfall seasonality. We detected the start and end of rainy season from 3-hourly TRMM rainfall data. The results indicate that the rainy season triggered the spatial and inter-annual variations in vegetation phenology, and the responses of phenology to the rainy season varied with land cover type, particularly tree percentage (Figure 3).
- We refined the algorithm of calibrating climatology vegetation indices between different satellites. The updated algorithm was to calibrate the MODIS-based climatology to be comparable to GOES-R ABI vegetation indices by combining the annual and seasonal time series of observations. The algorithm was tested based on VIIRS data in a single year and MODIS climatology from past 10 years.
- We examined the influences of data quality on the reconstruction of temporal greenness and on the phenology detections. Specifically, we used two indices which were the proportion of good quality observations (i.e., cloud-free observations) (*PGQ*) during a vegetation growing season and the model fitness index (*FQI*) of the reconstructed greenness trajectories from 2006-2013. FQI was defined based on the differences between modeled greenness and satellite measurements with good quality. These indices indicate that the quality of SEVERI time series was significantly better than MODIS data. PGQ differences between MODIS and SEVIRI EVI2 time series increased from less than 30% in surrounding Congo basin to as high as 80% in central Congo basin. The large difference of phenological timing between MODIS and SEVERI data was strongly dependent on the difference of PGQ. Low PGQ caused the large uncertainty in phenological detections, which could result in the uncertainty of phenological timing as high as 60 days in MODIS data.
- We investigated the impacts of solar angles on AHI observations and produced a new function (different from MSG SEVERI) to generate daily AHI vegetation index (Figure 4). Specifically, we investigated the variation of 30-minute NDVI and EVI with solar zenith angle and sun-satellite relative azimuth angle based on the AHI observations in 2015 (Figure 5). Finally, we generated the kernel weights to generate daily angularly-corrected vegetation index.
- We investigated and compared angularly corrected AHI time series with VIIRS time series in various different ecosystems over southeast Asia. The result indicates that AHI data have a significant improvement in charactering vegetation phenology development relative to VIIRS data that are frequently contaminated by clouds (Figures 6 and 7).
- We used time series of VIIRS data as the proxy of GOES-R to monitor phenological metrics and vegetation greenness in real time and to forecast the foliage development in 10 days ahead (Figures 8 and 9). This test was performed every three days during 2016.
- We generated global 1 km green vegetation cover (GVF) data in 2014 using our phenological detection algorithm and delivered to NOAA EMC for testing land model. Our collaborator in EMC tested the model run using real-time GVF. Specifically, total 72 runs were conducted with NAM and 3 GVF products (climatology GVF and two real time GVF). Model (NAM) is sensitive to GVF changes. Replacing climatology GVF changes surface albedo greatly. The albedo changes are larger in Summer than in winter. Further testing is needed.

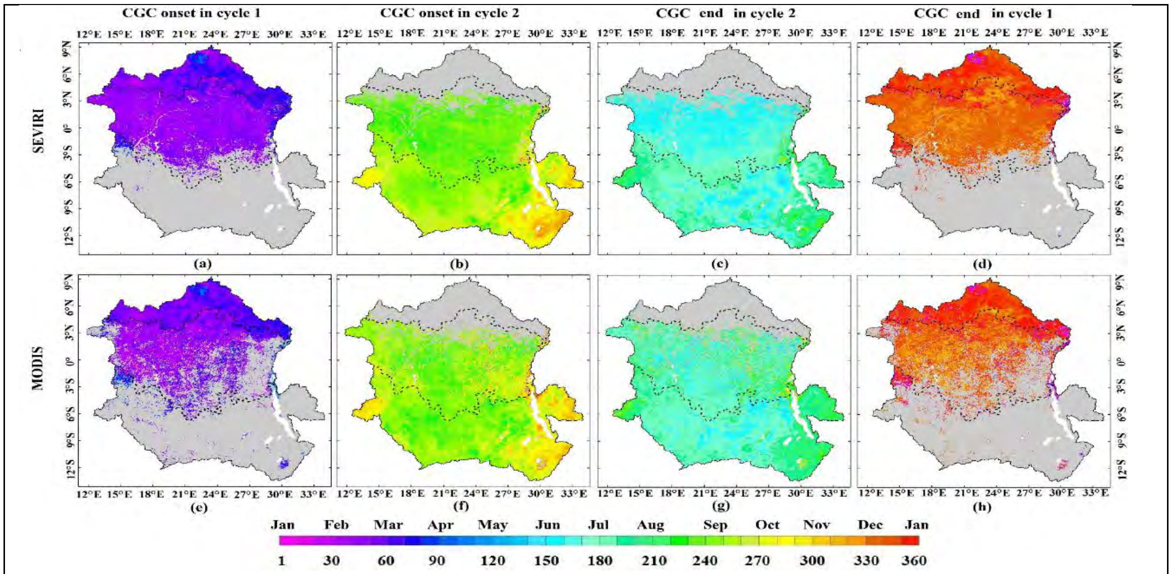

Figure 1. The mean onset and end of canopy greenness cycle (CGC) derived from SEVIRI and MODIS data between 2006 and 2013 across the Congo Basin. There were two cycles of vegetation growth. The CGC onset in the first cycle from SEVIRI (a) and MODIS (e), CGC onset in the second cycle from SEVIRI (b) and MODIS (f), CGC end in the second cycle from SEVIRI (c) and MODIS (g), and CGC end in the first cycle from SEVIRI (d) and MODIS (h). Note that the onset and end of the first CGC in center Congo basin occurred in the first and second cycle, respectively, and the onset and end of the second CGC occurred in the second and first cycle, respectively. Grey area indicates that the specified CGC transition event was detected less than four times between 2006 and 2013.

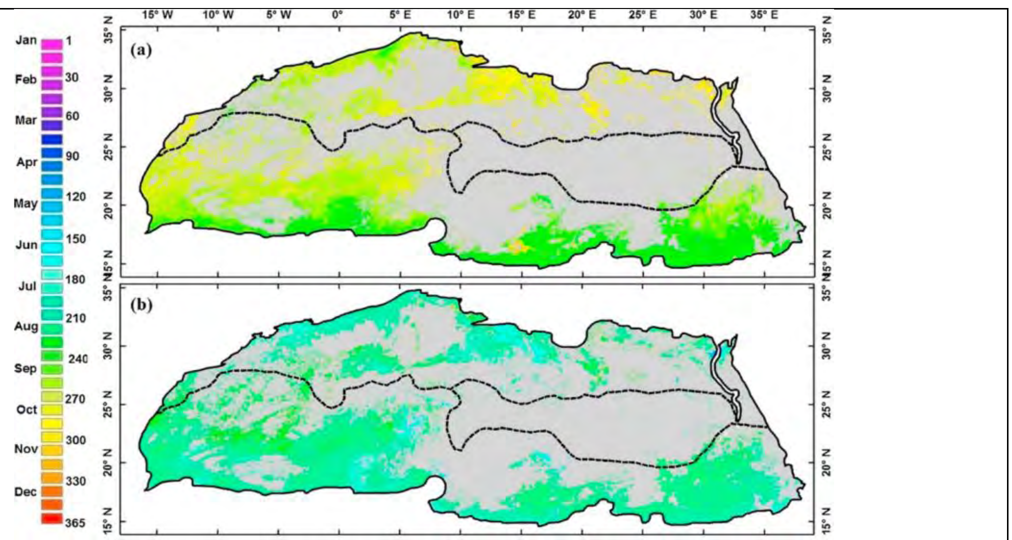

Figure 2. Spatial variation in mean timing between 2006 and 2012 for growing season in the Sahara Desert. (a) onset timing and (b) end timing. The grey color represents the areas where the number of detectable growing seasons between 2006 and 2012 was less than 4.

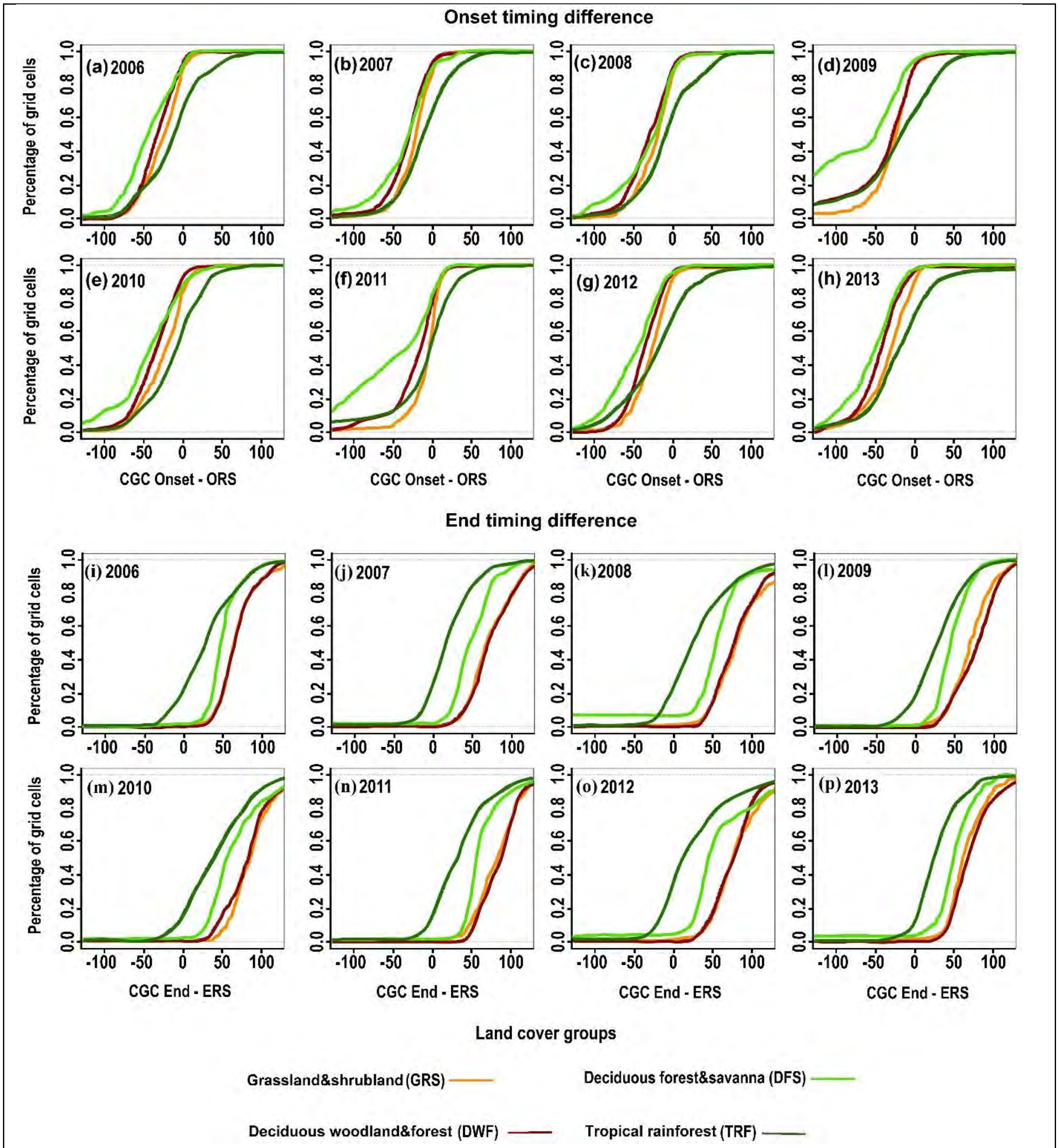

Figure 3. The cumulative distribution functions (CDF) of grids for the timing differences between Canopy Greenness Cycle (CGC) and the rainy season during 2006-2013. X-axis in (a – h) represents CGC onset lead time (i.e., CGC onset - ORS) whereas X-axis in (i – p) represents CGC end lag time (i.e., CGC end - ERS). Y-axis represents the proportion of grid cells. Orange, dark red, green and dark green curves represent grassland & shrubland, deciduous woodland & forest, deciduous forest & savanna mosaic and tropical rainforests, respectively.

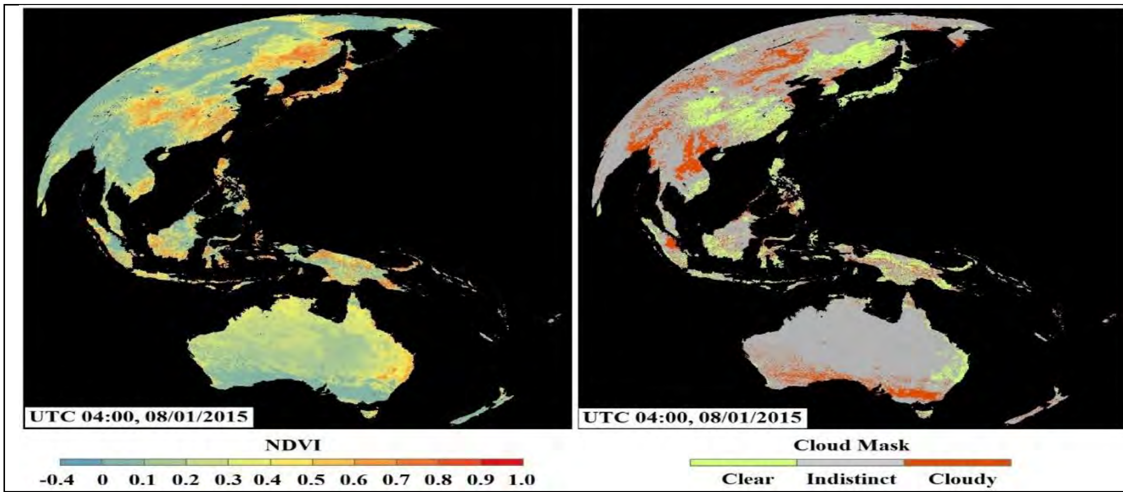

Figure 4. NDVI and cloud mask calculated from instantaneous AHI observations.

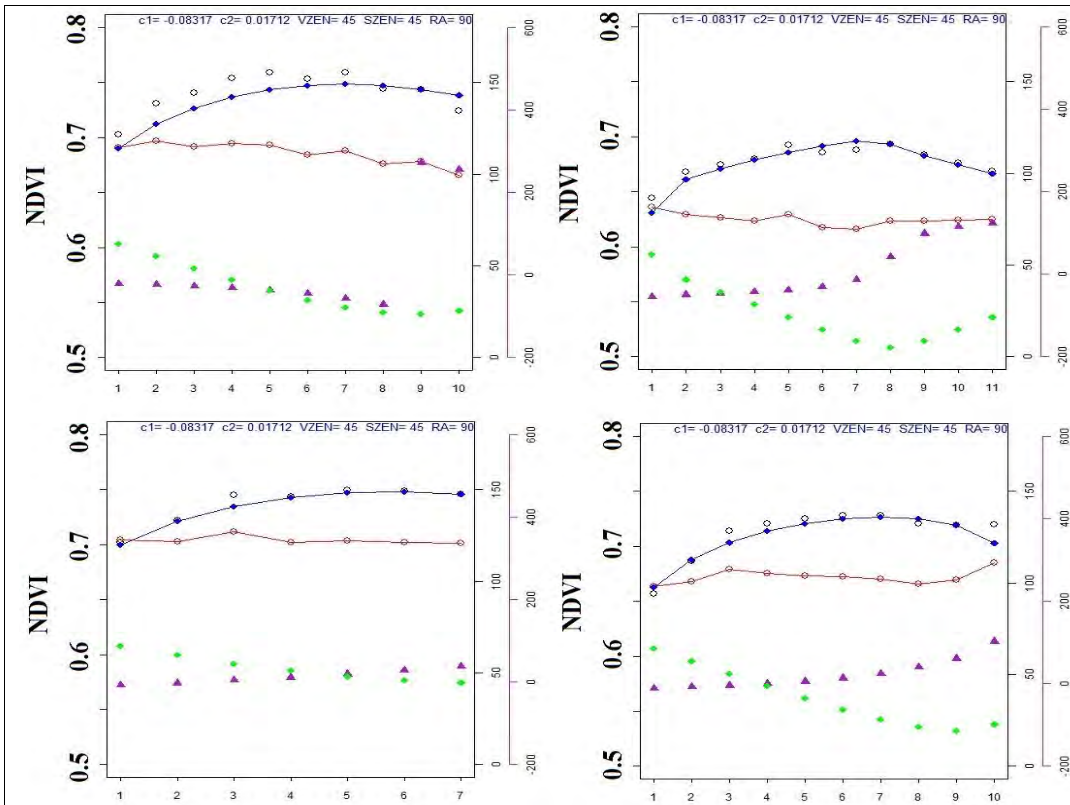

Figure 5. Adjustment of angular vegetation index observed from AHI. The reference geometry used in the angular correction is 45° (satellite zenith angle), 45° (sun zenith angle) and 90° (sun-satellite relative azimuth angle). Black circles – original NDVI (left Y-axis), blue circles – predicted NDVI (left Y-axis), red circles – angular-corrected NDVI (left Y-axis), green squares – sun zenith angle (the first right Y-axis), and purple triangles – sun-satellite relative azimuth angle (the second right Y-axis).

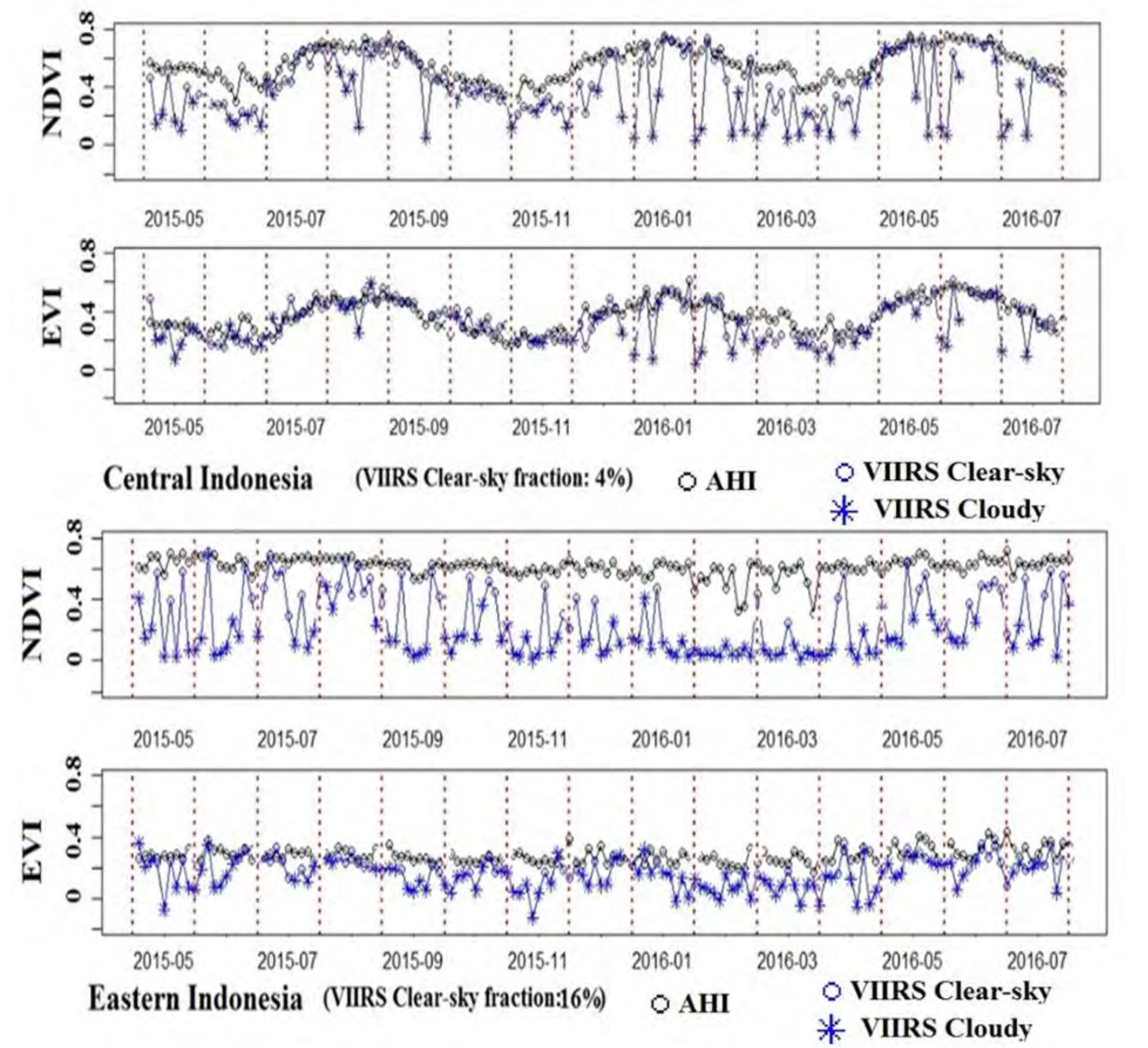

Figure 6. Daily angularly corrected AHI NDVI/EVI comparing with VIIRS data in agriculture area (central Indonesia, up two panels) and evergreen forests (bottom two panels).

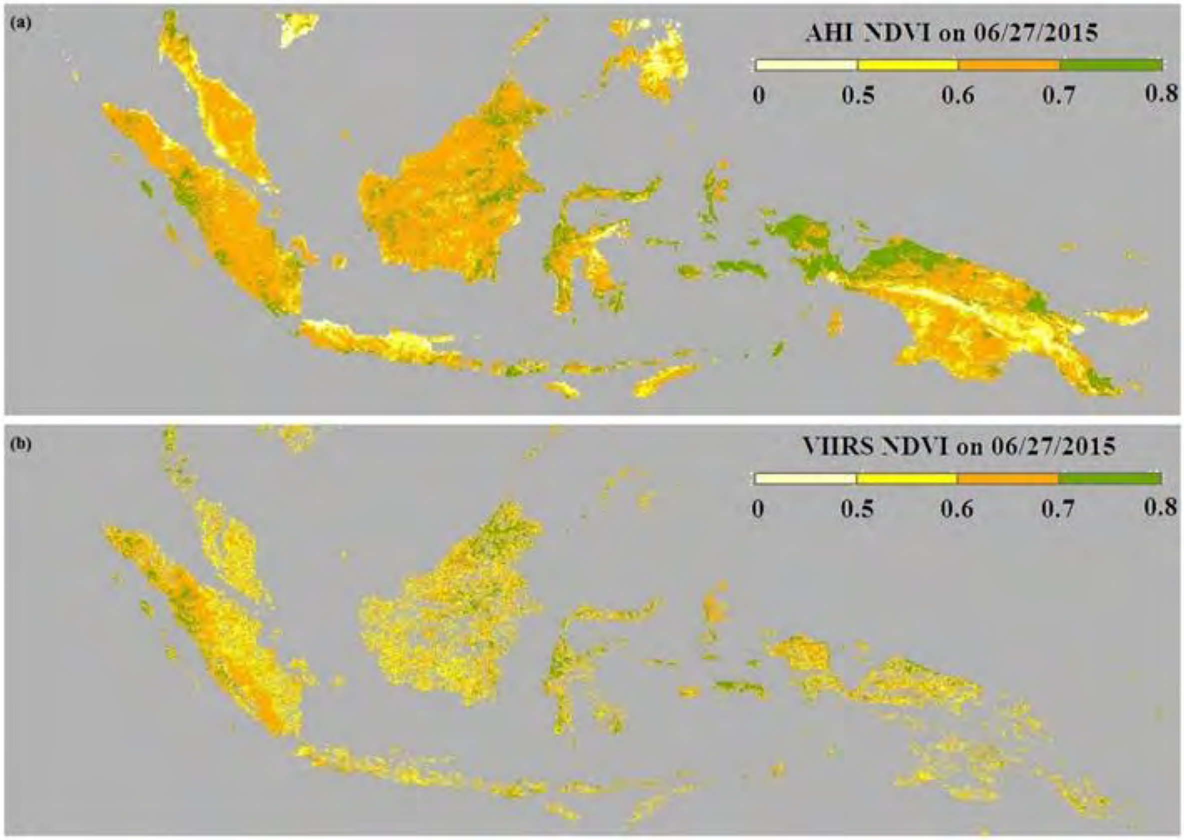

Figure 7. Spatial pattern of vegetation index observed from AHI (a) and VIIRS (b) on 27 June 2015. It evidently shows the heavily cloud impacts on VIIRS data.

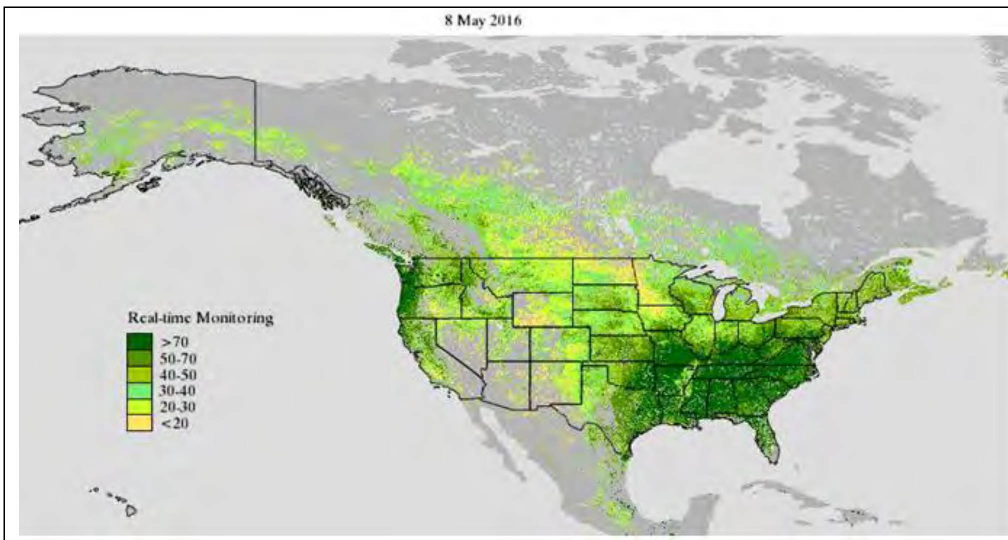

Figure 8. Real time monitoring of spring leaf out (%) in May 8 2016 using the proxy of GOES-R data.

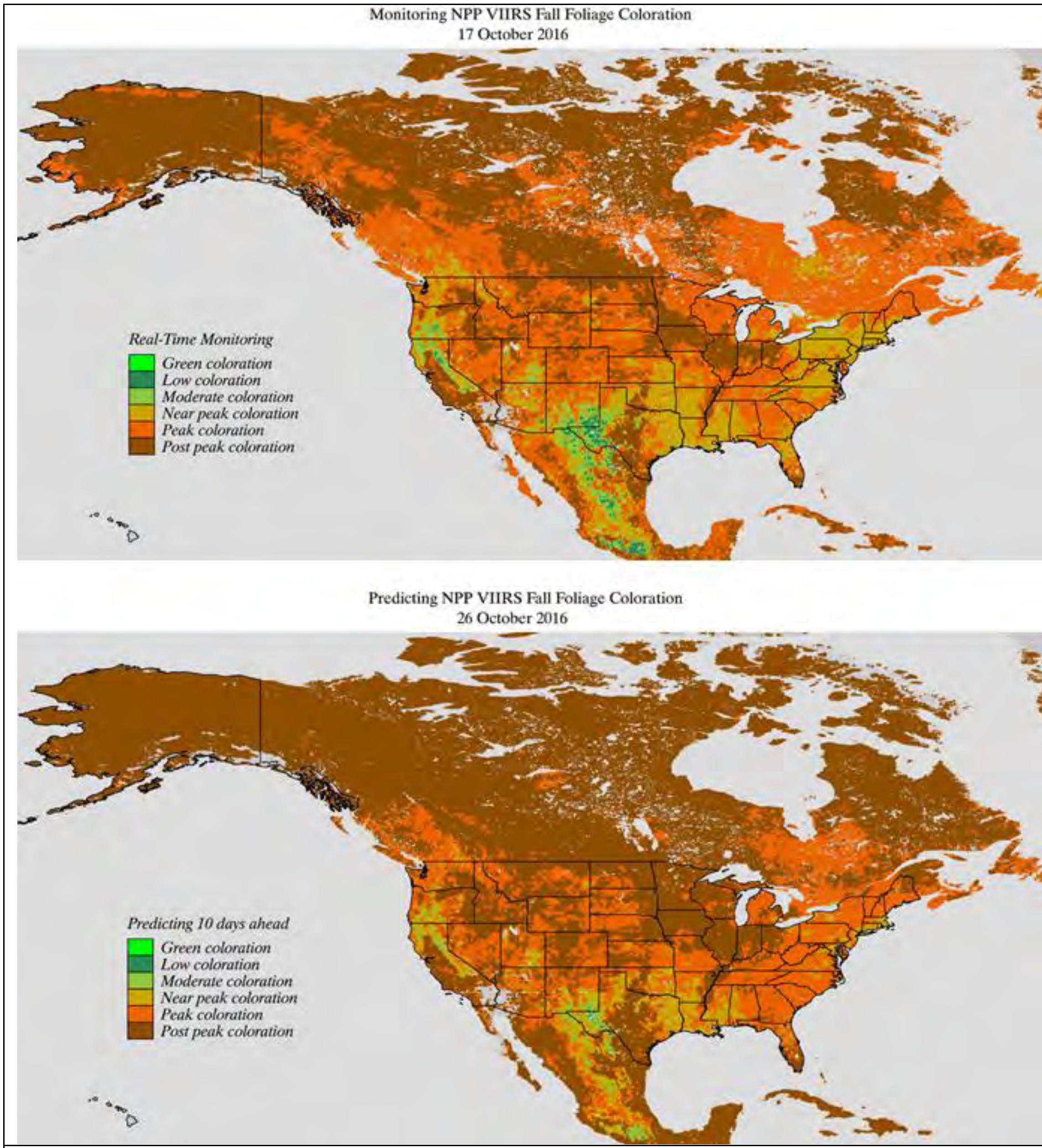

Figure 9. Real time monitoring and short-term forecasting of vegetation phenology development during fall using GOES-R proxy data (VIIRS). The top panel is real time monitoring on 17 October 2016 and the bottom panel is prediction in 10 days ahead (26 October 2016).

Planned work

- Investigate Himawari AHI time series as a GOES-R proxy for the retrieval of GVF phenology.
- Prepare phenological data for Numerical Weather Prediction Systems (NWPS)

Publications

1. Yan, D., Zhang, X., Yu, Y. Guo, W., 2017, Characterizing land cover impacts on the responses of land surface phenology to the rainy season in the Congo Basin, *Remote Sensing* (under review).
2. Liu, L., Zhang, X., Yu, Y. Guo, W., 2017, Real-time and short-term predictions of spring phenology in North America from VIIRS data, *Remote Sensing of Environment* (in press).
3. Yan, D., Zhang, X., Yu, Y., Guo, W. and Hanan, N. P., 2016, Characterizing land surface phenology and responses to rainfall in the Sahara Desert, *Journal of Geophysical Research- Biogeosciences*, 121, http://dx.doi.org/10.1002/2016JG003441.
4. Yan, D., Zhang, X., Yu, Y., and Guo, W., 2016, A comparison of tropical rainforest phenology retrieved from geostationary (SEVIRI) and polar-orbiting (MODIS) sensors across the Congo Basin, *IEEE Transactions On Geoscience and Remote Sensing*, http://doi.org/10.1109/TGRS.2016.2552462.

Presentations

1. Wang, J., Zhang, X., 2016, Impacts of Wildfires on Long-term Land Surface Phenology, AGU *Fall Meeting*, 12–16 December, San Francisco, California, USA.
2. Yan, D., Zhang, X., Yu, Y., Guo, W., 2016, Characterizing the Responses of Land Surface Phenology to the Rainy Season in the Congo Basin, *AGU Fall Meeting*, 12–16 December, San Francisco, California, USA.
3. Zhang, X., Yu, Y., Liu, L., Yan, D., 2016, Real-time Monitoring of Land Surface Phenology from Polar-Orbiting and Geostationary Satellites, *US-IALE 2016 Annual Meeting*, 3-7 April 2016, Asheville, North Carolina
4. Liu, L., Zhang, X., Yu, Y., 2016, Evaluating the potential of satellite data to track temporal trend in peak coloration of temperate forest in eastern United States, *2016 AAG Annual Meeting*, March 29 - April 2, San Francisco, California, USA.

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

SDSU Monitoring Land Surface Vegetation Phenology from VIIRS

Task Leader	Xiaoyang Zhang (South Dakota State University)
Task Code	XZXZ_VIIRS_16
NOAA Sponsor	Yunyue Yu
NOAA Office	NESDIS/STAR
Contribution to CICS Research Themes(%):	Theme 1: 20%; Theme 2: 40%; Theme 3: 40%.
Main CICS Research Topic	Earth System Monitoring from Satellites
Percent contribution to NOAA Goals	Goal 1: 60%; Goal 2: 40%
Strategic Research Guidance Memorandum:	2. Environmental Observations

Highlight: We developed algorithms and operational computer codes to monitor spring and fall foliage development from VIIRS data. The algorithms were extended to entire northern hemisphere in 2016. They were implemented to monitor in real time and forecast in 10 days ahead the green leaf development. The results were routinely produced every 3-days and delivered to NOAA JPSS Environmental Data Records. Further, the product was evaluated using PhenoCam data. Moreover, the phenological results were used for testing the Land Model in EMC.

Background

Patterns in land surface phenology at global scales reflect complex interactions among atmospheric, biospheric, and soil biogeochemical processes, and are particularly sensitive to climate changes. The AVHRR and MODIS data have been used to produce global metrics of land surface phenology during last three decades, and provide the opportunity to characterize the nature, magnitude, and timing of changes in land surface phenology. Moving forward, VIIRS provides a basis for continuing phenology record. However, in order to characterize and understand interannual-to-decadal scale changes in ecosystem response to climate change, a well-calibrated long-term phenology data record spanning the AVHRR, MODIS, and VIIRS era is required. While long-term phenology data serves the investigation of climate change, the VIIRS phenological metrics in near real time will provide relatively realistic data to the land model in the NOAA Numerical Weather Prediction Systems and will assist the crop growth monitoring in the US Department of Agriculture. To this end, the specific goals of this project are:

- *To develop and implement an operational land surface phenology data with a spatial resolution of 4km from NPP VIIRS.*
- *To evaluate the stability, precision, and accuracy of the proposed VIIRS phenology.*

To generate the land surface phenology, the VIIRS phenology algorithm will extend and improve upon the AVHRR and MODIS algorithm. In particular, the accuracy and uncertainty in phenology detection will be assessed and the resultant phenology data will be validated to provide the reliability of the data product

Accomplishments

- We completed the enhancement of the algorithm for the monitoring of phenology development. However, unexpected time series of vegetation indices could occur occasionally. In that case, some modifications are still needed.

- We prepared algorithm to generate 500m 3-day VIIRS observations and enhanced the speed of data processing. We converted daily VIIRS observations to 3-day observations from 2013 to 2015. The run of the computer code is relatively slow in processing 500m data sets. The code needs to be further improved for real time monitoring and forecasting.

- We extended the monitoring and forecasting of phenological development at 4km to entire north hemisphere by including Eurasia (Figure 1). We produced the spring phenology monitoring every three days and delivered the results to NOAA NESDIS STAR JPSS EDR website (Figure 2). We extended the real-time monitoring to Eurasia and tested the process in our local machine. We conducted validation and evaluation of the real-time monitoring in two ways. First, we compared the real-time monitoring with the phenology detections from the regular approach. Unlike the real-time monitoring using timely available satellite observations, the regular approach detects phenology with a latency of more than half year, which uses the time series of VIIRS data consisting of preceding half year, given year, and following half year. The evaluation shows the real-time monitoring is very comparable with the results detected from regular approach with a difference less 5 days in most region (Figure 3). Second, we compared the real-time monitoring with observations from PhenoCam. PhenoCam is the camera that is generally mounted in a high tower (around 30 m tall) and is connected to a local wireless network and a personal computer running camera image-capture software. It takes digital color photos every 30 minutes, which are used to observe temporal development of vegetation phenology. We analyzed the PhenoCam data across the US and compared with VIIRS real-time monitoring. The results show that their average absolute difference is 5 days for the greenup onset (Figure 4).

- We computed phenological metrics form VIIRS (4km), MODIS (5km) and AVHRR (4km) data in 2013 globally after reconstructing phenological curves from daily observations. The phenological metrics during a vegetation growing season include the timing of greenup onset, maturity onset, senescent onset, and dormancy onset (Figure 5).

- We generated global 1 km green vegetation cover (GVF) data in 2014 using our phenological detection algorithm and delivered to NOAA EMC for testing land model. Our collaborator in EMC tested the model run using real-time GVF. Specifically, total 72 runs were conducted with NAM and 3 GVF products (climatology GVF and two real time GVF). Model (NAM) is sensitive to GVF changes. Replacing climatology GVF changes surface albedo greatly. The albedo changes are larger in Summer than in winter. Further testing is needed.

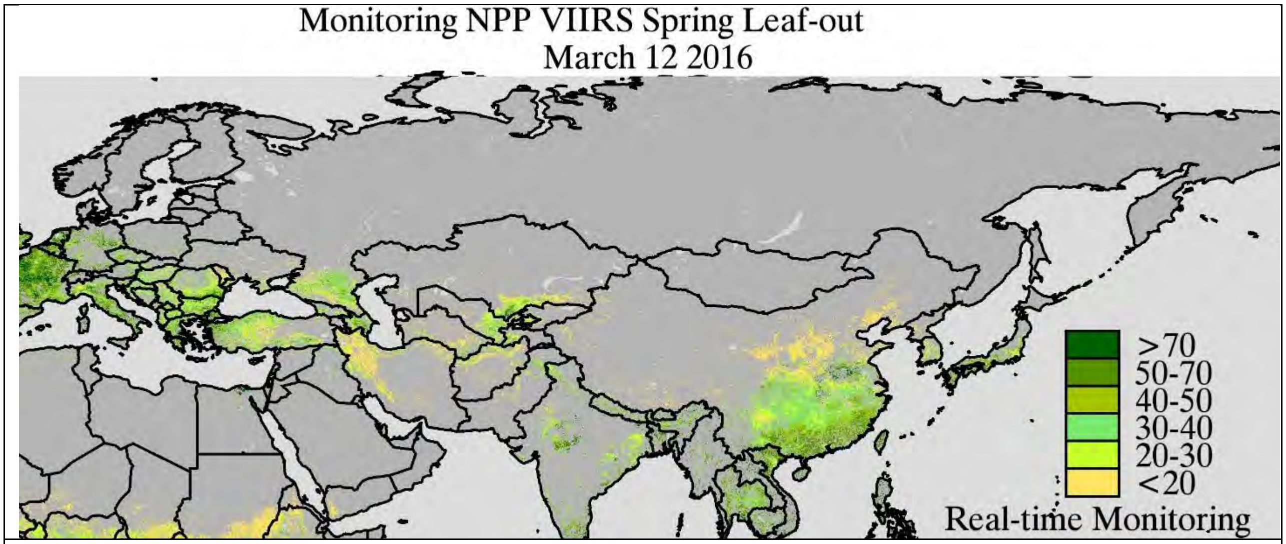

Figure 1. Spring green vegetation fraction monitored from VIIRS time series across Eurasia.

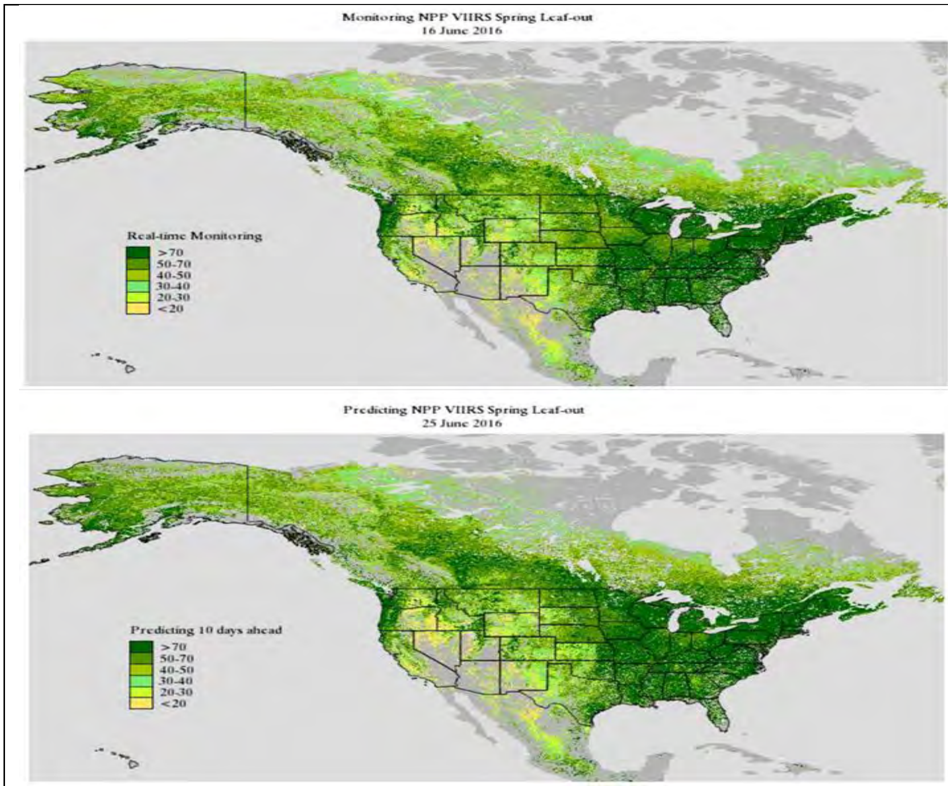

Figure 2. Real time monitoring of spring green vegetation fraction on 16 June 2016 (upper panel) and short term forecasting in 10 days ahead (below panel) across the North America.