Improvement of Cloud Ice Microphysics for ATMS Snowfall Rate Retrievals

Task Leader Cezar Kongoli
Task Code CKCK_EOY_14
NOAA SPONSOR JPSS PGRR
NOAA Office **NESDIS/STAR**
Main CICS Research Topic b. Scientific Support for the Future Satellite Missions (i) Scientific support for the JPSS Mission

Percent contribution to CICS Themes Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Percent contribution to NOAA Goals Goal 1: 20%; Goal 2: 80%

Highlight: The ATMS SFR algorithm has been modified to generate product using non-spherical ice particle shapes. A method has also been developed that determines which ice shape to use based on weather conditions

Background

The ATMS Snowfall Rate algorithm computes ice cloud properties of falling snow using an inversion method involving the simulation of brightness temperatures with a radiative transfer model, followed by calculation of SFR from the retrieved ice cloud properties. The SFR and snowfall detection (SD) algorithms have been extended to colder climate with encouraging results. Testing shows that the algorithms have skill in capturing snowfall in variable weather conditions including colder weather.

To estimate snowfall rate, the SFR algorithm retrieves cloud properties - ice water path and ice particle effective diameter - based on the radiative scattering effect of ice particles which for computational efficiency are assumed spherical in shape. However, snowfall ice particles are typically non-spherical and their microphysics including habit shape can have a considerable impact on the accuracy of the retrieved cloud parameters and snowfall rate. This project will incorporate non-spherical ice particle shapes in radiative transfer and SFR calculations.

Accomplishments

- Developed a method that determines the appropriate particle shapes to use depending on the degree of ice cloud super-saturation and relative humidity (Figure 1);
- Modified the ATMS SFR algorithm for non-spherical ice particle shapes and adopted an existing scattering property database for non-spherical ice particles;
- Carried out case studies to derive SFR with the original and the modified algorithms.
- Generated a database that include ground truth radar data for evaluation

Work Plan

The next step will be to compute SFR using the proper ice shape as determined by the new method and intercompare it with ground truth data.

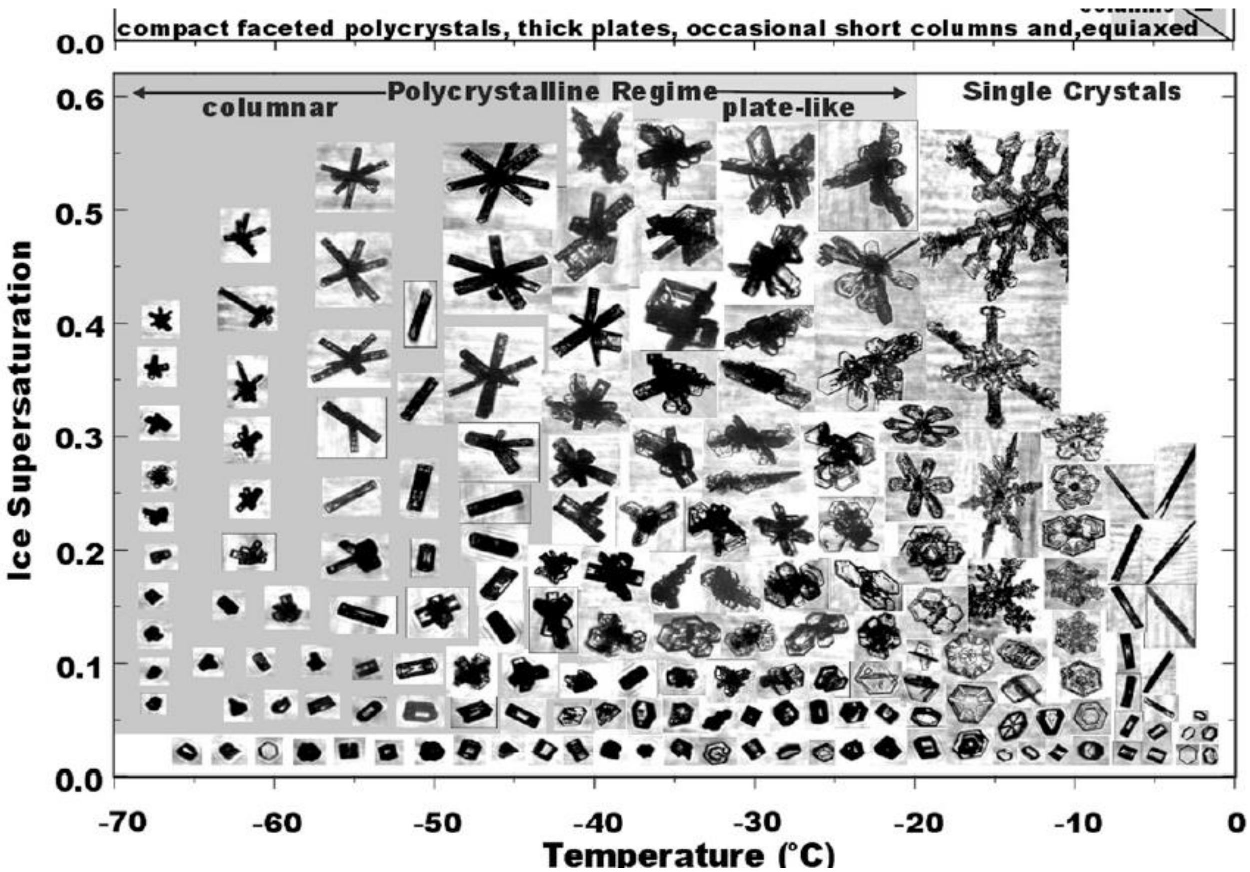


Figure 1. Ice habit based on temperature and ice super-saturation. The method derives ice super saturation based on relative humidity over water and cloud temperature.

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

Task Leader Jingfeng Huang
Task Code EBJH_JPSS_15
NOAA Sponsor Shobha Kongdragunta, Istvan Laszlo
NOAA Office NESDIS/OSGS
Contribution to CICS Research Themes (%) Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic Future Satellite Programs (Scientific Support for the JPSS Mission)
Contribution to NOAA goals (%) Goal 1: 20%; Goal 2: 80%; Goal 3: 0%

Highlight We have maintained and improved the S-NPP VIIRS Operational Aerosol Algorithm on the NOAA IDPS, conducted intensive Calibration and Validation of the VIIRS Aerosol Products, and provided the validated Products of daily global aerosol observations to user communities to support research and operational activities in weather, climate, and air quality.
Link to a research web page http://www.star.nesdis.noaa.gov/smcd/emb/viirs_aerosol/

Background

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

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

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

Accomplishments

Supported by the task, the CICS Scientists conducted the Intensive Calibration and Validation (ICV) on the S-NPP VIIRS aerosol products. The VIIRS aerosol products were compared to collocated AERONET measurements from May 2, 2012 to Dec 31, 2014. Over land, the VIIRS Aerosol Optical Thickness (AOT) Environmental Data Record (EDR) exhibits an overall global bias against AERONET of -0.0008 with an uncertainty of 0.12. Over ocean, the mean bias of VIIRS AOT EDR is 0.02 with an uncertainty of 0.06. The mean bias of VIIRS Ocean Ångström Exponent (AE) EDR is 0.12 with an uncertainty of 0.57. Based on the assessment, the VIIRS AOT EDR over land reached Validated maturity beginning Jan 23, 2013; the AOT EDR and AE EDR over ocean reached Validated maturity beginning May 2, 2012. The expected errors of the VIIRS aerosol products were quantified over land and ocean respectively (Figure 1). Increased uncertainty in the retrieval is linked to specific regions, seasons, surface characteristics and aerosol types, suggesting opportunity for future modifications as understanding of algorithm assumptions improves. These findings demonstrate the integrity and usefulness of the VIIRS aerosol products that will transition from S-NPP to JPSS1. The findings were summarized in the Huang et al. (2016) paper.

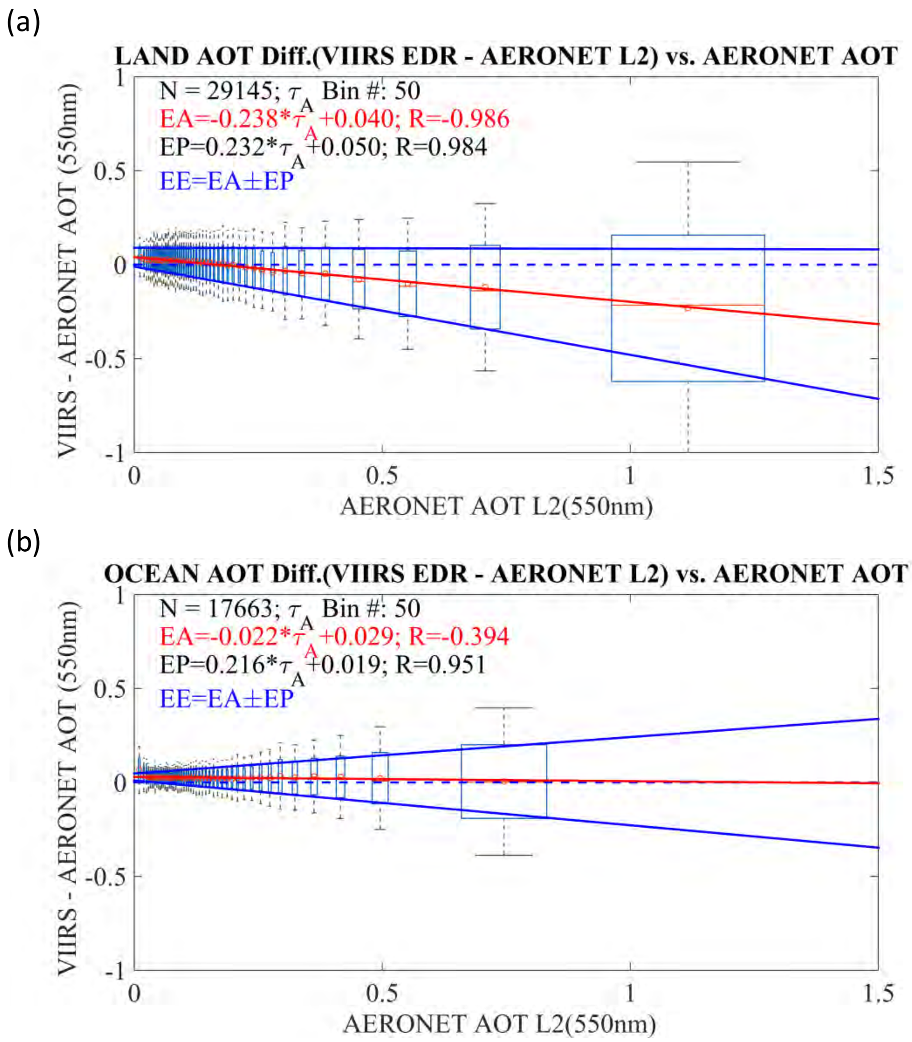


Figure 1. Expected Errors of the S-NPP VIIRS AOT as a function of the AERONET Level 2.0 AOT: (a) Over Land; and (b) Over Ocean.

CICS Scientists also performed large data array management of the VIIRS aerosol products to support data use activities of the NOAA STAR VIIRS aerosol team. This includes maintaining and improving an automated data archiving and processing system that can automatically fetch, process, and archive VIIRS aerosol EDR on local disk storage, and to generate daily global images of the VIIRS aerosol products for validation and monitoring purposes. This system supports the daily activities of data visualization, event monitoring, data reprocessing, and calibration/validation currently performed by members of the NOAA STAR VIIRS aerosol team. The CICS scientists also support the entire VIIRS aerosol team by monitoring and reorganizing the structure of data storage at local data servers. The archived datasets and any other special requested datasets were used to support other team members for their scientific and operational needs to develop and test new aerosol algorithms, such as the new algorithm developed in Zhang et al. (2016).

CICS scientists also conducted scientific research on new aerosol retrieval and internal testing schemes to further improve the operational NOAA VIIRS aerosol products (research to operation product #1). CICS scientists used the Algorithm Development Library (ADL) to run and test aerosol algorithms. The ADL testing was used to assess the impacts from code improvements, such as LUT and PCT updates, ocean model update and snow detection scheme update etc. for CICS scientists to support Discrepancy Report (DR) , Problem Change Request (PCR) and Configuration Change Request (CCR) submissions. As part of the Cal/Val activities, CICS scientists participated in the Factory Baseline Tests (FBT) regularly to ensure correct implementation of code changes in the VIIRS algorithms from Mx8.9 to Mx8.11. In the past year, CICS Scientists successfully transferred the following two internal test schemes to the operation during the past year (techniques for NOAA's operational use #1 and #2):

1) For a better snow screening to avoid snow contamination to the aerosol retrievals, a new snow detection scheme based on normalized difference snow index (NDSI) and brightness temperature at 11µm was developed. Additionally, a snow adjacency test was conducted to degrade aerosol retrievals with snow in adjacency. A spatial filter was also used based on spatial variability of deep blue band reflectance to screen out unfavorable heterogeneous retrieval conditions for aerosol algorithms. This scheme was transferred to operation (TTO) on Jun 22, 2015.

2) Ephemeral water quality flag, which sometime prevented aerosol retrievals over heavy smoke plumes, was removed from the aerosol algorithm. Bright surface detection scheme was also updated to adequately identify bright pixels for the aerosol retrieval. These changes were transferred to operation on Dec 17, 2015. To meet the user needs from global climate modelers, CICS scientists maintain the daily data processing of the gridded VIIRS aerosol 0.25°X0.25° resolution products and provide data support through the NOAA STAR website (research to operation product #2).

Planned Work

CICS scientists will continue working with the NOAA STAR scientists and the VIIRS aerosol science team to conduct the Calibration/Validation activities to further improve the VIIRS aerosol algorithm, to provide data support to the data user communities, and to support the prelaunch Calibration/Validation activities for JPSS 1. This includes but not limited to:

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

8) Writing up journal papers to publish and report scientific results in journals and at conferences.

Publications

Peer-Reviewed:

Jingfeng Huang, Shobha Kondragunta , Istvan Laszlo , Hongqing Liu , Lorraine Remer , Hai Zhang , Stephen Superczynski , Pubu Ciren , Brent Holben , Maksym Petrenko, 2016: Validation and Expected Error Estimation of Suomi-NPP VIIRS Aerosol Optical Thickness and Ångström Exponent with AERONET, *J. Geophys. Res. Atmos.,* Submitted

Hai Zhang, Shobha Kondragunta , Istvan Laszlo , Hongqing Liu , Lorraine Remer , Jingfeng Huang , Stephen Superczynski , Ciren Pubu, 2016: An enhanced VIIRS aerosol optical thickness (AOT) retrieval algorithm over land using a global surface reflectance ratio database, *J. Geophys. Res. Atmos.,* Submitted

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

VIIRS Aerosol Optical Thickness (AOT) and Particle Size Parameter Algorithm Theoretical Basis Document (ATBD): http://npp.gsfc.nasa.gov/sciencedocs/2015-06/474-00049_ATBD-VIIRS-AOT-APSP_C.pdf

VIIRS Suspended Matter Algorithm Theoretical Basis Document (ATBD): http://npp.gsfc.nasa.gov/sciencedocs/2015-06/474-00046__VIIRS_Suspended_Matter_ATBD_Rev-_20110422.pdf

VIIRS Aerosol Products (AOT, APSP & SM) Intermediate Product (IP)/Environmental Data Records (EDR) Software – Operational Algorithm Document (OAD): http://npp.gsfc.nasa.gov/sciencedocs/2015-09/474-00073_OAD-VIIRS-Aerosols-IP-EDR_H.pdf

JPSS Common Data Format Contrl Book (CDFCB) Vol IV-Part 2 - Imagery, Atmospheric, and Cloud EDRs: http://npp.gsfc.nasa.gov/sciencedocs/2015-06/474-00001-04-02_JPSS-CDFCB-X-Vol-IV-Part-2_0123D.pdf

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

VIIRS Aerosol Products User's Guide: http://www.star.nesdis.noaa.gov/jpss/documents/UserGuides/Aerosol_Products_Users_Guide.docx

Products

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

Presentations

Huang, Jingfeng, Istvan Laszlo, Validation of Suomi NPP VIIRS Aerosol Optical Thickness and Particle Size Parameter with AERONET, NOAA STAR *JPSS Annual Science Team Meeting*, NCWCP (Aug 24-28, 2015)

Huang, Jingfeng, S. Kondragunta, I. Laszlo, H. Liu, L. Remer, H. Zhang, S. Superczynski, P. Ciren, Validation and Expected Error Estimation of Suomi-NPP VIIRS Aerosol Optical Thickness and Angstrom Exponent with AERONET, *CICS-MD Science Meeting*, College Park, MD (11/23 to 11/24/2015)

Huang, Jingfeng, S. Kondragunta, I. Laszlo, H. Liu, L. Remer, H. Zhang, S. Superczynski, P. Ciren, B. Holben, and P. Maksym, Validation and Expected Error Estimation of Suomi-NPP VIIRS Aerosol Optical Thickness and Angstrom Exponent with AERONET, 12th Annual Symposium on New Generation Operational Environmental Satellite Systems, American Meteorological Society Annual Meeting 2016, Jan 10-14, 2016, New Orleans, LA, USA

Other

Awards: NOAA's Annual STAR Award for Innovation, NOAA NESDIS STAR, Sep 2015: Jingfeng Huang and the VIIRS Aerosol Cal/Val Team were recognized with NOAA's Annual STAR Award for Innovation, by accomplishing the goals of the VIIRS aerosol product validation and significantly reducing the data analysis time required. http://essic.umd.edu/joom2/index.php/current-news/featured-essic/2090-huangpart-of-star-innovation-award-group

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2***
# of products or techniques submitted to NOAA for consideration in operations use	**2****
# of peer reviewed papers	**2*****
# of non-peered reviewed papers	**0**
# of presentations (invited)	**3 (0)******
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

*: The improved products include the operational S-NPP VIIRS Aerosol Products and the 0.25°X0.25° gridded datasets.
**: The techniques include the new internal snow test scheme that was transferred to operation on Jun 22, 2015, and the updated ephemeral water test and bright surface test that were transferred to operation on Dec 17, 2015.
***: The two peer reviewed papers (Huang et al., 2016 and Zhang et al., 2016) were submitted to JGR for publication on Jan 21, 2016 and Jan 25, 2016 respectively.
****: The presentations were listed in the above presentation list.

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

Task Leader	**Yuling Liu**
Task Code	YLYL_TSJL_15
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%
Highlight	
Link to a research web page	

Background

This report summarizes the ongoing Joint Polar-Orbiting Satellite System (JPSS) project "Satellite Land Surface Temperature (LST) and Albedo". The Visible Infrared Imaging Radiometer Suite (VIIRS) LST, generated as part of Environmental Data Records (EDR) product suite , is derived using split-window regression algorithm with separate coefficients for the 17 International Geosphere-Biosphere Programme (IGBP) types and day/night conditions.

This project is to provide scientific and technical support on this effort, meanwhile to provide a test bed base for future JPSS satellite series. The ultimate objective of this project is to generate high quality LST product for the JPSS mission, through algorithm refinement and improvement, algorithm and product evaluation, long-term monitoring and algorithm maintenance. Furthermore, the STAR JPSS program management required to develop an enterprise LST algorithm that is applicable to different satellite missions. The emissivity explicit algorithm is targeted as a candidate for this request. The land surface emissivity 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 LST production as a continuous effort, and kept the maintenance schedule and milestone including ATBD update; made a great effort on the enterprise algorithm development and test; developed a prototype emissivity product; developed the gridded global VIIRS LST product. In addition, the draft version of long term monitoring tool for JPSS LST production has been built up. In detail, the accomplishments include

1) Evaluation and validation of the current VIIRS LST production
   - 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 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.

   - Extend the cross satellite comparison. Besides MODIS LST, AATSR LST, SEVIRI LST and AHI LST as a proxy for GOES-R have been included for cross comparison.

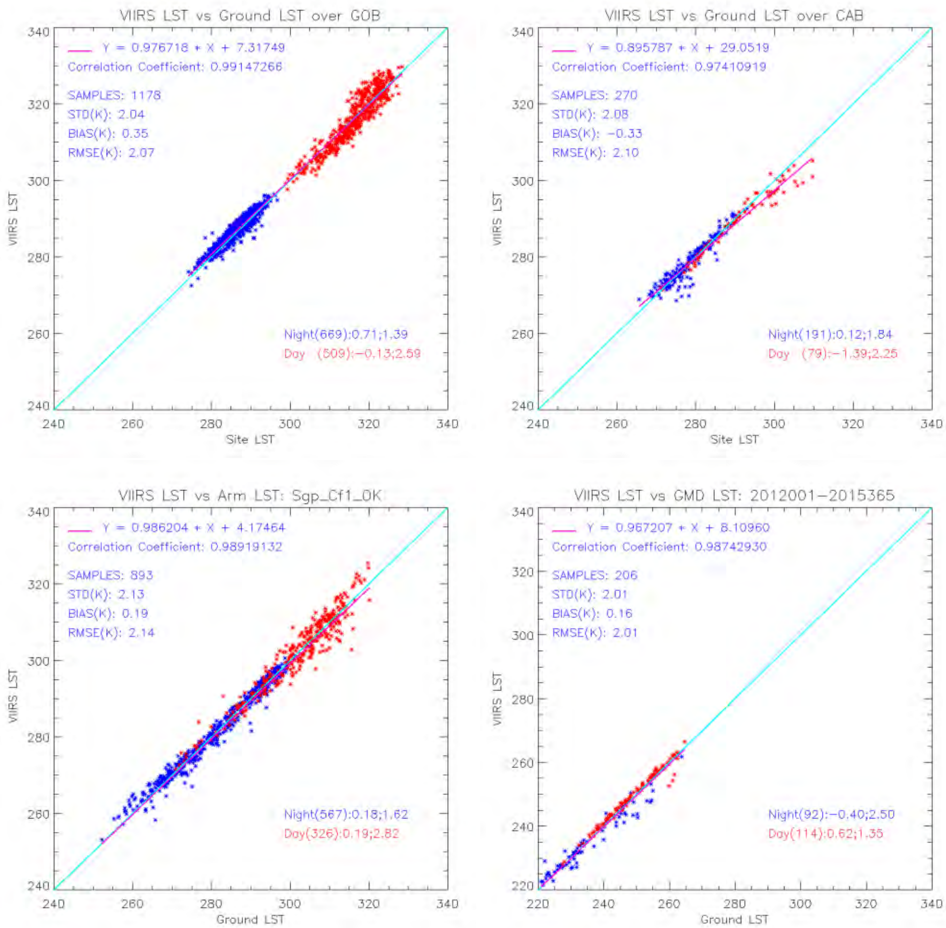


Figure 1. VIIRS LST valdition agianst the ground data from BSRN sites: Gobabeb, Namibia(top left), Cabauw, Netherlands (top right), ARM site Sgp_Cf1_Ok (bottom left) and GMD site in Summit, Greenland(bottom right).

2) Maintain the software package and related documentations
   - Support the actions taken for LST related DRAT. Attended DRAT meeting and the land team EDR/CalVal meetings.
   - Maintenance of the LST source code, ADL update, ATBD, OAD and some other related documentations update. ATBD is updated by including related validation results.

3) Extend the simulation database by involving the TIGR profiles into the current simulation database so as to improve the global representativeness. Profile quality control is conducted. MODTRAN is used for forward radiative transfer calculation. The comprehensive simulation database is built up, which covers wide spatial and temporal distribution, a variety of atmospheric conditions and wide LST range, to support scientific study related to VIIRS LST product, e.g. algorithm coefficients derivation, algorithm test and uncertainty analysis etc.

4) Validation tool development. Related Tools are developed to support LST evaluation and calibration work including the regression package for algorithm coefficient, the routine validation and deep-dive system, and a prototype 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.

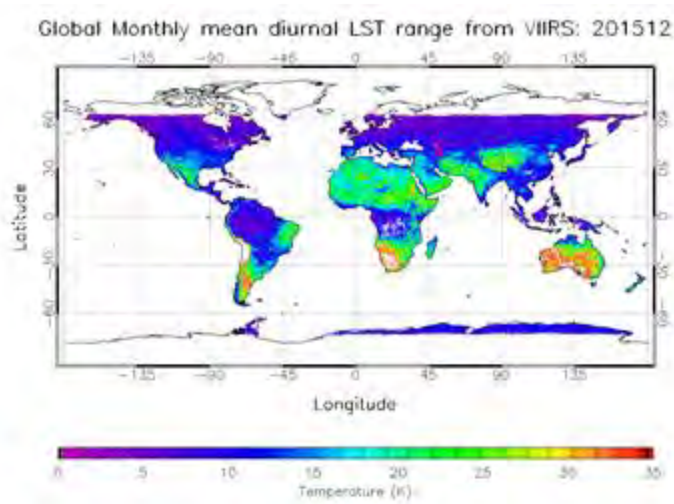


Figure 2. An example of the Global monthly mean diurnal LST range map, for Dec. 2015.

5) Gridded VIIRS LST has been produced. The L3 VIIRS gridded LST data is featured with high

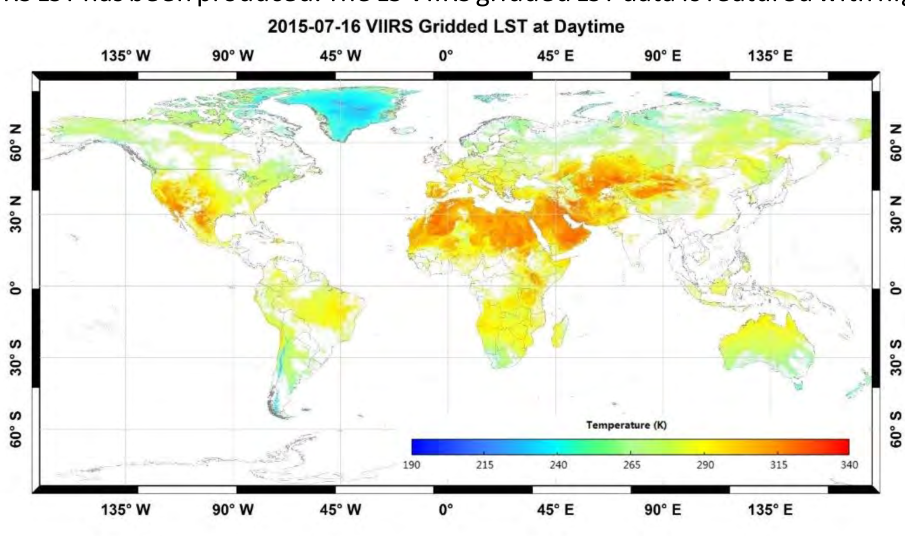


*Figure 3. An example of gridded VIIRS LST on July 16, 2015 at daytime spatial resolution of 0.009 degree and it is a daily product for both daytime and nighttime. It is managed in the 2*4 tiles to reduce the file size. ata gaps are filled at invalid pixels.*

6) A prototype emissivity product has been developed, which serves as an important input for emissivity explicit LST retrieval algorithm. It is proposed to combine historic emissivity product and real

time vegetation observations for a dynamic emissivity production. It is a daily global gridded dataset at 0.009 degree spatial resolution.

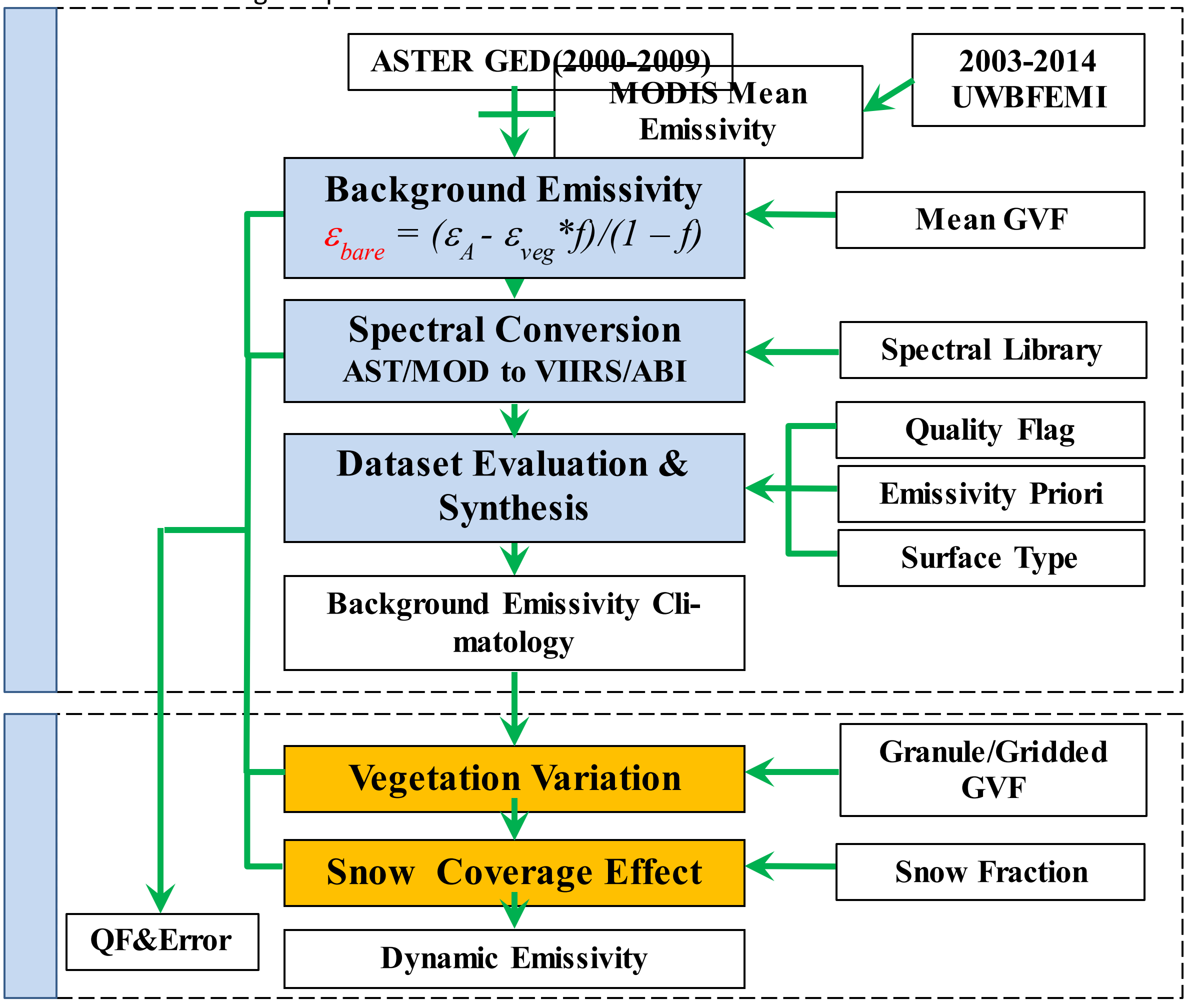


Figure 4. Emissivity algorithm flow chart

Planned Work

- Continue to work on the evaluation and validation of the current LST production, maintenance schedule and milestone will be kept.
- An enterprise LST algorithm (emissivity explicit LST algorithm) will be tested and finalized for J-1 mission, as well as for the S-NPP mission at STAR operational environment.
- Supporting the long term monitoring tool development
- Update LST software code and ATBD documentation and support the NPP/JPSS Mission Management
- The land surface emissivity production will be further improved and tested.
- The L3 gridded LST data will be further improved and tested.

Publications

1. Yuling Liu, Yunyue Yu, Peng Yu, Frank M. Göttsche, & Isabel F. Trigo (2015). Quality Assessment of S-NPP VIIRS Land Surface Temperature Product. *Remote Sens.* 2015, *7*(9), 12215-12241; doi:10.3390/rs70912215
2. 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
3. Yuling Liu, Yunyue Yu, Peng Yu and Heshun Wang, Ground Validation and Uncertainty Estimation of VIIRS Land Surface Temperature Product, 2015 Dec, Conference proceedings for IGARSS 2016. It is under review.
4. Heshun Wang, Yunyue Yu, Peng Yu, Yuling Liu, Developing Land Surface Emissivity Product for JPSS and GOES-R Missions, in preparation to be summated to Remote Sensing of Environment.

Products

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

Presentations

1. Group Presentation: Yuling Liu, Peng Yu and Heshun Wang, Production of Satellite Land Surface Temperature Dataset at STAR, CICS annual meeting, Nov, 2015, College Park, MD.
2. Yuling Liu, Yunyue Yu, Peng Yu & Heshun Wang, VIIRS LST Validation with Ground Based Measurements, JPSS Science meeting, August 2015, College Park, MD.
3. Yuling Liu, Yunyue Yu, Peng Yu, Quality Assessment and Uncertainty Estimation of S-NPP VIIRS LST Product, Global Temp 3rd User Consultation Meeting, June 2015, Reading, UK.
4. Yuling Liu, Yunyue Yu, Peng Yu, Quality Assessment of S-NPP VIIRS LST Product, Earth Temp 4th annual meeting, June 2015, Reading, UK.
5. Yuling Liu, Yunyue Yu, Peng Yu & Zhuo Wang, Quality Assessment of Suomi NPP VIIRS Land Surface Temperature Product, NOAA Satellite Conference, April 2015, College Park, MD.
6. Yuling Liu, Yunyue Yu, Peng Yu and Zhuo Wang, Quality Assessment of Suomi NPP VIIRS Land Surface temperature Product, NOAA Satellite Science Week meeting, February 23 - 27, 2015, Boulder, Colorado.
7. Yuling Liu, Yunyu Yu, Peng Yu, and Zhuo Wang, Concerns on cross comparison of satellite land surface temperature retrievals, a case study between VIIRS and MODIS LST product, AMS 95th Annual Meeting on Jan. 4-8th, 2015, Phoenix, AZ.
8. Yunyue Yu, Yuling Liu, Peng Yu, Yuhan Rao and Ivan Csiszar, Production of Satellite Land Surface temperature dataset at STAR, NOAA Satellite Conference, April 2015, College Park, MD.
9. Peng Yu, Yunyue Yu, Yuling Liu & Zhuo Wang, Testing of Emissivity Explicit Retrieval Algorithms for VIIRS Land Surface Temperature, NOAA Satellite Conference, April 2015, College Park, MD.

10. Peng Yu , Yunyue Yu, Yuling Liu and Zhuo Wang, Testing of Emissivity Explicit Retrieval Algorithms for VIIRS Land Surface temperature, NOAA Satellite Science Week meeting, February 23 - 27, 2015, Boulder, Colorado.
11. Yunyue Yu, Yuling Liu, Peng Yu and Jaime Daniels, Land Surface temperature Production for GOES-R and JPSS Missions, NOAA Satellite Science Week meeting, February 23 - 27, 2015, Boulder, Colorado.
12. Yunyue Yu, Yuling Liu, Peng Yu, Zhuo Wang and Ivan Csiszar, Issues in Developing and Validating Satellite Land Surface Temperature Product, AMS 95th Annual Meeting on Jan. 4-8th, 2015, Phoenix, AZ.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**3**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer reviewed papers	**4**
# of non-peered reviewed papers	**0**
# of invited presentations	**12**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

Scientific Support to JPSS ATMS Calibration

Task Leader: Hu Yang
Task Code: HYHY_ATMS_15
NOAA Sponsor: Fuzhong Weng
NOAA Office: STAR
Contribution to CICS Research Themes (%):
Main CICS Research Topic : Future Satellite Programs-Scientific support for JPSS Mission
Contribution to NOAA goals (%)

Background

In the past few decades, the requirement for accurate satellite measurements has rapidly increased as the satellite measurements became broadly used in weather forecasts as well as climate research. It has been shown that direct assimilation of satellite radiance data into weather forecast models results in positive impacts on weather forecasts. To benefit from using satellite data for weather and climate studies, both the calibration accuracy and stability are required. The primary objective of this proposal is to develop innovative techniques to improve the calibration accuracy of JPSS instruments for various advanced applications. A new radiance-based, end-to-end calibration system will, thus, be developed to support the use of the microwave instruments on-board JPSS satellites. This task includes the following parts: advanced radiance transformation system for microwave sounders, full radiance processing algorithm for microwave calibration in IDPS software and calibration validation for SNPP/JPSS ATMS instrument.

Accomplishments

1. ATMS Geolocation Validation Software Package

The Suomi National Polar-orbiting Partnership (NPP) satellite was launched on October 28, 2011 and carries onboard the Advanced Technology Microwave Sounder (ATMS). Currently, ATMS performance in orbit is very stable and the geolocation accuracy meets the specifications. This study documents an ATMS geolocation error budget and its results for community reference. The geolocation accuracy is also verified with the Global Self-consistent, Hierarchical, High-resolution Shoreline (GSHHS) by using an improved coastline inflection point method. It is shown that the ATMS has an average geolocation error of 3.4 km in cross-track direction and 2.5 km in along-track direction at the edge of scan. The errors also depend on scan angle. Thus, a math model is developed to transfer the ground geolocation error to instrument assembly Euler angle error, from which the instrument to spacecraft mounting matrix can be rebuilt and on-orbit geolocation accuracy gets improved.

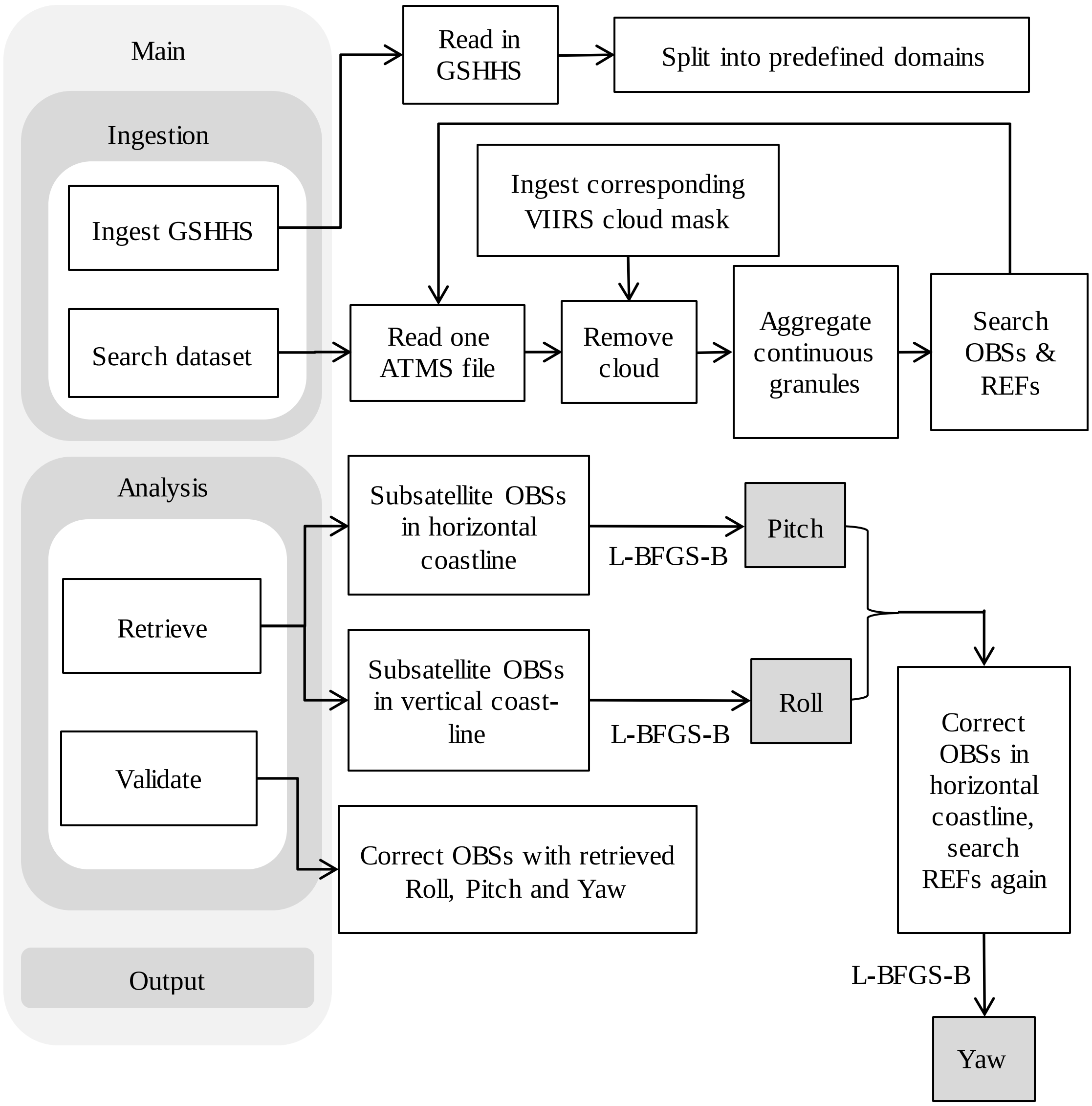


Figure 1: Flow chart of the retrieval algorithm.

2. ADL ATMS Full Radiance Pre-processing Software Development

Full radiance calibration processing of ATMS has been implemented in ADL software, there is no interface change made to old ADL version, only some new parameters were added to PCT. The output TDR products from ADL-Full Radiance are in brightness temperature, nonlinearity correction is based on "mu" parameter, which was derived in radiance space from TVAC datasets. Validation results shows that the TDRs from ADL-FRP are more consistent with ADL-Corrected PCT, the overall bias characteristic gets improved compare with TDRs from IDPS.

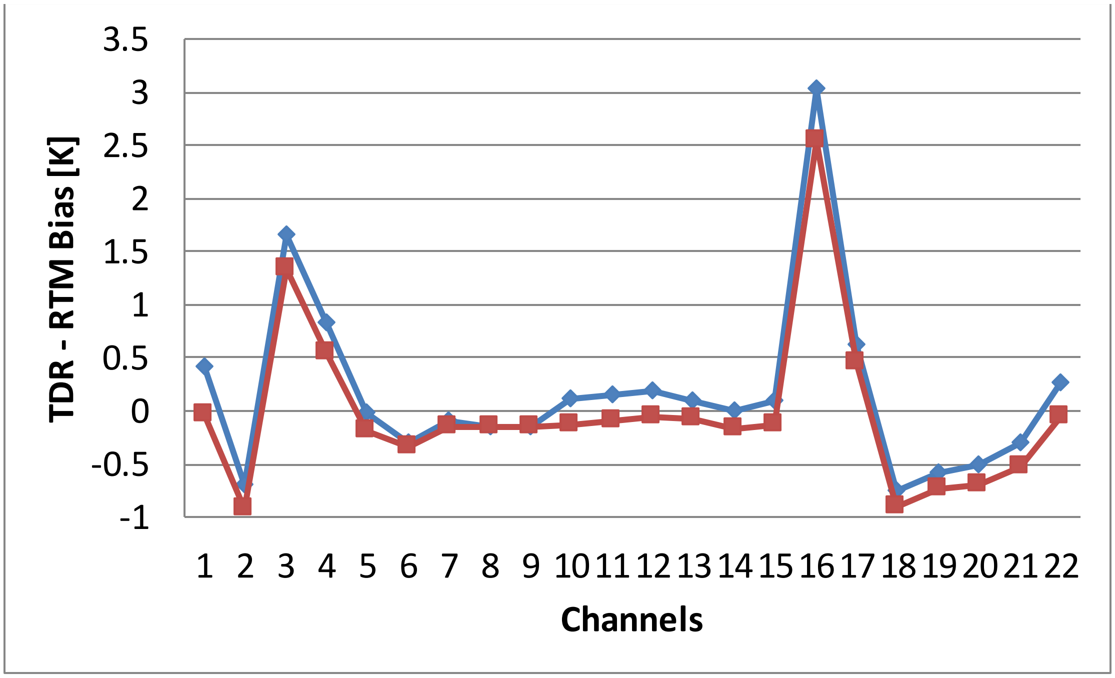


Figure 2: ATMS TDR-RTM bias using FRP(red) and using IDPS OPS (blue).

3. Reflector Emissivity Correction Algorithm for SNPP ATMS

ATMS scanning reflector is made of the beryllium coated with gold and can have an emission due to the surface roughness. During prelaunch phase, an estimate of the reflector emissivity was not explored. In this study, a new methodology is developed to assess the antenna emission from the ATMS pitch-over observations. It is found that the antenna emission is significant and dominates the scan angle dependent features in the ATMS antenna temperatures. Retrieved emissivity from K to G bands ranges from 0.002 to 0.006. Error model was also developed to assess the impact of antenna emissivity to calibration accuracy of antenna temperature products. Simulation results show that the calibration error are scene temperature dependent and can be as large as 2.5K for space view.

Planned Work

- Documents on ARTS validation
- Documents on inter-satellite calibration validation

Publications

Peer-reviewed

[1] Hu Yang, F. Weng, On-Orbit ATMS Lunar Contamination Corrections, IEEE Transactions on Geoscience and Remote Sensing, 2016, Vol. 54 Issue: 4, page(s):1-7

[2] H. Yang, F. Weng, Evaluate the Impact of Antenna Emissivity on ATMS TDR Products Based on a Full PolarizationRadiative Transfer Model, AMS 2016, New Orleans, 2016

Non peer-reviewed

[3] H. Yang, F. Weng, N. Sun, On-ORBIT antenna reflector loss measurements for Advanced Technology Microwave Sounder (ATMs) calibration, IEEE International Geoscience and Remote Sensing Symposium(IGARSS), Millan, Italy, 2015, 2015 IEEE International, pp: 4754-4756

[4] H. Yang, F. Weng, and K. Anderson, Estimation of ATMS Antenna Emission from Cold Space Observations, ITSC-20 Proceedings, Geneva, Wisconsin, 2015

Products

[1] ATMS Geolocation Validation Software Package
[2] ADL ATMS Full Radiance Pre-processing Software Development

Presentations

[1] H. Yang, F. Weng, Evaluate the Impact of Antenna Emissivity on ATMS TDR Products Based on a Full Polarization Radiative Transfer Model, AMS 2016, New orleans, 2016 Jan
[2] H. Yang, F. Weng, X. Zou, N. Sun, W. Chen, L. Lin , M. Tian, On-orbit Antenna Reflector Loss Measurements for Advanced Technology Microwave Sounder (ATMS) Calibration, EUMETSAT METEOROLOGICAL SATELLITE CONFERENCE 2015,TOULOUSE, FRANCE, 2015 Sep
[3] H. Yang, N. Sun, M. Tian, W. Chen, L. Lin, X. Zou, F. Weng, ATMS Full Radiance Calibration (FRC) Implementation and Validation, JPSS Annual Science Meeting, College park, Maryland, 2015
[4] H. Yang, F. Weng, and K. Anderson, Estimation of ATMS Antenna Emission from Cold Space Observations, ITSC-20 Proceedings, Geneva, Wisconsin, 2015

Performance Metrics	FY14
# of new or improved products developed (please identify below the table)	2
# of products or techniques submitted to NOAA for consideration in operations use	3
# of peer reviewed papers	2
# of non-peered reviewed papers	2
# of invited presentations	4
# of graduate students supported by a CICS task	N/A
# of graduate students formally advised	N/A
# of undergraduate students mentored during the year	N/A

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

CUNY Cloud Mask and Quality Control (CM/QC) for Sea Surface Temperature (SST) products from VIIRS

Task Leader Irina Gladkova
Task Code IGIG_CMQC_15
NOAA Sponsor Alexander Ignatov
NOAA Office STAR
Contribution to CICS Research Themes (%)
Main CICS Research Topic Future Satellite Missions–JPSS
Contribution to NOAA goals (%)
Highlight
Link to a research web page

Background

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

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

Accomplishments

The previously introduced automated SST Pattern Test first identifies ocean thermal fronts and adjacent contiguous areas with uniform SSTs, and then makes ocean vs. cloud decision based on the statistics of the whole regions.
Recent enhancements include improved:

1. Brightness temperature (BT) and SST imagery in the full VIIRS swath, using special resampling algorithms to minimize geometrical distortions and fill in the bow-tie deleted pixels;
2. front detection, using gradient behavior of the SST field, connectivity of the fronts, and bi-modality of SST distribution in their vicinity;
3. clustering, using the statistics of the BTs and derived SSTs over large regions.

These enhancements will be incorporated in the future versions of the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) SST system, to a) generate a new product – ocean fronts (which can be used to validate the gradients in various L4 analyses); and b) improve VIIRS clear-sky mask (especially in the dynamic areas of the ocean, in coastal zones, and in the high-latitude regions).

High-resolution composite maps of oceanic thermal fronts reveal their spatial distribution and variability, along with seasonal variability and climatology, which are used to study a variety of marine environmental phenomena. Customarily, fronts are detected in a clear sky domain of instantaneous Level 2 (swath) or 3 (gridded) SST images. However, dynamic regions of the ocean (e.g., ocean currents, eddies and upwellings) are often misidentified as cloud by many current cloud masks, thus significantly limiting the front detection, exactly in the areas where it is needed the most.

We have significantly improved the thermal front identification. The front detection uses the gradient behavior of the SST field, connectivity of the fronts, and bi-modality of the SST distribution in the vicinity of the thermal fronts. Since ocean thermal fronts have significant variation in gradient strength, we have introduced several front enhancements pre-processing procedures. Our multi-scale approach is based on the derivative of a Gaussian kernel at various scales, as well as eigenvalues of the Hessian matrix.

We plan to output the frontal product as an extra layer of the ACSPO SST product, which can be directly used in applications which require the estimation of thermal fronts, for example derivation of thermal front composite maps, validation of aggregated L4 products and physical models in terms of frontal locations, comparison with other related phenomena such as changes in chlorophyll, ocean salinity, sea surface height etc.

Planned work

We plan to continue improving cloud mask detection and continue developing thermal fronts algorithm
We plane to output the frontal product as an extra layer of the ACSPO SST L2 product, which can be directly used in the front composition process and in assimilation of L2 product in higher level products.

Publications

1. Gladkova, I., Y. Kihai, A. Ignatov, F. Shahriar, B. Petrenko, 2015: SST Pattern Test in ACSPO clear-sky mask for VIIRS. *Remote Sens. Env*., **160**, 87-98.

2. Gladkova, I., A. Ignatov, F. Shahriar, Y. Kihai, D. Hillger, B. Petrenko, 2016: Improved VIIRS and MODIS SST Imagery, *Remote Sens.*, *8*(1), 79

Presentations

I. Gladkova, Y. Kihai, A. Ignatov, F. Shahriar, B. Petrenko, Toward Improved VIIRS Imagery for fronts detection and enhanced clear sky mask in ACSPO, 16th GHRSST Meeting, ESA/ESTEC, The Netherlands, July 2015

I. Gladkova , A. Ignatov , F. Shahriar, Y. Kihai, Detection of ocean thermal fronts using thermal IR imagery, SPIE Remote Sensing, Toulouse, Sept. 2015

I. Gladkova , A. Ignatov , F. Shahriar, Y. Kihai, High resolution ocean fronts product from JPSS VIIRS for improved composite mapping, AGU Ocean Sciences Meeting, New Orleans, Feb 2016

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

Improved SST imagery which will be incorporated in the version 2.5 of the NOAA Advanced Clear-Sky Processor for Oceans (ACSPO) SST system.

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_15
Main CICS Research Topic Scientific Support of the JPSS Mission
Percent contribution to CICS Themes Theme 3, 100%
Percent contribution to NOAA Goals Goal 3, 100%

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

Background

This work is part of the JPSS Proving Ground and Risk Reduction (PGRR) program to promote JPSS data utilization in the National Weather Service (NWS) operational forecasting. 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) Organized JPSS Isoprene User Workshop

The Air Resources Laboratory (ARL), in collaboration with the NESDIS Center for Satellite Applications and Research (STAR), announced the release of a new satellite product that depicts marine isoprene emissions. Members of the air quality forecasting community and other "early adapter" users participated in a town hall meeting held in College Park, MD on September 2, 2015. As a contribution to one of NOAA's core missions to build a "Weather Ready Nation", chemical weather forecasting system called the US National Air Quality Forecast Capability (NAQFC) has been developed and made operational, providing numerical air quality guidance to the nation to prevent and reduce adverse health effects. NAQFC relies on forecasts of emissions and weather to predict surface levels of air pollutants, including ozone and fine particulate matter. Isoprene, emitted by trees, grass and phytoplankton, is a reactive biogenic hydrocarbon that is important for the formation of tropospheric ozone and secondary organic aerosols. Built upon the pioneering work developed in several isoprene emission algorithms, ARL teamed with the STAR Ocean Color Team and George Mason University to use the ocean color retrievals from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the NOAA Suomi-NPP satellite to derive a marine isoprene emission product. This research, funded by the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction Program, seeks to support NAQFC-like operations, as well as to improve climate models and Earth System models, all of which currently use predefined values to represent ocean-atmosphere exchange. A beta version of the new product was introduced to the air quality community at the 7th International Workshop on Air Quality Forecasting Research held in College Park, MD on September 2, 2015.

Participants of the JPSS Isoprene User Workshop include scientists and managers from NOAA OAR, NWS and NESDIS, Environment Canada, World Meteorological Organization, US Environmental Protection Agency, National Center for Atmospheric Research, Department of Energy, National Institute of Standards and Technology, New York Department of Environmental Conservation, Meteorological Agencies from Mexico, Japan, South Korea, China, India, and Chile, universities (Georgia Tech, University of Iowa, University of Alabama) and the private sector. This workshop was opened by ARL Deputy Director Richard Artz and JPSS Manager Mitch Goldberg, and coordinated by Daniel Tong and Menghua Wang. Participants have provided a number of valuable inputs to the JPSS Isoprene Project, and several new users have signed up.

Figure 1. JPSS Project Scientist Mitch Goldberg giving an opening speech to the well-attended JPSS User Workshop held in College Park, MD on September 2, 2015.

2) Assemble NAQFC benchmark system for data applications

The team worked with the NOAA NAQFC program to assemble the new modeling system that requires updates of different model components. NAQFC is building a base case that mimics the FY2016 forecasting operation. NAQFC leverages existing tools and datasets to build a base case system that will include the update of mobile sources to the 2011 NEI version 2 that will be become available in the summer through an existing collaboration between ARL and the US EPA Office of Air Quality Standards and Planning. The base case will include updates of emissions from mobile, power plants, oil/gas fields, ocean-going ships and fugitive dust emissions.

Currently, NAQFC is operating with CMAQ version 4.6, and the meteorology-dependent emissions are generated in the pre-processor PREMAQ (Otte et al., 2005). In concert with the aforementioned new approach the NAQFC emission modeling system requires a corresponding update. It invokes the CMAQ inline emission modeling capability in version 5.01 or newer. The new inventory updates will move emission modeling out of PREMAQ but into a newer version of CMAQ directly targeted for the NAQFC operation system in FY2016. Co-I Lee will be responsible of the CMAQ update leveraging funding support from the NAQFC program.

As part of the testbed building in conjunction with NAQFC annual updates, our team is working with the NAQFC team to update the new modeling system. A major challenge in quantifying the impact is to determine the magnitude in emission changes caused by the recession. While the CSAPR projection has considered possible emission changes caused by existing and predicted emission control regulations, there is no emission dataset available that is designed to capture the evolution of the emission changes. For instance, the 2011 National Emission Inventories (NEI) prepared by the US Environmental Protection Agency (EPA) used a different emission model for vehicle emissions, making the NEI data unsuitable to study the temporal trend of NO_x emissions during the study period (2005-2011). Tong et al. [2015] demonstrated that the consistent long-term trends observed by satellite and ground monitors make it feasible to accurately detect the changes of NO_x emissions over a long time span.

Here we have developed a new method to use space and ground observations to determine the emission changes in the recession scenario. This approach consists of three steps. First, monthly NO_2 changing emission rates is derived from ground and satellite observations. Ground NO_x measurements are obtained from the EPA Air Quality System (AQS) monitoring network. Morning rush-hour means are calculated from quality-controlled hourly NO_x values for the hours 0600, 0700, and 0800 local time, following the observed temporal patterns of NO_x variations presented by Godowitch et al. [2010]. These morning hours are associated with the highest NO_x concentrations contributed by both typical commuter traffic peaks and the shallow planetary boundary layer, making them an ideal indicator for assessing local emission conditions [Tong et al., 2015]. Besides ground data, the Ozone Monitoring Instrument (OMI) standard product (version 2.1, collection 3) described by Bucsela et al. [2013] is used to derive the satellite-based emission trends using the data filtering approach described in Tong et al. [2015]. In the normal global operational mode, the OMI ground pixel at nadir is 13 km × 24 km, with a local equator-crossing time of 13:45 h in ascending node. The OMI NO_2 data are filtered using quality flags, cloudiness and row anomaly. Additionally we apply a cut-off value (0.7×10^{15} molecules cm^{-2}) to the OMI data as low value pixels are less responsive to local emission density but more influenced by regional background and retrieval noise.

Next, a weighting function is used to combine the AQS-based and OMI-based rates of change to obtain merged state-level projection factors. To take advantage of both datasets, we adopt the following fusing function to construct the merged emission adjustment factor (AF) for each state:

$$\mathrm{AF} = \frac{\Delta S \times N_S \times f_S + \Delta G \times N_G \times f_G}{N_S \times f_S + N_G \times f_G} \tag{1}$$

where ΔS and N_S are the rate of change and the number of satellite data (OMI or GOME2), respectively, ΔG and NG are the rate of change and the number of ground data (AQS), respectively, and f_S and f_G are two weighting factors applied to the satellite and ground data, respectively. In this study, the value of f_S is set to be 1 and f_G to be 100 to avoid dominance by either data source. Finally, the projection factor *AF* derived from the fused data for each state is used to adjust the 2005 base NEIs to the year of 2011 to represent the recession emission scenario.

The effect of the emission changes on surface O_3 concentration is estimated using a CMAQ version tailored for the NOAA National Air Quality Forecast Capability (NAQFC) system [Pan et al., 2014; Tong et al., 2015]. This version of CMAQ is configured with the Carbon Bond 2005 chemical mechanism [Yarwood et al., 2005] and AERO5 aerosol module [Carlton et al., 2010]. The lateral boundary conditions used in the simulation are monthly averaged profiles extracted from the 2006 simulation with Harvard University's GEOS-Chem model [Bey et al., 2001]. We conducted three model runs using the 2005 NEIs, the CSAPR projected inventories, and the observation-adjusted inventories (Table 1). These cases represent the pre-recession, BAU, and recession scenarios, respectively. The model domain covers the continental United States with at 12 km horizontal grid spacing. All simulations use the same meteorology for July 2011, generated by the Weather Research and Forecasting Non-hydrostatic Mesoscale Model (WRF-NMM) [Janjic, 2003], to exclude the effect of varying weather conditions on surface O_3. The performance of this modeling system to predict O_3 and its key precursors have been extensively evaluated with ground and field campaign data [Chai et al., 2013; Pan et al., 2014; Tong et al., 2015]. This study will evaluate model predictions under each emission scenario using surface O_3 observations from the EPA AQS network following the protocols by Tong and Mauzerall [2006].

Changes of NO_x emissions under the BAU and Recession scenarios are compared first. Large reductions in NO_x emissions are seen in both cases, but there is a noticeable difference in the rates of change for most states. Figure 1 shows the differences in NO_x emissions between the base, BAU, and recession cases in July 2011. From 2005 to 2011, the BAU projection estimated that national NO_x emissions have been reduced by 21% (Fig. 2a), with the majority of the reduction seen over urban areas and along major highways. Increases of NO_x emissions are shown at isolated locations within the US, which are due to changes in point source emissions, which are treated separately from the state-level projections of mobile and area sources. Considerable changes are also seen in the Canadian and Mexican part of the domain due to different versions of inventories used in these scenarios. Figure 1b depicts the adjustment factor, or rate of change in NO_x emissions (%) derived from fused OMI and AQS observations (Eq. 1). The emission trend data are aggregated at the state level to be consistent with the CSAPR projection. Similar to the BAU projection, the observed trend shows large reduction (-20% to -50%) in most states, but smaller decrease and even slight increase are seen in several states (Fig 2b). The recession emissions differ from the BAU emissions over space and time (Fig 2c), which further complicates the estimated O_3 impact given the importance of regional O_3 transport [Tong and Mauzerall, 2008; Fiore et al., 2009] and the nonlinearity of O_3 photochemistry [Cohan et al., 2005]. Compared to BAU, the recession emissions are lower in the much of the east, lower Midwest, and the Pacific west, but slightly higher in the Southeast and the Rocky Mountain (Fig. 2c).

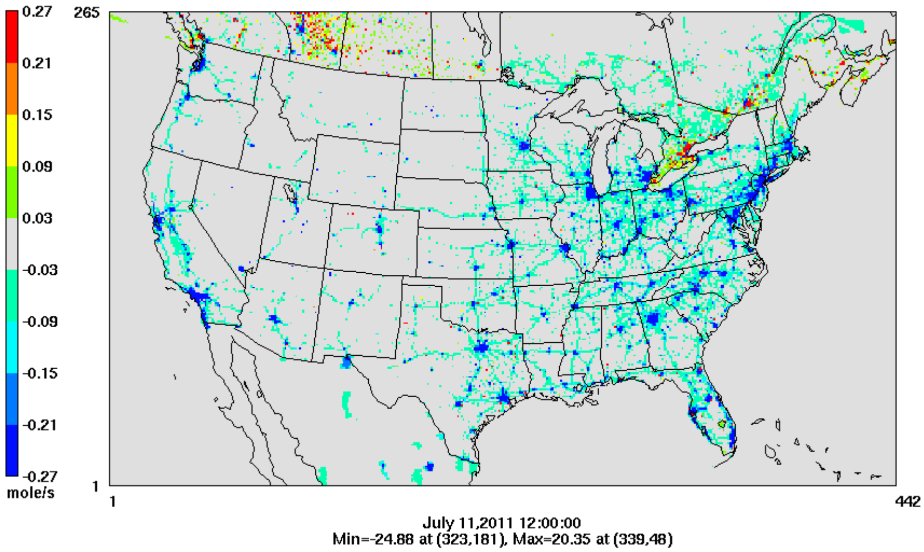
The regional difference is controlled by several factors that include the assumptions made in the CASPR projection and departures from these assumptions caused by socio-economic events. The CASPR approaches used to project future-year emissions vary from sector to sector, but these approaches consider only rules and settlements finalized by early 2009 [EPA, 2011]. Additionally, some local control programs were not included due to technical difficulty or being designed later to address new nonattainment problems. Besides these known issues, the emission trend was perturbed by several unexpected factors according to recent observations. The slower than expected emission changes in the Rocky Mountain region is likely caused by the rapid expansion in oil and gas production, the fingerprint of which on the climate, water, and air quality is an area of active research [Edwards et al., 2014]. Intensive oil and gas operations also took place in other parts of the country, e.g., Texas [Kemball-Cook et al., 2010]. Since the new oil and gas emissions are not included in the base emission inventories until NEI 2011, which cannot be directly used here for the reason mentioned earlier, the temporal adjustment can not accurately account for the spatial pattern of the new or increased emissions within the state boundaries.

Ozone impacts

Figure 3 shows the predicted changes in surface O_3 concentrations from the 2005 level under the BAU and Recession emission scenarios, and the difference between the two. Without considering the recession impact, the model simulation shows widespread decrease in surface O_3 concentration across the continental United States (Fig 2a), except a few areas downwind to large metropolitan areas where O_3 concentration increase as a result of diminished titration by freshly emitted NO_x [Tong et al., 2006]. Figures 2b and 2c indicate that the recession has caused considerable changes in surface O_3 concentration. Under the recession scenario, the largest decrease is found in the central Eastern U.S. and central and northern California, where surface O_3 concentration decreases by over 2 ppbv from the pre-recession level. Between the BAU and recession scenarios, there are distinct patterns in the O_3 changes, with large decrease in much of the eastern U.S., a slight increase or no change in the central U.S., and mixed changes in the western U.S. (Fig. 2c).

The spatial pattern of the O_3 variations reflects a combination of local O_3 production and regional transport of tropospheric O_3 in response to NO_x emission changes. The large decrease in the east is attributed to the significantly lower emissions in this region, especially in the states along and west of the Mississippi River extending from Texas to Wisconsin, and favorable O_3 production conditions where abundant volatile organic compounds (VOCs) are available to be mixed with NO_x to produce O_3. During the summertime, atmospheric circulation and regional O_3 transport in eastern U.S. is largely controlled by the Bermuda high pressure system [Tong et al., 2009], developing an "O_3 River" flowing from the south to northeast [Wolff and Lioy, 1980]. There is little change in surface O_3 concentration over Texas, upwind of the transport corridor where a noticeable decrease in NO_x emission was not transferred into O_3 benefits due to low O_3 production efficiency in the absence of sufficient reactive VOCs. The maximum reduction occurs in and around Illinois, where a slight increase in NO_x emissions was found. As the O_3 River further proceeds into the Ohio Valley, the decrease becomes smaller as a result of diminished O_3 transport and offset by increased local O_3 production due a positive change in NO_x emissions. Across the eastern US, however, the effect of large NO_x decrease in the upstream states dominates the O_3 changes in the downstream states. The O_3 changes in the Pacific West states display a similar pattern to that in the eastern states. The largest NO_x changes are seen in California, which influences O_3 concentrations in the states, most significantly over the Central Valley and southern California, as well as in several downwind states.

The O_3 responses over the Rocky Mountain region are more controlled by local emission changes than by regional transport. The western and central states are generally large in size and associated with complex topography and low emission density, which collectively leads to less cross-state transport than in the eastern states [Tong and Mauzerall, 2008]. Over the Rocky Mountain region, the small increase in surface O_3 concentration is caused by the observed lower NO_x decrease than in the BAU projection. The O_3 increase ranges from 0.5 ppbv to 1.5 ppbv over Colorado, Nebraska and the Dakotas. Our estimation is based on observed NO_x changes and the CB05 chemical mechanism [Yarwood et al., 2005] as implemented in the CMAQ version 4.7. Recently, Edwards and colleagues [2014] have identified a new mechanism in which excessive VOC emissions from oil and gas extraction operations can generate high O_3 under lower NO_x concentration through carbonyl photolysis. The impact of this new O_3 production pathway on the O_3 response to emission change is not quantified, although it is expected that this pathway is not significant in summertime due to deeper planet boundary layer and weaker photolysis flux without snow/ice covering the ground, critical setting needed to facilitate this alternative pathway [Ahmadov et al., 2015].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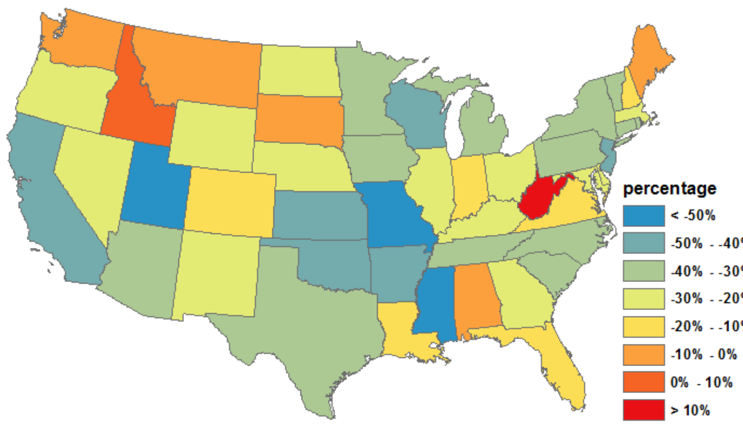
Min=-24.88 at (323,181), Max=20.35 at (339,48)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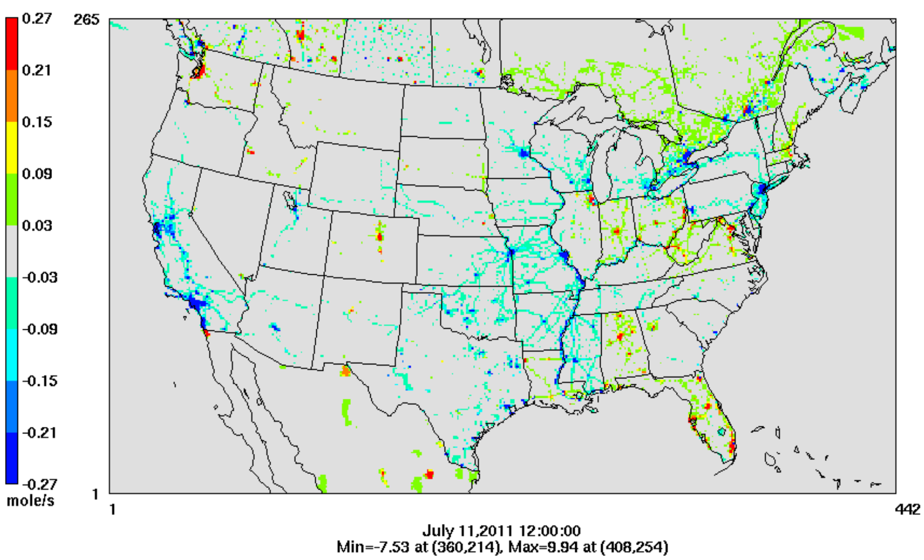
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Min=-7.53 at (360,214), Max=9.94 at (408,254)

Figure 2. Changes of NO_x emissions under the business as usual (BAU) and recession scenarios and their difference: a) changes based on the CSAPR projection (top); b) observed changes from OMI and AQS (middle); c) differences between BAU and recession (bottom).

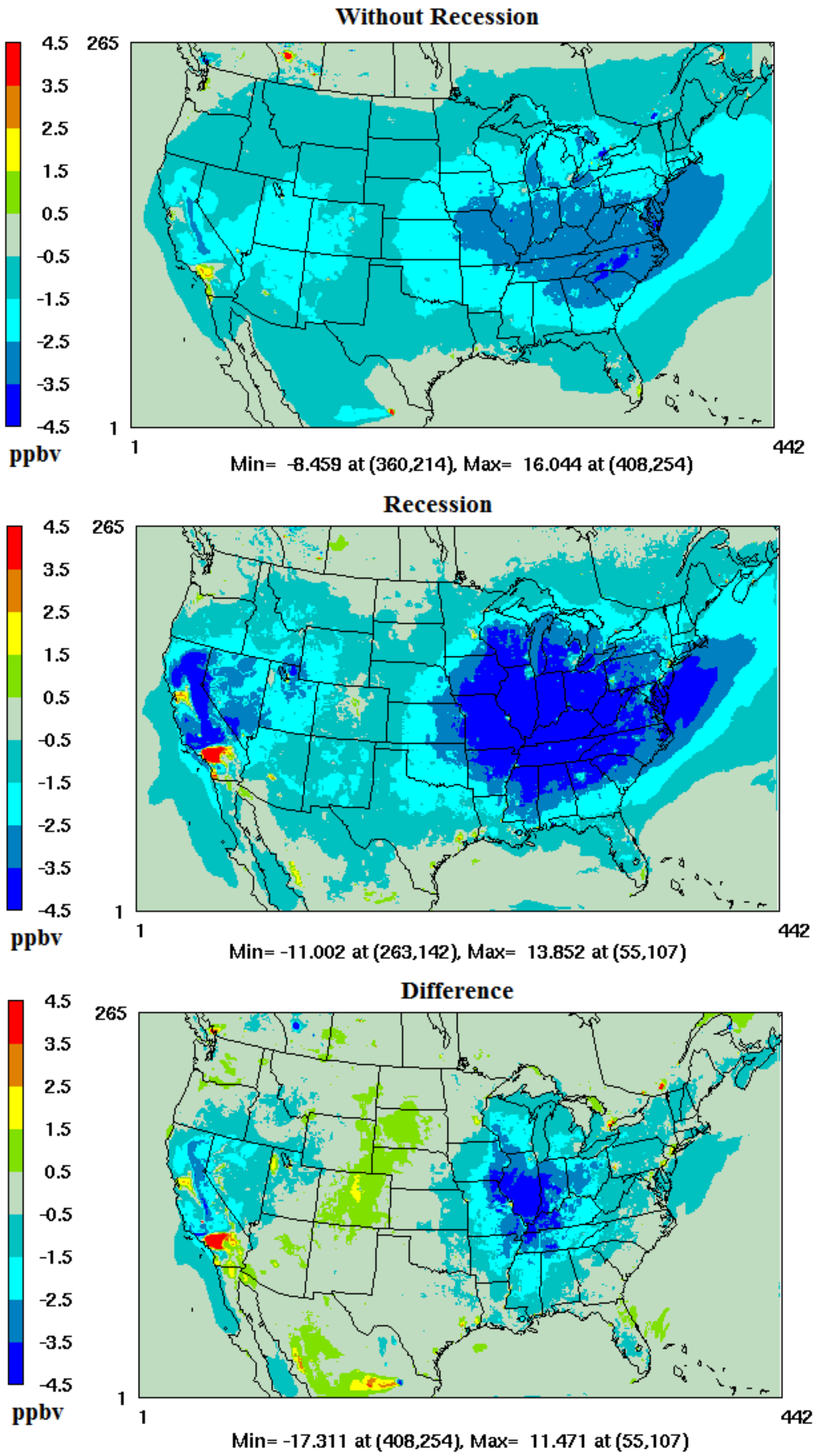


Figure 3. Changes of monthly mean surface O_3 concentrations in July from 2005 to 2012 under the BAU (upper) and Recession (middle) scenarios and the difference between BAU and Recession (Recession – BAU) (bottom).

Planned Work

- Work to finalize the scientific document for the revised marine isoprene algorithm. This work is behind the planned schedule due to insufficient funding that prevents us from supporting a dedicated project staff. We plan to focus on this task in the coming project year.
- *Generate VIIRS isoprene for NAQFC testing.* This task involves continuously generating VIIRS isoprene data and providing the product to the NAQFC application team for integration. spatial, temporal, and format, etc.) for end users.
- *Incorporation of VIIRS marine emission products into NAQFC* There are three steps to incorporate the isoprene product into the NAQFC system. First, a data processing tool will be developed to prepare "model-ready" data to meet end user requirements. Next, the model-ready isoprene data will be merged into the emission files to drive NAQFC chemical transport model. Finally, the effect on NAQFC forecast performance will be evaluated using the NAQFC standard evaluation package. In the second year, we finish two of the three steps needed to promote the JPSS isoprene product into NAQFC operation

Publications

1. **Tong, D.Q.,** L. Lamsal, L. Pan, C. Ding, H. Kim, P. Lee, T. Chai, and K.E. Pickering, and I. Stajner, 2014. Long-term NO_x trends over large cities in the United States during the 2008 Recession: Intercomparison of satellite retrievals, ground observations, and emission inventories, *Atmospheric Environment*, 107,70-84, doi:10.1016/j.atmosenv.2015.01.035.
2. Huang, M., **Tong, D.,** Lee, P., Pan, L., Tang, Y., Stajner, I., Pierce, R. B., McQueen, J., and Wang, J.: Toward enhanced capability for detecting and predicting dust events in the Western United States: the Arizona Case Study, Atmos. Chem. Phys. Discuss., 15, 20743-20774, doi:10.5194/acpd-15-20743-2015, 2015.
3. Tang, Y., T. Chai, L. Pan, P. Lee, **Daniel Tong**, H. Kim, and W. Chen, Using Optimal Interpolation to Assimilate Surface Measurements and Satellite AOD for Ozone and $PM_{2.5}$: A Case Study for July 2011. *Journal of the Air & Waste Management Association*, doi:10.1080/10962247.2015.1062439, 2015.

Presentations

Our team has contributed five presentations to the 2015 JPSS Science Team Meeting:

1) Richard Artz: JPSS users: an Air-Quality perspective
2) Daniel Tong: JPSS Marine Isoprene: Linking Ocean Phytoplankton to Air Quality and Climate.
3) Daniel Tong: Air quality applications using OMPS observations.
4) Pius Lee: Utilizing satellite data for trace gas to constrain air quality forecast;
5) Pius Lee: Assimilation of the VIIRS retrieved Aerosol optical Thickness (AOT) as an observation set for a regional air quality reanalysis product.

In addition, we have presented the following JPSS-related works.

1. Tong D., Hyuncheol Kim, Li Pan, Youhua Tang, Weiwei Chen, Tianfeng Chai, Min Huang, Pius Lee, Jeff McQueen, Jianping Huang and Ho-Chun Huang, Menghua Wang and Shobha Kondragunta, Lok Lamsal and Kenneth Pickering, Ivanka Stajner, 2015. Recent Progress in NAQFC Emission Forecasting, The 7th International Workshop on Air Quality Forecasting Research, September 1-3, 2015, College Park, MD.

2. Menghua Wang, Daniel Tong, Pius Lee, Hang Lei, Li Pan, Global Marine Isoprene Emission Data Derived from Satellite Ocean Color Measurements. The 7th International Workshop on Air Quality Forecasting Research, September 1-3, 2015, College Park, MD.
3. Daniel Tong, Menghua Wang, Hang Lei, Li Pan, Pius Lee, Brett Gantt, Sarwar Golam, Jeff McQueen, and Ivanka Stajner. Global high-resolution marine isoprene emission derived from VIIRS-SNPP and MODIS-Aqua ocean color observations. The *14th Annual CMAS Conference,* October 5-7, 2015, Chapel Hill, NC.

Other

1. **Community Services**
   As one of the local organizers, Daniel helped organize the 7th International Workshop on Air Quality Forecasting Research (IWAQFR) held on Sept 1-3, 2015 in the NOAA National Center for Weather and Climate Prediction, College Park, MD. Daniel also served as a co-chair to the emissions session. JPSS Project Scientist Mitch Goldberg presented the JPSS Earth observing capability to the audience as a keynote speaker.

CUNY Validation of JPSS-VIIRS Data on Long Island Sound Coastal Site

Task Leader Samir Ahmed
Task Code SAAG_JPSS_15
NOAA Sponsor Lihang Zhou
NOAA Office JPSS STAR
Contribution to CICS Research Themes (%) Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic Scientific support for the JPSS Mission
Contribution to NOAA goals (%) Goal 1: 0%; Goal2: 0%; Goal 3: 100%
Highlight The Project has continued to provide a consistent stream of data from the SeaPRISM instrument on the Long Island Sound Coastal Observatory (LISCO) to NASA – AERONET. This quality assured in-situ OC data stream permitted evaluation of the quality of VIIRS retrieved OC products for coastal waters conditions, statistical analysis of VIIRS, MODIS and AERONET-OC data, and the impacts of the different processing schemes NASA and NOAA MSL12. Possible applications of AERONET-OC data combined with RT simulations for the validation of the Sensor Data Records (SDRs) are considered.

Background

The reliability of Ocean Color (OC) satellite observations of the open ocean and coastal zones need to be regularly assessed and validated against actual *in situ* measurements, along with related atmospheric corrections and error trends. This need is recognized by worldwide efforts devoted to acquiring accurate *in situ* time series measurements in open ocean and coastal waters, in conjunction with OC satellite imagery, to produce high quality data records which can be used both in support of operations and in climate studies. AERONET-OC sites with SeaPRISM instruments provide continuous data streams, which through the use of established algorithms are converted to multi-spectral, normalized water leaving radiances (nLw), and remote sensing reflectances (Rrs), and successfully used for the validation of SeaWiFS, MODIS, MERIS and now the JPSS/NPP/VIIRS sensor. Our system, the Long Island Coastal Observatory (LISCO) established by the City College of the City University of New York (CCNY), supports JPSS/VIIRS cal/val activities through satellite – in situ and satellite – satellite data matchups. It provides a good representation of typical coastal water and atmospheric conditions, with a reasonable dynamic range of parameters for validation purposes. With the use of data acquired at LISCO and other coastal AERONET-OC sites in US and European waters, the validity of the VIIRS's OC and atmospheric data has been scrutinized and findings have been reported to the OC satellite remote sensing community, for better interpretation of physical or biogeochemical VIIRS data in coastal areas. Additional data for the validation of satellites were acquired during two VIIRS validation cruises in Nov 2014 and Dec 2015 on R/V Nancy Foster where underway hyperspectral measurements were made using a customized HyperSAS-POL system installed at the front of the ship, which also includes HyperSAS radiometers sensitive to polarization. These data were compared with standard above and below water Rrs measurements of CCNY and other groups demonstrating very high quality of the HyperSAS data.

Accomplishments

The Cimel SeaPRISM instrument at LISCO (Long Island Sound Coastal Observatory) was recalibrated in April/May 2015 at the Goddard facility, and subsequently reinstalled on the platform on June 10th. Intermittent measurements were collected immediately before that in the late-winter/early-spring period (January-March), due to bad weather conditions (snow/ice) as is typical in the area. In the following we report of comparisons between water leaving radiances (nLw) measured at the LISCO AERONET site and those derived after the atmospheric correction from VIIRS and MODIS (both NASA and MSL12 processing), for all year 2015.

The satellite data are averaged over a 3x3 pixel grid to minimize spatial inhomogeneities, retaining only pixels exempt from the following flags: Land, Cloudy, Bad navigation quality, High/moderate glint, High viewing/solar zenith angle. Scenes where nLw exhibits negative values are also excluded.

Temporal coincidence of $\pm$2h was then sought with the SEAPRISM measurements. Note that most of valid data points (i.e., nearly-simultaneous measurements) come from the late winter/early spring period and the fall, a fact already observed for many AERONET-OC stations (e.g. WaveCIS, USC_Seaprism).

Figure shows the time series resulting from the filtering procedure. The comparison is generally good and with no apparent differences between the pre- and post-calibration period. Interestingly, in a few instances an opposite performance for the satellite retrieval algorithms is observed at the shortest wavelength, see for example around day 60 and 210 where VIIRS significantly overshoots the AERONET measurement when compared to MODIS, and around day 15 and 255 where the opposite happens.

The goodness of the match-ups can be quantified by running linear regressions (not shown here) at each wavelength of these time series. This analysis highlights that, at the longest wavelengths (≥490nm), the NASA processing scheme applied to both MODIS and VIIRS tends to underestimate the AERONET nLw measurements. Regarding the MSL12 processing, the great majority of spectra showed negative nLw values at 413 nm (and partially at 442 nm).

In concluding, the nLw measurements at LISCO are higher than that retrieved from MODIS and VIIRS (NASA processing) observations at 490, 550, 670 nm and noisy at 410 and 443 nm. Regarding the MSL12 processing sufficient agreement is found at 550 and 670 nm, while the correlation is poor at the shortest wavelengths.

Very recently (February 2016), further successful maintenance was delivered to the SEAPRISM instrument, because of a known and recurring design issue linked to a tendency of the cabling to entangle as a consequence of the sun-tracking movement over the year.

In order to provide reliable estimates of water constituents, OC satellite sensors require first and foremost an accurate radiometric calibration. Vicarious calibration can be achieved post-launch by forcing satellite-derived water-leaving radiances to agree with in-situ measurements, to yield gain factors.

Simultaneous data from ancillary instrumentation can alternatively be used as input to a radiative transfer code to simulate the TOA radiances measured by the satellite, with the advantage of a complete independence of any atmospheric correction. To provide an example, we calculated the gain factors based on the match-ups between the radiances measured by VIIRS (and MODIS) and those simulated at the top of the atmosphere by a radiative transfer code which exploits the SEAPRISM measurements (Water-leaving radiance, and aerosol optical thickness, single-scattering albedo and phase functions). LISCO measurements were selected within ±2 hrs from satellite overpass, and the gains are determined from statistically significant amount of filtered pixels (i.e., free of clouds, glint, or other inconvenient anomalies) covering three years of operations of the satellite sensors.

The results are shown in Figure. Compared to NASA published values, the gain factors retrieved with the proposed method show acceptable agreement in the blue-green region of the spectrum. Larger discrepancies arise at longer wavelengths, only partially imputable to accuracy issues encountered when modeling low satellite signals. This kind of analysis obviously enables the determination of the sensitivity of the TOA radiances to the uncertainties in individual model parameters, thereby quantifying the accuracy of the vicarious calibration approach.

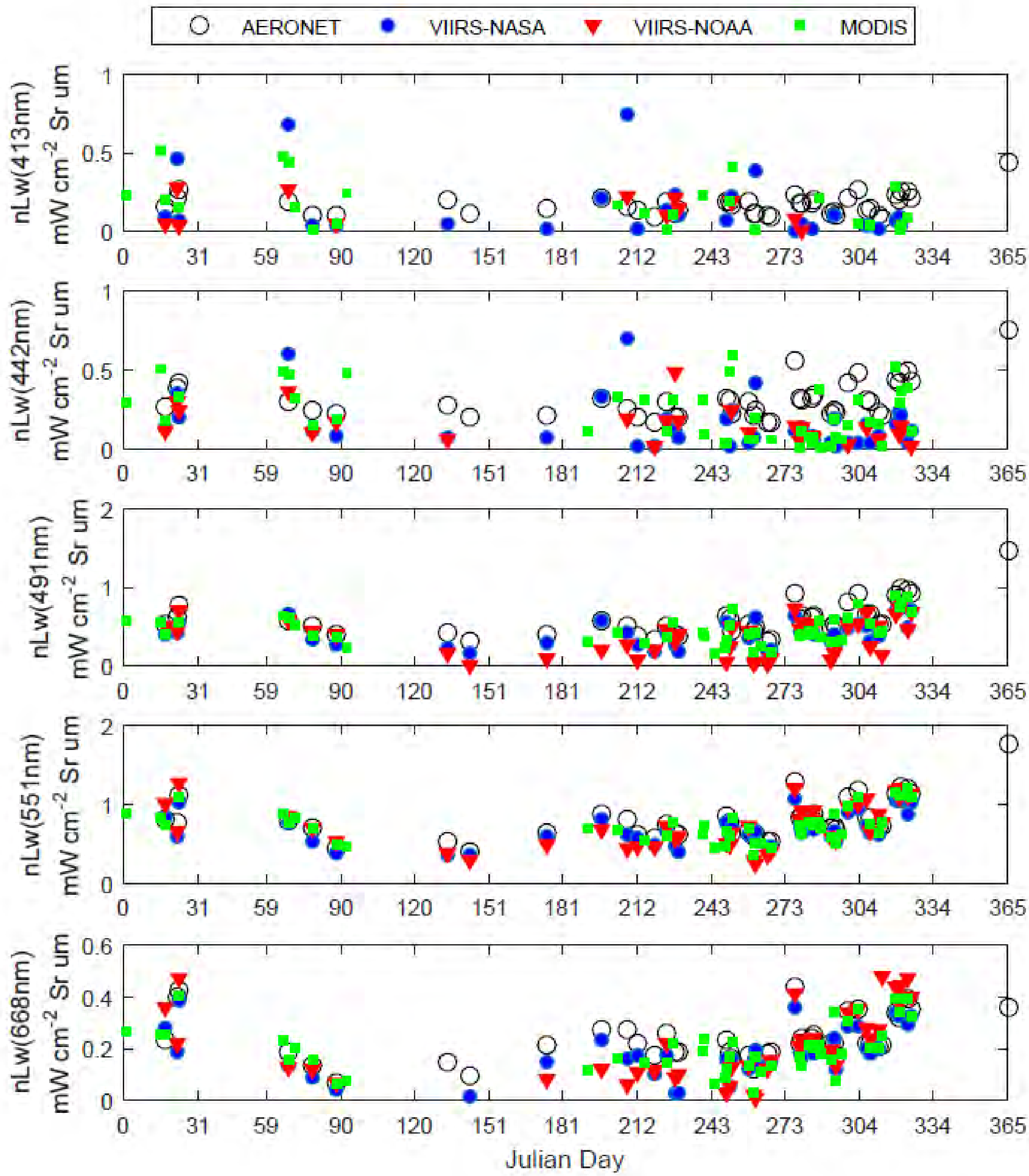


Figure 1: a) Coincident measurements of Water-leaving radiance by the AERONET-OC instrument at LISCO and either MODIS or VIIRS, for the year 2015.

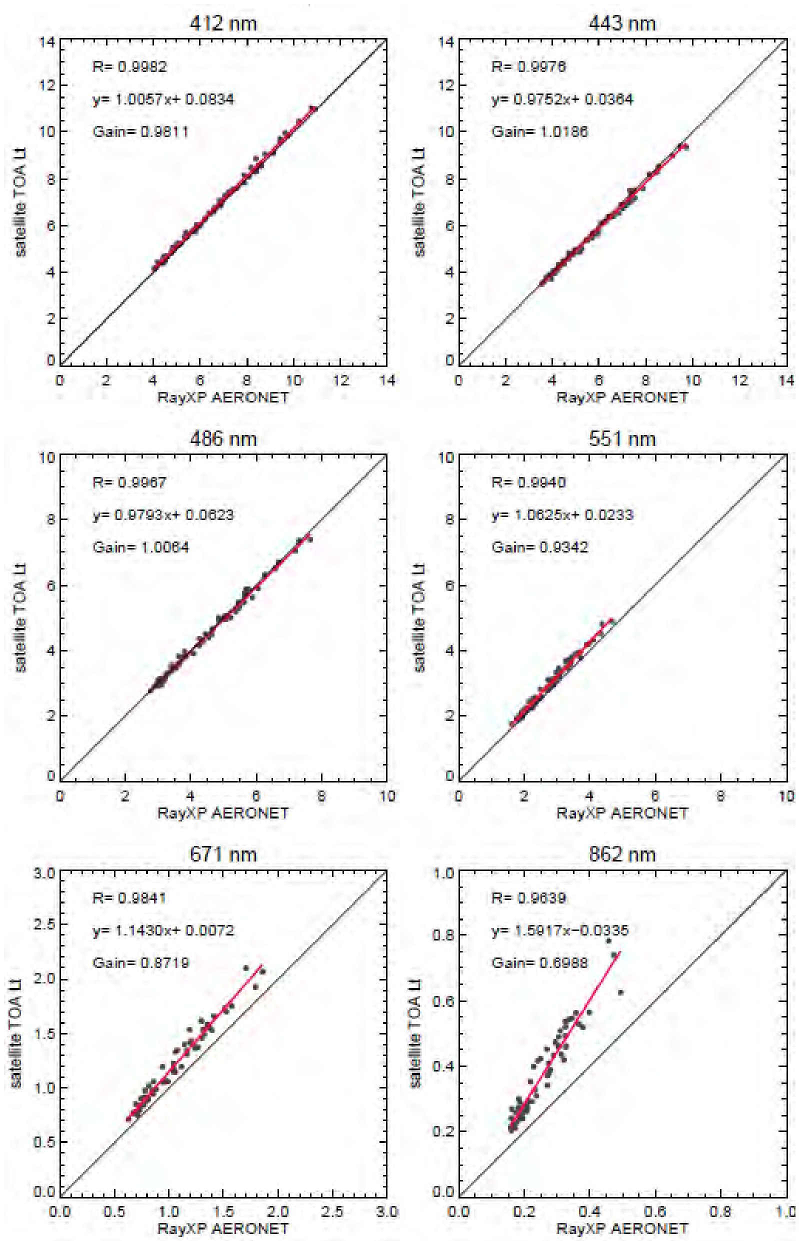


Figure 2: Multi-year analysis of match-ups between VIIRS measured and simulated top-of-the-atmosphere radiances. LISCO measurements are exploited to characterize the atmospheric and oceanic components in the radiative transfer computer simulations. Each panel represents a different observational wavelength, as indicated.

In addition to the operation of the LISCO site and utilizing its data for satellite validation throughout the year, the CCNY group participated in a major ocean VIIRS Validation cruise sponsored by NOAA (R/V Nancy

Foster, November 2015, East Coast from Charleston, SC) which had (NOAA cruise) components for OC satellite validation.

Planned work

- Provide a continuous data stream of high quality from the LISCO site to NASA AERONET group including instrument calibration at NASA to ensure traceability to NIST standards.
- Matchups between satellite data (MODIS, VIIRS) for the area of the platform and SeaPRISM data. Comparison of different processing schemes from MSL12 and NASA. Evaluation of data errors and uncertainties of the AERONET /SeaPRISM data stream.
- Comparison with other AERONET sites.
- Field measurements in the area of the platform and other areas of opportunity, and matchup with SeaPRISM data.
- Assessment of impact of atmospheric conditions on the retrieval accuracy and evaluation of approaches to minimize uncertainties in satellite OC retrievals for coastal waters.
- Deliverable: characterization of the quality of the satellite data in coastal areas, possible suggestions for algorithm improvements.

Publications

R. Foster, A. Ibrahim, A. Gilerson, A. El-Habashi, C. Carrizo, S. Ahmed,” Characterization of Sun and sky glint from wind rued sea surfaces for improved estimation of polarized remote sensing reflectance,” Proc. of SPIE 9613, 2015.

Presentations

1. R. Foster, A. Ibrahim, A. Gilerson, A. El-Habashi, C. Carrizo, S. Ahmed,” Characterization of Sun and sky glint from wind rued sea surfaces for improved estimation of polarized remote sensing reflectance,” SPIE Optics and Photonics, San Diego, 2015.

2. Matteo Ottaviani, Alex Gilerson, Robert Foster, Carlos Carrizo, Jacek Chowdhary, Sam Ahmed, “Accuracy of radiometric calibration of ocean color satellite sensors using AERONET-OC data”, AGU Ocean Science Meeting, New Orleans 2016

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**1**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**3**
# of undergraduate students mentored during the year	**2**

Scientific Support for Satellite Instrument Calibration and Application

Task Leader: Xiaolei Zou
Task Code: XZXZ_SICA_15
NOAA Sponsor: Fuzhong Weng
NOAA Office: STAR/SMCD
Contribution to CICS Research Themes (%): Theme 3 (100%)
Main CICS Research Topic: Scientific support for the JPSS Mission
Contribution to NOAA goals (%): Goal 1 (50%) Goal 2 (50%)
Highlight: Remote Sensing of Optically Thin Clouds from SNPP CrIS Data at Double CO2 Bands
Link to a research web page: None

Background

Satellite infrared sounding data had played and will continue to play a key role in numerical weather prediction (NWP) and climate study. Global NWP skills experienced a rapid and steady increase since microwave temperature sounding radiances provided by the polar-orbiting meteorological satellites were assimilated (Eyre *et al.*, 1993; Andersson *et al.*, 1994). The role of HIRS, AIRS and CrIS data for NWP could be fully realized if radiance measurements were directly and appropriately assimilate into operational NWP systems through three-dimensional or four-dimensional variational (3D/4D-var) approaches. Of particular importance for satellite infrared radiance data assimilation are an accurate fast radiative transfer models (RTM) which provide simulated radiances at AMSU-A observed frequencies for a given input atmospheric state of a NWP model (Saunders et al., 1999, 2007; Weng, 2007); a bias estimate, instrument noise and forward modeling error covariance matrices that are required input components for any data assimilation system; and a cloud detection for quality control of data to be assimilated. The former is often derived through the instrument calibration. Observation biases are a key component that must be known not only for NWP but also for climate applications of satellite instrument data. The proposed research aims at minimizing observation errors and correctly quantifying observation errors and observations biases.

Accomplishments

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 was developed in this project by using double CO2 bands of CrIS radiance data. The clouds from the CrIS double CO2 retrievals at various altitudes are validated with the Visible Infrared Imaging Radiometer Suite (VIIRS) day/night band (DNB) reflectance and Advanced Himawari-8/9 Imager (AHI) cloud types and cloud top pressures.

Detection of optically thin clouds from satellite infrared instruments is very challenging due to their small thermal contrasts to the background. A new method was developed to detect these clouds using the infrared hyperspectral data at two CrIS CO2 bands (4.5 and 14 μm). A set of CrIS longwave (14 μm) and shortwave (4.5 μm) channels is firstly paired through examining their weighting function peaks. A relationship between the paired-channel brightness temperatures is then derived in clear-sky conditions and used for predicting the shortwave channel values from the longwave observations. For a CrIS brightness temperature at a shortwave channel, a cloud emission and scattering index (CESI) is derived as a difference between the predicted and observed brightness temperatures. It is found that CESI is correlated well with optically thin clouds at different altitudes. For a winter storm that occurred in the eastern part of the United States during 22-24 January 2016 (Blizzard 2016), the CESI values in cirrus clouds, fog, supercooled water clouds are positive and distinctly different from those over other cloudy and clear-sky areas. Also, the positive CESI values in fog and water clouds over Gulf of Mexico are well indicated by the VIIRS day and night band (DNB) observations.

Figure 1 presents a spatial distribution of CESI derived from Pair 5 of the LWIR channel 123 (726.25 cm^{-1}) and SWIR channel 1175 (2225.0 cm^{-1}) with their WF peak around 778 hPa (Fig. 1, left panel) on the descending node of SNPP around 0712 UTC (nighttime ~02:12 EST) on 23 January 2016. Because the GOES-13 imager cloud products are not reliable during nighttime, the VIIRS DNB reflectance (Fig. 1, right panel) is used for qualitative validation of CESI. VIIRS DNB band is designed with a high sensitivity to observe the clouds from reflected lunar radiation (Walther and Heidinger, 2013; Cao et al., 2013). In the evening of 22 January, the sky is clear with a full moon. It is an ideal condition for VIIRS DNB data to be used for monitoring clouds. Indeed, the VIIRS DNB data have been widely used for monitoring the storms at high latitude areas such as Alaska during the winter season when GOES and POES solar visible data are unavailable. It is seen that the CESI is positive in clouds and negative in clear sky. The VIIRS DNB (Fig. 1, right panel) compares favorably with the CESI distribution around 469 hPa. The low-level water clouds and fogs in Gulf of Mexico are also well captured by the positive CESI distributions with the magnitude range of 2-3. After the storm moving away from the east coast, the city lights are visible from VIIRS DNB bands and are shown as brightest pixels over the snow-covered land in the eastern part of US.

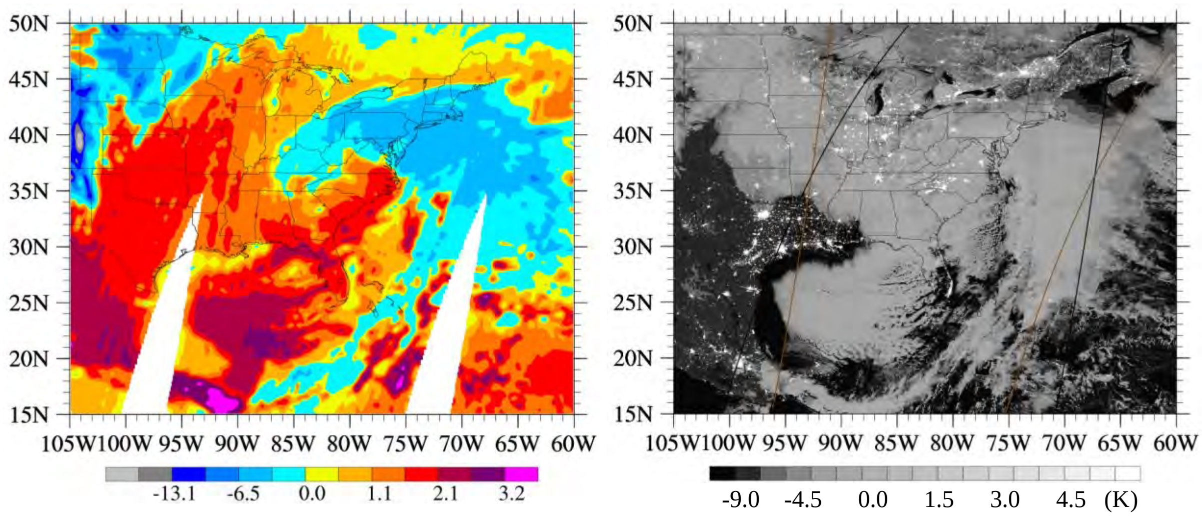


Fig. 1: Spatial distributions of CESI derived from the pair 5 (~778 hPa) at the descending node of SNPP (left panel) and VIIRS DNB radiance (unit: 10^{-8} W cm^{-2} sr^{-1}) (right panel) around 0712 UTC (nighttime ~02:12 EST) on 23 January 2016.

Planned work

- An algorithm will be developed for effective collocations between CrIS radiance measurements and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) lidar observations.
- The clouds from the CrIS double CO2 retrievals at various altitudes will be validated with CALIPSO lidar observations of cloud types and ice water content profiles.
- The sizes of ice cloud particles that are inferred from the CALISPO backscatter and extinction profiles will be used to improve the accuracy of CRTM simulations under thin cirrus clouds conditions.

- Quantitative estimate of CrIS brightness temperature biases under clear-sky condition.

Publications

Lin, L., X. Zou and F. Weng, 2016: Remote Sensing of Optically Thin Clouds from SNPP CrIS Data at Double CO2 Bands. Journal of the Atmospheric Sciences, (submitted in March 2016)

Products

Algorithm development

Presentations

The 96th Annual Meeting of America Meteorology Society, 11-14 January 2016, New Orleans, Louisiana. Five oral presentation entitled "Applications of CrIS Full Spectral Resolution Data in NWP Models to Improve the Quality Control of IR Radiance Assimilation" by Zou, Lin, Weng and Chen at the Fourth AMS Symposium on the Joint Center for Satellite Data Assimilation (JCSDA). The paper number is: 3.1.

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

1. A new cloud index product was developed for detecting optically thin cloud.
2. A peer review journal paper was completed and submitted.
3. An oral presentation was presented at the 2016 AMS meeting for this project.
4. A graduate student is advised.

5 Climate Research, Data Assimilation, and Modeling

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

Task Leader	Christopher Hain (Jifu Yin)
Task Code	CHCH_JPSS_15
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: 55%; Goal 2: 45%; Goal 3: 0%

Highlight:

1) Land-cover changes from primeval forest to grassland may increase root-zone soil moisture, thus reducing drought, while changes from grassland and primeval forest to cropland or reforested areas have increased the likelihood of drought;
2) The results suggest to Noah land model developers and users that near real time GVF and albedo should be used for better model performance;
3) Model skills can be significantly enhanced by assimilating soil moisture product system (SMOPS) blended soil moisture product into the Noah land surface model in both sparsely and densely vegetated areas;
4). Quality control rules for the satellite soil moisture data product from NOAA-NESDIS SMOPS are established for their assimilation into Noah land surface model using green vegetation fraction criteria, and applying the quality control rules in the assimilation of SMOPS data products significantly improves the agreement of Noah LSM soil moisture simulations with in situ measurements; and
5). These results offer a viable approach for addressing the issues of uncertainty propagation of satellite data rescale-match and quality control so that merging microwave soil moisture retrievals can improve agricultural drought estimation.

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, the benefit of assimilating the NPP/JPSS data products for soil moisture estimation is evaluated by comparing field measurements of root-zone soil moisture. In addition, the 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 surface types, GVF and albedo on Noah model performance have been evaluated. We also investigated how to quality control microwave soil moisture and estimated the benefits of assimilating satellite soil moisture into Noah land surface model. Additionally, a new blended drought index has been generated by merging the retrievals from thermal remote sensing land surface temperature-based evapotranspiration along with the remotely sensed and land surface modeling 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 Soil Climate Analysis Network (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.

The 2011 drought over the U.S. Southern Great Plains seriously affected agriculture, severely impacting crop and livestock sectors and significantly influencing food prices at the retail level (Grigg, 2014; Arndt and Blunden, 2012; Tadesse *et al.*, 2014) with the state of Texas experiencing its driest year since 1895 (Combs, 2012; Hoerling *et al.*, 2013). Figure 2 demonstrates the monthly drought maps on CONUS domain for the classified Blended Drought Index (BDI) and USDM in 2011. It can be seen that the BDI reasonably tracks the time evolution of drought patterns recorded in the USDM.

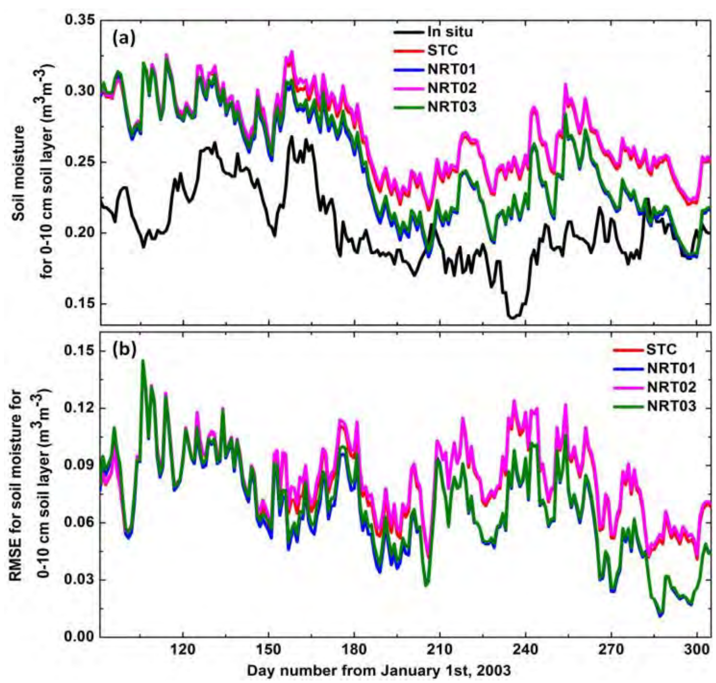


Figure 1. Model simulated [STC (static GVF and albedo), NRT01 (weekly GVF and static albedo), NRT02 (monthly albedo and static GVF) and NRT03 (weekly GVF and monthly albedo) cases] versus in situ soil moisture observations [In situ (black line)] from April 1st to October 31th 2003, (a) daily 0-10 cm soil

layer soil moisture, (b) daily RMSEs (m^3m^{-3}) against the in situ measurements for 0-10 cm soil layer soil moisture.

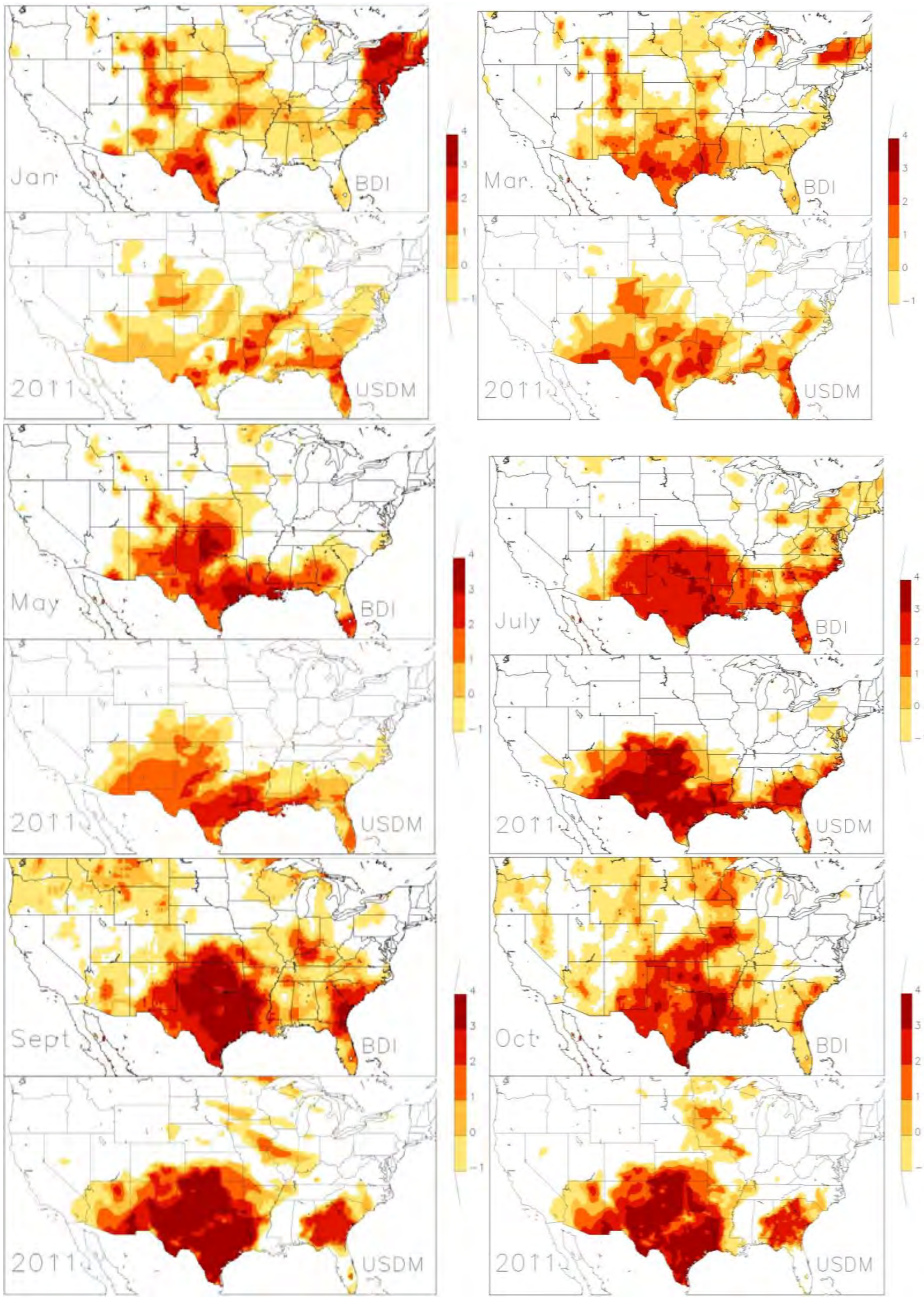


Figure 2: Monthly drought maps on CONUS domain for the classified BDI and USDM in 2011. The numbers -1, 0, 1, 2, 3 and 4 indicate no drought, abnormally dry, moderate drought, severe drought, extreme drought and exceptional drought, respectively.

Planned work

1) Continue to validate blended drought index using the Palmer Drought Severity Index (PDSI); and
2) Develop and test a semi-coupled system of Global Forecast System (GFS) and the NASA Land Information System (LIS), then assimilate microwave soil moisture retrievals into the GFS using an ensemble Kalman Filter.

Publications

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.

Yin, Jifu, Xiwu Zhan, Youfei Zhan, Jicheng Liu, Li Fang and Christopher Hain, 2015: Enhancing Model Skill by Assimilating SMOPS Blended Soil Moisture Product into Noah Land Surface Model, *J. Hydrol.*, **16**, 917-931

Yin, Jifu, Xiwu Zhan, Youfei Zheng, Christopher R. Hain Jicheng Liu and Li Fang, 2015: Optimal ensemble size of ensemble Kalman filter in sequential soil moisture data assimilation. *Geophys. Res. Lett.*, **42**, 6710-6715.

Yin, Jifu, Xiwu Zhan, Youfei Zheng, Christopher R. Hain, Qingfei Zhai, Changchun Duan, Rongjun Wu, Jicheng Liu and Li Fang, 2015: An assessment of impacts of land-cover changes on root-zone soil moisture. *Int. J. Remote Sens.*, **36**, 6116-6134.

Presentations

Yin, Jifu, X. Zhan, J. Liu, L. Fang, C. Hain, W. Zheng, M. B. Ek and M. C. Anderson. Satellite soil moisture products and their application to drought monitoring. *AMS Annual Meeting*, New Orleans, LA (1/10/2016 to 1/14/2016).

Zheng, Weizhong, J. Liu, L. Fang, J. Yin, X. Zhan, and M. B. Ek. Validation of Global Soil Moisture Products from SMAP Radiometer Observations and their Application in NCEP Global Forecast System. *AMS Annual Meeting*, New Orleans, LA (1/10/2016 to 1/14/2016).

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**4**
# of non-peered reviewed papers	**2**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

CICS Support for NOAA's Climate Prediction Center

Task Leader	E. Hugo Berbery (tasks performed by Li-Chuan Chen)
Task Code	EBLC_HACP_15
NOAA Sponsor	Huug van den Dool
NOAA Office	NWS/NCEP/CPC
Contribution to CICS Themes (%)	Theme 2: 25%; Theme 3: 75%
Main CICS Research Topic	Climate Research and Modeling; Land and Hydrology
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%

Highlight: CICS researcher validated ENSO precipitation and temperature forecasts in the North American Multi-Model Ensemble (NMME) and found discrepancies between the model temperature composites and the observed.

Background

This work is to support NOAA/NCEP Climate Prediction Center's (CPC's) efforts on North American Multi-Model Ensemble (NMME) forecasts and evaluations. NMME is an experimental multi-model forecasting system consisting of coupled climate models from U.S. modeling centers (including NCEP, GFDL, NASA, and NCAR) and Canadian Meteorological Centre (CMC), aimed at improving intraseasonal to interannual prediction capability. Tasks include (1) developing algorithms and techniques for multi-model ensemble forecasts and evaluations, (2) working on research to advance the science and technology necessary for sub-seasonal 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 2015, my colleagues at CPC and I conducted an investigation to examine precipitation and temperature forecasts during El Nino/Southern Oscillation (ENSO) events in six NMME models, including the CFSv2, CanCM3, CanCM4, FLOR, GEOS5, and CCSM4 models, by comparing the model-based ENSO composites to the observed. The composite analysis is performed using the 1982-2010 hindcasts for each of the six models with selected ENSO episodes based on the seasonal Ocean Nino Index just prior to the date the forecasts were initiated. Two types of composites are constructed over the North American continent: one based on mean precipitation and temperature anomalies, the other based on their probability of occurrence in a tercile-based system. The composites apply to monthly mean conditions in November, December, January, February, and March, respectively, as well as to the five-month aggregates (NDJFM) representing the winter conditions. For anomaly composites, we use the anomaly correlation coefficient (ACC) and root-mean-square error (RMSE) against the observed composites for evaluation. Figure 1 shows the matrix charts of ACC for all models and months, including NMME and NDJFM. For probability composites, we develop a probability anomaly correlation measure and a root-mean probability score for assessment. We found that all NMME models predict ENSO precipitation patterns well during wintertime; however, some models have large discrepancies between the model temperature composites and the observed. The fidelity is greater for the multi-model ensemble, as well as for the five-month aggregates.

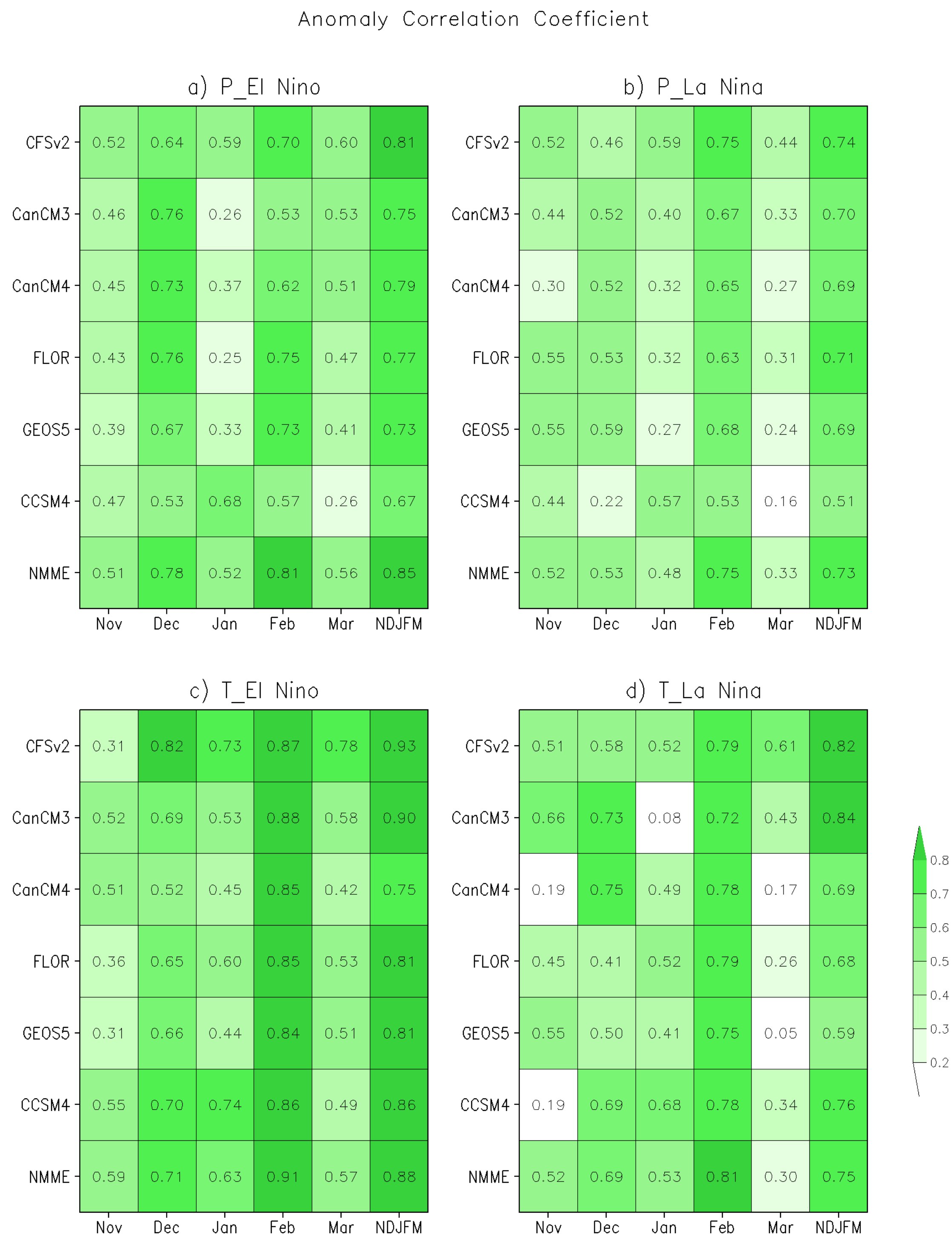


Figure 1 Anomaly Correlation Coefficient of all models and months for (a) El Nino precipitation anomaly composites, (b) La Nina precipitation anomaly composites, (c) El Nino temperature anomaly composites, and (d) La Nina temperature anomaly composites.

February tends to have higher score than other winter months. For anomaly composites, most models perform slightly better in predicting El Nino patterns than La Nina patterns. For probability composites, all models have superior performance in predicting ENSO precipitation patterns than temperature patterns. The results of this research were presented in the 40th NOAA Annual Climate Diagnostics and Prediction Workshop (CDPW) and the 4th Annual CICS-MD Science Meeting. A manuscript based on this research was submitted to the Journal of Climate for publication. An extended summary was published in the Climate Prediction S&T Digest, 40th CDPW special issue. ENSO has a large influence on the seasonal precipitation and temperature patterns over the United States and a profound impact on the global climate, resulting in many extreme events around the world. Understanding the prediction capability of ENSO events in climate models is the key to improve long-range forecasts of and prevent negative effects from such events.

Prior to this project, I worked on research to advance the science and technology necessary for drought prediction using NMME forecasts. In particular, I expanded the CFSv2-based Standardized Precipitation Index (SPI) Outlooks I developed in 2011 to using dynamical precipitation (P) forecasts from NMME. The system became operational in December 2012 and has been used to assist in CPC's monthly drought outlooks and briefing activities on current events, such as the 2013 Upper Midwest Flash Drought and the on-going California drought. A website to deliver the real-time NMME SPI Outlooks to the public was developed and started in operation in March 2013. In July 2013, the operational NMME SPI forecast system was successfully migrated to NCEP's new supercomputer system WCOSS. New products, such as real-time SPI persistence forecasts and skill maps, were added to the website in December 2013. The operational NMME SPI Outlooks products have been contributing greatly to the drought research and user communities, such as the National Integrated Drought Information System community.

Along with CPC's collaborators, I have conducted an assessment of the meteorological drought predictability using the retrospective NMME forecasts for the period from 1982 to 2010. Two performance metrics (ACC and RMSE) are used to evaluate forecast skill. For P forecasts, errors vary among models and predictive skill is generally low after the second month. All model P forecasts have higher skill in winter and lower skill in summer. Although P forecast skill is not large and quickly drops after one month, SPI predictive skill is high and the differences among models are small. Generally, model with lower P forecast skill has lower SPI forecast skill. The skill mainly comes from the P observations appended to the model forecasts. This factor also contributes to the similarity of SPI prediction among the six models. Still, NMME SPI ensemble forecasts have higher skill than those based on individual models or persistence. Overall, SPI predictive skill is regionally and seasonally dependent, and the 6-month SPI forecasts are skillful out to four months. SPI forecast skill at a region corresponds to local rainfall climatology and variability. Dynamical models improve SPI predictive skill from baseline skill when and where P forecasts are skillful. The improved skill of SPI prediction during the wet seasons spanning roughly late autumn to early spring over the Southwest and Gulf Coast region is attributed to the known impacts of ENSO signals on these regions' cold-season precipitation. These findings were presented in several conferences and meetings, including the 38th CDPW Workshop and 2013 AGU Fall Meeting. A manuscript is in preparation for submission to a peer-reviewed journal.

In addition to the hindcast evaluation, I have examined the predictive skill of real-time NMME SPI forecasts for the period from May 2012 to Dec 2014. The three major drought events occurred during the 2012-2014 period, the 2012 Central Great Plains Drought, the 2013 Upper Midwest Flash Drought, and 2012-2016 California Drought, are used as examples to illustrate the system's strength and weakness. For precipitation-driven drought events, such as the 2012 Central Great Plains Drought, NMME SPI forecasts perform well in predicting drought severity and spatial patterns. For fast-developing drought events, such as the 2013 Upper Midwest Flash Drought, the system failed to capture the onset of the drought. The results of this study were presented in the 2014 AGU Fall Meeting and 2015 World Environmental & Water Resources Congress. A manuscript on this topic is also in preparation for submission to a peer-reviewed journal.

Beside these research and development activities, I participate in NMME's planning, research to operation (R2O), and maintenance activities as well. I assist in new model assessment and data processing, hindcast update (up to December 2015), 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 operational forecasts at CPC. With all these work, I received a Certificate of Recognition from CPC for the contributions to the development of operational NMME seasonal forecast system.

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 (2016), ENSO Precipitation and Temperature Forecasts in the North American Multi-Model Ensemble: Composite Analysis and Validation, Journal of Climate, in review.

Van den Dool, Huug, Li-Chuan Chen, and Geert Jan van Oldenborgh (2015), Een Sterke El Nino in Aantocht, Meteorologica, 24(3), 12-17.

Non-Refereed Conference Proceedings:

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, Climate Prediction S&T Digest, 40th NOAA Annual Climate Diagnostics and Prediction Workshop Special Issue.

Becker, Emily J., Huug van den Dool, Qin Zhang, and Li-Chuan Chen (2016), Forecasting Temperature Extremes with the North American Multi-Model Ensemble (NMME), Climate Prediction S&T Digest, 40th NOAA Annual Climate Diagnostics and Prediction Workshop Special Issue.

Zhang, Qin, Yuejian Zhu, Hong Guan, Jon Gottschalck, Jin Huang, Huug van den Dool, Emily Becker, and Li-Chuan Chen (2016), New Measure of Forecast Uncertainty for the North American Multi-Model Ensemble, Climate Prediction S&T Digest, 40th NOAA Annual Climate Diagnostics and Prediction Workshop Special Issue.

Products

NMME ENSO Composites available at http://www.cpc.ncep.noaa.gov/products/NMME/enso/

Presentations

Chen, Li-Chuan, Huug van den Dool, Emily Becker, and Qin Zhang (2015), ENSO Precipitation and Temperature Forecasts in the North American Multi-Model Ensemble: Composite Analysis and Verification, the 4th Annual CICS-MD Science Meeting, College Park, MD.

Van den Dool, Huug, Emily Becker, and Li-Chuan Chen (2015), Probabilistic Forecast Products for the NMME Seasonal Forecast System: the CPC Component, NOAA Climate Test Bed Meeting, College Park, MD.

Van den Dool, Huug, Li-Chuan Chen, Emily Becker, and Qin Zhang (2015), Comparison of Model Data Based ENSO Composites and the Actual Prediction by These Models for Winter 2015/16, NOAA Climate Test Bed Meeting, College Park, MD.

Chen, Li-Chuan, Huug van den Dool, Emily Becker, and Qin Zhang (2015), ENSO Precipitation and Temperature Forecasts in the North American Multi-Model Ensemble: Composite Analysis and Validation, 40th NOAA Annual Climate Diagnostics and Prediction Workshop, Denver, CO.

Becker, Emily J., Huug van den Dool, Qin Zhang, and Li-Chuan Chen (2015), Forecasting Temperature Extremes with the North American Multi-Model Ensemble (NMME), 40th NOAA Annual Climate Diagnostics and Prediction Workshop, Denver, CO.

Zhang, Qin, Yuejian Zhu, Hong Guan, Jon Gottschalck, Jin Huang, Huug van den Dool, Emily Becker, and Li-Chuan Chen (2015), New Measure of Forecast Uncertainty for the North American Multi-Model Ensemble, 40th NOAA Annual Climate Diagnostics and Prediction Workshop, Denver, CO.

Chen, Li-Chuan, Kingtse Mo, Qin Zhang, and Jin Huang (2015), Predictive Skill of Meteorological Drought Based on Multi-Model Ensemble Forecasts: A Real-Time Assessment, World Environmental & Water Resources Congress 2015, Austin, TX.

Others

Chen, Li-Chuan, Certificate of Recognition, NOAA/NWS/NCEP/Climate Prediction Center, for contributions to the development of operational North American Multi-Model Ensemble (NMME) seasonal forecast system.

Chen, Li-Chuan, Lifeng Luo, Hamid Moradkhani, and Shahrbanou Madadgar (Convenors and Chairs), Hydroclimatic Extremes: Drought, 2015 Fall Meeting, American Geophysical Union, San Francisco, CA, 14-18 Dec.

Chen, Li-Chuan (Reviewer), Journal of Hydrologic Engineering, Water Resources Research, Journal of Hydrology, Journal of Geophysical Research, Bulletin of the American Meteorological Society, Advances in Meteorology, and International Journal of Climatology.

PERFORMANCE METRICS	
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer-reviewed papers	2
# of non-peer-reviewed papers	3
# of presentations	7
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

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
NOAA Sponsor	Mitch Goldberg
NOAA Office	JPSS/NESDIS
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%
Highlight	PQC was shown to improve 5-day forecasts
Link to a research web page	http://www.atmos.umd.edu/~ekalnay/#seminars_based

Background

Continuing from prior successful research carried out in Hotta (2014, doctoral thesis) that the proposed PQC algorithm was able to improve the model forecasts within 24 hours, we explored the impact of PQC on model forecasts for longer period, namely, 5-day forecasts. The temporal extension of the impact of PQC is important because, as shown in Kumar et al. (2009), forecast skill dropout events can take place for several days after the assimilation of flawed observations. We started from the identified 20 cases in Hotta (2014). The PQC-modified forecasts from 6 to 126 hours were verified using the before-PQC GSI analysis as truth using moist total energy norm.

Accomplishments

We show the snapshots of the evolution of relative forecast error improvements at 06-, 24-, 72- and 96-hour (Figure 1) of the case at 2012020618. In this case, there was one PQC-modified area on each hemisphere. In the first 6-hour forecast, the distribution of relative error improvements (blue grids) were corresponding to the location of rejected observations (not shown). There were also slight degradations (red grids) near the South Pole, but they vanished shortly. In the following days, the improvements started to propagate, expand, and intensify with synoptic weather disturbances. They reached the peak at around day 4 of the experiment period and started to decay. Nevertheless, the improvements, though decayi ng, still continued beyond day 5 (not shown).

In Figure 2, we show the average 5-day forecast error improvement of both (a) the 11 significant cases, chosen by requiring that the 6-hour forecast error decrease by at least 20% in the target region, and (b) the other 9 cases that are not significant according to this criterion. Since all the regional dropouts and the associated denied-observations were in higher latitudes the improvement took place mostly in the NH and SH extratropics. The forecast error in tropical belt, on the other hand, is apparently worse after PQC in the first 6 hours, but this degradation is due to the analysis change introduced PQC rather than being truly degraded. This is supported by the fact that the tropical degradation vanishes by 12-hours. In contrast, in higher latitudes, where the flawed observations were actually denied, the initial improvement persists and grows with time. The growth of improvement can also be seen in global integration. It almost reaches 1% after 5 days, demonstrating the long-term effect of PQC. It is noteworthy that the improvements in higher latitudes tend to expand in space and “leak” to lower latitudes (Figure 1), leading to a steady growth of improvements in the tropics for the 11 significant cases.

The average of the 9 non-significant cases in Figure 2 shows a different scenario. Although the forecasts in the higher latitudes were still improved until day 4, this improvement was limited and reached only 0.5%. In addition, the PQC-modified forecasts started degrading after 4 days in most regions.

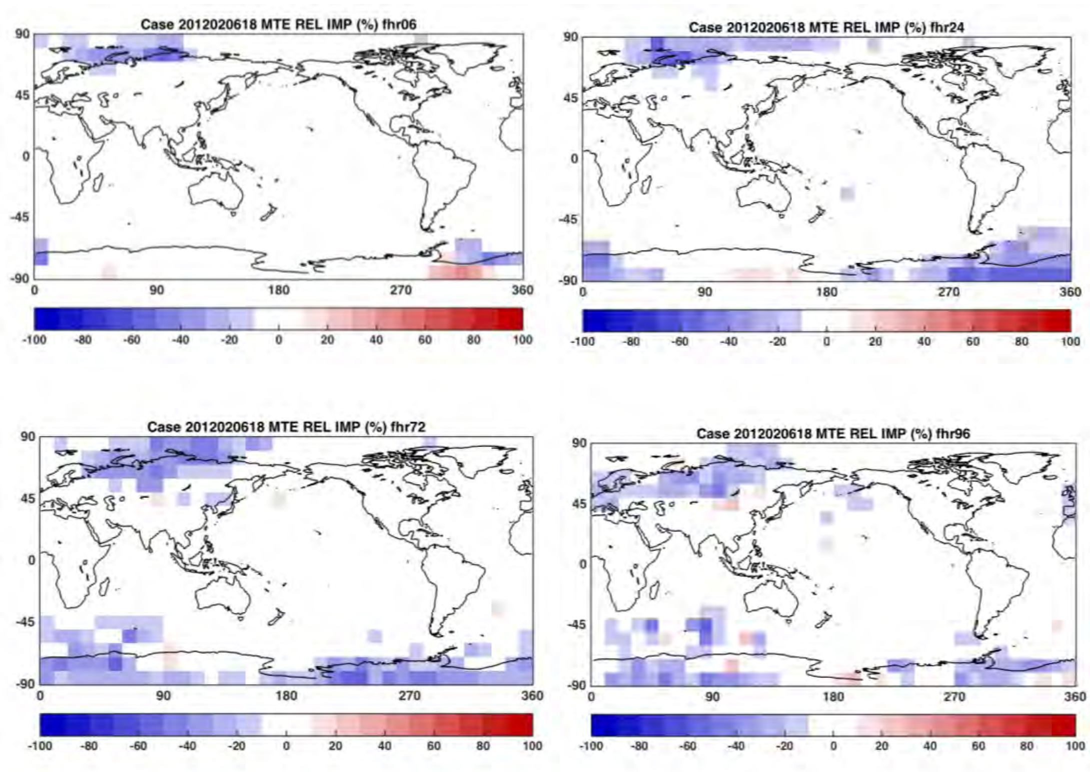


Figure 1: Relative improvement of forecast error measured by the changes in moist total energy over 10 degrees by 10 degrees boxes at 06-, 24-, 72-, and 96-hour for Case 2012020618. The improvements are marked with blue, while degradations marked with red.

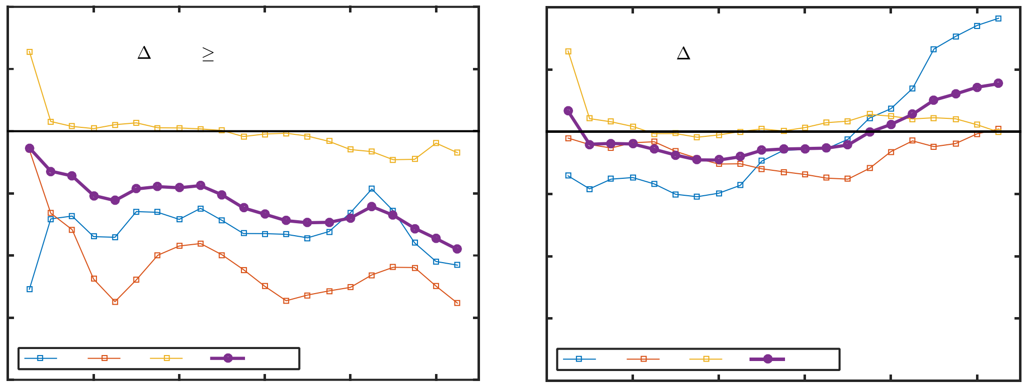


Figure 2: Average of 5-day relative forecast error improvement of (a) 11 significant cases and (b) 9 non-significant cases.

Planned work

- In order to complete the R2O process, student Tse-Chun Chen is carrying out experiments to show:
  - the EFSO approximation to the analysis change from withdrawing the detrimental observations is fairly accurate;
  - the online (accumulated) impact is at least as good as the average individual impact;
  - estimate the maximum impact by doing the full analysis correction online.

- We are working on developing more sophisticated strategy to reject the detrimental observations.
- After this is completed, Prof. Darryl Kleist has kindly offered to guide the NCEP implementation.
- In addition to the improvement of the forecasts, we have started discussion on improving observation with Dr. Brett Hoover and Dr. Dave Santek at CIMSS, Madison, WI who have experience with both MODIS winds and data assimilation.
- We proposed to Dr. Brett Hoover to create a sample of metadata in a case where we found detrimental MODIS wind observations to compare meta data (mostly O minus B) for detrimental versus beneficial observations, and try to identify and if possible the problem with the detrimental observations.
- We are starting an experiment testing VIIRS winds, the successor of MODIS winds and will soon be tested and finally assimilated in operational centers. Assessing its impact can be easily done by EFSO, and by EFSR, the observation error covariance R of this new system can be tuned.

Publications

Kalnay, E., Y. Ota, T. Miyoshi, and J. Liu, 2012: A simpler formulation of forecast sensitivity to observations: application to ensemble Kalman filters. Tellus A, 64, 18 462.

Ota, Y., J. C. Derber, T. Miyoshi, and E. Kalnay, 2013: Ensemble-based observation impact estimates using the NCEP GFS. Tellus A, 65, 20 038.

Hotta, Daisuke, 2014: PROACTIVE QUALITY CONTROL BASED ON ENSEMBLE FORECAST SENSITIVITY TO OBSERVATIONS, Ph. D. Thesis, U of Maryland

Hotta, D., T.-C. Chen, E. Kalnay, Y. Ota, and T. Miyoshi, 2016: Proactive QC: a fully flow-dependent quality control scheme based on EFSO. *Monthly Weather Review*, submitted.

Products

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

Presentations

This work was presented in more than 7 national and international data assimilation Symposia. The last one was on March 17, 2015 at NCEP (EMC). We were invited to give a similar seminar at the Climate Test Bed at NCEP on May 18 at 10am. These include:

Chen, T.-C., D. Hotta, and E. Kalnay, The Performance and Feasibility of Ensemble Forecast Sensitivity to Observations-based Proactive Quality Control Scheme, AGU, Fall Meeting, San Francisco, CA (12/14 to 12/18/2015)

Chen, Tse-Chun, Daisuke Hotta and Eugenia Kalnay, 899: "No-cost" Proactive Quality Control (PQC) by the use of linearly approximated analysis AMS Annual Meeting, Phoenix, AZ (1/4 to 1/8/2015)

Hotta, Daisuke and Eugenia Kalnay, Proactive QC based on Ensemble Forecast Sensitivity to Observations (EFSO) and Ensemble Forecast Sensitivity to observation error covariance matrix R (EFSR), AMS Annual Meeting, Phoenix, AZ (1/4 to 1/8/2015)

Kalnay, Eugenia and Tse-Chun Chen, Efficient Assimilation of Precipitation: Results with TRMM/TMPA and Plans for GPM, AGU Fall Meeting, San Francisco, CA (12/15 to 12/19/2014)

Chen, Tse-Chun, No-cost" Proactive Quality Control (PQC) by the Use of Linearly Approximated Analysis, CICS-MD Science Meeting, College Park, MD (11/12 to 11/13/2014)

Hotta, Daisuke, Proactive Quality Control based on Ensemble Forecast Sensitivity to Observation (EFSO), Environmental Modeling Center Seminar, College Park, MD (7/16/2014)

Kalnay, Eugenia, Daisuke Hotta, Yoichiro Ota, and Guo-Yuan Lien, Use of LETKF sensitivity to improve QC of data from JPSS polar orbiting instruments and to detect the origin of the NCEP "5-day forecast skill dropouts," JPSS PGRR Science Review, College Park, MD (4/29/14 to 5/1/2014)

Performance Metrics	
# of new or improved products developed (please identify below the table)	**4**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**3**
# of non-peered reviewed papers	**1**
# of invited presentations	**7**
# of graduate students supported by a CICS task	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Briefly explain Table

1. EFSO diagnostic tool to identify the impact of each observation (Kalnay, 2012)
2. EFSR diagnostic tool to estimate the optimal observation error covariance R (Hotta, 2014)
3. Proactive Quality Control Scheme (Ota et al. 2013, Hotta, 2014, Chen et al, 2015)
4. Sophisticated observation denial strategy (Chen, doctoral research, 2015)

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

Task Leader: Augustin Vintzileos
Task Code: AVAV_CPC_2015
NOAA Sponsor: Mike Halpert
NOAA Office: Climate Prediction Center
Contribution to CICS Research Themes: 3 (100%)
Main CICS Research Topic: Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals: 1 (100%)
Highlight: The Task Leader designed, developed, utilized in realtime applications and refined a Subseasonal Excessive Heat Outlook System (SEHOS). In its pilot phase, the SEHOS is targeting Week-2 using as input, predictions from the NCEP GEFS and the corresponding reforecast (from ESRL). Currently the refined baseline SEHOS is being augmented by using multi-model ensemble techniques, initially adding the ECMWF ensemble model and reforecast in the operational setting. This version of the SEHOS will be executed quasi-operationally in realtime during summer 2016 (beginning 1 May 2016) and evaluated by CPC forecasters. In parallel, the value added by the NMME suite of models is investigated for leads from Week-2 to Week-3&4. The Task Leader also developed and improving the product that uses Week-3&4 CFSv2 predictions to inform CPC forecasters.
Link to a research web page: Web page internal to CPC

Background

Heat waves disrupt several sectors of society including human health, agriculture, food safety and energy. Hot temperatures are associated with excess mortality due to cardiovascular, respiratory, and cerebrovascular diseases. High humidity aggravates the physiological effects of high temperature. The relationship between temperature and mortality is non-linear and time-lagged. To further complicate the relation between heat and health, tolerance of excess heat varies regionally according to the population and its preparedness. Future projections suggest the increase of the frequency, duration and intensity of heat waves. One way to resilience to such adverse weather/climate conditions is the use of multi-scale prognostic systems. These systems will inform sufficiently in advance decision makers thus optimizing the use of available resources. The monitoring, forecast and verification components of the SEHOS are described in detail in the next section.

Accomplishments

1. Definition of *Heat Events*

Amongst complexities of heat wave forecasting is that unlike other extremes events e.g., tornados, heat is more difficult to visualize and quantify. Quantification of heat events for the SEHOS was developed by the Task Leader based on mapping, observed and forecast, apparent temperature (NOAA's Heat Index) to percentiles. A given day is considered as a ***Heat Day*** when the maximum apparent temperature of this day exceeds a certain percentile threshold for a given grid point and period within the warm season. The statistics used for the percentile mapping are computed from the historical record of maximum apparent temperatures A ***Heat Event*** (*HE*) is defined as the sequence of at least two consecutive ***Heat Days***. This definition presents the following benefits and inconveniences.

Pros:

- The non-linear nature of the impact of temperature and humidity on human physiology is taken into account by using as a measure the *Heat Index*.
- Challenges of subseasonal ensemble forecasting are addressed.

Cons:

- Requirement for a sufficiently long and ensemble rich reforecast database.

  A *HE-Week* is defined as the occurrence or not of at least one *HE* during the target week. Two additional metrics: starting day and duration of the *HE* within the target week, allow for the full description of weekly *HEs*.

2. Applications

2.1 Monitoring Heat Events

One of the historical *HEs* occurred in Chicago, Illinois during the week of 11-17 July 1995. This *HE* resulted in abnormal human mortality in excess of 700. Quantitative visualization of this *HE* based on the definition of section 2.1 is presented in Figure 1. The occurrence, start day and duration of this *HE* at three levels of intensity L1 (*Heat Day* threshold 90%), L2 (95%) and L3 (98%) is compared to abnormal mortality. The meteorological data used for the computations presented on Figure 1 are the Day-1 GEFS reforecasts. Figure 1a shows a very intense, mostly L3, *HE* covering a vast area from the mid-west to the northeast and mid-Atlantic. Figure 1b shows that the HE started in the mid-west and propagated eastward during the week of 11-17 July. The maximum duration of the event (4-5 days) was observed in the larger Chicago area (Fig. 1c). The area of this *HE* as visualized in Fig.1a is collocated with a cluster of extreme human mortality shown in Fig. 1d; this suggests that this monitoring system have practical applications.

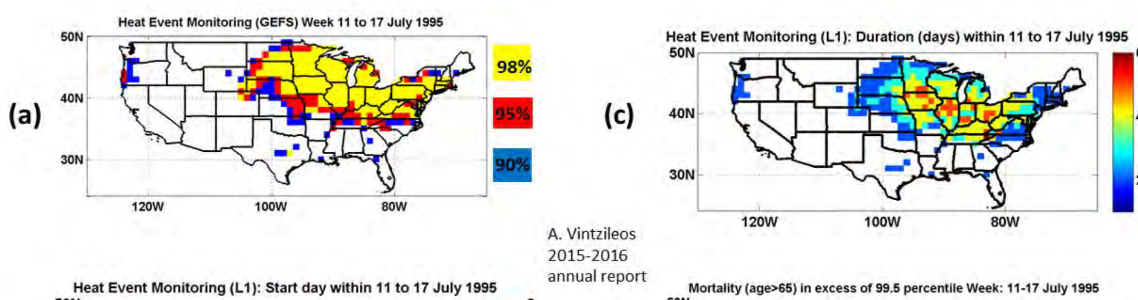


Figure 1: The July 1995 Heat Event visualized by the SEHOS monitoring system for the week 11 – 17 July 2015. Results here are based on data from the GEFS Day-1 forecast: (a) occurrence of L1 (blue), L2 (red) and L3 (yellow) intensity Heat Events, (b) starting day (within the 11-17 July week), (c) duration in days of the Heat Event at each grid point and (d) locations of human mortality exceeding the 99% percentile for at least one day during the week from 11-17 July.

2.2 Forecasting of Heat Events

The baseline version of the forecast component of the SEHOS uses predictions from the 84-ensemble members per day operational GEFS and the 11-ensemble member 1985-2014 reforecast. Implicit calibration is applied to the maximum Heat Index of the day because observed and forecast thresholds correspond to the same percentile and not to the same physical value. This automatically warrants that the number of *Heat Days* available to generate *Heat Events* is the same in the forecast model and in observations. However, this choice cannot impose that the frequency of forecast *HE* equals the frequency of observed ones and therefore calibration is a necessary post-processing stage. The real time forecast methodology consists of investigating the occurrence of at least one *HE* at forecast Week-2 for each of the daily 84 ensemble members. These calculations yield the probability of occurrence, the mean starting date and the mean duration of a *HE* for the given week

2.3 Forecast Verification

Extreme events are rare and as a consequence forecast verification is not a trivial task. The verification method used is based on the comparison between the probability of forecasting an observed event and the probability of false detection of an observed event. As the *HE* forecasts provided from SEHOS are probabilistic a number of different probability thresholds defining a *HE* are tested for this comparison. Results from this Receiver Operating Characteristics analysis are presented on Figure 2 for all grid points within the CONUS. One benefit of ROC is that it compares the columns of the contingency table and thus it is less sensitive to the asymmetry between the two classes (no-events *versus* events). The Area under Curve (AUC) of the ROC provides a measure of the forecast quality. The AUC for each grid point for the baseline SEHOS is presented on Figure 2(b). These results suggest that the baseline SEHOS is useful for forecasting *HEs* at Week-2.

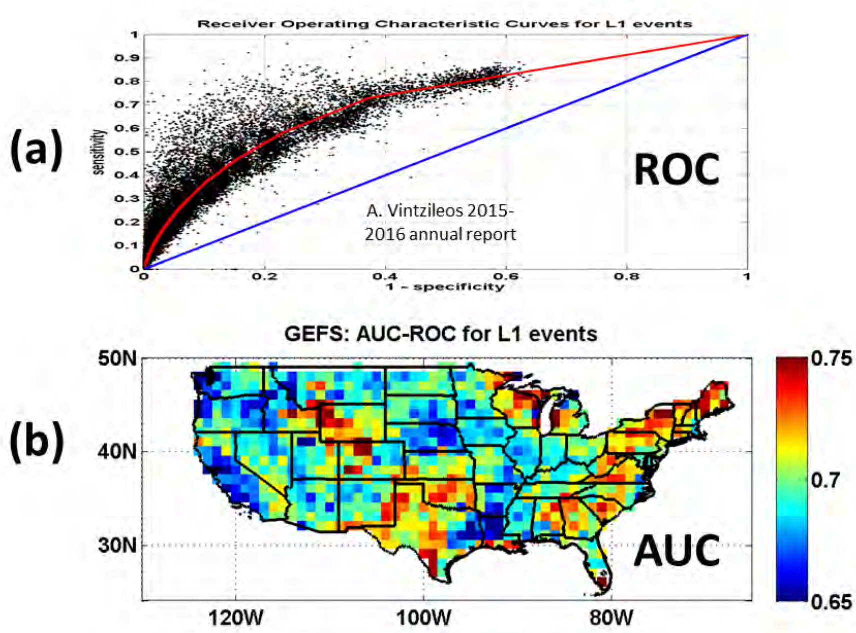


Figure 2: (a) Receiver Operating Characteristics (ROC) for L1 events for every grid point within the CONUS calculated from the 1985-2014 GEFS reforecast (b) Area Under Curve (AUC) for L1 events, typical AUC values are: 0.5-0.6 (fail), 0.6-0.7 (poor), 0.7-0.8 (fair), 0.8-0.9 (good) and 0.9-1.0 (excellent).

Planned Work

This is the work planned by the Task Leader for the next 2 years:

- Quasi-experimental realtime execution and calibration of the baseline SEHOS and interaction with CPC forecasters during summer 2016 to assess the realtime forecast capacity of the system.
- Develop a third realtime monitoring system that will be based on METAR observations with Heat Events interpolated to a 1x1 grid.
- Use extreme value theory to improve:
  - Computation of percentiles.
  - Bias correction and calibration of the SEHOS forecasts.
  - Verification of the SEHOS forecasts.
- Transition to operations the GEFS/ECMWF based SEHOS
- Finalize the assessment of the value added by NMME models (CFS and CanCMs).
- Extend the SEHOS to the Global Tropics/Subtropics and to Week-3&4.

Publications

In preparation:

Vintzileos et al., Global Lagged Large Scale Circulation Patterns Associated with Heat Events over the Contiguous United States.

Vintzileos et al., Forecasting Heat Waves at lead times of Week-2 and beyond.

Vintzileos et al., Multi-model ensemble forecasting of Heat Waves at subseasonal lead times.

Products

(1) A realtime 'ensemble' monitoring system based on data from the GEFS Day-1 forecast and CDAS.
(2) The baseline realtime SEHOS
(3) The verification system for the SEHOS

Presentations

Vintzileos, A. and J. Gottschalck and M. Halpert, 2016: A Baseline System for Forecasting Excessive Heat Events at Subseasonal Lead Times. Climate Prediction Applications Science Workshop. 24-26 March, Burlington, VT

Vintzileos, A. and J. Gottschalck, 2016: Towards a Multi-Model Subseasonal Excessive Heat Outlook System. AMS Annual Meeting, 10-15 January 2016, San Francisco, California.

Vintzileos, A. and J. Gottschalck, 2015: Towards a Multi-Model Subseasonal Excessive Heat Outlook System. AGU Annual fall meeting, 14-18 December 2015, San Francisco, California.

Gottschalck J., and A. Vintzileos, 2015: Spanning the Weather-Climate Continuum. Workshop on the development of climate information systems for heat health early warning. 28-30 July, Chicago, IL.

Vintzileos, A. and co-authors, 2015: Heat waves over the US and the Madden-Julian Oscillation: prospects for subseasonal excessive heat outlooks. Climate Prediction Applications Science Workshop. 24-26 March, Las Cruces, New Mexico.

Vintzileos, A. and J. Gottschalck, 2015: Heat waves and MJO: prospects for subseasonal excessive heat outlooks. AMS Annual Meeting 4-8 January, Phoenix, Arizona.

Vintzileos, A. and co-authors, 2015: Investigating co-variability between mortality and slow atmospheric oscillations. AMS Annual Meeting 4-8 January, Phoenix, Arizona.

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

Full explanation of the developed products can be found in the core text.

Comparison of 4DVAR and LETKF in Assimilating JPSS-derived Sea-surface Temperature in the Chesapeake Bay Operational Forecasting System

Task Leader Bin Zhang
Task Code BZBZ_LETKF_15
NOAA Sponsor Christopher W. Brown
NOAA Office NOAA/NESDIS/STAR/CPRD/SCSB
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 3: 50%; Goal 4: 50%;
Highlight Comparison of 4DVAR and LETKF two data assimilation methods in the Chesapeake Bay Operational Forecasting System was completed.
Link to a research web page

Background

Temperature and salinity are critical factors in understanding and predicting physical and biological processes in the coastal ocean where they vary considerably in time and space. The ability to measure or estimate temperature and salinity synoptically and in near-real time would improve our understanding and forecasting of the physical and biological environment in coastal ocean waters. Though estimates of temperature can be relatively accurately modeled in coastal ocean and estuarine waters, temperature of the Bay generated by the Chesapeake Bay Operational Forecasting System (CBOFS), the operational hydrodynamic model for the Chesapeake Bay developed by NOAA's Ocean Services Coast Survey Development Laboratory (CSDL), would benefit from the assimilation of accurate, synoptic observations of SST to further improve the skill of its forecasts. CBOFS, however, does not presently possess the capability to assimilate satellite data.

To provide more accurate forecasts of temperature generated by CBOFS, we propose to evaluate the skill of two data assimilation techniques –4D-VAR and LETKF – in assimilating JPSS-derived SST into the CBOFS, NOAA's operational hydrodynamic model for Chesapeake Bay. The implementation of CBOFS containing the data assimilation technique deemed most effective will be transferred to CSDL. In addition, the skill associated with using VIIRS- versus AVHRR- SST in CBOFS forecasts will be estimated to quantify the improvements of the VIIRS sensor over heritage.

Accomplishments

1. Finished Assimilation of Swath VIIRS SST

Sequential data assimilation of VIIRS SST with CBOFS has been carried using out all available VIIRS SST dataset during period of 08/2014-11/2014.

a.) *SST bias reduction over the whole model domain is significant in a month time series.*

The area-mean (over whole model surface) SST from the forward model run during the first month is 27.4 and is reduced to 26.3, compared to the mean VIIRS SST of 25.8, corresponding to a bias reduction from 1.6 ◦ C to 0.5 ◦ C. As noted, the bias reduction is immediate after the data assimilation. And the SST bias does not bounce back in a few forecasting windows (6 hours) without assimilating VIIRS SST data.

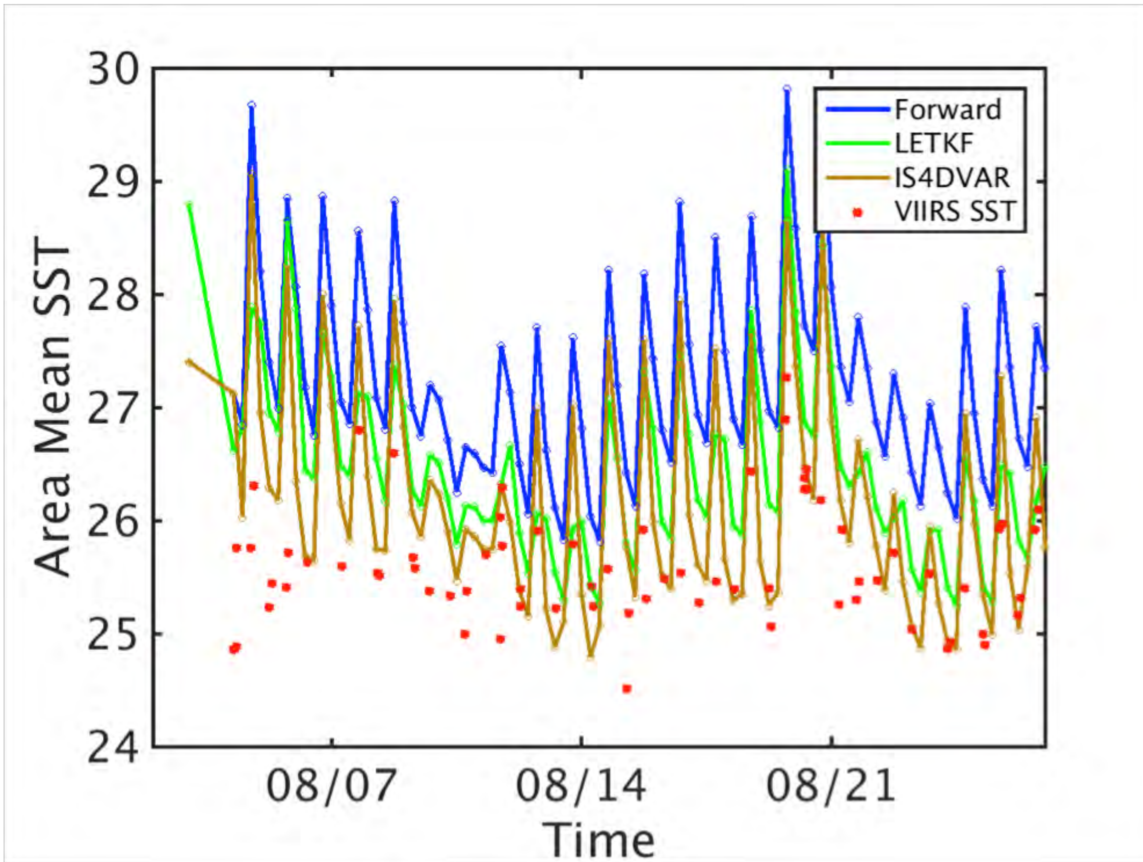


Figure 1: 4DVAR and LETKF comparison of model SST results with observations at CBIBS stations. Red line is the observed surface temperature at CBIBS. Blue line represents the model SST without data assimilation. Green and brown lines are the model result with data assimilation using LETKF and 4DVAR, respectively.

b.) *For all CBIBS stations, the SST bias has been greatly reduced*.

Maximum mean reduction (of all CBIBS stations) is at station Patpsco, the bias is reduced from 1.44C to 0.20C; minimum mean reduction occurs at station RCU, the bias is reduced from 0.29C to 0.11C. This indicates that general bias is reduced, but the bias reduction varies with location changes. Notice the standard deviation is also reduced significantly, regardless of how the model SST mean value changes.

c.) *Comparison with CBP stations shows warm bias over whole water columns is reduced and salinity is reduced in a little amount by assimilation of VIIRS SST*.

Comparison with CPB data shows a warm bias exists over the whole water column in the forward model. This is consistent with surface warm bias observed at CBIBS stations. Generally, the CBOFS forward model bias exists through all stations, which has been existed since the initialization of CBOFS. The forward model has a warm bias averaged over all the observational stations (surface and below) of 1.27±0.70◦ C. While with data assimilation, the model has a bias of -0.08 0.6◦ C. The bias is greatly reduced through data assimilation, and the standard deviation is also reduced, though with a smaller amount (0.7◦ C to 0.6◦ C). The overall mean absolute difference is reduced from 1.33 ◦ C to 0.46 ◦ C through column. The salinity results from 4DVAR experiments does not change significantly in terms of reducing the bias. The good thing indeed decreases but with a very small amount, the overall average bias reduction of 0.03 compared to the forward model bias of 2.73. The mean absolute difference changes from 2.90 to 2.87, similar amount as the bias reduction. From the salinity profiles, we can see CBOFS needs lots of improvements needed, especially in salinity field.

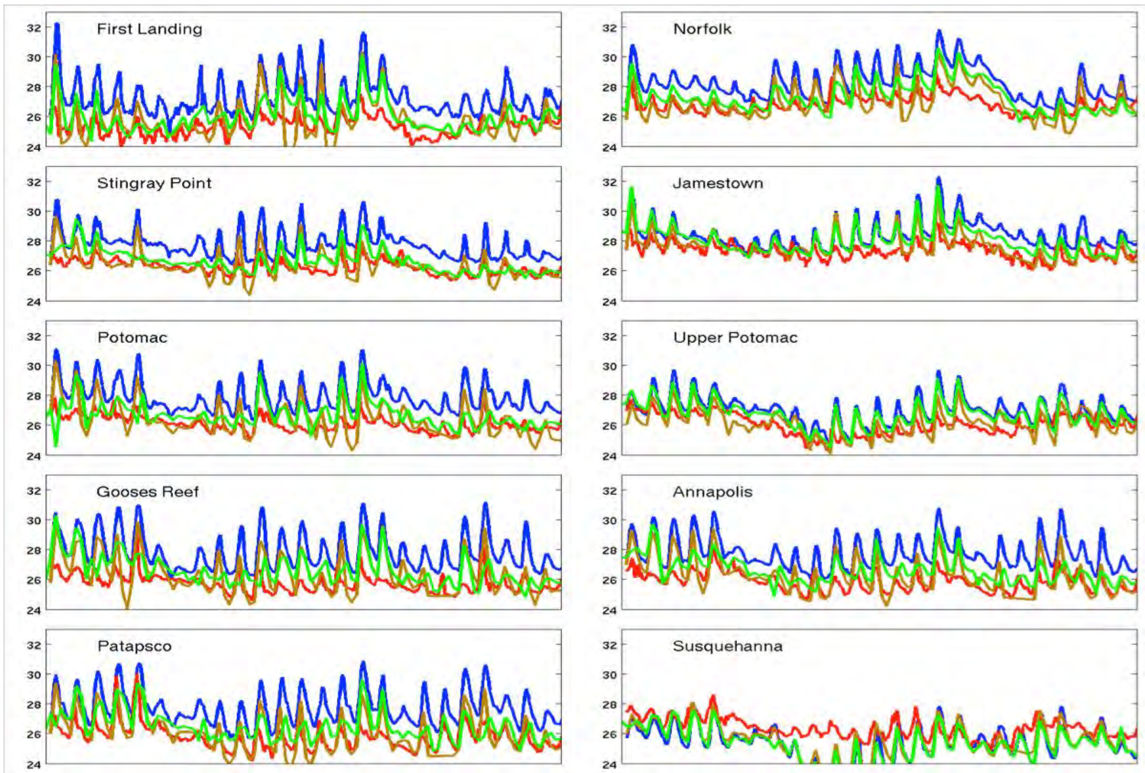


Figure 2: 24DVAR and LETKF comparison of model SST results with observations at CBIBS statio ns. Red line is the observed surface temperature at CBIBS. Blue line represents the model SST without data assimilation. Green and brown lines are the model result with data assimilation using LETKF and 4DVAR, respectively.

d.) *Forecasting skill are generally improved through all CBIBS stations*

We run forecast of CBOFS to 48 hours from each new 4DVAR adjusted initial condition and compare with those no 4DVAR initialization. The averaged SST difference for forecasting results between these tw o shows improvement in SST bias reduction during forecasting with 4DVAR adjusted initial condition. At the nowcast time (forecasting hour 0), the difference is about 1.1C, changes to 0.78C at the end of forecasting time(forecasting hour 48) The forecasting results are compared with observations at the CBIBS stations, considering the consistent observations at all CBIBS. The forecasting skill is calculated (1 for perfect data assimilation (completely agrees with observation), 0 for no improvement and negativ e number for worse performance). At most of CBIBS stations, the forecasting skill is generally close to 0.6, a very good performance with 4DVAR. There exists a daily fluctuation in the forecasting skill controlled by the diurnal flux from boundary conditions. For those stations near the open boundary (such as Susquehanna station), the temperature is controlled by the open boundary condition, and shows very little impact from data assimilation.

e.) *Comparison of LETKF with 4DVAR*

The initial comparison between the 4D-Var and LETKF implementations on the CBOFS model indicates that both techniques provide improvement over the free running model (Figs. 1,2,3). The 4D-Var system demonstrates more improvement than the LETKF, especially at depth. We note that the CBP profiles in the test month of August 2014 indicate that there is little stratification in the Bay during this time, especially for this time of year. It is unclear how the vertical improvement in both 4D-Var and LETKF would be affected by stratification that can reduce the correlation between surface information and the bottom layers. OSSE experiments on a different ROMS model have indicated that corrections to the bottom in the presence of stratification could lead to incorrect corrections at depth (Hoffman et al. 2012).

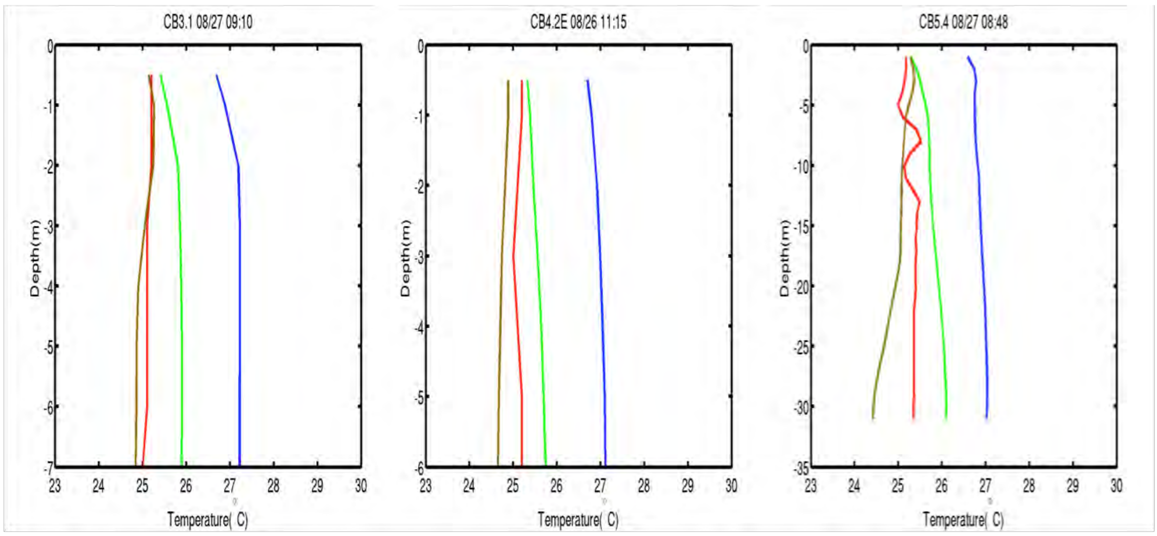


Figure 3: 4DVAR and LETKF comparison of model SST vertical profiles with observations at CBIBS stations. Red line is the observed surface temperature at CBIBS. Blue line represents the model SST without data assimilation. Green and brown lines are the model result with data assimilation using LETKF and 4DVAR, respectively.

While the 4D-Var system mostly outperformed the LETKF system in these tests, the LETKF was quicker. With 64 processors the LETKF completed a 6 hour window in approximately 1.25 hours, compared to approximately 6 hours for 4D-Var using 96 processors.

2. Finished data assimilation with daily composite AVHRR SST

The AVHRR SST data are assimilated to CBOFS at the same time periods (Aug-Nov, 2014). Generally speaking, assimilating of AVHRR SST has very close performance at most of CBIBS stations in lowering the model SST compared with assimilating of VIIRS SST. Both types of SST assimilation can significantly reduce the model biases and errors. But there exist some unreliable AVHRR data values which make the model produce too low surface temperature.

Planned work

- Finish a draft and submit iit to the *Journal of Atmospheric and Oceanic Technology*.
- Will deliver the final codes to NOAA/CO-OPS/CDL.

Products

Implementation of I4DVAR and LETKF for CBOFS.

Presentations

- ✓ Comparison of 4D-VAR and LETKF in Assimilating JPSS-derived Sea-surface Temperature in the Chesapeake Bay Operational Forecasting System (with Chris Brown etc), NOAA/NOS/COOPS, 12/04/2015
- ✓ 4DVAR and LETKF Data Assimilation for the NOAA Chesapeake Bay Operational Forecasting System, JCSDA Annual Review Meeting, College Park, 05/2015

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

*1 LETKF and I4DVAR implementation for CBOFS.
*2 See the presentation list for details.

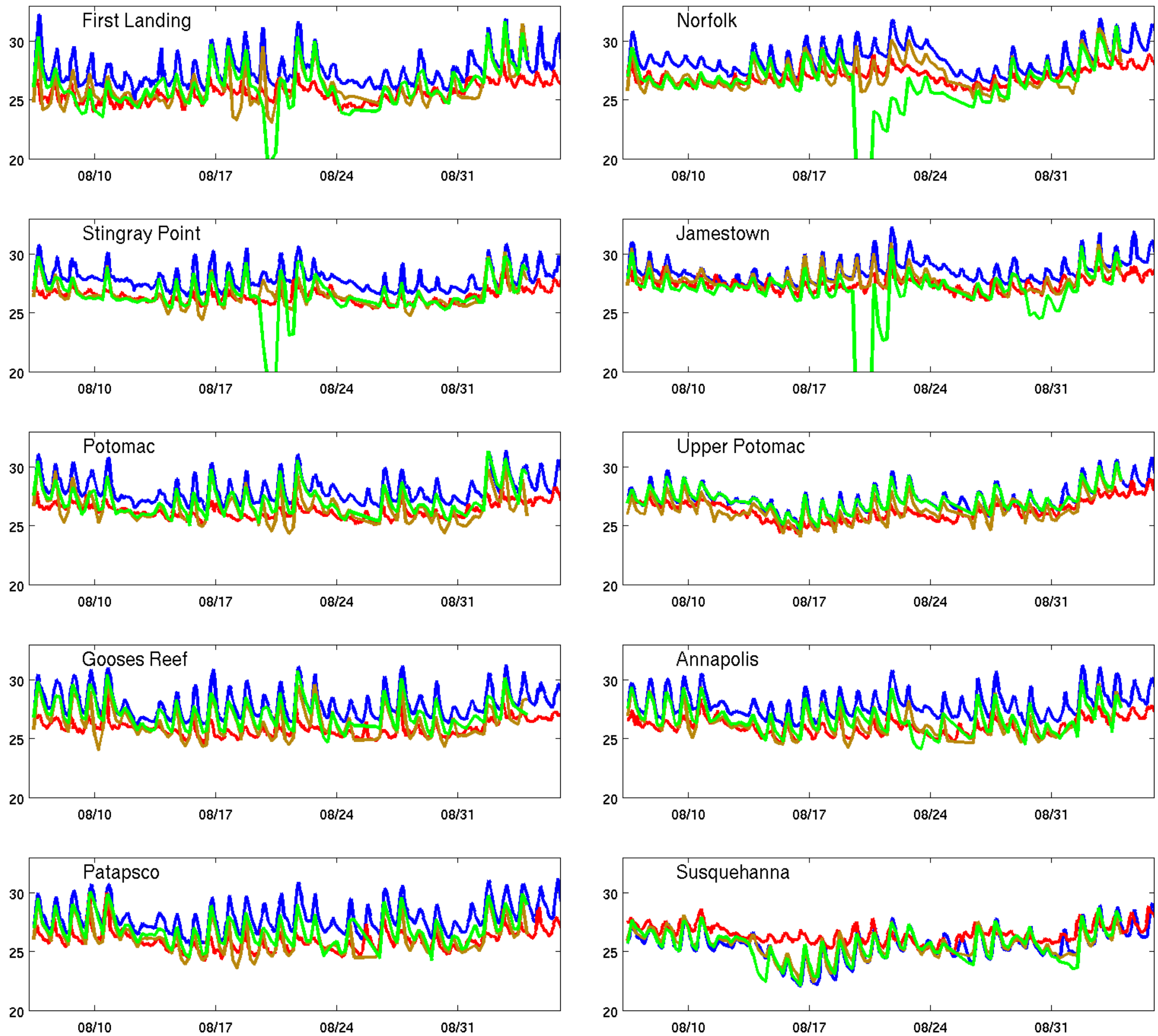


Figure 4: Comparison of SST results with assimilation of AVHRR SST, VIIRS SST and CBIBS observations. Blue line represents the forward model results. Red line is CBIBS observations. The green line is result with assimilation of AVHRR SST. The orange line is result from assimilation of VIIRS SST.

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

Task Leader	Christopher Hain
Task Code	CHCH_NCEP15
NOAA Sponsor	Xiwu Zhan
NOAA Office	NOAA/NESDIS/STAR
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 35%; Goal 2: 65%; Goal 3: 0%

Highlight:

We set up a fully coupled NASA LIS and WRF assimilation system (NU-WRF) in which EnKF DA algorithm is implemented to assimilate multiple land observations (SM and LST) into NWP model. We then tested the insertion of near real time (NRT) GVF observations into NUWRF and assessed the impact in weather forecast. We further evaluated the effectiveness of assimilating satellite SM product using EnKF technique and its impact on WRF weather forecast.

Background

With enhanced observations from the GOES-R, 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 vegeta-tion dynamics into the NCEP NAM in order to improve NAM weather forecasts.

Accomplishments

We set up a fully coupled NASA LIS and WRF assimilation system (NU-WRF) in which EnKF DA algorithm is implemented to assimilate multiple land observations (SM and LST) into NWP model. We further implemented model evaluation tools (MET) to provide verification statistics for forecasts after the assimilation of land surface variables. Based on the land data assimilation framework (NUWRF) and evaluation tool (MET), we accomplished the following tests: 1) In- gested near real time (NRT) GVF observations into WRF and assessed the impact in weather forecast; 2) Implemented EnKF data assimilation utility that will be used to directly assimilate GOES/GOES-R LST observations and LST-based ALEXI SM data; 3) Evaluated the effective- ness of assimilating SM data and its impact on WRF weather forecast. The preliminary results are presented as follows.

Assess impact of the real time GVF on weather forecasts

The average GVF differences between NRT GVF and climatology GVF are shown on the left in Figure 1, while the differences in 2m surface air temperature forecasts by using those two different GVF inputs are shown on the right. The results are physically sound as 2 m surface temperature forecast using NRT GVF increases in response to the negative anomaly compared to GVF climatology, and vice versa.

Two NUWRF runs are performed using climatology GVF and near-real-time GVF as input while other meteorological forcing parameters are kept the same. Forecasts of 2 m temperature of the two runs are validated using in situ observations (~1000 sites over CONUS domain). Compari- sons of bias and root-mean square error (RMSE) on 2 m surface air temperature between those two runs are shown in Figure 2. Mean absolute error (MAE) and RMSE over the Lower Missis- sippi Valley (LMV) sub-region are shown in Figure 3, respectively. The validation results show that the use of NRT GVF, which is more representative to the reality of surface green cover, can reduce the bias (both warm and cool bias) in model forecasts compared to the forecasts using multi-year average GVF.

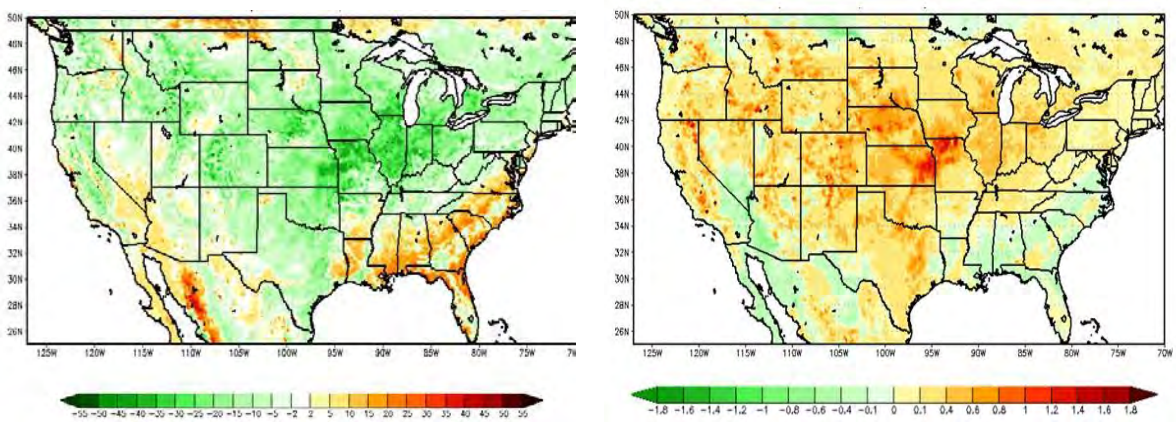


Figure 1. (left)The average GVF differences between NRT GVF and climatology; NRT minus climatolo- gy (right) Differences in 2 m surface air temperature (unit: K) at 42 forecast hour over July, 2012 by using NRT GVF and using GVF climatology (NRT minus climatology)

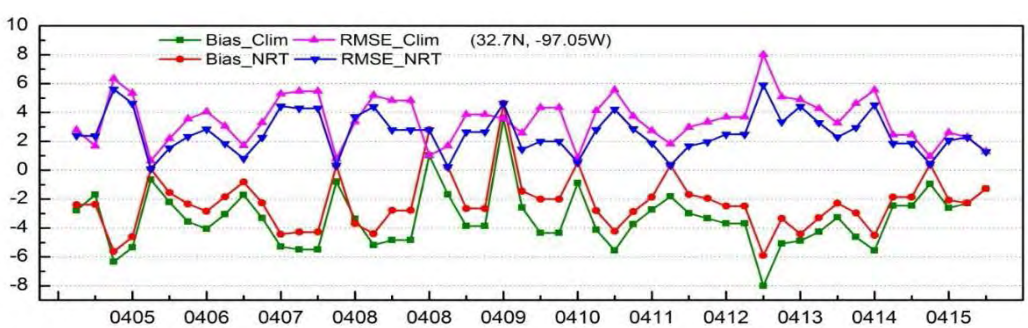


Figure 2. Bias and RMSE in 2 m surface air temperature forecast from NUWRF with NRT GVF and climatology; at (32.7N, -97.05W); over April 4th – 16th

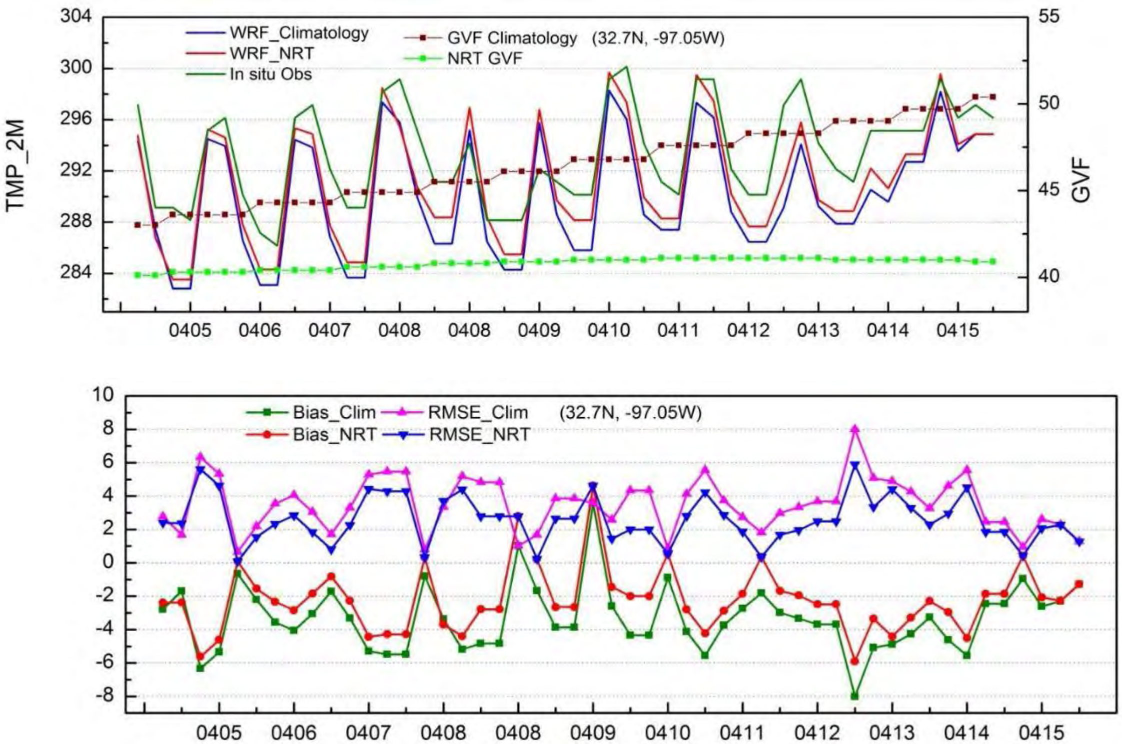


Figure 3. MAE and RMSE in 2 m surface temperature for LMV region (a) for 60h forecast on July 16th; (b) over the period of May to July

Test assimilation of GOES/GOES-R LST-based ALEXI SM data into NCEP-NAM

Similar to the NRT GVF test, two NUWRF runs are performed, one without SM data assimila- tion and the other with SM assimilation using EnKF technique, while other meteorological forc- ing parameters are kept the same. 2 m specific humility, 2 m temperature, 2 m relative humility and 2 m dew point temperature are validated using in situ observations over CONUS domain. Average RMSE of these four validation variables are shown in Figure 4. These preliminary re- sults on SM assimilation show the overall positive impact on 2 m relative humidity and tempera- ture.

The spatial distribution of time series RMSE difference in 2 m RH is shown in Figure 5 with positive values represent added value by SM assimilation. The statistics of percentage of in-situ sites with im- provement in terms of GVF level are shown in Table 1. The distribution patter illus- trated that greater impact by assimilating SM is shown over the regions with modest and low vegetation cover, while limited improvement or even slight degradation is observed over dense vegetation areas. The statis- tics also show the impact of assimilating SM product on validated variables steadily decreases as sur- face vegetation cover grows.

Finally, we tested the impact of SM data assimilation on precipitation forecast. The MAE of ac- cumu- lated precipitation at 12, 18, 24, 36 and 48 hours from May 10th to May 19th are shown in Figure 6. Positive impact has been shown on the model precipitation forecasts by assimilating CCI SM merged product into WRF using EnKF. The added value with the assimilation of CCI SM is gradually enhanced as the forecast hour moves forward.

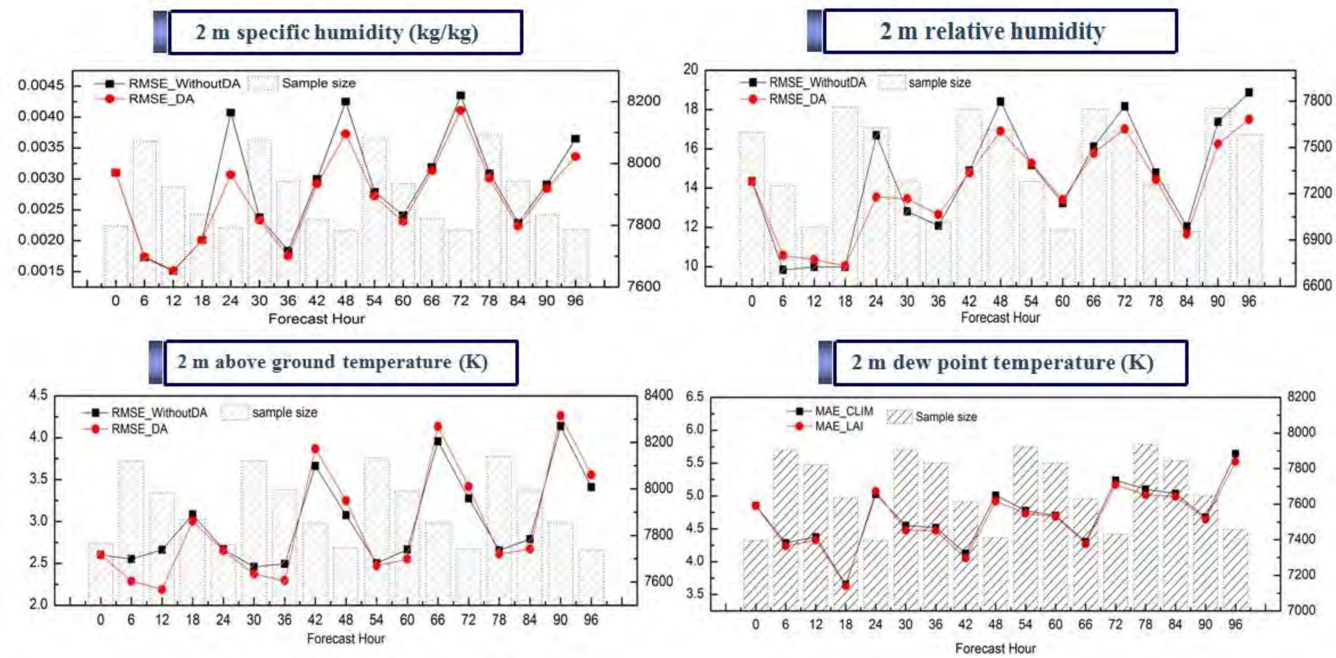


Figure 4. Average RMSE of NUWRF forecast with and without CCI SM assimilation over 96 forecast hours for 2 m specific humility, 2 m temperature, 2 m relative humility and 2 m dew point temperature

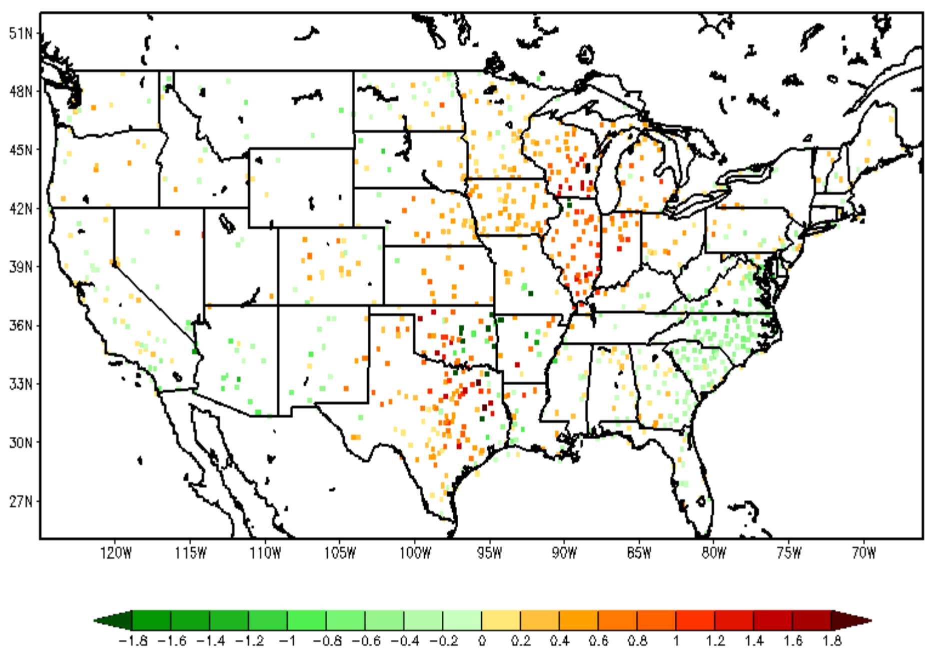


Figure 5. Spatial distribution of RMSE difference in 2 m RH (forecast without DA minus forecast with CCI SM data assimilation) over the period of May 10th to May 19th

GVF_bin	Total Sample	RH Improvement (%)	DPT (%)	SH (%)	TMP2m (%)
<20	162	60.06	65.28	62.61	48.77
20-40	297	55.88	66.31	69.44	45.45
40-60	237	51.61	58.63	64.27	37.55
60-80	214	53.57	51.86	53.59	28.97
>80	137	45.29	41.06	43.95	24.82

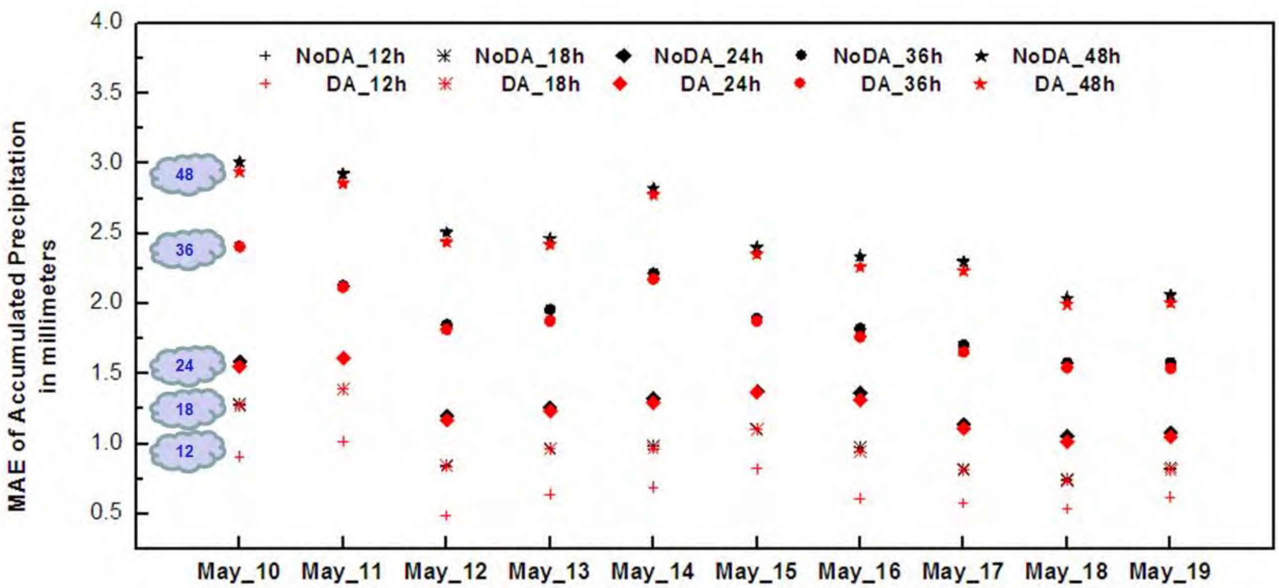


Figure 6. MAE of accumulated precipitation at 12, 18, 24, 36 and 48 hours from May 10th to May 19th

Planned Work

- Evaluate the effectiveness and efficiency of the two assimilation approaches and report data assimilation evaluation statistics;
- Collect feedbacks from NCEP NAM operations for implementation of the GOES/GOES- R LST and/or LST-based ALEXI soil moisture data assimilation (O2R).

Publications

Fang, L., C. R. Hain, X. Zhan and J. Yin, 2014: Impact of near-real-time satellite observations of solar insolation, green vegetation fraction and albedo on soil moisture estimates from the No- ah land surface model. To be submitted to J. Hydrometeor.

Fang, L., C. R. Hain and X. Zhan, 2014, Impact of GVF derivation methods on Noah land sur- face model performance. To be submitted to J. Hydrometeor.

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

Performance Metrics Explanation

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 assimi- lation utility in NAM. There are total of 2 journal papers have been prepared and ready to sub- mit.

Water Sustainability, Drought Risk and Food Security in the 21st Century – A Systematic Assessment of Climate and Competing Demands using In-situ and Satellite Data Products

Task Leader: Naresh Devineni
Task Code: CUNY_WATER_15
NOAA Sponsor: None
NOAA Office: None
Contribution to CICS Research Themes (%): Theme 1: 0%, Theme 2: 50%, Theme 3: 50%
Main CICS Research Topic: Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%): Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Highlight:
Link to a research web page:

Background

Global Droughts and Food Security: Drought has cascading impacts on the environment, economy and society. In the recent 20-30 years, vagaries of droughts have caused a number of shortfalls in the world grain production, which is a main staple food and feed. Since the 1990s, rising commodity prices and declining per capita cultivated area have led to decreases in food production, eroding food security in many communities. These shortages had pronounced negative impacts on food supply and demands, leading to food shortages. At the background of growing world population, these shortages raised serious concerns about food security. This situation requires investigation of climate constraints, especially during the warmest global time. To address this issue we are focusing on the following main goals:

- Finding cyclical trends of droughts.
- Finding the relationships between crop yields of global countries and ENSO, drought, jet streams (geo-potential height), temperature, precipitation, CO_2, technology improvement.
- Understanding the co-relationships between global food prices and production.

Droughts in the New York Area:
In recent history, the 1960s drought severely stressed water supply reliability, aquatic ecology, agriculture, and recreation across the Northeast. Impacts on fisheries during the summer low flow period have led to questions on the long-term sustainability of reservoir operating policies that are principally designed to avert the 1960s drought risk. Given the role of increasing consumptive use, rising populations throughout the urban Northeast, and the uncertainty of future climate, it is perhaps ironic that because the Northeast has not historically been the focus of national drought planning efforts, the region lacks much of the critical analytical and decision-making infrastructure that is used in more historically drought-prone regions of the U.S. This exposes an unappreciated climatic and institutional vulnerability to drought that needs immediate attention.

Accomplishments

New York Drought Project: A review of the water policy of the New York.

Since 1954, the Delaware River has been managed under the framework of a Supreme Court decree and the subsequent concomitant intergovernmental collaboration between New York State, New Jersey, Pennsylvania, Delaware, New York City (NYC) and the US federal government. Taking an environmental perspective, we reviewed the evolution of water release policies for three NYC reservoirs from the issuance of the 1954 decree through the implementation of the Flexible Flow Management Program (FFMP) of 2007-2015, and examined the policies' impact on the upper Delaware River. We described governmental and institutional constraints on the development of Delaware water policy and show how modifications of release policies have enhanced aquatic habitat and ecological health in the upper Delaware while reliably delivering water to NYC and the Delaware's other principal stakeholders. We described the development of the FFMP in 2006, its subsequent modification, and its augmentation by NYC's Operations Support Tool in 2012. Finally, we discussed the negative ecological consequences of the 2010-2016 stalemate on Delaware water policy resulting from conflicts between the decree parties about current and future water rights, and how the stalemate derives partially from the decision structure imposed by the 1954 decree and the Good Faith Agreement of 1983.

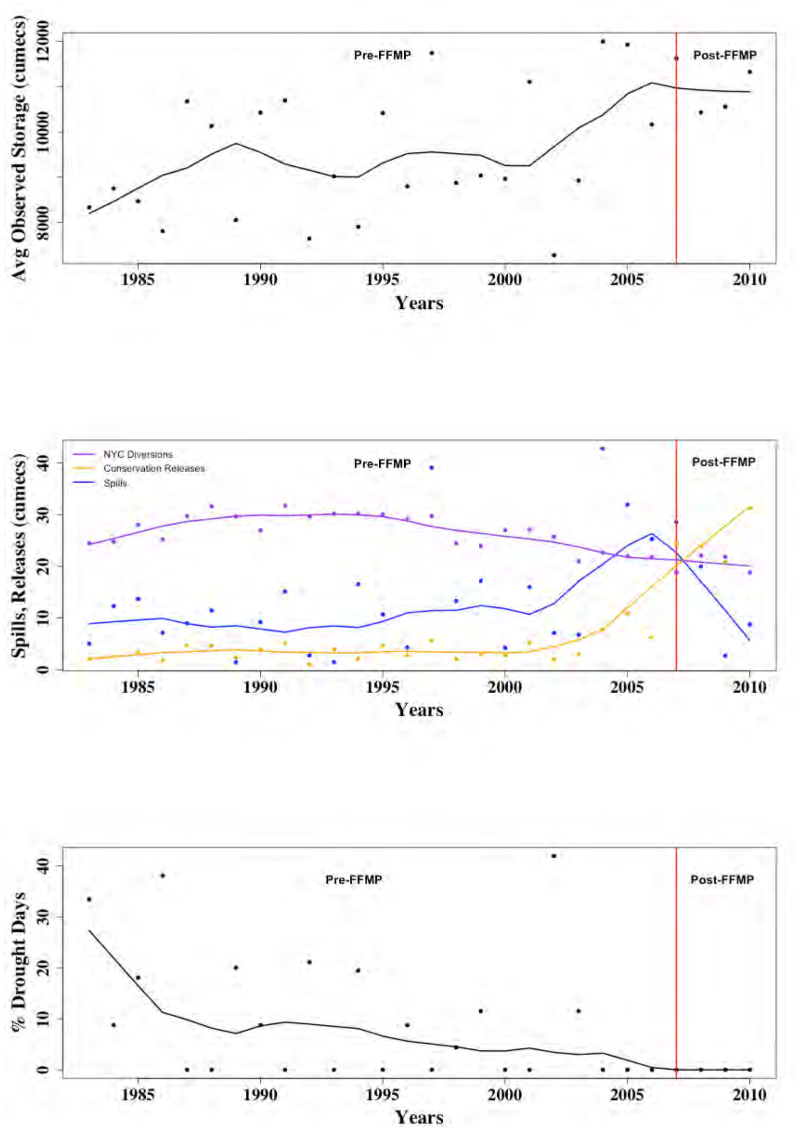


Figure Caption: From top to bottom: Figure a shows total observed average storage across the three reservoirs, for each of the twenty-eight years on record. The black line is the LOWESS-smoothed time series of the data with a smoothing coefficient of 0.3, and the black dots are the scatter plot of the actual yearly averages. Figure b shows the total NYC diversions in purple, the total conservation releases in orange, and the total (annually-averaged) spills in blue LOWESS-smoothed lines. Figure c shows the LOWESS-smoothed time series of the percentage drought days across all three of the NYC reservoirs for each of the twenty-eight years on record. Each panel includes a red line dividing the pre-FFMP and post-FFMP years to illustrate the change in trends. Note: cumecs = m^3/s.

Global Food Security Project: Interplay of drought and crops: setting platform for global food security For each year, we compute the number of countries under drought, and relate to the food production for those countries to identify how whether food production shocks can be explained by droughts. To identify other causal variables, we perform an analysis on the trend. For each country we model yield against time, PDSI for that country, ENSO index, a new Jet Stream index and CO2 emissions. We want to explain the variance in yields by technology and climate factors.
Key Figure: Are the Global extreme droughts increasing?

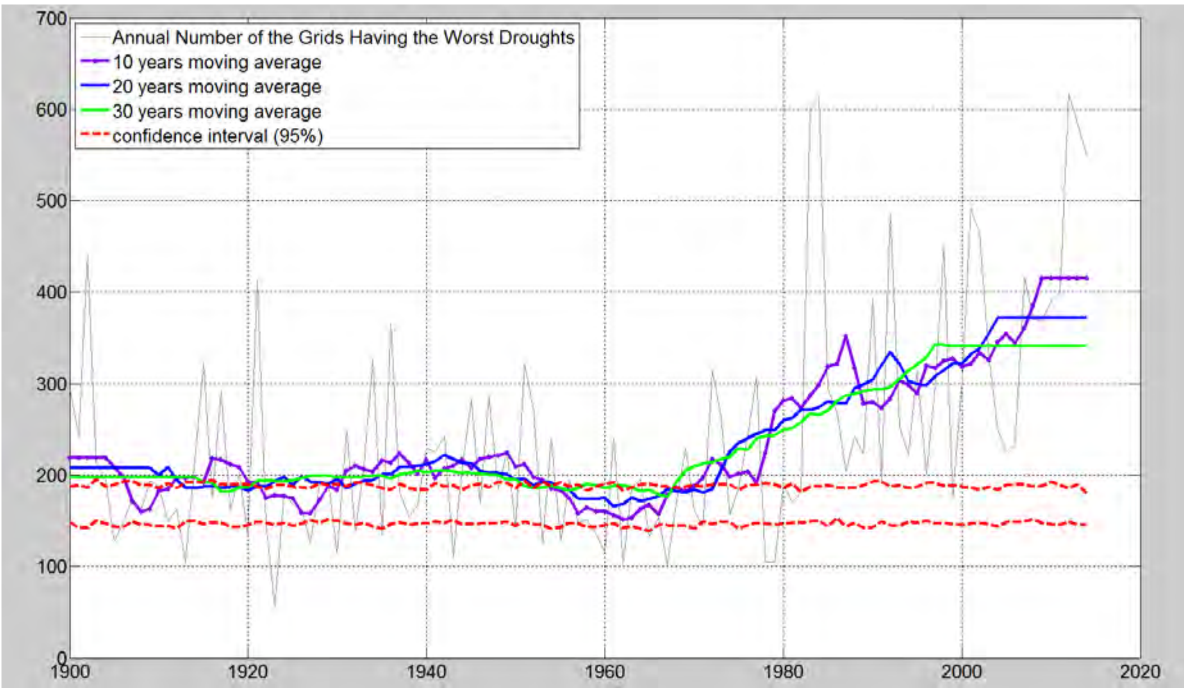


Figure: Time series of total number of grids (globally) under worst drought in history.

Planned work

- Finding a way to feed 9 billion people. How can we feed 9 billion people, minimize the cost of food and maximize the production (this problem can be studied for some major crop producer countries like US and China and then expanded globally). In each part of world how much and what crop should be planted to feed people and whether we have enough food in an year or not.
- In addition the influence of floods and wet condition on world crop production will be investigated.
- Measuring the impact of climate change on different crops on different countries.

Publications

1. A review of the water management policies of the upper Delaware River basin, Ravindranath A*, **N Devineni**, Water Policy, 2016 (accepted, under second review).

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

Two graduate students are being supported from this project. Ehsan Najafi is fully supported from this project and is working on the global droughts and food security issues. Arun Ravindranth was partially supported from this project and worked on the New York City droughts. The paper on New York City droughts is accepted in Water Policy journal. Ehsan Najafi is preparing his first paper on yield modeling for the crops.

GMU Activities in Support of FSOI Evaluation and Scientific Improvement

Task Leader	**Jianjun Xu**
Task Code	**EBJX_GMU_15**
NOAA Sponsor	**Thomas Auligne**
NOAA Office	**STAR & JCSDA**
Contribution to CICS Research Themes (%)	**Theme 1: 25%; Theme 2: 25%; Theme 3: 50%**
Main CICS Research Topic	**Climate Research, Data Assimilation and Modeling**
Contribution to NOAA goals (%)	**Goal 1: 10%; Goal 2: 80%; Goal 3: 10%**

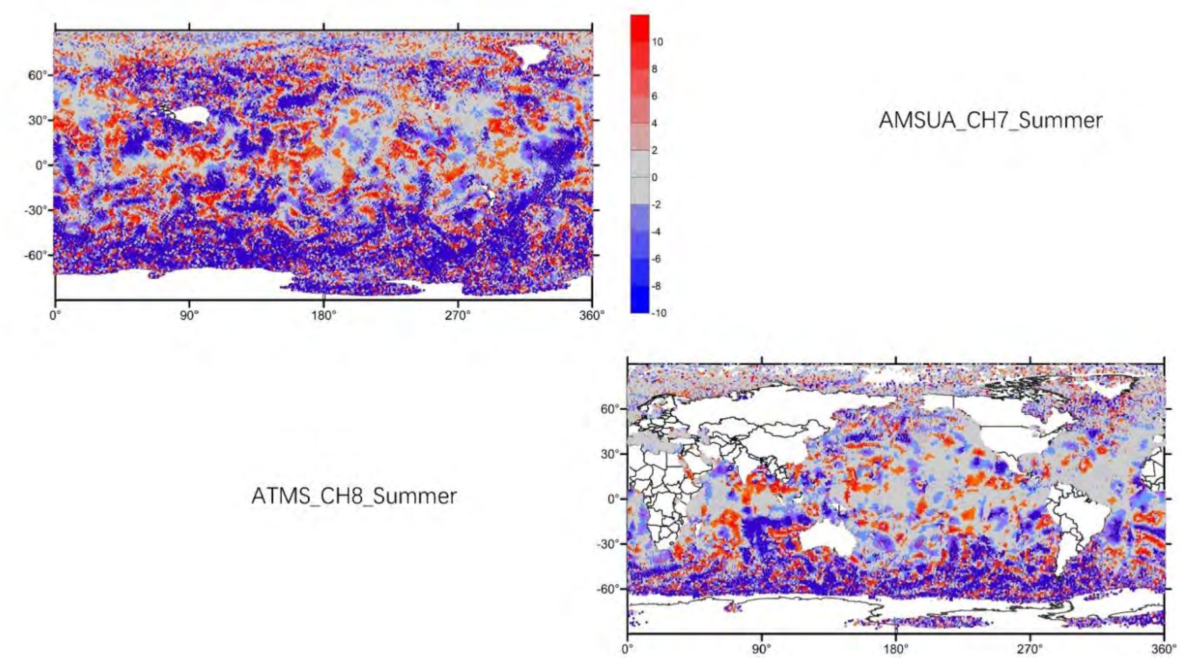
Highlight: Continuing study of satellite impacts on the weather forecasts

Link to a research web page

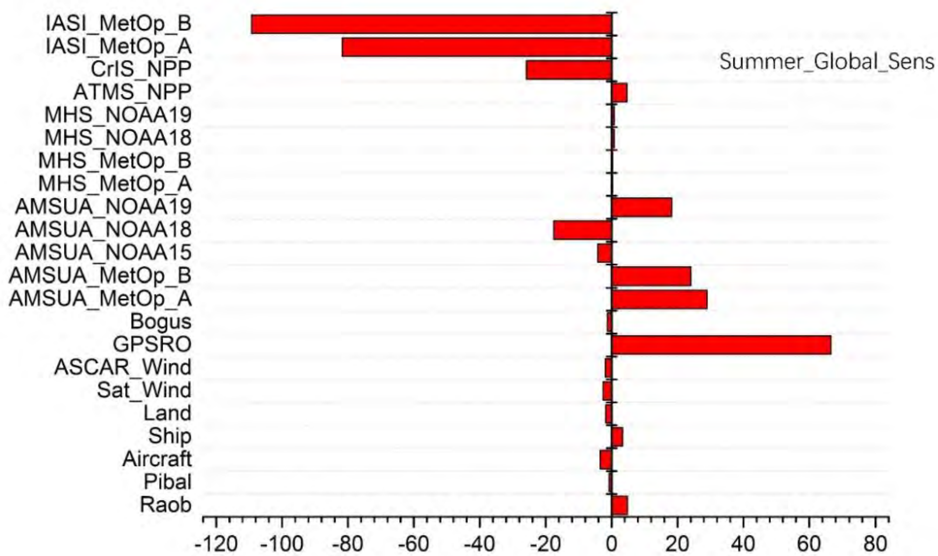
Background

Forecasts sensitivity to Observation Impacts (FSOI) is useful methodology to evaluate the impacts of satellite radiance and conventional data on the weather forecasts. The method has been used in the different weather agencies. The purpose of this project is to compare performances in different weather agencies, including GMAO, EMC, NRL, Met office and JMA.

Accomplishments



Total norm for the impacts of AMSUA channel 7 and ATMS channel 8. Based on the Figure 1, the results shows the AMSUA channel made a goof contribution to the forecasts. In contrast, the ATMS channel is worse than the contribution from AMSUA.



Impacts of radiance and conventional data assimilation on the forecasts. It clearly shows the good contribution from IASI, CrIS and AMSUA, but GPSRO is not good for the NRL systems.

Planned work

1) The five experiments from NASA, NRL, MET office, EMC and JMA has been analysis.
2) All output data has been unified with ASCII format
3) The total norm, observation number and innovation have been analyzed.

Publications

We have not yet any publications.

Products

We will finish the experiment analysis by end of May.

Presentations

The results will be presented in WMO conference in May 2016.

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

Student Support for NOAA's Climate Prediction Center

Task Leader:	E. Hugo Berbery
Task Code:	EBEB_CPC_15
NOAA Sponsor:	Mike Halpert
NOAA Office:	NWS/CPC
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%;
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 80%; Goal 2: 20%; Goal 3: 0%

Highlight: Graduate Student Katherine E. Lukens has been researching storm tracks and their influences on precipitation in the boreal winter using measures of potential vorticity. This year, her results revealed that storms produce the majority of precipitation where the storm tracks are strongest (i.e., over the oceans), while orographic effects play a significant role in the storm precipitation distribution over land.

Link to a research web page

Background

This report summarizes the research conducted from April 2015 to March 2016 by Katherine E. Lukens, GRA III with the working title, "*Storm Tracks and their Influences on Precipitation in the Boreal Winter: A Potential Vorticity Perspective*."

Katherine continued to conduct research on storm tracks and their relationships to precipitation in the Northern Hemisphere and over North America. She read the literature to inform herself of the results, methods, and background needed to explore storm tracks represented by isentropic potential vorticity, including Hoskins et al. (1985) and Hoskins 1991. Storm tracks are identified from the Lagrangian diagnostic employed by Hoskins and Hodges (2002), which has since been proven to be an accurate measure of storm track behavior when examining relative vorticity. A variety of statistics were computed to examine the characteristics of climatological storm tracks. The results of Hawcroft et al. (2012, 2015) and Zappa et al. 2015 aided her in understanding the impacts of storm tracks on precipitation in the Northern Hemisphere winter season.

Accomplishments

Under the advisement of Dr. E. Hugo Berbery, Katherine analyzed the benefits and limitations of defining boreal winter mid-latitude storm tracks by the tracking of potential vorticity anomalies at various vertical levels. Isentropic potential vorticity on the θ=320K (hereafter PV_{320}) surface provides the optimal combination of variable and methodology to illustrate storm track behavior. The Lagrangian framework allows for the direct identification of strong cyclogenesis and cyclolysis regions associated with the storm tracks. Figure 1a shows the PV_{320} storm tracks that affect North American climate: the Pacific track (PAC) and the North-American Atlantic track (NAA). The storm tracks' corresponding cyclogenesis and cyclolysis regions are shown in Figures 1b and 1c, respectively. Storms that propagate along the PAC track develop in the central North Pacific Ocean and decay along the west coast of North America. Storms that follow the NAA track develop in central North America and the northeastern United States and decay east of the continent. A region of strong cyclogenesis exists just east of Canada, coinciding with the area where Nor'easters tend to form.

Katherine determined the quantifiable influence of storm tracks on winter precipitation over North America. Influences on reanalysis precipitation from NCEP's Climate Forecast System Reanalysis (CFSR) product and observed precipitation from the Global Precipitation Climatology Project (GPCP) were analyzed. The results reveal that storms produce the majority of precipitation where the storm tracks are strongest (i.e., over the oceans), while orographic effects play a significant role in the storm precipitation distribution over land. Figure 2a shows the observed climatological precipitation produced by storms, and Figure 2b shows the percentage of the total observed precipitation that the storms produce. Both tracks produce about 50% of the total precipitation over the respective oceans. The PAC track yields 50-60% of the total observed precipitation in western North America, and the NAA track produces 60-70% in eastern North America.

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

Planned Work

- Publish results of potential vorticity storm tracks and related precipitation analyses.
- Examine global winter storm tracks and their influences on precipitation.
    - How do austral winter storm track behaviors and influences compare to those in the boreal winter?
- Analyze the behaviors of anticyclone tracks in the Northern and Southern Hemisphere winters.
    - Do persistent blocking disturbances contribute to the durations and intensities of drought-like conditions?
- Conduct CFSv2 retrospective forecast analyses on boreal winter storm tracks and their effects on North American precipitation.
    - How far in advance can we predict storm track changes and corresponding precipitation changes with relative confidence?

Publications

- *Peer reviewed*
    - In preparation:

      Lukens, K. E., and E. H. Berbery, 2016: Storm tracks and their influences on precipitation in the boreal winter – a potential vorticity perspective.
- *Non-peer reviewed*
    - Publication:

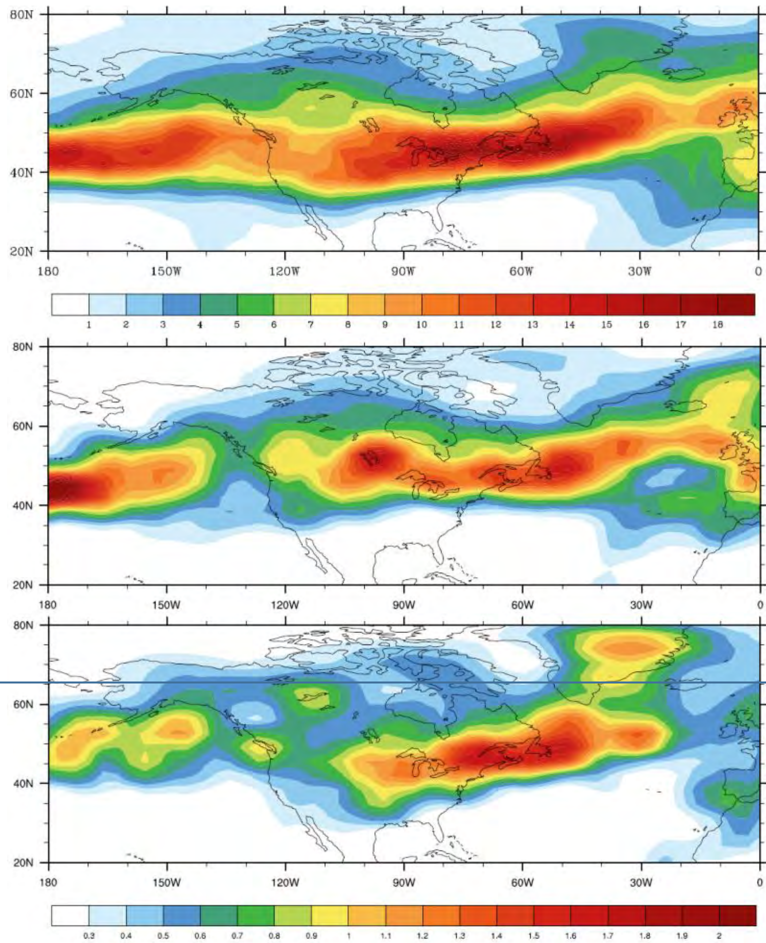
      Lukens, K. E., and E. H. Berbery, 2015: Boreal Winter Storm Tracks and Related Precipitation in North America. *CICS-MD Circular,* Dec. 2015. *Available online:* < http://cicsmd.umd.edu/assets/1/7/Dec_2015_Circular.pdf >

      Online Publication of Master of Science Scholarly Paper:

      Lukens, K. E., 2015: On the Relation Between Storm Tracks and North American Precipitation in the Boreal Winter. *Available online*: < www.atmos.umd.edu/theses_archive/ >

b)

c)



a)

Fig. 1: DJF storm tracks derived from potential vorticity anomalies at θ=320K. (a) Storm track density, (b) cyclogenesis density, and (c) cyclolysis density.

Units for each plot are number

b)

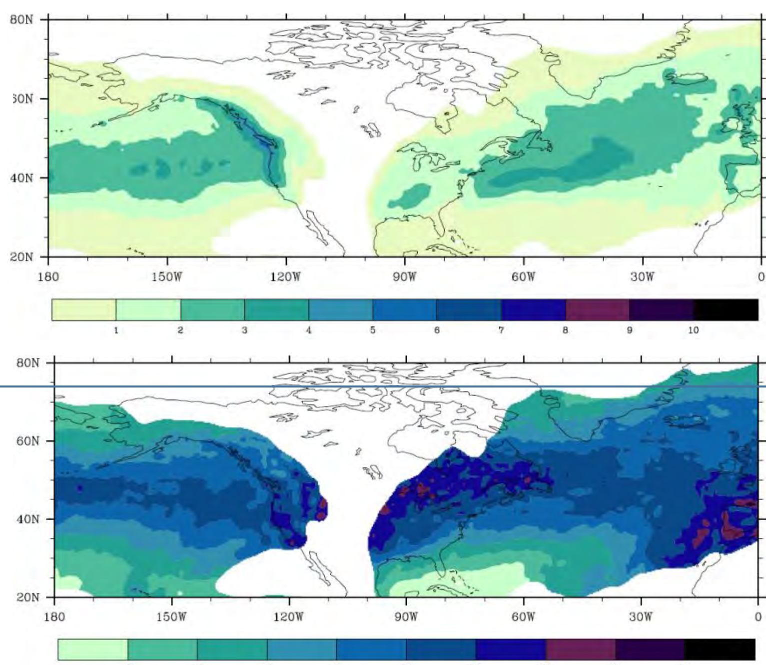


Fig. 2: DJF precipitation analyses.

(a) GPCP precipitation produced by storms with a contour interval of 1.0 mm day^{-1}, and (b) ratio of total GPCP precipitation produced by

Presentations

Lukens, K. E., and E. H. Berbery, 2016: Boreal Winter Storm Tracks and Associated Precipitation in North America: A Potential Vorticity Perspective (oral), *96th AMS Annual Meeting*, New Orleans, LA, 10-14 January 2016.

Lukens, K. E., and E. H. Berbery, 2015: Boreal Winter Storm Tracks and Associated Precipitation in North America: A Potential Vorticity Perspective (oral), *4th Annual CICS-MD Science Meeting,* College Park, MD, 23-24 November 2015.

Lukens, K. E., and E. H. Berbery, 2015: On the relation between storm tracks and North American precipitation in the boreal winter (oral), *Annual Joint GWU-JHU-UMD Students/Postdoc Showcase Research Symposium on Environmental and Applied Fluid Dynamics*, George Washington University, Washington, D.C., 26 May 2015.

Other

- Advanced to Candidacy by successful completion of the Candidacy Qualifying Examination, Part II (Dissertation Prospectus/Oral Examination) in January 2016.
- Obtained Master of Science in Atmospheric and Oceanic Science in May 2015.

References

Hawcroft, M. K., L. C. Shaffrey, K. I. Hodges, and H. F. Dacre, 2012: How much Northern Hemisphere precipitation is associated with extratropical cyclones? *Geophys. Res. Lett.,* **39,** L24809.

Hawcroft, M. K., L. C. Shaffrey, K. I., Hodges, and H. F. Dacre, 2015: Can climate models represent the precipitation associated with extratropical cyclones? *Clim. Dyn.*, 1-17, doi: 10.1007/s00382-015-2863-z.

Hoskins, B. J., M. E. McIntyre, and A. W. Robertson, 1985: On the use and significance of isentropic potential vorticity maps. *Quart. J. Roy. Meteor. Soc.,* **111,** 877-946.

Hoskins, B. J., 1991: Towards a PV-θ view of the general circulation. *Tellus,* **43AB,** 27-35.

Hoskins, B. J., and K. I. Hodges, 2002: New Perspectives on the Northern Hemisphere Winter Storm Tracks. *J. Atmos. Sci.* **59,** 1041-1061.

Zappa, G., M. K. Hawcroft, L. Shaffrey, E. Black, and D. J. Brayshaw, 2015: Extratropical cyclones and the projected decline of winter Mediterranean precipitation in the CMIP5 models. *Clim. Dyn.*, 1-12, doi: 10.1007/s00382-014-2426-8.

Science Support for Mesoscale Data Assimilation at EMC & JCSDA

Task Leader	Xiaoyan Zhang
Task Code	EBXZ_MDA2_15
NOAA Sponsor	Steven Goodman/Geoff DiMego
NOAA Office	GOES-R Program
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%)

Highlight: The assimilation of overcast SEVIRI water vapor channel radiance has been optimized and well tested in NCEP data assimilation system. The month-long global assimilation experiments have been set up to investigate the forecast performance of SEVIRI radiance data towards to merge this new function into GSI trunk code. Cloud affected Infrared brightness temperature of 12-km NAM model/CRTM has been initially visited comparing with SEVIRI cloudy product.

Background

The primary tasks of this project were focused on the development and testing of the ability to assimilate cloudy radiances from GOES-R, and investigate the potential to improve the numerical prediction of high impact weather. Before GOES-R is launched, radiance data from Meteosat Second Generation (MSG) SEVIRI was used as a proxy for the GOES-R data to be assimilated in NCEP's mesoscale data assimilation systems. Because of this, the NAM domain was placed over Africa and the Atlantic Ocean to be consistent with the coverage of the SEVIRI data. This also allowed research to be done on high impact weather events over Lake Victoria where it is likely other observational assets will be deployed in a future field program. The proposed effort is highly relevant to the GOES-R program because both code developed and knowledge gained while assimilating real SEVIRI observations in NCEP's mesoscale data assimilation systems should be transferable to assimilating real GOES-R ABI observations when they become available due to their similar spectral and spatial characteristics.

Accomplishments

There are several major accomplishments made during the prior year that are described in greater detail in this section. All-sky radiances (ASR) from Meteosat-10 SEVIRI have been assimilated into the NCEP North American Mesoscale Rapid Refresh system (NAMRR, https://ams.confex.com/ams/27WAF23NWP/webprogram/Paper273567.html), which uses the Nonhydrostatic Multiscale Model on the B grid along with the Gridpoint Statistical Interpolation data assimilation system. Work began with the assimilation of cloud-affected radiances for restricted conditions, such as overcast scenes. EUMETSAT SEVIRI ASR products have also been received in near real-time by NCEP/EMC. The hourly data assimilation and forecast system for Lake Victoria has been updated with the latest NAMRR version. The current version of NAMRR for Lake Victoria features the 3-d hybrid data assimilation cycle, and self-contained workflow management system – Rocoto. Work is ongoing to verify high resolution model forecast cloud fields with SEVIRI all-sky brightness temperature by using GSI. This is accomplished by passing the NAMRR model forecasts through the Community Radiative Transfer Model (CRTM) within the GSI to simulate SEVIRI infrared brightness temperatures for comparison against observed SEVIRI brightness temperatures. In addition to the work with NAMRR, a month-long GSI global run was performed to assimilate SEVIRI overcast cloudy infrared brightness temperatures from the 6.2 and 7.3 µm channels that are sensitive to clouds and water vapor in the middle and upper troposphere.

System Development for Assimilating SEVIRI Cloudy Radiances

This scheme developed by NASA/GMAO in GSI to directly assimilate cloud-affected AIRS infrared radiances from the polar orbiting satellite Aqua was extended to make use of the overcast radiances from SEVIRI. Several code developments have been made which include: properly reading in the EUMETSAT SEVIRI ASR products in GSI; computing the SEVIRI zenith angle which is not currently contained in ASR products; quality control for overcast SEVIRI data; testing the cloud detection scheme with different channels, as well as in radiance space (rather than brightness temperature). The other most recent development is simulating SEVIRI infrared brightness temperature in cloudy conditions by including cloud liquid water and cloud ice water, rain, snow, hale and graupel as additional inputs to the CRTM in GSI. This allows validation of the high resolution NAMRR model forecasted cloud fields, and is the first step towards assimilation of infrared brightness temperatures in all-sky conditions in the near future.

Experiments

After implementing the assimilation of overcast SEVIRI radiances in the GSI, several assimilation experiments were performed to assess the impact of the overcast SEVIRI observations on the analysis accuracy and the sensitivity of the results with both NAMRR for the Africa system and the NCEP global system. The global assimilation experiments were initiated at 00 UTC on 01 November 2015 and run for 30 days with observations assimilated at 6 hour intervals. There are two on-going global experiments: one is using the same observations as current NCEP operations but replaces clear-sky SEVIRI radiance data from the CSR products with those from the ASR products; the other adds the overcast cloudy SEVIRI radiances to this baseline. As these experiments are still running, results are not yet available.

For the NAMRR over Africa, the experiments focused on a case study. A series of sensitivity experiments for NAMRR were performed, which included a sensitivity test for separately assimilating high, middle, low cloud, as well as assimilating all overcast cloudy SEVIRI radiances; a sensitivity test for different data thinning meshes; a sensitivity test for initializing the bias correction from the global bias values or from zero. Those experiments helped inform the decision on how to use SEVIRI overcast radiances properly. Assimilation of SEVIRI clear-sky radiance data made the wind at 400mb and 850mb stronger than without SEVIRI data for Lake Victoria storm (figure 1). However, the overall performance of assimilating SEVIRI clear-sky radiance only and both clear-sky and overcast radiance are similar

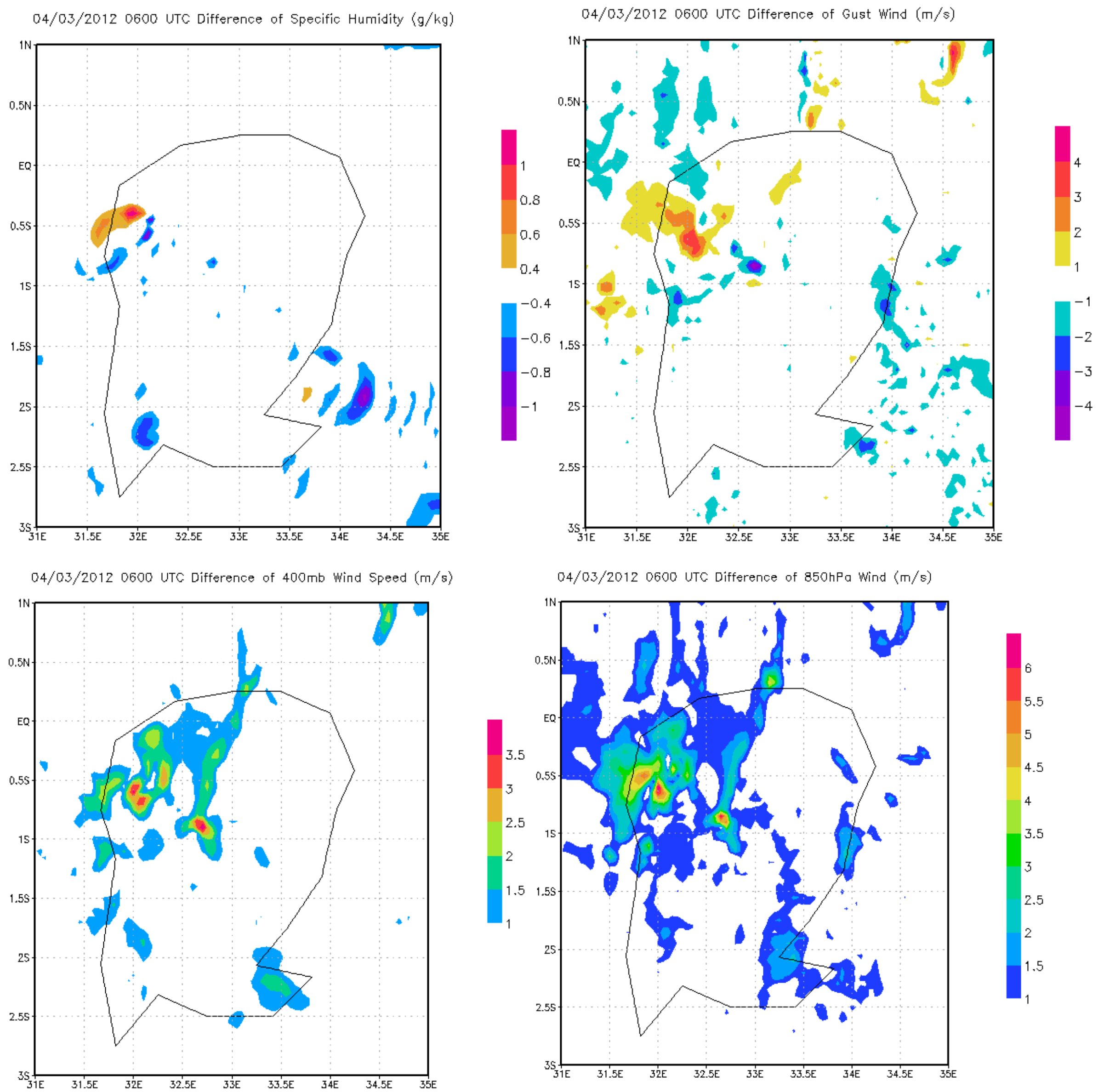


Figure 1: The difference of 6-hour model forecast with and without assimilation of SEVIRI clear sky brightness temperature for (upper left) specific humidity at 400 mb; (upper right) gust wind; (lower left) wind speed at 400 mb, and (lower right) wind speed at 850 mb).

<u>New investigation</u>

The work of validating the high resolution NAMRR model forecasted cloud with SEVIRI all-sky brightness temperatures has been initially started. SEVIRI infrared brightness temperatures for the water vapor and window channels has been simulated for each NAMRR model forecast cycle using the Community Radiative Transfer Model (CRTM) implemented in NCEP data assimilation system (Grid-point Statistical Interpolation). The model's output of cloud mixing ratio profiles of cloud liquid water, ice water, snow, rain, hail, and graupel have been used to simulate the SEVIRI infrared brightness temperature in all-sky conditions at SEVIRI observed point. By comparing these model simulated fields with the observed SEVIRI all-sky radiances, the 12-km model is able to identify the accuracy of model forecast of convective cloud, but it can not precisely describe the coldest brightness temperatures along the equator associated with particularly deep convection (figure 2). That means the model under-predict the convective intensity and not putting enough ice aloft at very high levels, or are the assumed properties of the ice (like its effective radius) poorly handled. Therefore, the different microphysics parameterizations is necessary to be tested to define the convective cloud of Lake Victoria storms.

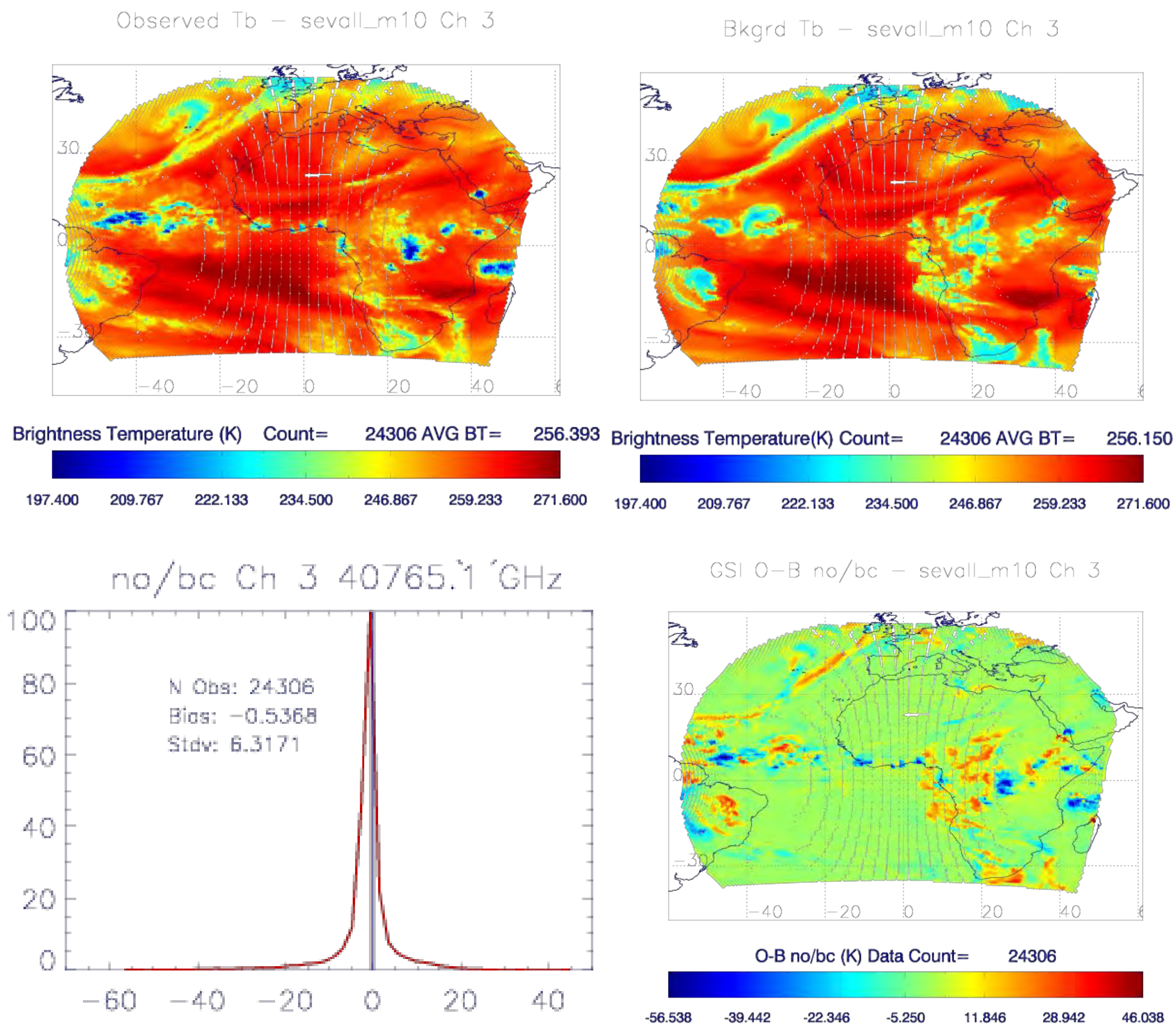


Figure 2: SEVIRI 7.3 um water vapor channel brightness temperature from (upper left) EUMSAT SEVIRI ASR product, (upper right) 12-km NMMB model simulated, (lower right) histogram of observed brightness temperature minus model simulated brightness temperature; (lower left) difference of the observed and model simulated brightness temperature.

Planned work

In the next year, the first item to be completed is to summarize the global run and merge the completed code into the GSI trunk. The most important work will be focused on reporting the current accomplishments in a formal report or publication. It will include the introduction of assimilation of SEVIRI overcast cloudy radiance in GSI, and the Lake Victoria storm forecast with NCEP's NAMRR system. Work will also be continued to validate the high resolution NAMRR model forecasted cloud with SEVIRI all-sky brightness temperatures and to start investigations into direct assimilation of these data.

Presentations

Xiaoyan Z., A. Collard and G. DiMego, 2015: **Assimilation of SEVIRI Radiance Data in NAMRR System over Africa Region, JCSDA workshop,** College Park, Maryland - May 13 - May 15, 2015

Xiaoyan Z., A. Collard and G. DiMego, 2015: **Assimilation of SEVIRI Radiance in NCEP NAMRR System,** ***AMS 27WAF23NWP,*** Chicago 29 June - 3 July 2015

Xiaoyan Z., A. Collard and G. DiMego, 2015: **Assimilation of SEVIRI Radiance in NCEP NAMRR System**, ***2015 EUMETSAT Conference,*** *Toulouse France 21-26 September 2015*

Xiaoyan Z., A. Collard and G. DiMego, 2015: **Assimilation of All-sky SEVIRI Radiance Data in NCEP Hourly-update NAM System, ITSC-20,** Lake Geneva, Wisconsin 28 October-3 November 2015

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

Warm Anomalies in the Nordic Seas and the Role of Oceanic and Atmospheric Circulation

Task Leader James Carton (Leon Chafik)
Task Code JCLC_WANS_15
NOAA Sponsor Paul DiGiacomo and Laurence Miller
NOAA Office STAR/SOCD/OPB
Contribution to CICS Research Themes (%) Theme 1: 10%; Theme 2: 30%; Theme 3: 60%
Main CICS Research Topic Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%) Goal 1: 60%; Goal 2: 40%
Highlight 1) Resolving the flow of Atlantic water from satellite altimetry and the transit time for warm anomalies to reach the Fram Strait (Chafik et al. 2015, JGR). These results were presented at AGU (invited talk), conferences and national as well as international institutes. 2) The response of the global ocean circulation and ENSO to a high-latitude volcanic eruption (Pausata et al. 2015, PNAS).

Background

For the first time, the flow of Atlantic water in the Nordic Seas and all the way to the Fram Strait is resolved. This is done by developing a method from satellite altimetry. This along-stream flow allowed us to look into the dynamical mechanisms driving the current transport toward the Barents Sea and Arctic Ocean. Furthermore, combining transports from altimetry and hydrography, we were able to infer the transit time it takes for warm anomalies to reach the Fram Strait, which is of valuable for predictions of Arctic sea-ice.

Large volcanic eruptions can have major impacts on global climate, affecting both atmospheric and ocean circulation. In this work, published in PNAS, we investigated the response of the ocean circulation and ENSO to a high-latitude volcanic eruption. Our results highlight the potential for large high-latitude eruptions to affect global climate through long-lasting changes in ocean circulation and heat content beyond the lifetime of the injected stratospheric aerosols. It also provides new insights for a better understanding of volcanic impacts on ENSO variability. In general, our results suggest that multidecadal changes in the AMOC—owing to either natural internal or forced (e.g. volcanic eruptions) variability—may modulate ENSO statistics for several decades into the future.

Accomplishments

In **Chafik et al. 2015 (JGR: Oceans)**, we developed a novel method from altimetry to calculate the transport along the Norwegian Atlantic slope current up to Fram Strait (Figure 1). We also investigated how temperature anomalies propagate in the Nordic Seas toward the Arctic (Figure 2). These results suggest that hydrographic anomalies both upstream from the North Atlantic, and locally generated in the Norwegian Sea, are important for the oceanic heat and salt transport that eventually enters into the Arctic.

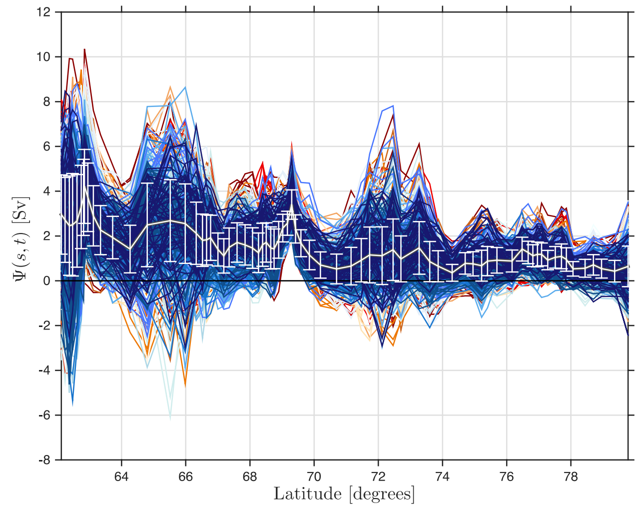


Figure 4: The transport proxy along the Norwegian Atlantic slope current as a function of latitude as calculated from satellite altimetry. The thin colored lines represent the raw weekly transport between 1992 and 2012. The gray line is the time-mean transport and the associated vertical bars indicate the spread.

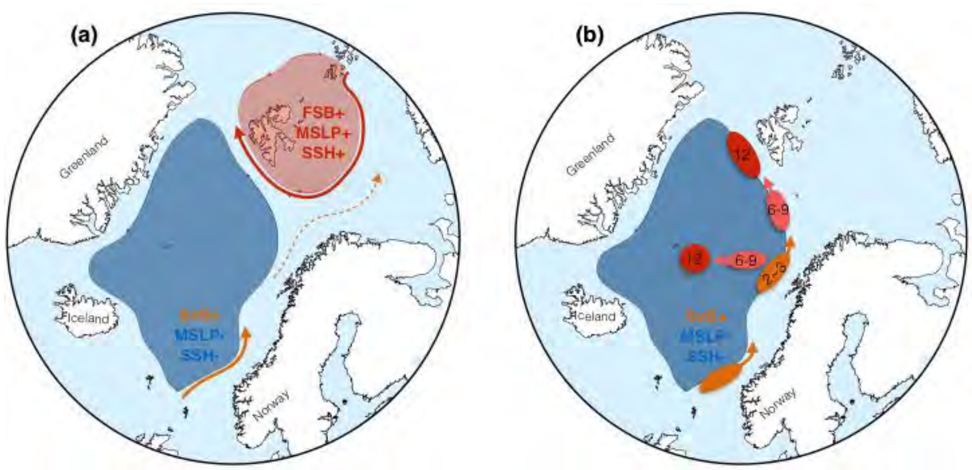


Figure 2: Schematic diagrams of the main findings (a) Different mean sea level pressure patterns driving the ocean current linking the Atlantic to the Arctic. (b) Transit time in months (numbers) of temperature anomalies propagating toward the Arctic.

In **Pausata et al. 2015 (PNAS)**, we found that large high-latitude volcanic eruptions have global and long-lasting effects on climate, altering the spatiotemporal characteristic of the El Niño–Southern Oscillation (ENSO) on both short (<1 year) and long timescales and affecting the strength of the Atlantic Meridional Overturning Circulation (AMOC). In the first 8–9 months following the start of the eruption, El Niño-like anomalies develop over the equatorial Pacific (Figure 3). The large high-latitude eruptions also trigger a strengthening of the AMOC in the first 25 years after the eruption, which is associated with an increase in ENSO variability (Figure 4). This is then followed by a weakening of the AMOC lasting another 30–35 years, associated with decreased ENSO variability.

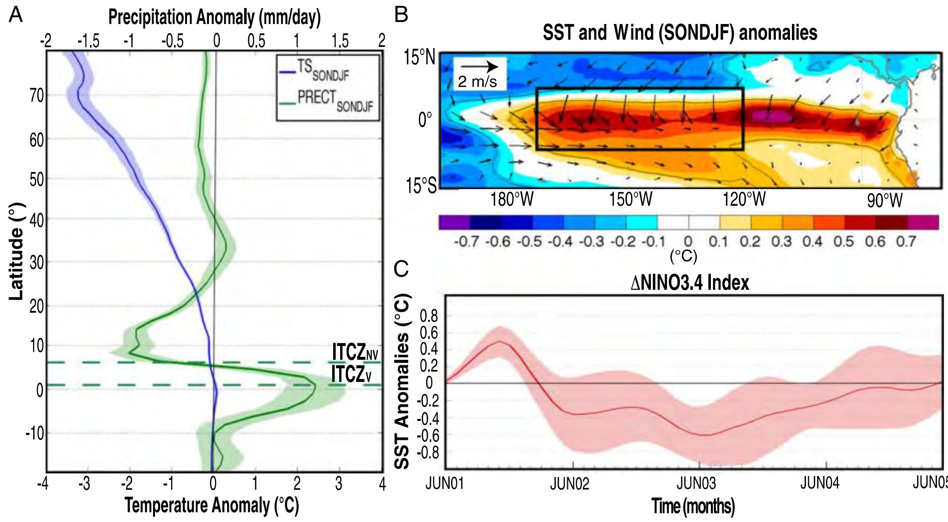


Figure 3: Temperature, precipitation and wind anomalies following the eruption. (A) Ensemble average change (ensemble simulations with minus without volcano) in the zonal-mean surface temperature (blue) and precipitation (green) over the Pacific basin (150°E to 90°W), for the period 4–9 months following the start of the eruption (September to February). Shading shows the approximate 95% confidence intervals (twice the SEM) of the change seen in all 20 pairs of experiments. The bold green dashed lines show the ensemble-averaged position of the ITCZ in the no-volcano and volcano simulations. (B) Ensemble average changes in near-surface wind (arrows) and SST (shading) 4–9 months following the start of the eruption. The box shows the Nino3.4 area. (C) Ensemble average changes in Nino3.4 index due to the eruption.

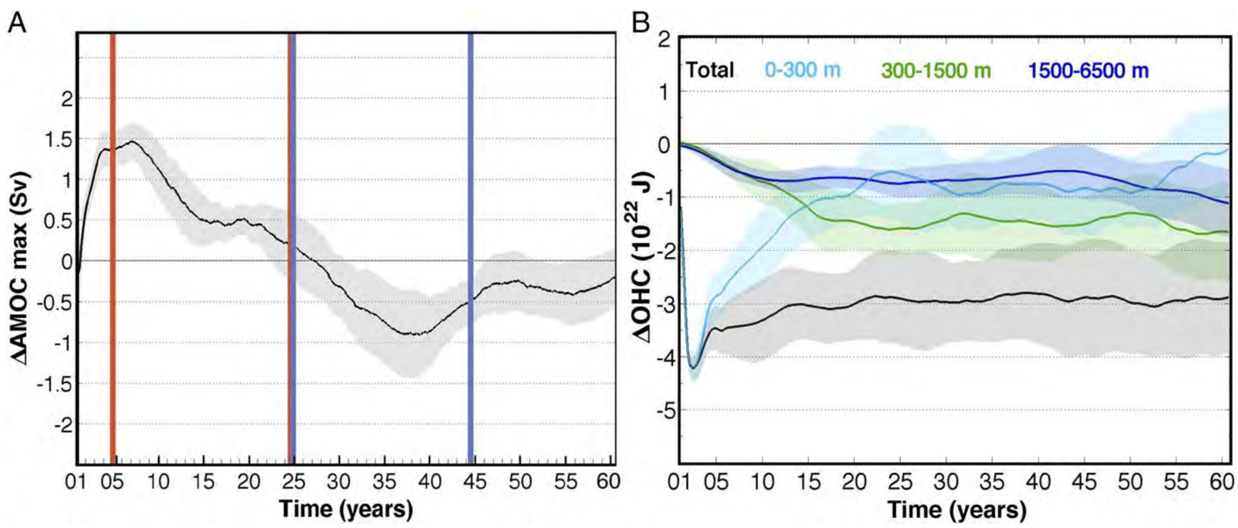


Figure 4:: AMOC index and integrated OHC differences between ensemble mean simulations with and without volcanic eruption. (A) Long-term changes in the AMOC, as indicated by the change in the maximum of the overturning stream function (in Sverdrup). (B) Ensemble average change in OHC (in joules) averaged from the surface to selected depths for the global ocean. Solid lines denote the ensemble average change, and shading represents the standard deviation of the ensemble difference.

Planned work

- Investigation of Atlantic water variability and its global oceanic and atmospheric linkages. Manuscript is currently in preparation will be submitted during summer 2016.

- Examination of Atlantic water variability in CMIP5 models and how well they compare with observations. This work is initiated and data analysis is underway.

Publications

2016

Chafik, L., Häkkinen, S.: Origin of the Warming Hole: A Precursor of Atlantic Multidecadal Regime Shift, *submitted.*

Francesco S.R. Pausata, Qiong Zhang, Francesco Muschitiello, Zhengyao Lu, Léon Chafik, Eva M. Niedermeyer, J. Curt Stager, and Zhengyu Liu: Greening of the Sahara suppressed ENSO variability during the Mid-Holocene*, submitted.*

Søiland, H., Chafik, L., and Rossby, T.: On the Long-term Stability of the Lofoten Basin Eddy*, under review in JGR: Oceans.*

Tongmei Wang, Qiong Zhang, Léon Chafik, Stefan Lossow, Camille Risi, Donal Murtagh: Dynamical and chemical stratospheric processes revealed by stable water isotope measurements from Odin/SMR, *under review in JGR: atmospheres.*

2015

Chafik, Nilsson, Ø. Skagseth, and Lundberg (2015), On the flow of Atlantic water and temperature anomalies in the Nordic Seas toward the Arctic Ocean, *Journal of Geophysical Research: Oceans*, doi:10.1002/2015JC011012.

Pausata, F. S., **L. Chafik**, R. Caballero, and D. S. Battisti (2015), Impacts of high-latitude volcanic eruptions on ENSO and AMOC, *Proceedings of the National Academy of Sciences*, *112*(45), 13784–13788, doi:10.1073/pnas.1509153112. [online] Available from: http://www.pnas.org/content/112/45/13784.short

Presentations

Talk at John Hopkins University, MD, USA, 2016: "On the Flow of Atlantic Water and Temperature Anomalies in the Nordic Seas toward the Arctic"

Talk at National Oceanographic Data Centre, Silver Spring, MD, USA, 2016: "On the Flow of Atlantic Water and Temperature Anomalies in the Nordic Seas toward the Arctic"

Invited talk at the American Geophysical Union, San Francisco, 2015 in the session "Advances in altimetry of the Polar Regions"

Poster presentation at the Ocean Surface Topography Science Team Meeting, Reston, Virigina, 2015: ''Atlantic Water Transport and Temperature Anomalies through the Nordic Seas Toward the Arctic Ocean"

Poster presentation at the 9th Coastal Altimetry Workshop, Reston, Virginia, 2015: ''On the Lofoten Basin and its Permanent Eddy"

Invited talk at Stockholm University, Sweden, 2015: "Atlantic Water Variability in the Subpolar North Atlantic Ocean"

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of non-peered reviewed papers	**0**
# of invited presentations	**4**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

Observing System Simulation Experiments (OSSEs) In Support of JCSDA's Contribution to NOAA's Future Observing Systems

Task Leader	Kayo Ide
Task Code:	KIKI_NFOS_15
NOAA Sponsor:	Dr. Sid Boukabara
NOAA Office:	JCSDA
Contribution to CICS Research Theme (%):	1 (35%) + 2 (35%) + 3 (30%)
Main CICS Research Topic:	Climate Research, Data Assimilation and Modeling
Contribution to NOAA Goals:	1 (50%) + 2 (50%)

Report: This project is part of the effort to support JCSDA's contribution through Observing System Simulation Experiments (OSSEs). It is a close follow-up of the project supported by the Sandy Supplemental funds to be expired at the end of April 2016. We are currently focusing on the Sandy part of the effort, and this project will start as soon as the Sandy funds ends, i.e., May 2016. We will conduct OSS experiments to determine the impact of Geo-Infra red, microwave, and radio occultation on the global numerical weather prediction.

Graduate Student Support: ENSO-related Precipitation in Recent Reanalyses and CMIP5 Models

Task Leader Phillip Arkin/Fernando Miralles Wilhelm (Ni Dai)
Task Code PAND_BASE_15
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 5. Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%) Goal 1: 100%; Goal 2: 0%; Goal 3: 0%
Highlight CMIP5 models are able to simulate similar mean states and seasonal evolutions of ENSO-related precipitation as recent precipitation reanalyses, though the biases in the CMIP5 models precipitation climatology such as dry equator, "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.
Link to a research web page N/A

Background

This task started from 2013 and is a major part of my PhD degree research. The goal of this task is to investigate El Niño/Southern Oscillation (ENSO) and the related precipitation biases in current state-of-the-art general circulation models (GCMs). ENSO is the most significant interannual climate phenomenon, and is associated with large-scale changes in sea surface temperature (SST), surface pressure and atmospheric circulation. As a result, ENSO is the single most important determinant of variability in global precipitation fields on seasonal to interannual time scales. It is important to understand and predict ENSO and ENSO-related precipitation due to its association with environmental and societal problems in many populated regions. However, since ENSO is associated with complex atmosphere-ocean coupling, it is still difficult for models to accurately simulate its behavior, as well as the related precipitation. The Coupled Model Intercomparison Project Phase 5 (CMIP5) (Taylor et al. 2012) collects most of the current state-of-the-art GCMs and provides excellent opportunities to compare inter-model diversity of ENSO-related precipitation variability and to further understand ENSO. The objectives for this task include:

- To examine the ability of the CMIP5 models in simulating mean states and variabilities of ENSO-related precipitation
- To study how ENSO-related precipitation changes during the 20th and 21st century;
- To investigate how the model biases of precipitation mean states and atmospheric/oceanic circulations affect the ENSO-related precipitation biases in the CMIP5 models.

In the past years, this research focused on comparing the 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. Precipitation climatology, Empirical Orthogonal Function (EOF), ENSO-related precipitation composites based on SST-constructed ENSO index and Singular Value De-composition (SVD) are employed to study the biases in precipitation climatology, mean state and variations of ENSO-related precipitation/sea surface temperature signals in the CMIP5 models during the 20th century.

Accomplishments

Our previous results suggest that the CMIP5 models are capable of simulating mean states and seasonal variabilities of ENSO-related precipitation that are similar to the 20CR and the REC, though detailed patterns may vary. In addition, DJF-averaged ENSO-related precipitation mean state becomes stronger in the 2nd half of the 20th century than the 1st half. In the past year, we have expanded the selection of the CMIP5 models from 9 to 30 models. The multi-decadal changes of ENSO-related precipitation in the 20CR, the REC and the CMIP5 models are further studied using Morlet wavelet power spectrum and Monte Carlo methods. We have also investigated the influences of biases of precipitation mean states and ENSO-related SST in the models on the ENSO-related precipitation ones.

In the multi-decal ENSO precipitation variation results, most of the CMIP5 models along with the 20CR and the REC show more robust El Niño- and La Niña-related precipitation and drought in the 2nd half of the 20th century, especially in DJF. The Morlet wavelet power spectrum analysis is applied on the time series of the first combined with the second EOF modes of precipitation anomalies. The results show that the power of the classic ENSO period (2-7 years) in the 2nd half of 20th century is larger than the first in the REC, the 20CR and most of the CMIP5 models, same as the Niño 3.4 Index one. The decadal ENSO variability also increases its power in the second half, though the power itself is much smaller than the classic one and its increase failed the significance test. A Monte Carlo method is employed to test whether the change of the extreme values of ENSO-related precipitation and drought is significant larger in the 2nd half of last century. The results show that the differences between annual- and DJF-averaged El Niño and ENSO precipitation index (Curtis and Adler 2000) of the 2nd half and the 1st half are statistically significant in the REC, the 20CR, and a few of CMIP5 models.

In the ENSO-related precipitation biases study, it is found that the "dry equator", "double-Intertropical Convergence Zones (DI)" and overly zonal Southern Pacific Convergence Zone (SPCZ) biases in the models precipitation climatology are the major reasons for lowering correlations with the observations in either precipitation climatology or the ENSO-related precipitation. The detailed ENSO-related precipitation spatial patterns in both CMIP5 groups are strongly related to the mean states of precipitation in the models. For example, the grouped models in Fig. 1 with a more severe "DI" ("dry equator") biases in the precipitation climatology show more obvious bias of the double positive anomaly bands over the eastern Pacific (near zero equatorial anomaly band in the Pacific Ocean) in the ENSO-related precipitation.

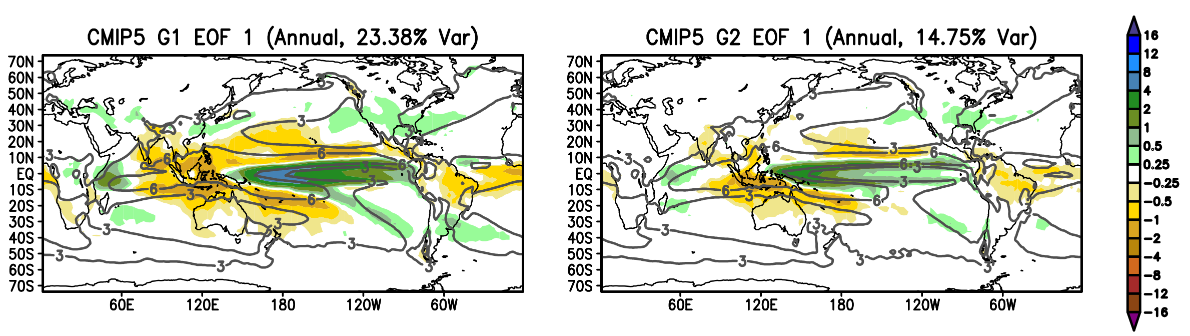


Fig. 1 EOF first mode spatial results of the mean of the CMIP5 group 1 and 2 models precipitations anomalies (mm/day, 1901-2005) (mean of ensemble members of each model) (shading is the precipitation anomalies EOF results; contours are the annual-averaged precipitation climatology of 3 and 6 mm/day)

The most consistent CMIP5 ENSO-related precipitation biases locate over the Maritime Continent, the western Indian Ocean and the equator, which are strongly connected with the overestimated/underestimated precipitation mean states over these regions. One possible explanation for the connection between near zero equatorial anomalies bias in ENSO-related precipitation and "dry equator" bias in the precipitation climatology is that the models with wide "dry equator" may not be able to close the gap between the SPCZs and the ITCZs during El Niño when these two convergence zones merging together, thus leaving obvious near zero anomaly bands in the their ENSO-related precipitation patterns. Another bias of the ENSO-related precipitation, the eastern Pacific double positive anomaly bands that is associated with the well-known "double-ITCZs" precipitation bias, seems to be sensitive to the number of observations. The model agreement maps on same sign shared by precipitation climatology biases and El Niño-related ones as well as the SVD results suggest that the double positive anomaly bands bias is related with both "double-ITCZs" bias in the precipitation mean states as well as the ENSO-related SST biases in the models.

Planned work

- Use CMIP5 models future projections to study the multi-decadal changes of ENSO and ENSO-related precipitation in the 21st century;
- Compare CMIP5 models with recent satellite products and short-term reanalyses, in an ENSO perspective;
- Continue to investigate how the biases of atmospheric circulation and air-sea coupling in the models affect the ENSO-related precipitation biases, with a focus on the ITCZ and SPCZ regions;

Publications

- 20th Century ENSO-related Precipitation Mean States in 20th Century Reanalysis, Reconstructed Precipitation and CMIP5 Models (submitted to Climate Dynamics in Oct. 2015, currently under second-round review)
- 20th Century ENSO-related Precipitation Seasonal Evolution and Multi-decadal Changes in 20th Century Reanalysis, Reconstructed Precipitation and CMIP5 Models (draft paper)

Products

- 2.5° ×2.5° re-gridded CMIP5 monthly precipitation, sea surface temperature and diabatic heating outputs (historical runs)

Presentations

- Ni Dai, 2016: ENSO-related Precipitation biases in CMIP5 Models (student seminar), Dept. of Atmospheric and Oceanic Science, University of Maryland – College Park (26 April)
- Ni Dai and Phil Arkin, 2015: ENSO-related Precipitation Seasonal Evolution and Multi-decadal Changes in Recent Reanalysis Datasets and CMIP5 Models (poster), 48th annual Fall Meeting of American Geophysical Union, San Francisco, California (14-18 December)
- Ni Dai and Phil Arkin, 2015: ENSO-related Precipitation Change in 20th Century (oral), Graduate Research Interaction Day 2015 at University of Maryland - College Park (8 April)

- Ni Dai, 2015: ENSO-related Precipitation in CMIP5 Models and Change of ENSO-related Precipitation in 20th Century (student seminar), Dept. of Atmospheric and Oceanic Science, University of Maryland – College Park (31 March)

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

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Applying Snow Products from SNPP/JPSS and SNODAS to Streamflow Forecasting at the NWS National Water Center

Task Leader **Peter Romanov**
Task Code **PRPR_NWC_15**
NOAA Sponsor **Mitch Goldberg**
NOAA Office **NOAA/NESDIS**
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%**
Highlight The project is focused on the development of a snow data assimilation testbed for streamflow forecasting and on the basic research in snow data assimilation for streamflow forecasting. The later includes investigation of SNODAS, SNPP/JPSS satellite snow product error quantification, product fusion, and investigation of snow model error and DA methods.
Link to a research web page

Background

The new inter-agency National Water Center (NWC) in Tuscaloosa, Alabama is tasked with developing a unified, science-based operational water prediction capability for the nation. Over large regions of the United States, streamflow response at a variety of spatial scales (from headwater catchments to larger river systems) and temporal scales (from minutes to months) is driven by snowmelt. Improved forecasts of snowmelt-driven streamflow have the potential to both save lives (rain-on-snow flooding) and contribute enormous economic benefits (water management, hydropower). Climate change will result in changes in snow behavior, which will need to be anticipated over all timescales. Despite the clear connections between snowpack and water supply, satellite observations of snow properties have yet to demonstrate significant value for operational streamflow forecasting over the CONUS in physically-based models of the type that will underpin operations at the National Water Center. The JPSS/SNPP-based research to operations tasks outlined in this proposal will address this shortcoming.

Accomplishments

Within this project CREST/CCNY provided information on capabilities of various satellite systems with respect to the snow cover monitoring and on the properties of various datasets generated with satellite data. The primary focus of the work was on the snow products derived from observations of SNPPVIIRS sensor in the visible and infrared spectral bands and from ATMS sensor in the microwave. VIIRS-based products include the binary and the fractional snow cover at 375m spatial resolution. Observations from ATMS are used to infer information on the snow depth and he snow water equivalent. Samples of all products were provided to the project PI to assess potentials for using them in the stream flow simulation experiments.

Planned work

Within the project it is planned to continue consulting the project PI and the NCAR Team on the properties of SNPP-based snow products and on changes of these properties due to changes in the retrieval algorithms. We are planning to automate acquisition, regridding and resampling available SNPP based satellite products for easy use in the NCAR's stream flow simulation experiments.

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

GMU Support of NOAA Air Quality Forecasting, Research and Operations

Task Leader	Daniel Tong
Task Code	QTQT_GMU_15
NOAA Sponsor	Rick Artz
NOAA Office	OAR/ARL
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Percent contribution to CICS Themes	Theme 3, 100%
Percent contribution to NOAA Goals	Goal 3, 100%%

Highlight: CICS scientists have (1) Validated MODIS-based marine isoprene retrieval algorithm; (2) Compared MODIS and VIIRS based marine isoprene products; and (3) Prepared to integrate and test the new Soumi-NPP VIIRS marine product in the NAQFC system.

Background

This work is part of the collaboration between NOAA Air Resources Laboratory (ARL) with UMD to advance climate research. The specific task is to 1) Support ARL Observational System Simulation Experiments (OSSEs) Project; 2) Improve NAQFC dust emission model; 3) Integrate and test Soumi-NPP VIIRS marine emission product into NAQFC.

Accomplishments

1. Support ARL Observational System Simulation Experiments (OSSEs) Project

The Observational System Simulation Experiments (OSSEs) project is a NOAA Research Office's multiple line offices effort to evaluate the potential impact of proposed new observing systems. Satellite-based and high-altitude airborne remotely sensed air quality data complement land-based and routinely commercial-flight and other measurement-campaign acquired remotely sensed and in situ observations. It is important to optimize the combination and placement of these wide ranges of measurements and data acquisition options for cost-effectiveness. Under this initiative we attempt to quantify the gain by a regional state-of-the-science chemical data assimilation and chemical transport modeling system when incremental sets of observation are acquired into the syste m. This study represents a first step in a series of steps to ingest such proposed incremental additions of observation. The efficacy of such proposals is quantified systematically by Observation Simulation System Experiments (OSSEs). We compared two end-to-end regional air quality forecasting simulations using: (a) the Weather Forecasting and Research (WRF) regional application initialized by the U.S. national Weather Service (NWS) Global Forecasting System (GFS) coupled with the U.S. Environmental Protection Agency Community Multi-scale Air Quality (CMAQ) chemical model (Byun and Schere 2006), and (b) the same as above but with a new GFS enhanced by assimilating a fictitious addition of Atmospheric Infrared Sounder (AIRS) retrieved radiances at 13 km spatial resolution at nadir from a proposed geostationary satellite positioned over 75oW staring over the U.S. Both sensitivity runs were performed in 12 km horizontal grid resolution and with daily initialization for 12 days between July 29 and August 9 2005. Noticeable forecast skill improvement in surface concentration for O3 and particulate matter smaller than 2.5 μm in diameter (PM2.5) was achieved (Lee et al., 2016).

2. Improve NAQFC dust emission model

The proposed work targets the NOAA Operational Dust Forecasting Capability. As one of its core missions to build a "Weather Ready Nation", NOAA has developed and is operating the US Dust Forecasting Capability Program. Dust is recognized as an important contributor to air quality in the western US. It is also now becoming more important for numerical weather prediction as the operational High Resolution Rapid Refresh (HRRR) will be using an aerosol aware microphysics parameterization, and a version of the operational Global Forecast System (GFS) will also be using a dust parameterization. This work focuses on the development of a unified dust modeling capability which should result in a verified NOAA-uniform dust model that can be used from all modeling systems (through in-lining or offline coupling) and has improved capabilities. We propose to evaluate the performance of the various approaches in 2 different modeling systems with the best meteorology possible (from the HRRR).

Wind-blown dust impacts human health, visibility, ground and air transportation, and radiative forcing. As one of its core missions to build a "Weather Ready Nation", NOAA has developed and is operating the US Dust Forecasting Capability Program, based on the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler et al., 2010). The dust forecasting has been continuously running over the continental United States since November 2011 at the National Centers for Environmental Prediction (NCEP). Real-time forecasting products are released to the public through the National Weather Service (NWS) (http://airquality.weather.gov). The information of real-time dust forecasting is being widely used to assist in assessing and mitigating the impact of dust storms on the society and the environment, including human health (e.g., Valley Fever), air and ground transportation (traffic accidents), local economy (e.g., real estate prices in Maricopa, Arizona), and climate change.

On the other hand, for NWP, the High Resolution Rapid Refresh (HRRR), an operational modeling system, is currently running at the National Centers for Environmental Prediction (NCEP). The HRRR model runs on a 3km horizontal grid over the CONUS domain and is cycled on an hourly basis. Because of this high temporal and spatial resolution used in the forecast model, the HRRR is credited with providing more detailed information to key decision makers than other operational forecast models (http://www.noaanews.noaa.gov/stories2014/20140930_hrrr.html). The HRRR is based on the Weather Research and Forecasting numerical model (WRF, Skamarock et al. 2008), with many modifications for operational applications developed at ESRL where several developmental versions are being tested in real-time (http://rapidrefresh.noaa.gov/HRRR). One version of the HRRR has recently been upgraded to use the improved Thompson aerosol-aware microphysics parameterization (Thompson and Eidhammer, 2014). This aerosol-aware microphysics scheme includes the explicit treatment of cloud droplet activation and ice nucleation via aerosol concentrations. This version of HRRR will be operational in 2015.

Several improved dust modules can now be used in the HRRR without the use of complex chemistry. These include the original GOCART dust module, an improvement upon the this version (more physically based), which is also known as AFWA module, and three version of an approach from Shao (Shao 2001, Shao 2004, Shao et. al. 2011) that represent different levels of complexity and is physically based. Shao's schemes were adjusted to have the same size distribution as GOCART and AFWA. The wet deposition for the Shao schemes was also improved. Work is starting to compare the different schemes for the proposed study period. May 6 – May 14. Additionally, ESRL has invited Daniel Tong for a visit to Boulder to help implement the CMAQ routine. The changes and eva,uation of the latest version from the CMAQ dust module are described nest.

The US NAQFC 12 km CMAQ (Byun and Schere, 2006; Chai et al., 2013; Pan et al., 2014) model simulations were used to depict the PM distributions during a recent strong dust event in the western US that was accompanied by a stratospheric ozone intrusion. Dust emissions for NAQFC's CMAQ simulations were calculated by the FENGSHA dust emission model based on a modified Owen's equation, which is a function of wind speed, soil moisture, soil texture and erodible land use types (Tong et al., 2015). Both the FENGSHA and CMAQ model calculations were driven by meteorological fields from the NAM model, which is known to usually have positive biases in temperature, moisture, and wind speed in the continental US (e.g., McQueen et al., 2015a,b). The CMAQ base simulation was evaluated against surface observations at the AirNow and IMPROVE sites, and we focused on PM2.5 concentrations as it is one of the standard NAQFC products. To quantify the impact of western US dust emissions on PM2.5 concentrations during this event, an additional sensitivity simulation was conducted in which no dust emissions were included. NAQFC CMAQ lateral chemical boundary conditions were downscaled from a monthly mean output from a global GEOS-Chem simulation of year 2006 (http://www.geos-chem.org/; http://acmg.seas.harvard.edu/geos/geos_chem_narrative.html, and the references therein. The details of this GEOS-Chem simulation and the boundary condition downscaling methods are included in Barrett et al., 2012). These boundary conditions do not represent the day-to-day variability in the transboundary chemical species impacting the CMAQ model domain. Stratospheric ozone intrusion during this dust event is indicated by meteorological conditions and chemical fields from the global Realtime Air Quality Modeling System (RAQMS; Pierce et al., 2007), which assimilated satellite ozone observations. Case study of a recent strong dust event accompanied by a stratospheric ozone intrusion Multiple satellites identified a recent dust event (10–11 May 2014) in the western US: as described by NOAA's HMS text product (http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014E111659.html; http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014E120143.html), dust was originated in southern California. It swept across northern Baja California and Arizona, and then entered New Mexico after a cold-frontal boundary and impacted Texas, Oklahoma and Kansas.

We evaluated the current NAQFC PM2.5 (a standard NAQFC air quality modeling product) forecasting skill during this event and assessed the impact of dust emission on the regional air quality based on model sensitivity analysis. The NAQFC 12 km CMAQ base simulation produced 24 h mean PM2.5 of over 50 μgm^{-3} in western Arizona and > 15 μgm^{-3} in southwestern Arizona on 11 May 2014 (Fig. 1a). A sensitivity analysis using the base and no-dust simulations indicates that over 50 μgm^{-3} of hourly PM2.5 during this event were contributed from dust emissions in populated urban regions in Arizona (such as Phoenix in the Maricopa county and Tucson in the Pima county) and, on average, dust contributed to > 70% of the total PM2.5 in most Arizona grid cells (Fig. 1b). The modeled PM2.5 was evaluated mainly for the Maricopa and Pima counties in Arizona where both IMPROVE and AirNow observations were available during this event. Time series of observed and modeled PM2.5 are shown in Fig. 1c and d. AirNow observations indicate daily maxima to be over 100 μgm^{-3} in Maricopa (at 08:00 LT) and over 50 μgm^{-3} in Pima (at 14:00 LT), with PM2.5 / PM10 ratios at the dust times below 0.2 (not shown). Both the model and observations show significant temporal variability (standard deviations), indicating the advantages of the AirNow data for capturing the extremely high PM concentrations during the dust events. The model was fairly well correlated with the observations (with median/high correlation coefficients of 0.7–0.9; Table 2). CMAQ underpredicted the daily maxima in Maricopa by a factor of 2 with a 2 h lag, while it slightly overpredicted them in Pima with the right timing. PM was measured at more AirNow sites than at IMPROVE sites in both counties on this day. The observed 24 h mean concentration at the AirNow sites was lower than at the IMPROVE sites in Maricopa, but those in Pima were close. This can be mainly due to the different sampling areas that AirNow and IMPROVE networks cover. The model underpredicted the 24 h mean values in both counties, with more significant negative biases in Maricopa than in Pima.

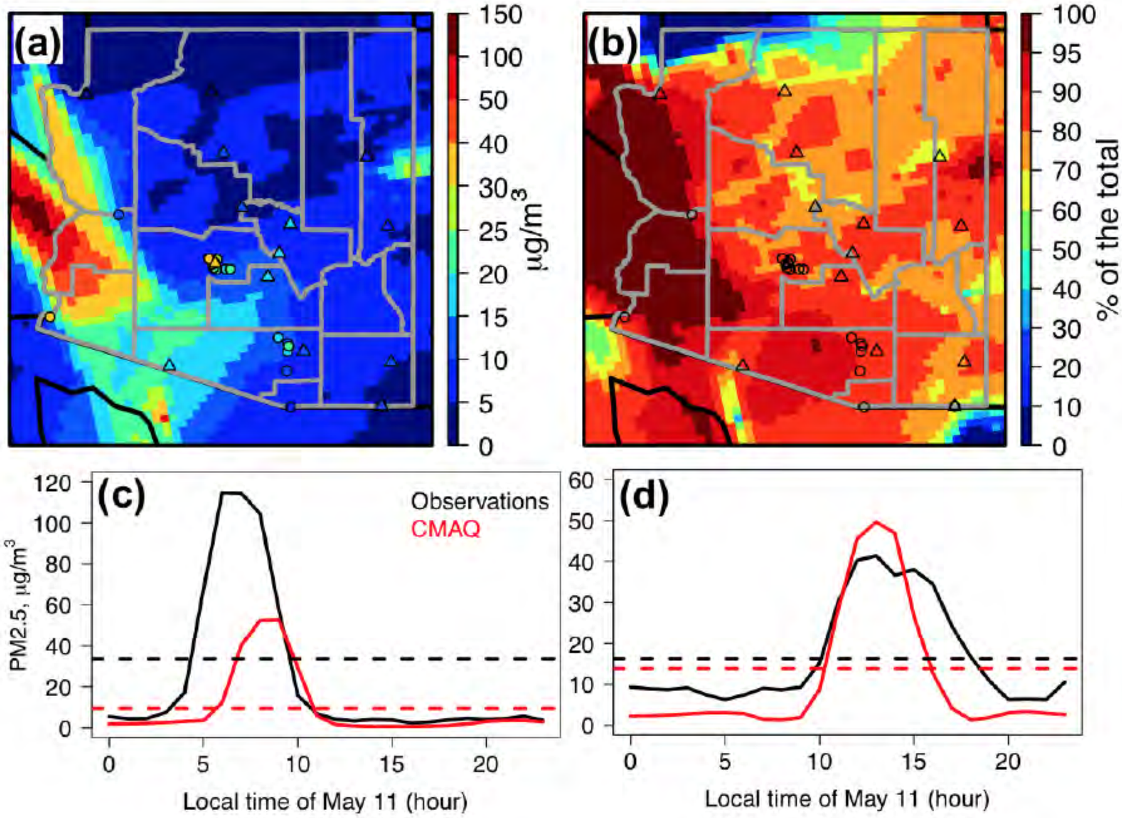

Figure 1. (a) NAQFC 12 km CMAQ modeled 24 h mean surface PM2.5 on 11 May 2014, with the AirNow (circles) and IMPROVE (triangles) observations overlaid. (b) CMAQ modeled dust contributions (%) to the total PM2.5 on this day. Locations of AirNow (circles) and IMPROVE (triangles) are shown. Observed (black) and modeled (red) surface PM2.5 in (c) Maricopa and (d) Pima counties on this day, at AQS (solid lines) and IMPROVE (dashed lines) sites.

This dust event was accompanied by a stratospheric ozone intrusion, as shown from a RAQMS model simulation that assimilated ozone columns from the Ozone Monitoring Instrument and ozone profiles from the Microwave Limb Sounder, as well as the AIRS satellite products (Figs. 2). Descending dry air containing rich ozone enhanced the surface ozone concentrations in eastern Arizona and New Mexico at late morning and early afternoon times, when dust was strongly impacting the same locations. Observed surface ozone at the Petrified Forest National Park in eastern Arizona (AQS/AirNow site no. 040170119) at this time exceeded 65 ppbv. However, the current NAQFC CMAQ modeling system is unable to capture the exceptionally high ozone during stratospheric intrusion episodes, as the CMAQ lateral boundary conditions were downscaled from the monthly mean GEOS-Chem simulation in 2006 and no upper boundary conditions were used.

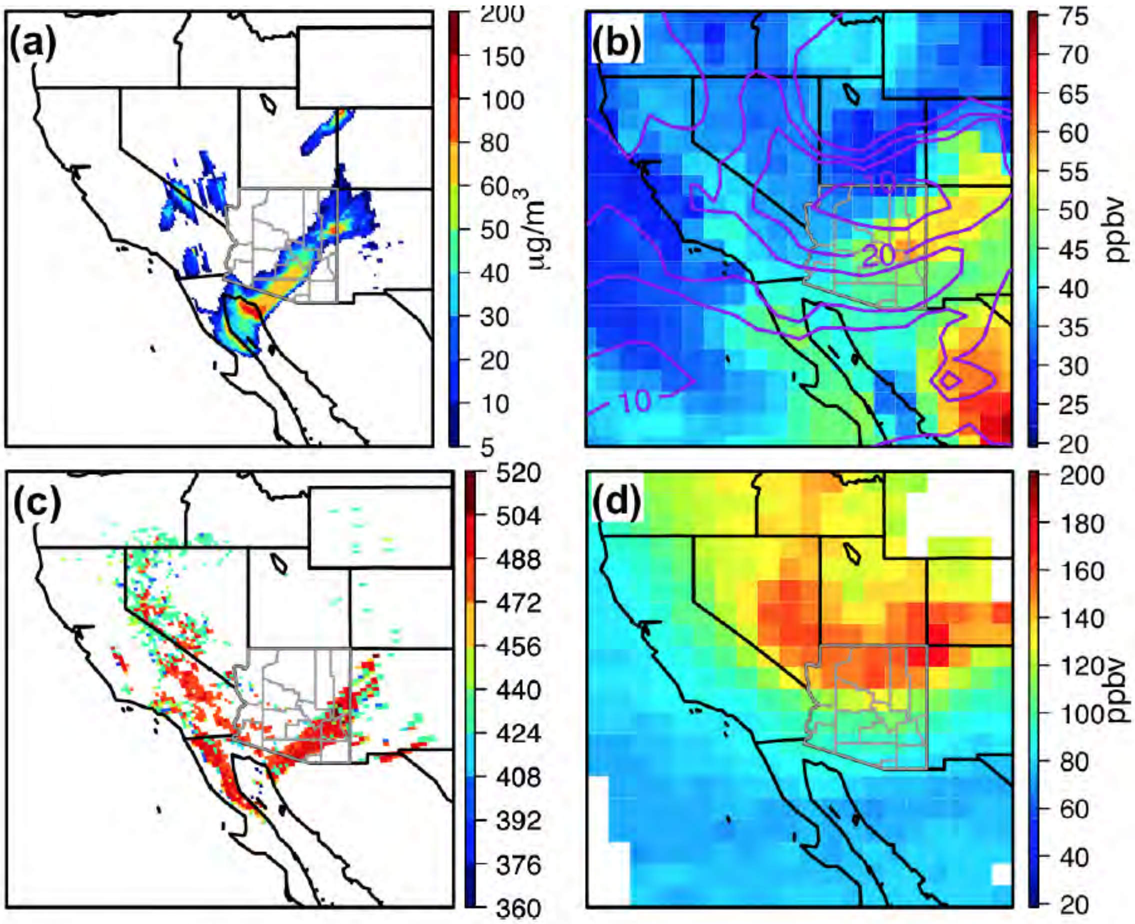

Figure 2. (a) CMAQ modeled dust contributions to PM2.5 and (b) RAQMS modeled surface ozone at 11:00 mountain standard time on 11 May 2014. The purple contour lines in (b) indicate RAQMS relative humidity (%) at the upper troposphere (300 hPa). (c) and (d) indicate, respectively, the AIRS daytime (early afternoon overpass time) dust score and ozone concentrations at 300 hPa. Following the criteria at http://disc.sci.gsfc.nasa.gov/nrt/data-holdings/airs-nrt-products, the dust score values below 360 were rejected.

3. Prepare to integrate and test the new Soumi-NPP VIIRS marine product in the NAQFC system

While the team is working on further understanding of the uncertainties of the VIIRS isoprene product, the NOAA NAQFC modeling system has been prepared for testing the beta version of the product. This study compares multi-year NO_x trends derived from satellite and ground observations and uses these data to evaluate the updates of NO_x emission data by the US National Air Quality Forecast Capability (NAQFC) for next-day ozone prediction during the 2008 Global Economic Recession. Over the eight large US cities examined here, both the Ozone Monitoring Instrument (OMI) and the Air Quality System (AQS) detect substantial downward trends from 2005 to 2012, with a seven-year total of -35% according to OMI and -38% according to AQS. The NO_x emission projection adopted by NAQFC tends to be in the right direction, but at a slower reduction rate (-25% from 2005 to 2012), due likely to the unaccounted effects of the 2008 economic recession. Both OMI and AQS datasets display distinct emission reduction rates before, during, and after the 2008 global recession in some cities, but the detailed changing rates are not consistent across the OMI and AQS data. Our findings demonstrate the feasibility of using space and ground observations to evaluate major updates of emission inventories objectively.

The combination of satellite, ground observations, and in-situ measurements (such as emission monitoring in power plants) is likely to provide more reliable estimates of NO_x emission and its trend, which is an issue of increasing importance as many urban areas in the US are transitioning to NO_x-sensitive chemical regimes by continuous emission reductions (Tong et al., 2015).

Planned Work

1. Improve windblown dust emissions

Evaluate and improve windblown dust emission module to support NOAA NAQFC operations and US-WRP dust modeling research. This task is to evaluate the current operational version of the windblown dust emission module, FENGSHA, and identify new methods to improve natural dust emission for two NOAA projects: A) the PM2.5 forecasting with the NAQFC CMAQ model (NAQFC project) and the high-resolution dust modeling driven by the HRRR meteorology (USWRP project).

2. Test and implement NO_x emission data assimilation (EDA) algorithm in NAQFC

Funded by a USWRP award (PIs Pius Lee and Daniel Tong), GMU will work with the NAQFC team to implement a new approach to update EPA NOx emission inventories with ground and satellite observations. The NEI2011 is five years behind the forecast year, and is known to be biased high. Hence, it is necessary to develop the NOx EDA to bridge the gap between NEI year and forecasting year, and to offset the projected effect of the MOVES updates on NAQFC performance. Built upon a recent study (Tong et al. 2015), which demonstrated that satellite and ground observations can provide consistent trends of NOx emissions over major urban areas., we will develop a new capability for NAQFC emission system. The goal of EDA is to rapidly assimilate satellite and ground observations to update major NOx emission sectors in a timely fashion. Once the capability is developed, we will use the new system to update NAQFC emissions to support FY2016 operations.

Publications from the above activities

4. 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.
5. Tang, Y., L. Pan, P. Lee, D. Tong, D., H. C. Kim, J. Wang and S. Lu. The Performance and Issues of a Regional Chemical Transport Model During Discover-AQ 2014 Aircraft Measurements Over Colorado. In *Air Pollution Modeling and its Application XXIV* (pp. 635-640, Chapter 103). *ISBN:978-3-319-24476-1*, Springer International Publishing, 2016.
6. Lee, P., Atlas, R., Carmichael, G., Tang, Y., Pierce, B., Biazar, A.P., Pan, L., Kim, H., Tong, D. and Chen, W., 2016. Observing System Simulation Experiments (OSSEs) Using a Regional Air Quality Application for Evaluation. In *Air Pollution Modeling and its Application XXIV* (pp. 599-605). Springer International Publishing.
7. Dong, X., Fu, J. S., Huang, K., and Tong, D.: Model development of dust emission and heterogeneous chemistry within the Community Multiscale Air Quality modeling system and its application over East Asia, Atmos. Chem. Phys. Discuss., 15, 35591-35643, doi:10.5194/acpd-15-35591-2015, 2015.
8. Tong, D.Q., L. Lamsal, L. Pan, C. Ding, H. Kim, P. Lee, T. Chai, and K.E. Pickering, and I. Stajner, 2014. Long-term NO_x trends over large cities in the United States during the 2008 Recession: Intercomparison of satellite retrievals, ground observations, and emission inventories, *Atmospheric Environment*, 107,70-84, doi:10.1016/j.atmosenv.2015.01.035.
9. Huang, M., Tong, D., Lee, P., Pan, L., Tang, Y., Stajner, I., Pierce, R. B., McQueen, J., and Wang, J.: Toward enhanced capability for detecting and predicting dust events in the Western United

States: the Arizona Case Study, Atmos. Chem. Phys. Discuss., 15, 20743-20774, doi:10.5194/acpd-15-20743-2015, 2015.

10. Tang, Y., T. Chai, L. Pan, P. Lee, Daniel Tong, H. Kim, and W. Chen, Using Optimal Interpolation to Assimilate Surface Measurements and Satellite AOD for Ozone and $PM_{2.5}$: A Case Study for July 2011. *Journal of the Air & Waste Management Association*, doi:10.1080/10962247.2015.1062439, 2015.

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
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%
Highlight	
Link to a research web page	

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:

1. **Develop the methodology and software package to composite VIIRS LST**:
   Generate daily global gridded VIIRS LST Level3 data (VLSTL3) at resolution of 0.036° and tile-based gridded VIIRS LST at resolution of 0.009° with daytime and nighttime separately. The scientific datasets (SDSs) in the product include LST_Day, QC_Day, view_time_day and view_angle_day in day VLSTL3 and LST_Night, QC_Night, view_time_night and view_angle_night in night VLSTL3 as described in Table 1.

Table 1. The SDSs in the VLSTL3 product

Variable Name	Long Name	Number Type	Units	Valid Range	Fill Value	Scale Factor	Offset
LST_Day	Daily daytime Land Surface Temperature	uint16	K	0, 65527	65533-65535	0.0025455	183.2
QC_Day	Quality Control for daytime LST	uint16	none	Details to QA	NA	NA	NA
View_Time_Day	Time of Daytime LST Observation	uint16	second	0, 43200	65535	2	0
View_Angle_Day	View zenith angle of Daytime LST	uint8	deg	0, 180	255	1	-90
LST_Night	Daily nighttime Land Surface Temperature	uint16	K	0, 65527	65533-65535	0.0025455	183.2
QC_Night	Quality Control for nighttime LST	uint16	none	Details to QA	NA	NA	NA
View_Time_Night	Time of Nighttime LST Observation	uint16	second	0, 43200	65535	2	0
View_Angle_Night	View zenith angle of Nighttime LST	uint8	deg	0, 180	255	1	-90

The bit flags defined for the quality assurance SDSs QC_day and QC_Night are listed in Table 2.

Table 2. Two bytes QC in the VLSTL3 product

Bits	Long Name	Comment
1 & 0	Data Quality Flag	00= High;
		01= Median;
		10= Low;
		11= No retrieval
3&2	Mandatory QA Flag	00=Pixel produced;
		01=Pixel produced but from filled value;
		10=Pixel not produced due to cloud effects or invalid land surface;
		11=Pixel not produced due to other reasons
5 & 4	Cloud Confidence Indicator	00: Confidently Clear;
		01: Probably Clear;
		10: Probably Cloudy;
		11: Confidently Cloudy
6	Active Fire	0 = no active fire 1 = active fire
7	AOT Condition	0 = within range, (AOT ≤ 1.0) 1 = outside range

10-8	Land/Water Back-ground	Bit 2 Bit 1 Bit 0 0 0 0 = Land and Desert 0 0 1 = Land / No Desert 0 1 0 = Inland Water 0 1 1 = Sea Water 1 0 1 = Coastal
15-11	Surface Type	1: Evergreen Needleleaf Forests; 2: Evergreen Broadleaf Forests; 3: Deciduous Needleleaf Forests; 4: Deciduous Broadleaf Forests; 5: Mixed Forests; 6: Closed Shrublands; 7: Open Shrublands; 8: Woody Savannahs; 9: Savannahs; 10: Grasslands; 11: Permanent Wetlands; 12: Croplands; 13: Urban and Build-up; 14: Cropland/Natural Vegetation Mosaics; 15: Snow and Ice; 16: Barren; 17: Water; 31: Fill

2. **Prepare the ATBD and product specifications for the VIIRS gridded LST.**

3. **Produce the gridded VIIRS LST testing datasets**:
   On the monthly basis, all VIIRS granule data including all VIIRS granule-level temperature and geo-location data were downloaded to produce the trail global gridded VIIRS LST data at 0.009° and 0.036°. Provide the data to model group for the model LST evaluation.

Planned Work

- Gridded VIIRS LST data will be further improved and tested.
- Update software codes and ATBD/product specification documentation.
- Build the Diurnal Temperature Model (DTM) based on GOES LST and VIIRS LST for hourly LST pro-ducing.
- Evaluate the model LST by gridded VIIRS LST.

Products

- Gridded global VIIRS LST product

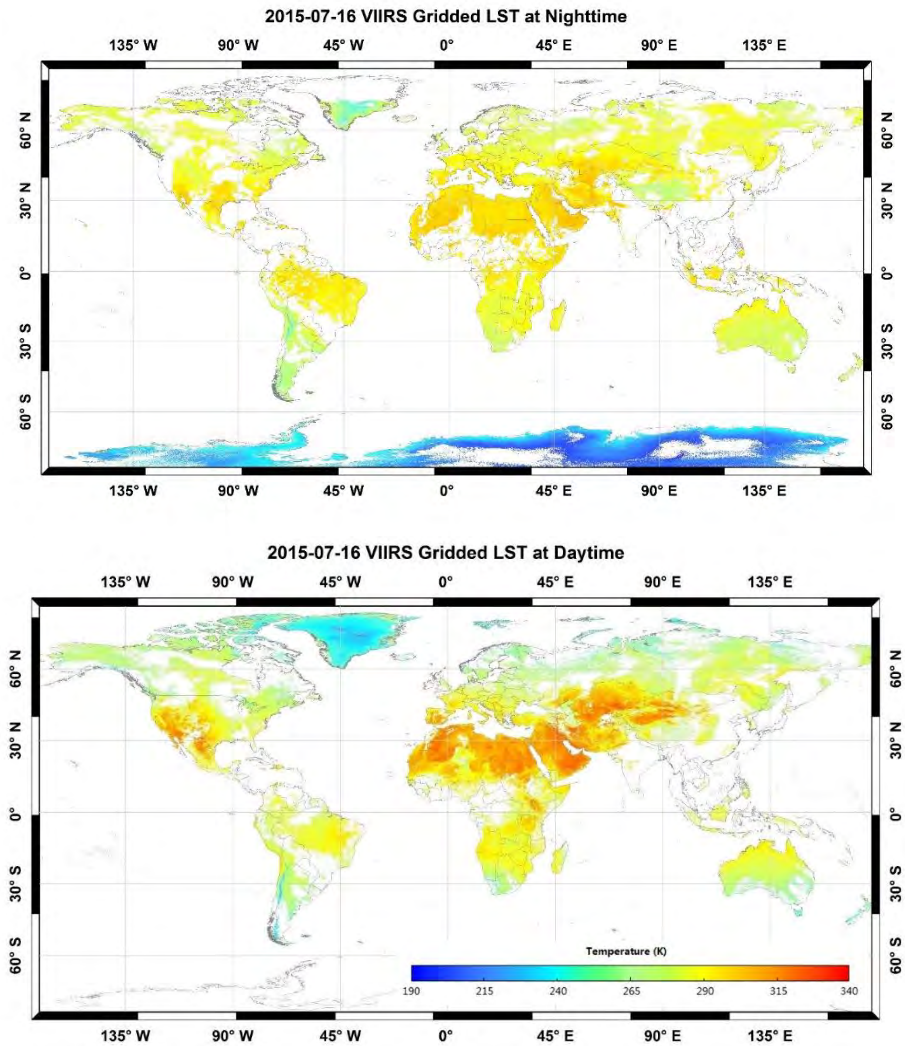

Figure 1. An example of gridded VIIRS LST on July 16, 2015 at nighttime and daytime

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

New products developed: VIIRS Gridded LST

Improvements to the HYSPLIT Mercury Code

Task Leader: Timothy Canty
Task Code: TCTC_HYSP_15
NOAA Sponsor: Richard Artz
NOAA Office: ORA/ARL
Contribution to CICS Research Themes (%):
Main CICS Research Topic: Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%):
Highlight:
Link to a research web page: http://www.arl.noaa.gov/Mercury_modeling.php

Background

Mercury, a well known neurotoxin, is 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 contributing 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 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.

The purpose of this project is to improve the operation and capabilities of HYSPLIT-Hg with the goal of better representation of mercury transport and deposition within the model framework. This code has been parallelized to decrease run times for this project. Nested-grid capabilities will be added to allow for higher resolution simulations. A subsurface layer or layers will be developed to account for mercury in these regions. The numerical finite-difference grid calculation within the Eulerian component of the model will also be improved.

Accomplishments

Since this project began in mid-October 2015, parallelization has been implemented into the HYSPLIT-Hg model code for the puff (which tracks the dispersion of an aerosol plume), Eulerian (which uses a fixed three-dimensional grid as a frame of reference to compute pollutant air concentrations) , and combined puff and Eulerian modes. This was accomplished using the Message Passing Interface (MPI); the code update allows the model to use multiple computer processors on a distributed processing system and results in a decrease in model run times. Table 1 indicates the improvement to run time as more processors are made available for use in the model simulations. Using a relatively modest number of processors (8) realizes a significant improvement in model runtime. Sufficient quality control on HYSPLIT-Hg model output was performed in both the puff and Eulerian modes to demonstrate that the updated code run serially (with 1 CPU) obtains identical results with simulations using multiple CPUs via MPI. We expect similar agreement when the model is run in the combined puff and Eulerian mode and when more processors are used to perform simulations.

During the implementation of these model improvements, the codes for the “standard, off the shelf” version of the HYSPLIT model and the modified HYSPLIT-Hg models were compared. It was recognized that an area of improvement in the implementation of MPI in the “standard” HYSPLIT model run in puff mode was identified to improve model efficiency (i.e., decrease model run times). This improvement will soon be incorporated into an update to the “standard” version of HYSPLIT to speed up model puff simulations. In addition, the base HYSPLIT model run in the Eulerian mode has not been parallelized. As with the puff simulations, parallelization capabilities will be ported from the HYSPLIT-Hg model into the Eulerian section of the standard HYSPLIT model.

Table 1: Change in run time for parallelized version of HYSPLIT-Hg

# CPUs	Run time relative to serial run
2	1.9 times faster
4	3.6 times faster
6	5.0 times faster
8	6.3 times faster

Planned Work

- Porting over updates from the HYSPLIT-Hg code into the base HYSPLIT model
  Improvements in the MPI implementation of puff simulations and the inclusion of MPI in Eulerian simulations will be added to the base HYSPLIT code.
- Adding nested-grid capabilities to the global Eulerian simulation algorithms
  There are some regions (i.e. around major cities, land/water interface) where higher resolution simulations are needed to improve representation of the meteorological influences on air masses. High resolution model runs are computationally expensive and are often not feasible to perform for the entire model domain so coarse grid inputs are used for fine grid simulations over specific areas.
- 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.

Publications

The following paper was submitted to Elementa:

Cohen, M.D., R.R. Draxler, R.S. Artz, 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.-R. Ren, F. Steenhuisen, R. Tordon, S.J. Wilson, 2016, Modeling the global atmospheric transport and deposition of mercury to the Great Lakes. submitted to Elementa.

Products

Model improvements to the HYSPLIT-Hg model were implemented, as discussed above.

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

Model improvements to the HYSPLIT-Hg model were implemented, as discussed above. The following manuscript was submitted to Elementa: Cohen, M.D., R.R. Draxler, R.S. Artz, 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.-R. Ren, F. Steenhuisen, R. Tordon, S.J. Wilson, 2016, Modeling the global atmospheric transport and deposition of mercury to the Great Lakes. submitted to Elementa.

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

Task Leader **Zhanqing Li**
Task Code ZLZL_RCBH_15
NOAA Sponsor **Mitch Goldberg**
NOAA Office **STAR**
Contribution to CICS Research Themes (%)
Main CICS Research Topic **Remote Sensing**
Contribution to NOAA goals (%)
Highlight
Link to a research web page **www.atmos.umd.edu/~zli**

Background

The planetary boundary layer (PBL) height, moisture in the PBL, cloud base height (H_b), and updraft speed at cloud bases (W_b) are all important meteorological variables that influence cloud, precipitation and air pollution transportation, etc. Despite their importance, we don't have a good knowledge about these variables, which is especially poor, if there is any, at high spatial resolution on large scales obtained real-time or near real-time.

The **objectives** of the proposed study are to develop the following new remote sensing products for PBL convective clouds by taking advantage of the high-resolution VIIRS imager data:

1) cloud base temperature;
2) cloud base height;
3) cloud base updraft speed;
4) PBL water vapor mixing ratio.

For each of the variables, we will conduct the following tasks:

(1) Understanding the limitations and improvement of the algorithms
(2) Operational applications of the algorithms
(3) Quantification of the product uncertainties

Demonstration of potential applications of the products for NWP/QPF

The planned **milestones** of our study include:

(1) Development of procedures that ingest a full VIIRS granule and that produce a field of retrieved parameters: cloud base temperature, height, updraft, and boundary layer vapor mixing ratio;

(2) More extensive and rigorous validation of all retrieved properties against DOE/ARM and any other available high-quality in-situ or ground-based measurements;

(3) Automation of a system for handling the incoming stream of VIIRS data;
(4) Generation of some experimental products for NWP model applications;
(5) Quantification and understanding of retrieval uncertainties by cloud-resolving modeling;
(6) Investigation of potential impact of the products on the NCEP-GFS model simulations.

Accomplishments

We have worked on the following tasks with varying degree of progress.

(1) Development of procedures that ingest a full VIIRS granule and that produce a field of retrieved parameters: cloud base temperature, height, updraft, and boundary layer vapor mixing ratio;
(2) Validation of all retrieved properties against DOE/ARM and other available high-quality in-situ

or ground-based measurements;

(3) Automation of a system for handling the incoming stream of VIIRS data;

(4) Development of procedures that ingest a full VIIRS granule and that produce a field of retrieved parameters: cloud base temperature, height, updraft, and boundary layer vapor mixing ratio.

We proposed a suite of methods to ingest VIIRS granule to retrieve the following four parameters: cloud base temperature, height, updraft, and boundary layer vapor mixing ratio. In addition, the DOE/ARM observational datasets from Southern Great Plains, Amazon region, and east Pacific ocean were used to validate the retrieved parameters from NPP/VIIRS. There are good agreements with mean-average-percentage error (MAPE) of 8%, 15%, 23% and 9% for cloud base temperature, height, updrafts and boundary layer vapor mixing ratio, respectively. The work we did is primarily for shallow convective clouds. We found a tight linear relation between the cloud top radiative cooling rate and the updrafts from the cases of marine stratocumulus from MAGIC. If we can utilize the JPSS satellite to retrieve the cloud top radiative cooling rate, the marine stratocumulus cloud base updrafts would be computed from the retrieved cloud top radiative cooling rate based on the relations we found. We have made some progress on satellite-retrieval of cloud top radiative cooling rate.

Unlike the convective clouds, the stratocumulus is typically full cloudy, obscuring satellites from observing the cloud base. Here, we assume a coupled PBL topped by stratocumulus, in which the air parcel ascents dry adiabatically from surface to cloud base and then wet adiabatically from cloud base to cloud top. For specific sea surface temperature and cloud top temperature, both of which are retrievable from VIIRS, there is a series of possible sounding profiles with variant cloud depth. With the observed liquid water path, we can identify the right sounding and hence get the cloud base height and temperature. Assuming a relative humidity of 100% at cloud base, the BL water vapor mixing rate can be estimated. Utilizing the radiative transfer model along with the satellite-retrieved parameters as the input, we can compute the BL radiative cooling rate, which is used to estimate the cloud base updrafts according to the relationship between the two found in our previous work shown in our proposal.

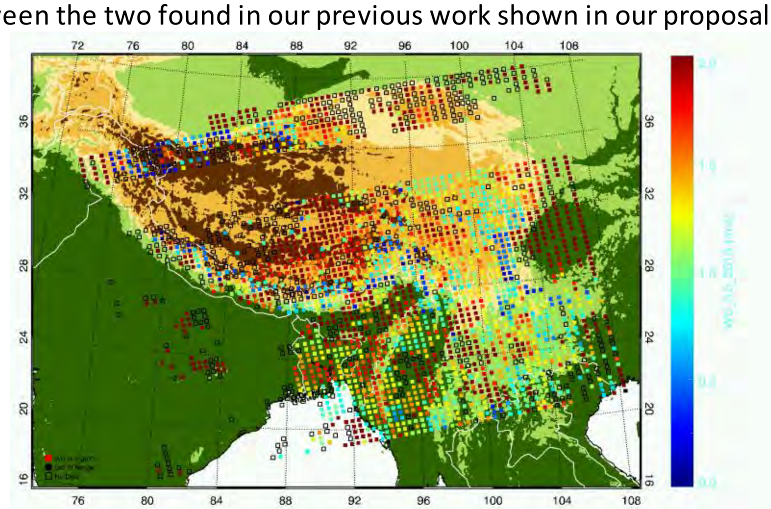

Figure 1:. An example of convective cloud base updraft retrieval by automation system on Jun 9th, 2014.

The results are very encouraging, which indicates a possibility of satellite retrieval of cloud top radiative cooling rate and therefore cloud base updrafts for marine stratocumulus. Some issues, however, have to be solved. First, only cases with 100% cloud cover were selected. For partially cloudy stratocumulus, the cloud cover has to be considered in computation to get the real integrated cloud top radiaitve cooling rate for the area of cloud groups. Second, after the revision with constraint from satellite-retrieved cloud top temperature, the reanalysis match the sounding very well and give us good estimate of cloud top radiative cooling rate. The reanalysis, however, is impossible to be that accurate everywhere in the world. The good performance of the reanalysis for the cases studied here is due to the fact that ARM/DOE measurements were used to produce the reanalysis. For regions without ground measurements, the performance of the reanalysis is possibly unsatisfactory. It is therefore necessary to use temperature/moisture profile form ATMS/CrIS to do the same analysis, which will be studied in our next step.

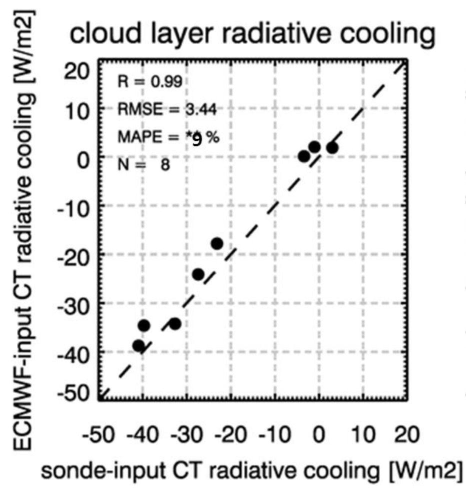

Figure 2: Validation of cloud top radaitive cooling rate computed by SBDART with satellite and reanalysis measurements as inputs against that with the ground measurements as inputs.

We are now preparing for simulations using a cloud-system resolving model (CSRM). The Advanced Research Weather Research and Forecasting (ARW) model, which is a nonhydrostatic compressible model, is adopted as the CSRM Prognostic microphysical variables are transported with a 5th-order monotonic advection scheme. Shortwave and longwave radiation parameterizations have been included in all simulations by adopting the Rapid Radiation Transfer Model (RRTMG; Mlawer et al., 1997; Fouquart and Bonnel, 1980). RRTMG considers the effects of aerosol on effective sizes of hydrometeors.

As a preliminary step, we plan to simulate a case of convective clouds over the SGP (36.61N, 97.49W), which is one of the permanent observational sites of the ARM program, to represent mid-latitude inland summer convective clouds. This case lasts 12 hours from 12 GMT on July 19th to 20 GMT on July 20th in 2012.

Planned Work

- Conduct extensive and rigorous validation of all the automated properties against DOE/ARM measurements.
- Select cloud systems observed during the field campaigns and perform the CRM simulations for them.
- Evaluate the CRM simulations against observations.
- Compare the simulated field of the parameters to the retrieved one to aid the rigorous validation of the retrieved properties. Here we have to bear in mind though that the model simulations are often far from representing reality.
- Generate some experimental products for NWP model applications.

Publications

Zheng, Y. and D. Rosenfeld (2015), Linear relation between convective cloud base height and updrafts and application to satellite retrievals, *Geophys. Res. Lett.*, 42, doi:10.1002/2015GL064809.

Zheng, Y., D. Rosenfeld, and Z. Li (2015), Satellite inference of thermals and cloud base updraft speeds based on retrieved surface and cloud base temperatures, *J. Atmos. Sci., 72(6), 2411–2428.*

Rosenfeld, D., B. Fishman, **Y. Zheng**, T. Goren, and D. Giguzin (2014), Combined satellite

Products

1. Algorithms developed for retrieving cloud updraft at cloud base over land and oceans
2. Research products for validating our algorithms.

Presentations

Invited talks

Z. Li, "Retrieving a suite of cloud and aerosol parameters from satellite sensors", EUMESAT, November, 2015.

Rosenfeld, D., "Remote sensing of cloud condensation nuclei at cloud base", Atmospheric System Research, 2015.

Contributed talks

Zheng Y., D. Rosenfeld and Z. Li, 2015: "Retrieving the Convective Thermals and Updraft Speeds at Cloud Base from VIIRS" ". AGU Fall meeting, San Francisco, California, December, 2015.

Other

Fellow, American Association for Advancement of Sciences (AAAS), 2015
Humboldt Research Award, Alexander von Humboldt Foundation, Germany, 2015
Outstanding Author Award, Wiley Pub. for AGU journals, 2015

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

6 Climate Data & Information Records/Scientific Data Stewardship

CICS Support for for Ocean Data at the National Centers for Environmental Information (NCEI)
[The previously known National Oceanographic Data Center (NODC) is now part of NCEI.]

Task Leader: Dr. Ernesto Hugo Berbery.

Task Codes: EBEB_NODC_15, EBEB_AOML_15, EBEB_OADS_15, SBSB_OSSI_15, SBSB_PSST_15, SBSB_SARS_15, EBEB_VDMS_14, EBEB_WOD_15, SBSB_SOHCS_15; SBSB_IOOS_15, EBBB_CORAL_15.

NOAA Sponsor: Dr. Krisa Arzayus.

NOAA Office: NCEI.

Contribution to CICS Research Themes (%): Theme 1: 38% Theme 2: 30% Theme 3: 32%.

Main CICS Research Topic:
Climate Data and Information Records and Scientific Data Stewardship

Contribution to NOAA goals (%):
Goal 1: 57%; Goal 2: 11%; Goal 3: 32%

Highlights: In 2015, CICS played a significant role developing improved satellite data products, working with the ocean science community to provide global and regional ocean data, and 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.

CICS team actively participated in the continued development, maintenance, and enhancement of the World Ocean Database, the World Ocean Atlas, and Regional Climatology Projects.

Link to a research web page: www.nodc.noaa.gov

CICS-UMD NOAA/NESDIS/NCEI Staff: **Dr. Sheekela Baker-Yeboah** (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Paul DiGiacomo, Dr. Eric Bayler, Dr. Eileen Maturi, Dr. Eric Leuliette, Dr. Kenneth S. Casey, Dr. Laury Miller, Dr. Menghua Wang, Dr. David Donahue); **Brian Beck** (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons); **Mathew Biddle** (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons, Dr. Huai-min Zhang); **Liqing Jiang** (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons); **Dr. Alexey Mishonov** (NOAA Collaborators: Dr. Krisa Arzayus, Tim Boyer, Dr. Rost Parsons); **James Reagan** (NOAA Collaborators: Dr. Krisa Arzayus, Tim Boyer); **Dr. Korak Saha** (NOAA Collaborators: Dr. Kenneth S. Casey, John Relph, Thomas Ryan, John Sapper); **Dr. Yongsheng Zhang** (NOAA Collaborators: Dr. Eric Bayler, Dr. Banghua Yan, Dr. David Donahue, Dr. Eileen Maturi); **Dr. Zhankun Wang** (NOAA Collaborators: Dr. Huai-min Zhang, Tim Boyer), **Fred Katz** (NOAA Collaborators: Sharon Mesick, Dr. Rost Parsons, John Relph, Donald Collins).

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 2015, **Dr. Sheekela Baker-Yeboah** joined CICS-MD and leads the satellite team at NCEI. Sheekela writes and reviews proposals that support CICS-MD staff; serves as a Principal Investigator; works with budgets; works on satellite product development; collaborates with NOAA/NESDIS/STAR PIs and Project Leads on STAR satellite products that go into the NCEI archive; serves as a member of Ocean Surface Topography Science Team; and sits in on various NOAA/NESDIS/ Center for Satellite Applications and Research (STAR) and Center for Weather and Climate Prediction (NCWCP) meetings regarding to a variety of satellite data products and development.

In January of 2015, **Fred Katz** joined CICS-MD and began 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, NOAA/CLASS and the NOAA Central Library. The VDMMI team is responsible for standardizing and optimizing documentation, discovery and access to environmental data collected on video media.

In June of 2015, **Dr. Brian Beck** joined CICS-MD and is the NESDIS representative on CRCP SEA Team. The SEA Team is responsible for reviewing proposals and developing an annual spending 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 MD office.

In January of 2016, **Dr. Zhankun Wang** joined CICS-MD and is working on developing a Thermosalinograph (TSG) Database. The TSG database will be a valuable dataset and used in comparison studies and calibration of satellite salinity and temperature data.

Archive and Scientific Stewardship of Ocean Satellite Data. The NCEI Ocean Satellite Team consists of CICS members **Dr. Sheekela Baker-Yeboah** (Team Lead), **Dr. Korak Saha**, and **Dr. Yongsheng Zhang**, and is responsible for the product development and scientific stewardship of ocean satellite data into the archive. The Satellite Team works 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 Suit, 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 the Coral Reef Watch (CRW) product, 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 online tools 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/).

Archive and Scientific Stewardship of In Situ Data. NCEI CICS Team members working with *in-situ* data include **Dr. Brian Beck**, **Mathew Biddle**, **Fred Katz**, **Dr. Alexey Mishonov**, **James Reagan**, and **Dr. Zhankun Wang**. NCEI has one of the largest and most comprehensive publicly available *in-situ* data archives. 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 14.5 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 and applications, 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. WOD also offers a multitude of different XBT biased corrected data based on various XBT bias correction algorithms that have been published in the literature. 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) has been created from the WOD. Preparation of the global and regional climatologies requires extensive amounts of quality control 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/. CICS staff is involved in the creation and quality control of these products.

The regional climatologies are created based on the public's need and additionally constrained by the regional hydrographic data availability and distribution. Because regional climatologies are only calculated in regions of high data density, vertical resolutions of 102 standard levels and horizontal resolutions up to 1/10th degree are attainable. The World Ocean Atlas 2013 also increased, at least for some variables and time periods, its vertical resolution to 102 standard levels and horizontal resolution to a quarter-degree. One of the major improvements of the World Ocean Atlas 2013 comparing to its previous version is addition of the decadal climatologies to 'all data' fields. Version 2 of WOA consist of 6 subsets of Temperature & Salinity fields for 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, and 2005-2012 time periods. The movement to higher vertical and horizontal resolutions in both regional and global climatologies as well as adding decadal sub-sets is important for resolving small scale structures (i.e. fronts) and usage in ocean and climate models, among others.

NCEI has been funded by the Integrated Ocean Observing System (IOOS) Program Office to perform various data management. It 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. 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.

One of the roles of NCEI is to fully steward environmental data, which consists of converting and applying quality control tests as applicable. Currently at NCEI, there is a significant amount of thermo-salinograph (TSG) data that comes in through various pathways and in various file formats. CICS staff worked with NCEI to steward the TSG data and provide various reformatted aggregations of the Shipboard Automated Meteorological and Oceanographic System (SAMOS) data sets submitted to the archive.

NCEI was funded by NOAA's Ocean Acidification Program to manage their data through the Ocean Acidification Data Stewardship (OADS) project. The overarching goal of the OADS project is to serve the OA community by providing dedicated online data discovery, access to NCEI-hosted and distributed authoritative data sources, long-term archival, coordinated data flow, and scientific stewardship for a diverse range of OA and other chemical, physical, and biological oceanographic data.

Accomplishments

A. Archive and Scientific Stewardship of Satellite Data

1. **NCEI Long Term Stewardship and Reanalysis Facility (LTSRF) for the Sea Surface Temperature Products.** NCEI maintains a leading role in the world's Sea Surface Temperature (SST) community by stewarding the international Group for High Resolution SST (GHRSST), which is called the Long Term Stewardship and Reanalysis Facility (LTSRF). The GHRSST LTSRF archives over 50GB of SST data each day. These data are provided by various Regional Data Assembly Centers (RDACs). There are 70 plus GHRRST products from these RDACS that are archived each day using a very robust automation system. CICS affiliates in the Satellite Oceanography Team are responsible for generating and improving software necessary for archive the process, providing quality assurance for the archive, and generate complementary products for GHRSST. During FY2015 five new GHRSST SST products were successfully quality controlled and archived. CICS Research Associate **Dr. Korak Saha** developed Open Source PYTHON codes and scripts to generate GHRSST Level 2P, Level 3 and Level 4 browse images in in near real time (Figure 1.1).

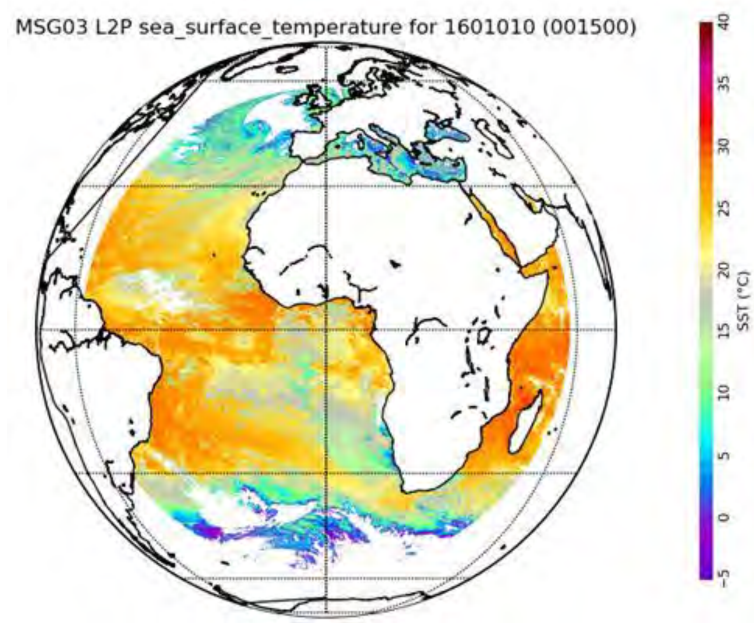

Figure 1.1. Global image of a Level 2P browse graphic for the Meteosat Second Generation (MSG03) SST data.

2. **Pathfinder SST processed in an Amazon Web Service (AWS) Cloud.** The Satellite Team produced the Pathfinder Sea Surface Temperature Climate Data Record in an AWS Cloud environment. All previous versions of Pathfinder included L3C products. CICS Research Scientist **Dr. S. Baker-Yeboah** and **Dr. K. Saha** worked to update the Pathfinder SST product (Version 5.3, Figure 1.2). Updates include: L2P, L3U, and L3C products**,** SST values of all quality levels (giving the user more pixels to work with) processing done using cloud computation in AWS under NOAA cloud pilot project, anomalous hotspots at land-water boundaries better identified and flagged, updated land mask and sea ice data over the Antarctic ice shelves masked, improved data pixels in sun glint areas, consistent cloud tree tests for NOAA07 and NOAA-19 satellites, and revised netCDF attributes with respect to GHRSST requirements. Python code was also written to generate the browse image used for visual inspection, which will be

archived along with the netCDF data. A comparison of L3C PFv53 was made with the level -4 Canadian CMC global SST data by developing a matchup database using 7 years of available data (Figure 1.2).

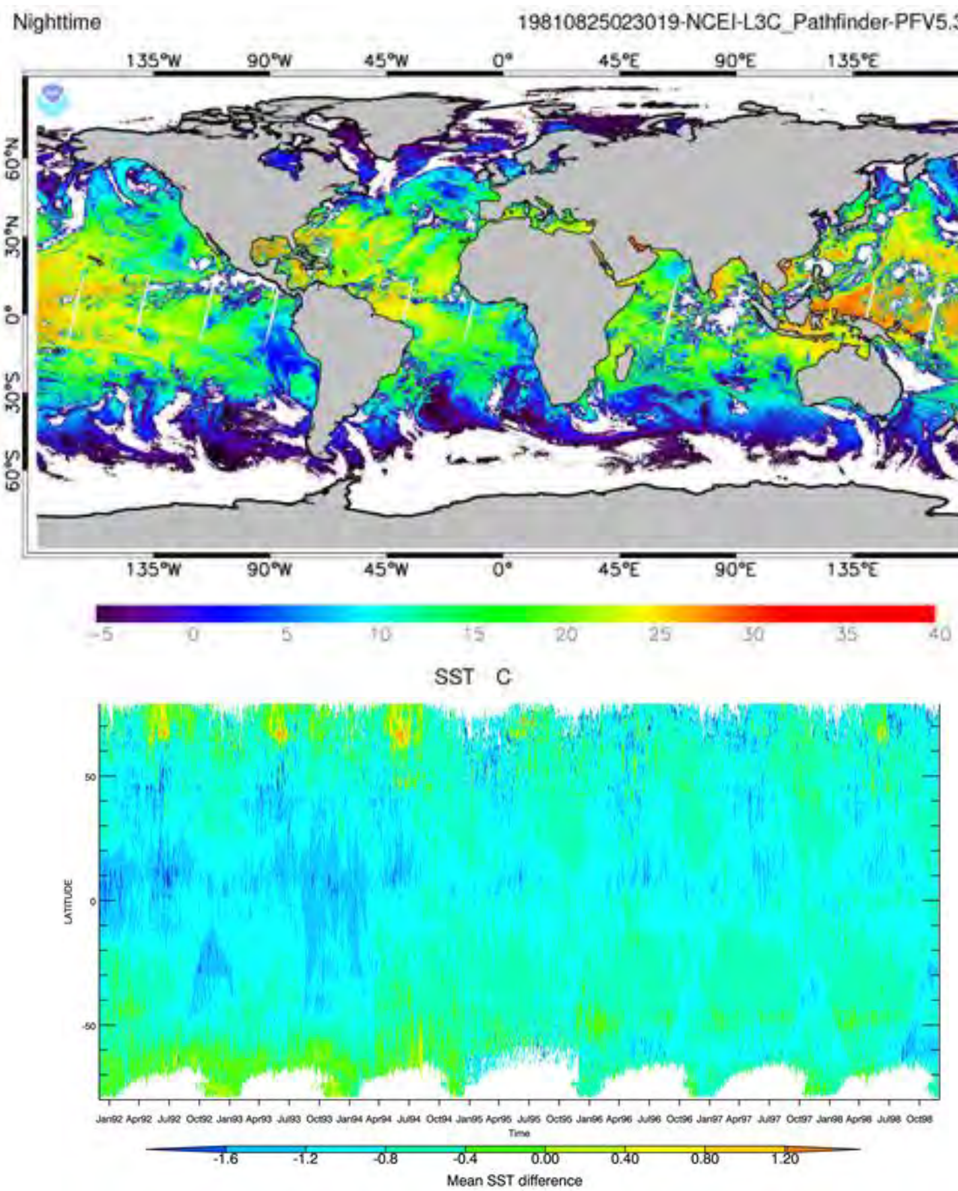

Figure 1.2. Pathfinder SST (upper panel) and Hovmöller diagram of the PFv5.3 in comparison with CMC SST (lower panel).

3. **Completed generation of NCEI-binned level-3 SMOS (V6.0) and Aquarius (V4.0) sea surface salinity (SSS) data.** The best application of the European Space Agency's (ESA) Soil Moisture – Ocean Salinity (SMOS) mission and the NASA Aquarius mission SSS data relies on completely understanding the impact on data quality from choices for the thresholds of the different filters available for the Level-2 products. Quick-look Level-3 datasets generated directly from SMOS and Aquarius Level-2 products will improve the use of satellite SSS products in NOAA's data applications and *in-situ* data comparisons, as well as for near-real-time data quality monitoring of Level-2 products. CICS Research Scientist

Dr. Y. Zhang worked to generate 1°×1° binned Level-3 SSS products from SMOS and Aquarius Level-2 swath data, minimizing latency to within 24 hours of Level-2 data availability. These satellite SSS products include SMOS monthly and 3-day (global coverage) means and Aquarius monthly and 7-day (global coverage) means. Comparison studies among NCEI level-3 SSS and other sources data from NASA, ESA and in situ observations demonstrates that in the tropical and subtropical open oceans, NCEI's binned Level-3 SMOS and Aquarius SSS products agree well with the Level-3 fields produced by the NASA and ESA satellite mission programs and community experts, as well as with NCEI assessments derived from *in-situ* observations. Larger biases, however, are observed along coastal regions and within the high-latitude oceans. The NCEI-binned SMOS and Aquarius Level-3 SSS data products are available via the NCEI SSS data quality monitoring homepage:

http://www.nodc.noaa.gov/SatelliteData/sss/ .

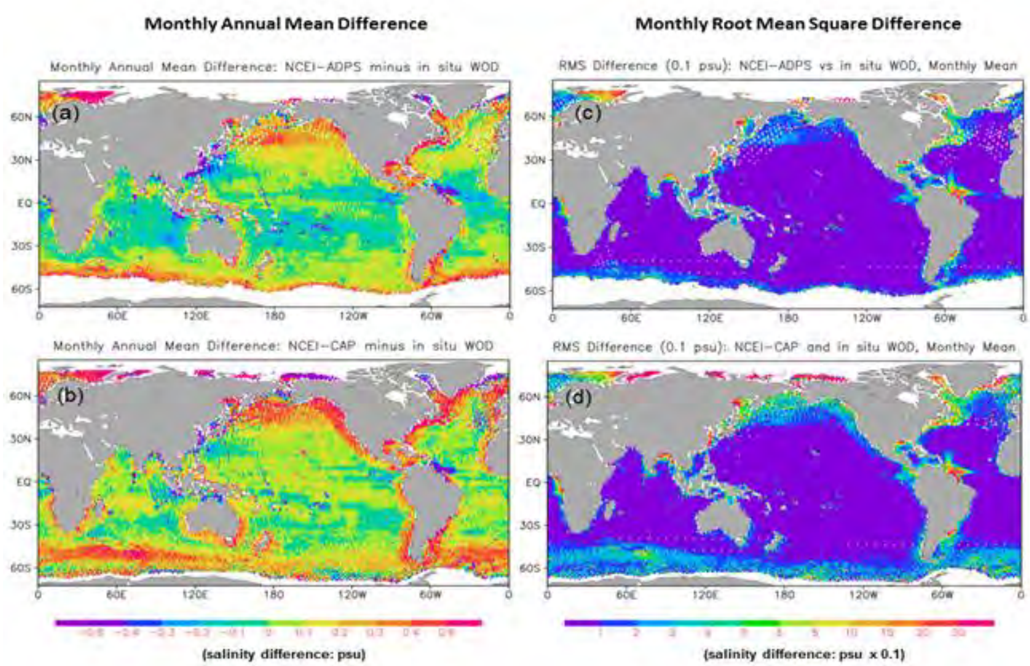

Figure 1.3. Monthly annual mean SSS difference between level-3 NCEI-binned Aquarius and NCEI WOD in situ-derived gridded fields from September 2011 to May 2015: (a) V4.0 NCEI ADPS (Aquarius Data Processing System) minus NCEI WOD SSS, and (b) NCEI-binned CAP (Combined Active-Passive) minus WOD SSS. Monthly mean squared (RMS) deviation between NCEI-binned and NCEI WOD in situ-derived gridded SSS: (c) NCEI-binned ADPS and WOD SSS, and (d) NCEI-binned CAP and WOD SSS.

4. **Developed NCEI data quality monitoring for SMOS and Aquarius level-2 sea surface salinity, NCEI Pathfinder V5.3 SST and RADARSAT-2 sea surface winds data produced from Synthetic Aperture Radar (SAR).** An important component of NCEI's data stewardship for satellites oceanographic products is to develop a data quality monitoring system known as the Rich Inventory to monitor and track the data assurance statistics and metadata attributes in each data file (swath), and to provide those results to the public. **Dr. Y. Zhang** worked to establish NCEI data quality monitoring on these new datasets.
5. **Completed scientific stewardship of Operational MODIS/Aqua Ocean Color Frontal Products in the NESDIS Comprehensive Large Array-data Stewardship System (CLASS).** This product, produced by

NOAA Coast Watch Program, is a daily set of chlorophyll frontal information derived from the MODIS/Aqua instruments. The frontal information from satellite chlorophyll data has been used by scientists in Northeast Fisheries Science Center of NOAA National Marine Fisheries Service to provide fundamental information needed for ecosystem-based fishery management. **Dr. Y. Zhang** made the products to be successfully archived in CLASS.

6. **Completed scientific stewardship of NESDIS Satellite Ocean Heat Content Suite (SOHCS) products.** This product, generated by the NESDIS, contains daily average satellite-derived oceanic heat content for the Northern Atlantic, Northern and Southern Pacific Basins. The SOHCS product measures the integrated vertical temperature from the sea surface to the depth of the 26°C isotherm based on objectively analyzed blended sea surface height anomaly fields from operational altimeters and Geo Polar blended SST analyses. CICS Research Scientists **Dr. S. Baker-Yeboah and Dr. Y. Zhang** successfully archived these products at NCEI and **Dr. S. Baker-Yeboah** published a white paper with NOAA collaborators**.**

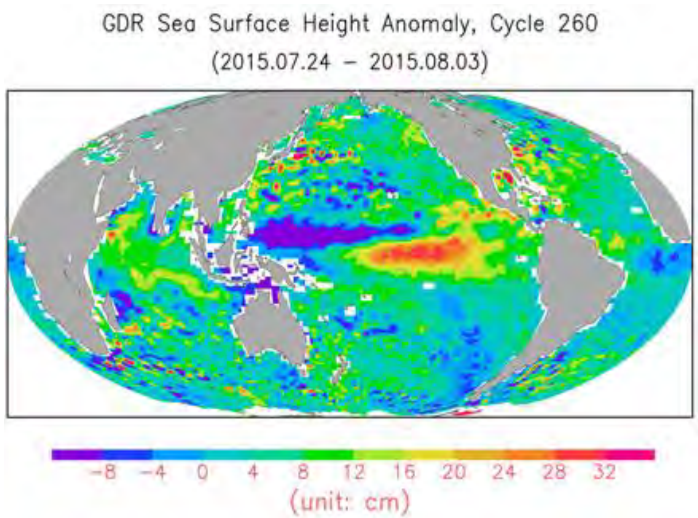

Figure 1.4. Ocean surface topography sea surface height anomaly from Jason-2 Geophysical Data Records.

7. **Implemented routine data archive, access and distribution tasks for Jason-2 and Jason-3 products.** The CICS-NCEI Satellite Team works collaboratively with the Jason-3 Team to provide open access to the Jason-2 data (Figure 1.4) used in comparison with the new Jason-3 data for calibration purposes. Jason-3 Team launched the Jason-3 satellite platform on 17 January 2016 and NCEI will archive these new data and work with STAR on providing more user products. **Dr. S. Baker-Yeboah** and **Dr. Y. Zhang** will continue interacting with the NOAA Jason Team and provide public access to the Jason-3 level-2 data in July of this year.

B. Archive and Scientific Stewardship of In Situ Data

1. Fostering relationships with IOOS Regional Associations. CICS staff archived numerous accessions. For example, CICS Research Assistant **M. Biddle** developed automations for two different data streams (1) IOOS RA SECOORA and (2) IOOS RA GLOS over the FY14/15 time period. Together, these two automations consist of 84 Archival Information Packages that 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 93 archival packages, contributing 1+TB of *in-situ* observational data to the NCEI archive. While these two data streams were already established pathways into the archive, NCEI fostered relationships with 9 other RAs to follow a similar paradigm in automated archiving. Through the two test cases of automated archival, CICS staff developed and delivered a cookbook on how to archive in-situ observational data at NCEI (Figure 2.1), “Archiving your data at NCEI: A Guide for IOOS Regional Association Data Managers”. This webpage provides a step-by-step procedure on how to develop an automated archival process with NCEI. The cookbook was released on the NCEI-IOOS Google Site “NCEI-IOOS Regional Association and Data Assembly Center Archive” which is also maintained by CICS staff. The cookbook and Google Site serve as a resource for the RA data managers and has been integral in fostering NCEI’s relationships with the IOOS Regional Associations. The information provided therein can also be propagated to other user communities, outside of the IOOS RAs, who would like to know how to better manage their data.

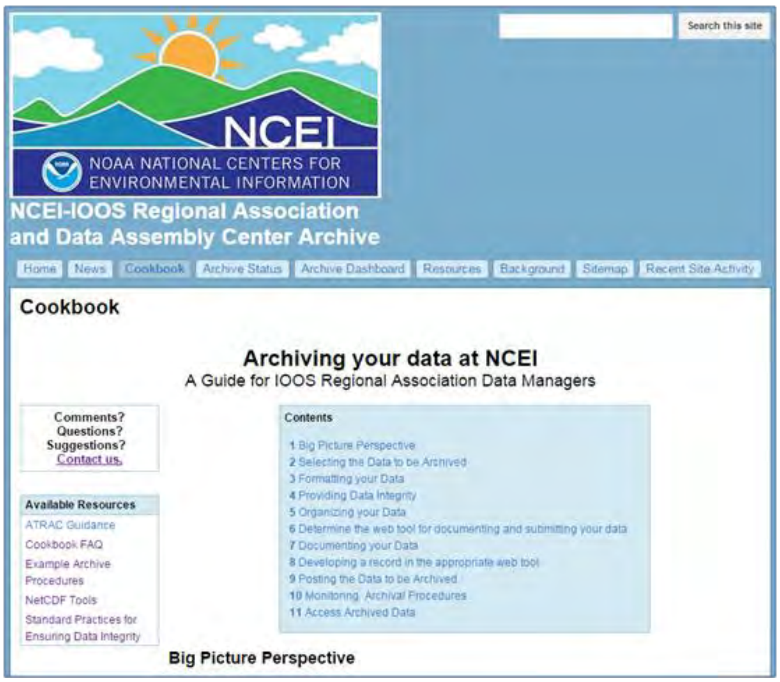

Figure 2.1. A screen capture of the NCEI-IOOS Google Site cookbook page where Integrated Ocean Observing System Regional Association (IOOS RA) data managers can find information about archive activities at NCEI and how to format and archive their data through an automated process.

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 was 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. Also, 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. In August 2015, the Pacific Islands Coastal Ocean Observing System (PacIOOS) was formally certified as a Regional Information Coordination Entity (http://archive.constantcontact.com/fs101/1105866148764/archive/1122044627499.html). CICS staff is currently providing input and consolidating responses for the second application for certification.

2. World Ocean Database and World Ocean Atlas 2013 v2. The World Ocean Database (WOD) is being updated four times every year (i.e. quarterly updates). 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 profile ocean data collected by various oceanographic instruments submitted by different research Institutions or found in archives all over the World. Some examples would be the CLIVAR & Carbon Hydrographic Data Office (CCHDO) and the International Council for the Exploration of the Sea (ICES). CICS researches also process annual updates of CTD data from the Northeast Fisheries Science Center (NEFSC) and dealing with other miscellaneous datasets throughout the year for inclusion in WOD. Additionally, during 2015, they updated all historical CCHDO bottle data in WOD. Figure 2.2 shows all data CICS Research Scientist **Dr. A. Mishonov** and Faculty Specialist **J. Reagan**, added/updated (~200,000 profiles) in WOD over the past year.

The World Ocean Atlas 2013 version 2 (WOA13v2) was released in mid-2015 (http://www.nodc.noaa.gov/OC5/woa13/). This release addressed some methodology and quality control (QC) concerns arising after the release of WOA13 version 1 (WOA13v1). CICS staff performed additional QC that helped resolve numerous quality control issues. Figure 2.3a,b shows the improvement in the surface salinity fields just west of Panama that was a result of additional QC work.

3. *In-Situ* Ocean Heat and Salt Content. Dr. A. Mishonov and **J. Reagan** played a key role in the creation and quality control of the 2015 globally gridded seasonal temperature and salinity anomaly products, which were released four times (quarterly) over the past year. Additionally, during January 2016 CICS staff quality controlled the 2011-2015 (pentad) and the 2015 annual/seasonal temperature and salinity anomalies along with the 2015 monthly salinity anomalies. The January 2016 updates are especially important and time sensitive due to latest extreme El-Nino event and because these products being extensively used in both "Salinity" (co-authored by **J. Reagan**) and the "Ocean Heat Content" sections of the "State of the Climate in 2015" report in the Bulletin of the American Meteorological Society (BAMS).

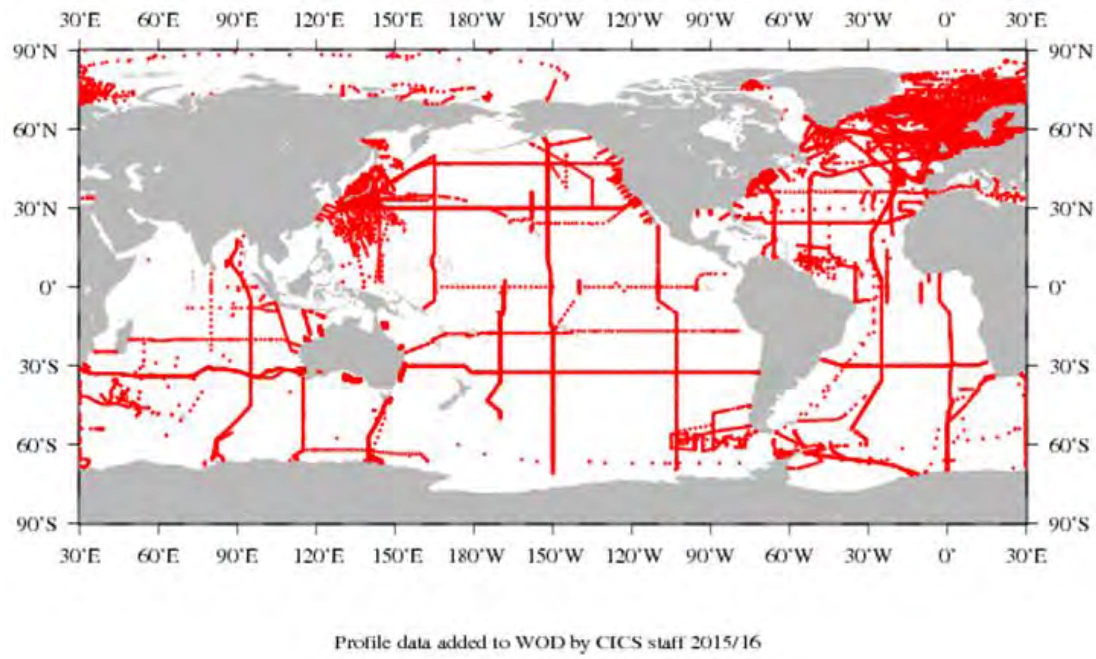

Figure 2.2: Spatial distribution of ocean profiles added to the World Ocean Database from 4/1/2015-3/31/2016 by CICS staff. There were a total of 199,879 profiles that came from: bottles, conductivity-temperature-depth instruments (CTDs), gliders, moored buoys, expendable bathythermographs (XBTs), mechanical bathythermographs (MBTs), and undulating oceanographic recorders.

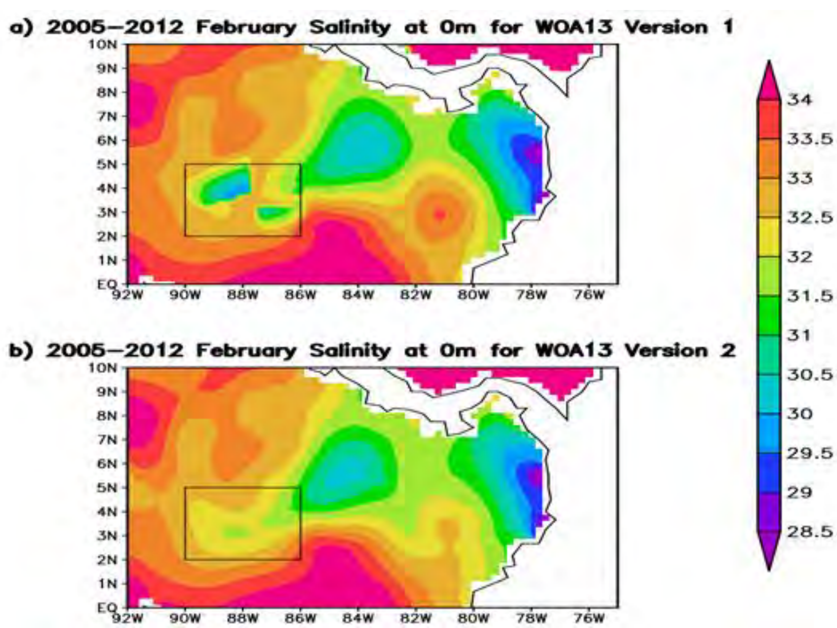

Figure 2.3. The February 2005-2012 Salinity at 0m just west of Panama for a) WOA13v1 and b) WOA13v2. The boxed region is where additional QC was applied in WOA13v2.

Furthermore, utilizing the aforementioned salt content products, **J. Reagan** has begun analyzing long-term (~60 years), medium-term (~30 years), and short-term (~10-years) linear trends in near-surface salinity (0-10m average). It has been found that long-term trends do indicate an amplification of the global ocean salinity patterns (i.e., salty regions are becoming saltier and fresh regions fresher) and therefore are likely related to an amplification of the global hydrological cycle; however, these salinity pattern amplifications appear to break down at shorter time scales indicating natural climate variability plays a major role even at multi-decadal (~30-year) time scales. Figure 2.4 shows the 60-year (1951/55-2010/14) near-surface salinity trend computed from the pentadal salinity anomalies.

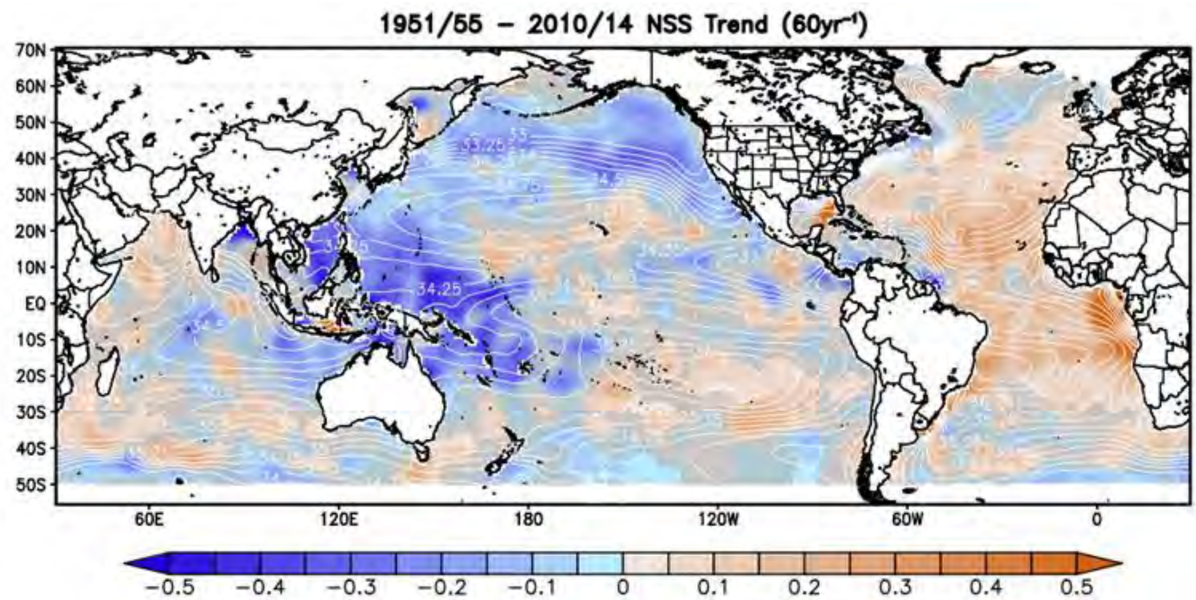

Figure 2.4. The 1951/1955-2010/2014 Near-Surface Salinity Linear Trend (60yr-1). Blue regions are regions where salinity is decreasing (freshening) and orange regions are regions where salinity is increasing (salinification). The white contours represent the climatological salinity mean (from World Ocean Atlas 2009).

4. Data synthesis product: Climatological distribution of aragonite saturation state in surface and sub-surface waters of the global oceans. CICS-MD Research Engineer Li-Qing Jiang (supporting activities at NCEI) worked with scientists from NOAA's Pacific Marine Environmental Laboratory, NCEI, and Ocean Acidification Program to map the distribution of aragonite carbonate saturation state in both surface and subsurface waters of the global oceans. Along with pH, aragonite saturation state is an important indicator of ocean acidification.

This study will improve our understanding of the current status of ocean acidification in the global oceans, identify the most vulnerable regions, and form a baseline for any future changes. On October 13, when this article was published online, both NOAA and AGU issued press releases about it. The story has been picked up by EurekAlert, Phys.org, Summit County Citizens Voice, as well as NOAA's STAR web-site. The CICS-MD Winter Circular (2015) also featured Li-Qing Jiang on the first ever global climatology of ocean acidification using an aragonite and calcite saturation states.

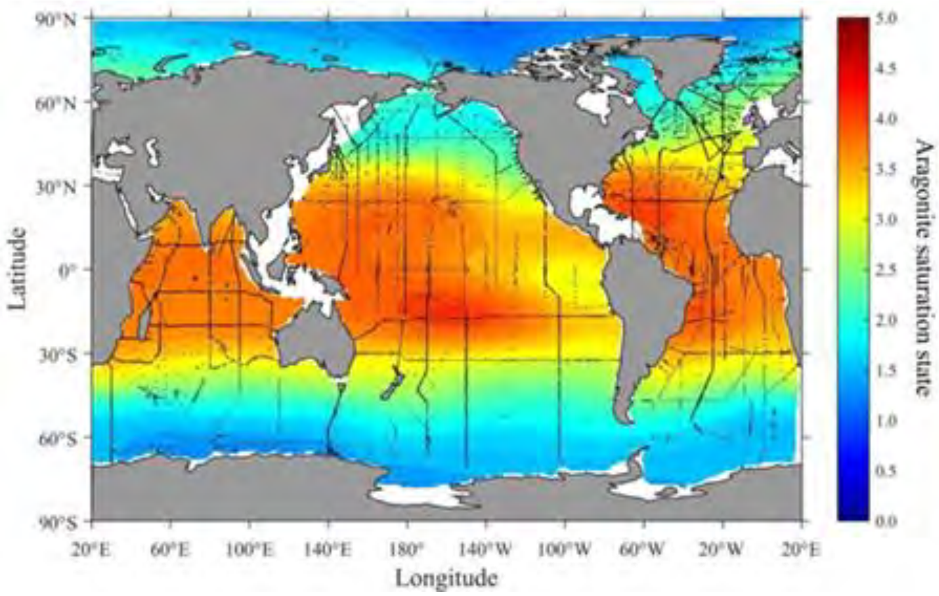

Figure 2.5. The climatological distributions of aragonite saturation state (Ωarag) in surface waters of the global oceans (black dots show the sampling stations).

5. Ocean acidification data management. Li-Qing Jiang developed a new comprehensive ocean acidification metadata template to lay the foundation for NOAA's ocean acidification data management effort; redesigned the Ocean Acidificaiton Data Stewardship (OADS) Project website to make it easier for users to submit or access ocean acidification data; designed a new metadata display page so that ocean acidification metadata can be displayed in the best possible way and archived all of the 50 plus datasets received from NOAA's ocean acidification investigators . **Li-Qing Jiang** also worked with NCEI's IT department to restart the data transfer effort from Carbon Dioxide Information Analysis Center (CDIAC). (See http://www.nodc.noaa.gov/oceanacidification/data/0137723.xml)

6. Involvement with the Coral Reef Conservation Program (CRCP). CICS Post-Doctoral Associate **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 all internal proposals for funding and drafting a recommended annual spending plan for the CRCPs $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 (e.g. NEPA). CICS staff 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.

CICS staff 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. CICS staff coordinates the upkeep and further development of the Coral Project Database with the NOS's Office of Coastal Management, which is used to track all funding and deliverables of CRCP projects. CICS staff also serves as Data Content Manager for incoming CRCP funded data to NCEI.

7. Involvement with development of Regional Climatologies. CICS Research Scientist **Dr. Alexey Mishonov** has been working on further development of the Northwest Atlantic Regional Climatology

(NWARC) project performing Quality Control of the 0.10-degree sea water temperature/salinity fields and re-calculating climatological fields for all spatial resolution fields (1.00, 0.25, 0.10-degree) over six decades time span (1955-2012), as well as for each individual decade: 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-5004, & 2005-2012. **Dr. A. Mishonov** created collection of maps on T & distribution over NWARC accessible via web-interface at http://www.nodc.noaa.gov/OC5/regional_climate/nwa-climate/.

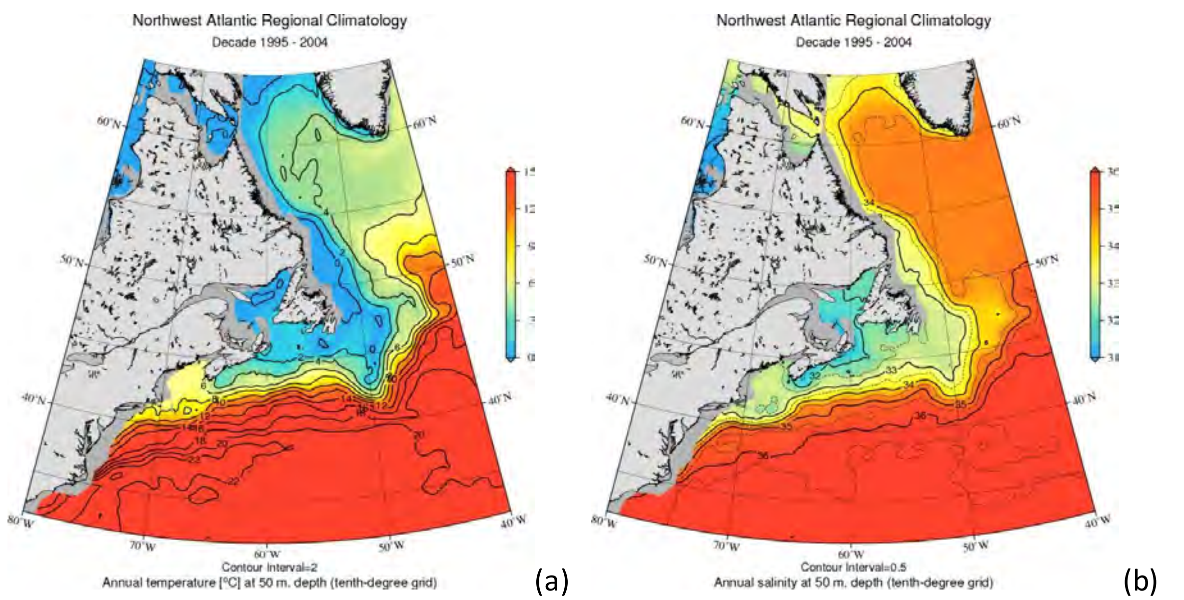

Figure 2.6. Northwest Atlantic Regional Climatology: 0.10-degree T (a) & S (b) annual fields at 50m depth for 1995-2004 decade.

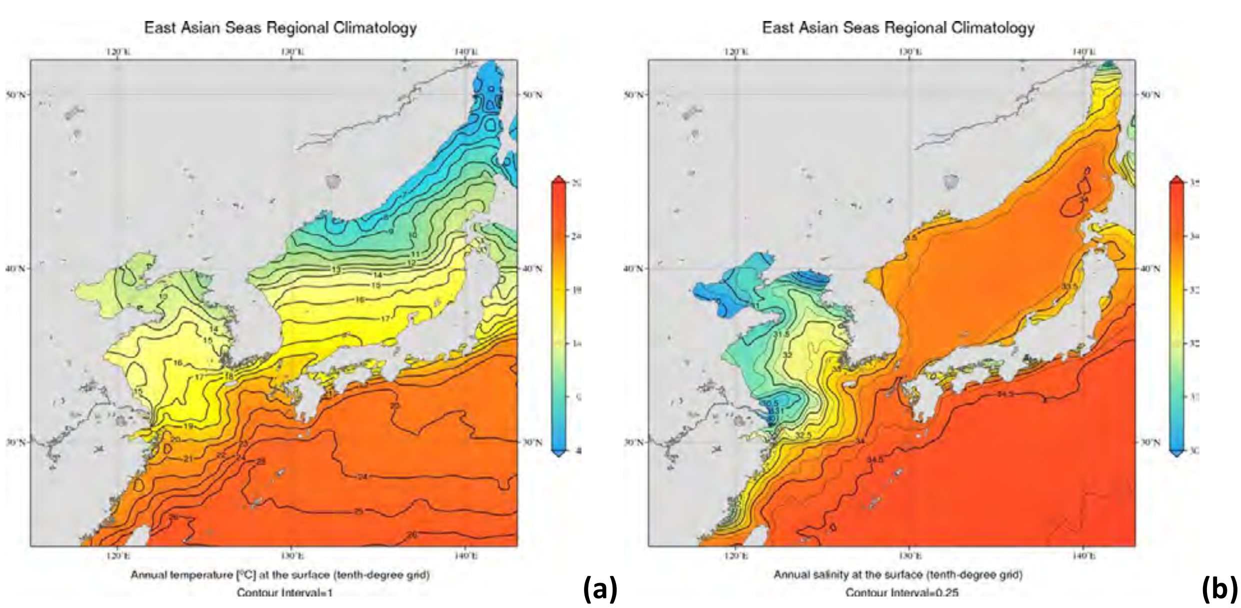

Figure 2.7. East Asian Seas Regional Climatology: 0.10-degree T (a) & S (b) annual fields at the surface.

Dr. A. Mishonov participated in preparation of the East Asian Seas Regional Climatology published at http://www.nodc.noaa.gov/OC5/regional_climate/EASclimatology/.

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.
- Prepare for the upcoming World Ocean Database and World Ocean Atlas 2017 releases.
- Archiving the RADARSAT-2 SAR-wind data generated by NOAA/NESDIS/STAR.
- Archiving the Sentinal SAR-wind data.
- Working for the development of SST coefficients for Pathfinder 6.
- Act as the lead for NCEI to work with the IOOS Program Office and interact with the remaining nine Regional Associations to enable smooth transfer of data into the archives.
- Coordinate NCEI review of the Data Management and Communication section of the IOOS Regional Association Certification process.

  (See http://www.ioos.noaa.gov/certification/welcome.html.
- Continue roles supporting the CRCP. This includes releasing a second version of the Coral Project Database.
- Develop a well-organized uniformly quality controlled thermosalinograph (TSG) database
- Develop NCEI *in Situ*-Satellite data quality monitoring and validation system for SMOS and NASA Soil Moisture Active Passive (SMAP) satellites Level-2 Sea Surface Salinity (SSS) data.
- Development of altimeter and ocean color products in collaboration with NOAA/NESDIS/STAR.
- Continue to upgrade and archive NCEI-binned level-3 SMOS and produce SMAP satellite SSS products, compare V6.22 NCEI-binned SMOS Level-3 and other datasets (e.g., ESA-BEC level-3 and NCEI WOD in situ-derived gridded SSS data).
- Establish NCEI data quality monitoring system for Jason-3, which has been developed at NCEI based on Jason-2.
- Complete routine data archive, access and distribution tasks for Jason-2 and Jason-3 satellite products, incorporating new Jason 3 products.
- Complete NCEI archive and distribution system for Jason-3 satellite products.
- Complete building Rich Inventory for NCEI PFV5.3 SST and SAR wind.
- Support development of NCEI data archive, access and discovery service for NOAA ocean color satellite products.
- Continue working towards archiving of upcoming GHRSST data and maintaining the ongoing archiving system.

- Archiving climatological data for the pathfinder 5.3 (1981-2014) generated in the Amazonweb services.
- Archiving the Sentinal SAR-wind data.
- Working for the development of SST coefficients for Pathfinder 6.
- Work towards a validation of the pathfinder CDR and publication of the results in peer reviewed journal.
- Develop next version of CoRTAD using the new pathfinder ver5.3.
- Archiving the 5Km Coral Reef Watch data.
- Continue development of the new Regional Climatology – North-Northern Pacific.
- Continue maintenance of published Regional Climatologies (Greenland-Iceland-North Sea and Arctic) splitting entire 1955-2012 time onto decadal sub-sets, which involves re-calculating all climatological fields on T&S and creation of maps collections.
- Continue to ingest and process in-situ oceanographic data submitted by various Institutions with focus on gliders.
- Continue to curate data on beam attenuation in WOD with collaboration with Texas A&M University, with emphasis on recent CLIVAR, Repeat Hydrography, and GEOTRACERS cruises.
- Continue to develop video data discovery geoportal for OER video archived in CLASS.
- Develop usability guidelines for OER video discovery geoportal.
- Document VDMMI history and process as a case study/model for BEDI.
- Direct usability and access improvements to OER video geoportal website.
- Archive 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.
- Support migration of OEDV video from Central Library to NCEI servers.

Publications

Peer-reviewed:

- Boyer, T., J. Antonov, **J. Reagan**, C. Schmid, and R. Locarnini (2015), [Subsurface salinity] Global Oceans [in State of the Climate in 2014], *Bull. Amer. Meteor. Soc.*, 96, S74-S76.
- Johnson, G. C., **J. Reagan**, J. M. Lyman, T. Boyer, C. Schmid, and R. Locarnini (2016), [Salinity] Global Oceans [in State of the Climate in 2015], *Bull. Amer. Meteor. Soc.* (in review)
- Tyler, R., T. Boyer, T. Minami, M. Zweng, **J. Reagan** (2016), Electrical conductivity of the global ocean, *Earth and Planetary Science Letters* (in review)
- **Jiang, L.-Q.**, R. A. Feely, B. R. Carter, D. J. Greeley, D. K. Gledhill, K. M. Arzayus (2015). Climatological distribution of aragonite saturation state in the global oceans Global Biogeochem. Cycles, 29, 1656–1673, doi:10.1002/2015GB005198.
- **Jiang, L.-Q.**, S. Oconnor, K. M. Arzayus, A. R. Parsons (2015). A metadata template for ocean acidification data, Earth Syst. Sci. Data, 7, 117-125, doi:10.5194/essd-7-117-2015

- Xue, L., H. Wang, **L.-Q. Jiang**, W.-J. Cai, Q. Wei, H. Song, **B. Beck**, L. Liu, and W. Yu. 2015. Aragonite saturation state in a monsoonal upwelling system off Java, Indonesia. Journal of Marine systems, 153:10-17, http://dx.doi.org/10.1016/j.jmarsys.2015.08.003
- Xue, L., W.-J. Cai, X. Hu, C. Sabine, S. Jones, A. J. Sutton, **L.-Q. Jiang**, and J. Reimber (2015). Sea surface carbon dioxide at the Georgia time series site (2006-2007): air-sea flux and controlling processes. Progress in Oceanography, 140, 14–26.
- Benfield, M., M. Chierici, K. Cooerman, R. A. Feely, C. Hagebro, J. M. Hall-Spencer, D. J. Hydes, S. Hjalmarsson, H. M. Jensen, **L.-Q. Jiang**, C. Kivimae, A. De Kluijver, A. Kozyr, E. Mcgovern, J. R. Larsen, S. Mesuck, M. C. Nielsdottir, S. Olafsdottir, A. Olsen, H. Parner, D. J. Pearce, B. Pfeil, B. Phelan, H.-O. Portner, J. M. Roberts, M. Sorensen, T. Tanhua, K. Vorkamp, P. Walsham, S. Weigelt-Krenz, P. Williamson, A.W. Wranne, P. Ziveri (2015). ICES (2014) Final report to OSPAR of the Joint OSPAR/ICES Ocean Acidification Study Group (SGOA). ICES CM 2014/ACOM:67. 141 pp.
- **Zhang, Y.**, E. Bayler and **S. Baker-Yeboah**, 2016: Comparison between SMOS and Aquarius NCEI-binned Level-3 sea surface salinity and those from JPL, SMOS-BCE and NECI WOD in situ derived fields. To be submitted to IEEE Transactions on Geoscience and Remote Sensing.
- **Reagan, J.**, T. Boyer, and M. Zweng. Comparing 60-year, 30-year, and 10-year trends in global ocean salinity - does water cycle intensification dominate the signal? *J. Geophys. Res. Oceans*, in preparation.

Not Peer-Reviewed:

- **Baker-Yeboah, Sheekela,** Tim Boyer, Lynn K. Shay, Eileen M. Maturi, and David Donahue. Sea Surface Temperature and Ocean Heat Content from Space. White Paper 2015 NOAA/NESDIS.

Products

1. **World Ocean Atlas 2013 version 2** – Released mid-2015
2. Most recent release of pentadal (2011-2015), annual (2015), seasonal (2015), and monthly (2015) temperature and salinity anomaly gridded products
3. **World Ocean Database** – Quarterly Updates/Releases
4. **Northwest Atlantic Regional Clymatology –** Updated after Quality Control for separate decades sub-sets.
5. The blue print for NOAA/NCEI's new online data submission system – Send2NCEI, and coordinated with the IT department to successfully implement the tool. (https://www.nodc.noaa.gov/s2n/)
6. Ocean Acidification Data Portal (http://www.nodc.noaa.gov/oceanacidification/stewardship/data_portal.html)
7. NCEI cookbook for automatically archiving your in-situ observational data.
8. The Coral Project Database was developed, with NOS/OCM, and successfully used for FY16 CRCP spend plan development.
9. **NCEI-binned Level-3 Aquarius Data Processing System (ADPS) V4.0** 7-day and monthly mean SSS data derived from Level-2 Aquarius ADPS V4.0 products.
10. **NCEI-binned Level-3 Aquarius Combined Active-Passive (CAP) V4.0** 7-day and monthly mean SSS data derived from Level-2 Aquarius CAPv4.0 products.
11. SMOS NCEI-binned level-3 V3.0 3-day and monthly mean SSS data derived from V6.22 Level-2 SMOS SSS data.

Presentations

- Angulo, A. R., A. Costa, S. DiMarco, S., J. Ledwell, K. Polzin and **Z. Wang**. Boundary mixing along the northern deep water Gulf of Mexico. 2016 Ocean Sciences Meeting, New Orleans, LA (poster).
- **Baker-Yeboah**, **S.,** Assimilation of ACSPO VIIRS LST in L4 Analyses: NCEI/Silver Spring ACSPO Archive Update. STAR JPSS Annual Science Team Meeting, College Park, MD. Aug 2015 (Talk)
- **Baker-Yeboah, S., K. Saha, D. Zhang**, and K.S Casey, Pathfinder Sea Surface Temperature Climate Data Record, AGU 2016 Ocean Sciences Meeting New Orleans, LA. Feb 2016 (poster).
- **Baker-Yeboah, S., K. Saha**, **Y. Zhang,** K.S. Casey, Y. Li. Scientific Stewardship of VIIRS Ocean Satellite Data. STAR JPSS Annual Science Team Meeting College Park, MD. Aug 2015 (Poster)
- **Baker-Yeboah, S.,** Satellite Altimetry Sea Surface Height Variability and In Situ Observations along an Eddy Corridor. 4th Annual CICS-MD Science Meeting**.** College Park, MD. Nov 2015 (talk).
- **Baker-Yeboah, S., Y. Zhang** and D. Byrne: NOAA archive and access services for Jason-2 and 3 Products, 2015 Ocean Surface Topography Science Team (OSTST) Meeting, October 20-23, 2015, Reston, Virginia. (Poster)
- Banzon, V., G. Liu, **K. Saha**, and C. Wilson. Climate applications for NOAA 1/4° Daily Optimum Interpolation Sea Surface Temperature, 2015 AGU Fall Meeting Dec 2015.
- Banzon, V., **K. Saha**, A. Krishnan, Y. Li, J. Relph, D. Zhang, Y. Zhang, and **S. Baker-Yeboah**: G16 RDAC update from NCEI, GHRSST Science Team Meeting. ESA/ESTEC, The Netherlands, 20 – 24 July 2015.
- **Biddle, M**. Archiving at NCEI: An IOOS RA Perspective, 2016. NOAA Environmental Data Management Workshop. Washington D. C. Jan 2016 (oral).
- **Biddle, M.** NCEI-IOOS Project updates to the IOOS Data Management and Communications (DMAC) group. 2015 IOOS DMAC Meeting. Silver Spring, MD. May 2015 (oral).
- Boyer, T., L. Sun, R. Locarnini**, A. Mishonov**, N. Hall, M. Quellet. World Ocan Database and the Global Temperature and Salinity Profile Programm Database: Synthesis of historical and near real-time ocean profile data.
- DiMarco, S., A. Knap, **Z. Wang**, J. Walpert and K. Dreger. Deadzones, dying eddies, and the loop current: stability, ventilation, and heat content from buoyancy glider observations in the Northwest Gulf of Mexico in Spring and Summer 2015. 2016 Ocean Sciences Meeting, New Orleans, LA (poster).
- Gardner, W., MJ Richardson, **A. Mishonov**. Global Distribution and Intensity of Deep-Water Benthic Nepheloid Layers. 2016 Ocean Sciences Meeting, New Orleans, LA (poster).
- **Jiang, L.-Q.** An Ocean Acidification Data Discovery Portal. Meeting towards a GOA-ON data portal. Jun 2015, IAEA Environment Laboratories, Monaco.
- **Jiang, L.-Q**. Climatological Distribution of Aragonite and Calcite Saturation States in the Global Oceans. CICS-MD Science Meeting, Nov 2015, College Park, MD
- **Jiang, L.-Q.**, A. R. Parsons, and K. M. Arzayus. The Ocean Acidification Data Stewardship Project. NOAA Ocean Acidification Working Group Meeting, Aug 2015, Silver Spring, MD.
- **Jiang, L.-Q.**, R. A. Feely, B. Carter, D. J. Greeley, D. Gledhill, K. M. Arzayus, R. Wanninkhof and R. Key. Data-based aragonite saturation state climatology. NOAA Ocean Acidification PI Meeting Webinar Series, Jun 2015.
- Locarnini, R., T. Boyer**, A. Mishonov, J. Reagan**. Subsurface Ocean Climate Data Records: Global Ocean Heat and Freshwater Content. 2015 AGU Fall Meeting. San Francisco, CA. Dec 2015.

- **Mishonov, A.,** K. Arzayus, O. Baranova, T. Boyer, R. Parsons, D. Seidov. Regional Ocean Climatologies: A New Line of Ocean Climate Research Tools. 2016 Ocean Sciences Meeting, New Orleans, LA (poster).
- Polzin, K., J. Ledwell, A. Angel, S. DiMarco and **Z. Wang.** Boundary Mixing along the Northern Deep Water Gulf of Mexico, 2016 Gulf of Mexico Oil Spill and Ecosystem Science Conference, Tampa, FL (oral).
- R. A. Feely, S. R. Alin, B. Carter, **L.-Q. Jiang**, D. Greeley, and J. T. Mathis. Responses to ocean acidification on varying temporal and spatial scales. 3rd U.S. Ocean Acidification PI Meeting, Woods Hole, MA, Jun 2015.
- **Reagan, J.**, T. Boyer, and M. Zweng. Comparing 60-year, 30-year, and 10-year trends in global ocean salinity - does water cycle intensification dominate the signal? 2016 Ocean Sciences Meeting. New Orleans, LA. Feb 2016 (oral).
- **Reagan, J.**, T. Boyer, R. Locarnini, M. Zweng, C. Paver, I. Smolyar, H. Garcia, O. Baranova, and **A. Mishonov**. World Ocean Database as a dissemination tool for distributed quality controlled ocean profile data. 2016 Ocean Sciences Meeting. New Orleans, LA. Feb 2016 (poster).
- **Saha, K.**, A. Krishnan, Y. Li, J. Relph, **D. Zhang, Y. Zhang, and S. Baker-Yeboah.** Long Term Stewardship and Reanalysis Facility (LTSRF) at NCEI, G16 LTSRF Update, GHRSST Science Team Meeting. ESA/ESTEC, the Netherlands, Jul 2015.
- **Wang Z**., S. DiMarco and S. Socolofsky, 2016, How Was the Deep Scattering layers (DSLs) Influenced by the Deepwater Horizon Spill? - Evidences from 10-year NTL Oil/Gas ADCP Backscattering Data Collected at the Spill Site, 2016 Gulf of Mexico Oil Spill and Ecosystem Science Conference, Tampa, FL. (poster).
- **Wang Z.**, S. DiMarco and S. Socolofsky, 2016, How Was the Deep Scattering layers (DSLs) Influenced by the Deepwater Horizon Spill? - Evidences from 10-year NTL Oil/Gas ADCP Backscattering Data Collected at the Spill Site, 2016 Ocean Sciences Meeting, New Orleans, LA. (oral).
- **Wang Z.**, S. DiMarco and S. Socolofsky, 2016, Turbulence Measurements in the Northern Gulf of Mexico: Application to the Deepwater Horizon Oil Spill on Droplet Dynamics, 2016 Gulf of Mexico Oil Spill and Ecosystem Science Conference, Tampa, FL. (oral)
- **Zhang, Y.**, E. Bayler and **S. Baker-Yeboah**: Toward improved application of SMOS and Aquarius Level-2 Sea-surface Salinity products. 2016 Ocean Science Meeting, Feb 2016, New Orleans, LA.
- **Zhang, Y.**, K. Casey and **S. Baker-Yeboah**: Development of NCEI satellite data quality monitoring system, NOAA 2016 EDM Workshop, January 4-6, 2016, Washington D.C.

Other:

- **J. Reagan** volunteered (and was elected) chair of the ESSIC Oceanography/Sea Surface Temperature affinity group. The goal of this affinity group is to share with each other ongoing work that each group member is involved in, and to foster collaboration among us.
- **Li-Qing Jiang** received NOAA National Centers for Environmental Information 2015 Employee's Choice Award For Innovative Product of the Year. The award is for his contribution in the development of the NCEI's online submission tool (Send2NCEI).
- **M. Biddle** received a nomination for National Oceanic and Atmospheric Administration's (NOAA) Team Member of the Month award for his work in automating the archival of NOAA Office of Marine and Aviation Operations (OMAO) Scientific Computer System (SCS) data directly from the NOAA fleet.

- **Dr. B. Beck** ran a one day workshop "Coral Reef Data Management and Analysis" at the University of Diponegoro in Semarang, Indonesia with students and professors. This workshop covered both best practices for data management and reviewed research currently being conducted at the university.
- **Dr. Korak Saha,** as a Data content manager helped archiving five new GHRSST products during FY2015. These products are NOAA OSPO VIIRS Level-2P and Level-3U SST, European OSISAF VIIRS Level-3C SST, the SEVIRI Level-3C SST, and IASI Level-2P SST from Metop-A.
- **Dr. A. Mishonov** performed a duty of Technical Editor of NCEI publication Johnson, D.R., Boyer, T.P., 2015: Regional Climatology of the East Asian Seas: An Introduction. NOAA Atlas NESDIS 79, Silver Spring, MD, 37 pp., doi: 10.7289/V5D21VM9, available at http://data.nodc.noaa.gov/woa/REGCLIM/EAS/DOC/nesdis79-doi107289V5D21VM9.pdf
- **Dr. S. Baker-Yeboah CICS funded proposals and collaboration proposals**
  - SBSB_IOOS_15: Management of Ocean and Climate Data originating from member Regional Associations of the US Integrated Ocean Observing System (IOOS)
  - SBSB_PSST_15: Pathfinder Sea Surface Temperature
  - SBSB_SARS_15: Synthetic Aperture Radar (SAR) Sentinel-1 Archival Services FY15
  - SBSB_SOHCS_15: Archive Services for Satellite Ocean Heat Content Suite
  - SBYZ_OSSI_15: Ocean Surface Salinity Investigation
  - EBEB_AOML_15: Archival Services for Ocean Indices and Indicators in the Tropical and South Atlantic Ocean
  - EBEB_NODC_15: NODC Data Stewardship
  - EBEB_OADS_15: Ocean Acidification Scientific Data Stewardship
  - EBEB_WOD_15: World Ocean Database Updates and Seasonal Estimates of Ocean Temperature, Salinity, Heat Content, and Steric Sea Level

Performance Metrics	
# of new or improved products developed (please identify below the table)	**11**
# of products or techniques submitted to NOAA for consideration in operations use	**10**
# of peer reviewed papers	**8**
# of non-peered reviewed papers	**1**
# of invited presentations (presentations)	**26**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

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

Outgoing Longwave Radiation – Monthly CDR – Software Rejuvenation

Task Leader Hai-Tien Lee
Task Code HLHL_CDR_15
Main CICS Research Topic Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to CICS Themes Theme 1: 10%; Theme 2: 90%
Percent contribution to NOAA Goals Goal 1: 100%

Highlight: NOAA/NCDC CDR Program has decided to move Monthly OLR CDR production into the Full Operational Capability (FOC) model. Software package rejuvenation will review and revise 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

This is the second year of the Monthly OLR CDR rejuvenation project.

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 are being revised for better organization and execution efficiency.

Accomplishments

The Monthly OLR CDR production code package has been significantly re-structured and modernized with Fortran90 standards. Thanks to Jim Biard and Chunying Liu of NCDC for their significant contributions in this task.

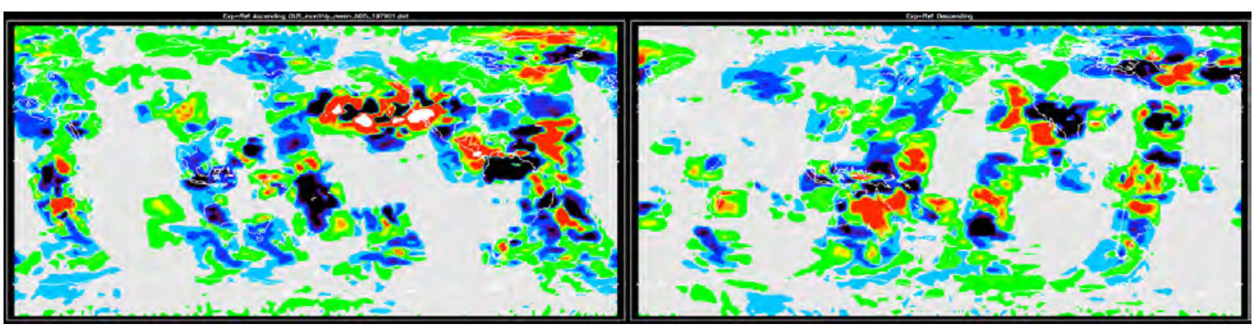

Figure 1. Examples show changes in OLR retrievals for TIROS-N satellite for the ascending orbits (left) and descending orbits (right) January 1979 monthly composite maps. The color contours show where the OLR retrievals have changed (grey area is ±0.1 Wm^{-2}) due to the increased availability of radiance observations that were previously discarded by the missing data handling. The change in monthly averaged OLR for some locations can exceed ±10 Wm^{-2} (red/white and deep blue/black).

The refactored codes for HIRS radiance calibration improved the handling of satellite scanning swath data in HIRS1b data set. The new codes increased the number of successful OLR retrievals due to the better constructing method for the "superswath", i.e., the unit calibration block. The new package also provides better symmetry between HIRS/2/2i and HIRS/3/4 instruments, thus greatly increases the efficiency in code maintenance.

Performance Metrics	FY14
# of new or improved products developed	0
# of products or techniques transitioned from research to ops	1
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of Contributed presentations	0
# of graduate students supported by a CICS task	0
# of undergraduate students supported by a CICS task	0

Planned Work

- Deliver final code package for v02r07 OLR-Monthly CDR production package
- Deliver documentations and testing packages
- Provide assistance to CDR Program for implementation and product verification at NCEI

Products

1. OLR-Monthly OLR CDR v02r07 production code package.
2. 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.

HIRS OLR CDR Development, Sustainment and Maintenance

Task Leader Hai-Tien Lee
Task Code HLHL_OLR_15
Main CICS Research Topic Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to CICS Themes Theme 1: 10%; Theme 2: 90%
Percent contribution to NOAA Goals Goal 1: 100%

Highlight: CICS is in charge of the development, sustainment and maintenance of the OLR CDR products for NCDC Climate Data Record Program, including two versions of the Monthly OLR CDR product (v02r02a and v02r07) and two versions of the Daily OLR CDR product (v01r02 and v01r02-interim).

Background

This is a continuing project for OLR CDR product.

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Being in the Initial Operational Capability (IOC) phase of both the OLR-Monthly and OLR-Daily CDR products, CICS is charged to the continued development and maintenance of these products before Full Operational Capability (FOC) is attained. Daily and monthly OLR CDR data are generated and delivered to CDR Program for public access. Quality assurance and quality control mechanisms are 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

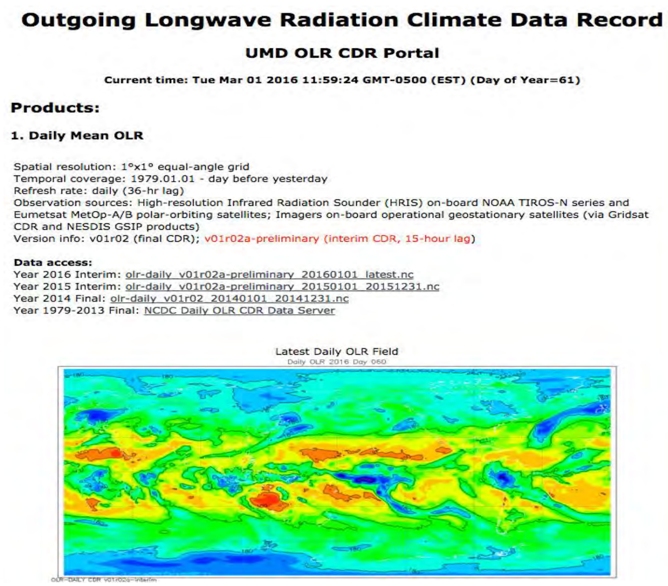


Figure1. Sample snapshot of OLR CDR data access portal web site dated on March 1, 2016, showing Daily OLR CDR v01r02a-preliminary product.

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

Publications

Turner, E. C., H.-T. Lee and S. F. B. Tett, 2015: Using IASI to simulate the total spectrum of outgoing long-wave radiances, *Atmos. Chem. Phys.,* 15, 6561-6575, doi:10.5194/acp-15-6561-2015.

Presentations

Xie, Pingping, Hai-Tien Lee, Jesse Meng, Kingtse Mo, and Michael Ek, 2015: A Gauge – OLR Blended Analysis of Global Daily Precipitation: A 37-Year Data Record for Hydroclimate Applications. 2015 AGU Fall Meeting, 14-18 December 2015, San Francisco, California

Lee, H.-T., 2015: Global Warming, Tropical Expansion and ENSO in OLR – A QC Benchmark Exercise. The CERES II Science Team Meeting, May 5-7, 2015, Hampton, VA (Oral)

Turner, Emma C., Hai-Tien Lee, and Simon F. B. Tett, 2015: Using IASI to Simulate the Total Spectrum of Outgoing Longwave Radiances. EGU General Assembly 2015, 12-17 April, 2015, Vienna, Austria

Products

1. Monthly delivery of OLR-Monthly CDR v02r02a and v02r07 products.
2. Daily delivery of OLR-Daily CDR v01r02-Interim product and Annual delivery of v01r02 updates.

The Global Precipitation Climatology Project (GPCP) Data Products—Transfer to Operations at NCDC

Task Leader	Robert Adler
Task Code	RARA_GPCP_15
NOAA Sponsor	Xuepeng Zhao
NOAA Office	NCDC
Contribution to CICS Research Themes (%)	Theme 2: 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%

Highlight The routine production of monthly, pentad and daily products from the Global Precipitation Climatology Project (GPCP) products will be transferred to NCDC for archival and dissemination. The ICDR of monthly GPCP is being routinely produced and distributed.

Link to a research web page http://eagle1.umd.edu/GPCP_ICDR/index.htm

Background

The objective of this work is to successfully transfer the routine production of (GPCP) products to NCDC from the ad-hoc processing at the current GPCP centers. The current monthly (1979-present), pentad (1979-present) and daily products (1997-present) have been developed by research groups over the last 15 years and are produced by a consortium of those groups, funded by various agencies. Transfer of the routine processing of the GPCP products to an operational entity will ensure continuation of these important data analysis sets. This activity involves the development of a detailed strategy for transfer of scientific knowledge, satellite and other data source accesses, and processing code for successful implementation of an end-to-end processing system that would routinely produce the GPCP current (Version 2) products for archival and dissemination. Initial data processing with the new system will take place at University of Maryland CICS.

Accomplishments

During the past six months, the focus of work has been on the further development of the one-degree, daily (1DD) GPCP CDR and on the production for a new version 2.3 of the CDR. The 1DD CDR software is now complete and in the test phase with all key elements in place. Combined with the completed software for the monthly product we are now running the main GPCP CDR product software. The Pentad product is still to be developed. We have also been doing detailed analysis of the new monthly version (2.3) to identify any weaknesses. The production of the monthly ICDR is ongoing.

We now have the production code for the monthly and daily products for the new Version 2.3 working and in testing. The new code has taken into account the corrected SSMI/SSMIS transition and the corrected TOVS/AIRS transition that had been affecting the products. The products are now more homogeneous and do not show any obvious problems as did the Version 2.2. The new V2.3 also uses the latest GPCC gauge analysis. In the last several months, GPCC has released a new version of their climate quality gauge analysis, Full Analysis V7. The previous version (Full Analysis V6) was used as the land gauge component of GPCP from 1979 to 2010, with the GPCC Monitoring Product V4 (which was calibrated to the

Full Analysis V6 climatology) used thereafter. The Full Analysis V7 improves slightly upon the V6 analysis with the addition of gauges over mainly data sparse regions, most notably over the tropics. The V7 dataset also will become the standard calibration climatology for the Monitoring product (which is set to become Monitoring Product V5). We will use the new Full Analysis V7 from 1979 to 2013 for version 2.3, with the soon-to-be released Monitoring Product V5 from 2014 into the future.

Routine production of the ICDR has continued over the past six months. We have been very successful in our aim to produce these interim data with 10 days of the end of the month, with 5 days after the end of the month being the current normal. We continue to update the new website: http://eagle1.umd.edu/GPCP_ICDR/index.htm

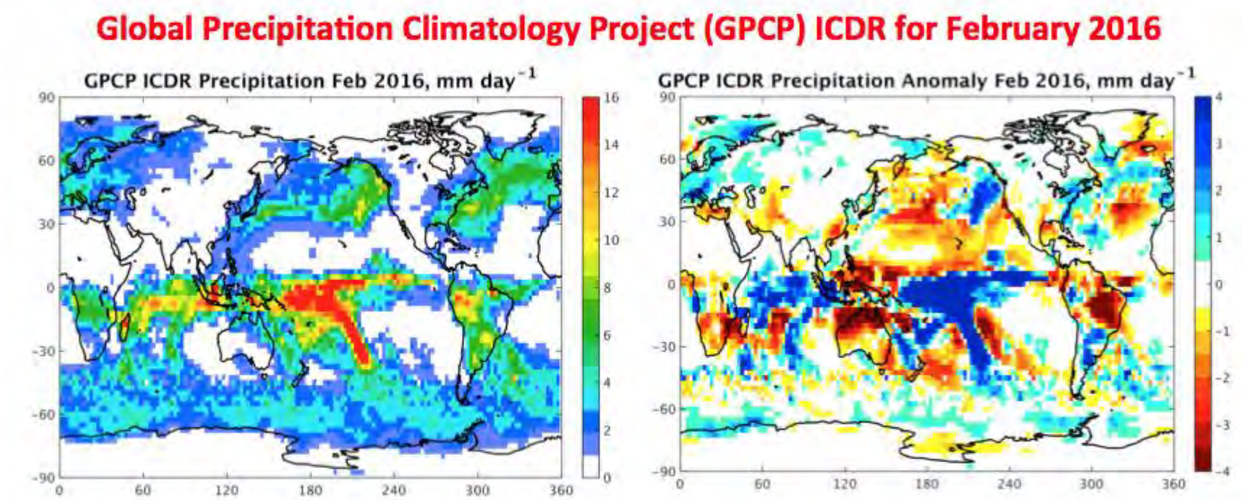


Fig. 1. Example of GPCP ICDR for most recent month—February 2016.

Planned work

1) Transition of GPCP CDR.

GPCP Monthly CDR—Code is ready to begin transition. Draft ATBD delivered. Discussion between PI group and CDR program to define status and needs for additional development to meet IOC criteria.
GPCP Daily CDR—Code is under development and based on results of lessons learned from transition to IOC for Monthly.

GPCP Pentad CDR—Code development will start this coming year.
All these timelines need to be discussed with and reviewed by NCEI

2) Maintenance of the GPCP CDRs

The GPCP CDR products have multiple time resolutions and a number of input data sets that change with time due to shifts between satellites (e.g., SSMI to SSMIS), re-processing of input data sets (including gauge data sets) and quality issues noted by the developers and/or users. This leads to substantial time spent by the developers on quality control issues, finding problems and making changes and implementing them, which results in re-processing.

Recently significant changes were implemented to address serious issues and were tested both from a code standpoint and from a science impact. We are currently in process of establishing a new Version 2.3 of GPCP incorporating these changes. Since the Monthly product drives the daily and pentad, they will all need to be re-processed too. This re-processing will replace the current Version 2.2. The timeline for these changes and the completion of the new version is March 2016.

3) GPCP Monthly ICDR

Over the last year we have successfully produced a GPCP monthly ICDR within about 10 days of the end of the month. The ICDR uses some different input data sets from the CDR, is not automated, and takes some additional resources to produce. We also need to do quality control, against the CDR product when it becomes available and understand differences.

The developers desire to do additional work to improve the product (e.g., using a different "real-time" gauge product) and further automate the process. We are also interacting with NCEI groups who could make use of this product in operational climate monitoring and for quick turnaround activities such as Annual State of the Climate.

Publications

Publications using GPCP information (partially supported from this task)

Gu, G., R. Adler, and G. Huffman, 2015. Long-Term Changes/Trends in Surface Temperature and Prcipitation during the Satellite Era (1979-2012), *Climate Dynamics* 1-15. DOI 10.1007/s00382-015-2634-x

Rodell, M., H.Beaudoing, T. L'Ecuyer, W. Olson, J. Famiglietti, P.Houser, R. Adler, M. Bosilovich, C. Clayson, D. Chambers, E. Clark, E. Fetzer, X. Gao, G. Gu, K. Hilburn, G. Huffman, D. Lettenmaier, W. Liu, F. Robertson, C. Schlosser, J. Sheffield, and E. Wood, 2015. The Observed State of the Water Cycle in the Early 21st Century, *J. Climate*, 28, 8289-8318. doi:http://dx.doi.org/10.1175/JCLI-D-14-00555.1

Behrangi, A., M. Christensen, M.Richardson, M.Lebsock, G. Stephens, G. Huffman, D. Bolvin, R.Adler, A. Gardner, B.Lambrigtsen, E.Fetzer, 2016. Status of High latitude precipitation estimates from observations and reanalyses, *J. Clim.,* (in review).

Products

Each month for the past year, the Interim Climate Data Record (ICDR) of the monthly GPCP has been produced in near real time, as well as the final CDR 2 months after real time.

Presentations

The Global Precipitation Climatology Project (GPCP) CDR: Research to Real-time Climate Monitoring, AMS Meeting, Phoenix, AZ, Jan. 2015 R. Adler, M. Sapiano, G. Huffman, D. Bolvin, L. Chiu

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

This year, the new datasets developed were the monthly CDR using the CDR code and the near real time ICDR.

The Development of AMSU Climate Data Records (CDR's)

Task Leader Ralph Ferraro; Huan Meng; Wenze Yang; Isaac Moradi; Jim Beauchamp; Tom Smith
Task Code WYWY_CDR_15
NOAA Sponsor NCEI
NOAA Office
Contribution to CICS Research Themes (%) Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2: 50%
Highlight All Beta CDRs are online
Link to a research web page http://cics.umd.edu/AMSU-CDR/home.html

Background

Current passive microwave sounder data, used in hydrological applications, are derived from POES satellites for which the primary mission is operational weather prediction. These data are not calibrated with sufficient stability for climate applications. A properly calibrated FCDR needs to be developed to enable the utilization of these data for TCDR and Climate Information Records and to extend their application into the JPSS era (e.g., POES/AMSU to NPP/ATMS to JPSS/ATMS). Once developed, TCDR's for water cycle applications (precipitation, water vapor, clouds, etc.) will be developed for use as key components in international programs such as GEWEX, CEOS and GPM.

Passive microwave sounder data have proven their worth in more than just tropospheric temperature and moisture monitoring. NOAA/NESDIS generates operational products from the Advanced Microwave Sounding Unit (AMSU) focused on the hydrological cycle (e.g., rainfall, precipitable water, cloud water, ice water, etc.) through two product systems known as the Microwave Surface and Precipitation Products Systems (MSPPS) and the Microwave Integrated Retrieval System (MIRS) since the launch of NOAA-15 in 1998. These data offer the unique opportunity to develop CDR's that can contribute to other satellite time series with similar capabilities such as the DMSP SSM/I and SSMIS, the TRMM TMI, and Aqua AMSR-E. This project will focus on the development of AMSU FCDR's for the AMSU-A window channels (e.g., 23, 31, 50 and 89 GHz) and the AMSU-B/MHS sensor.

Accomplishments

During the sixth year of the project, we continue to make progress towards the creation and evaluation of AMSU-A and AMSUB/MHS FCDR's and TCDR's.

A. Assessment of AMSU-A frequency shift for NOAA-15 ASMU-A channel 15

The sequential adjusting process described in previous section does not work for the 89 GHz channel on NOAA-15, as no optimal μ and δR combination could be found to form a reasonable time series. To verify if this is a frequency error and find the actual value of frequency shift, we examine the change of the standard deviation of $\Delta Tb'$ by adjusting frequency shift *df*. In doing this, CRTM is selected as the radiative transfer model, and the ERA-Interim as the model input for the simulation. Different experimental frequencies, centered at 89 GHz on NOAA-15, were examined in the CRTM simulations, with the frequency shift, *df*, relative to its prelaunch measurement, being chosen from -1.5 GHz to 1.5 GHz with an interval of 25 MHz, as shown in Figure 1.

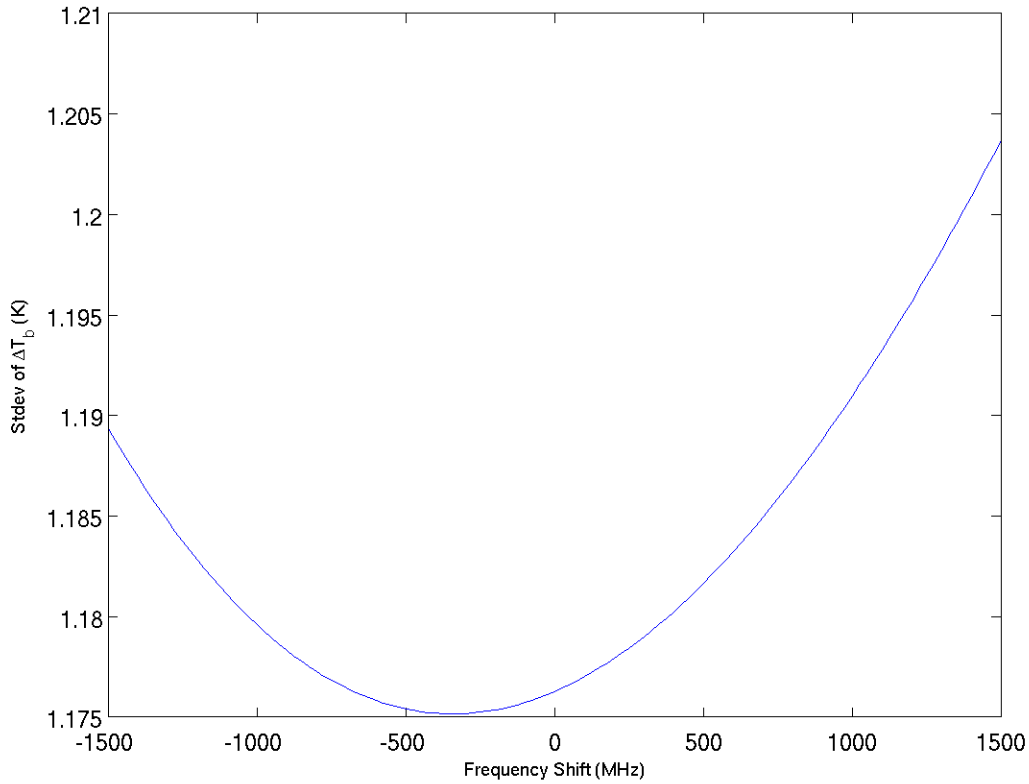


Figure 1. Amplitude of the standard deviation of $\Delta Tb'$ using SNO pairs over the tropical ocean versus the 89 GHz channel of NOAA-15 frequency shift, df.

A optimum *df* of -350 ~ -325 MHz was found to minimize the standard deviation of $\Delta Tb'$, yet the frequency shift still cannot explain the large variation of $\Delta Tb'$, so we leave the time series of NOAA-15 AMSU-A 89 GHz channel uncorrected.

B. An Improved AMSU CDR Web Page Developed

An improved web page for the AMSU CDR project has been created, and access through http://cics.umd.edu/AMSU-CDR/home.html. The project progress, output data, relative documentation, publication and presentation are available from the site.

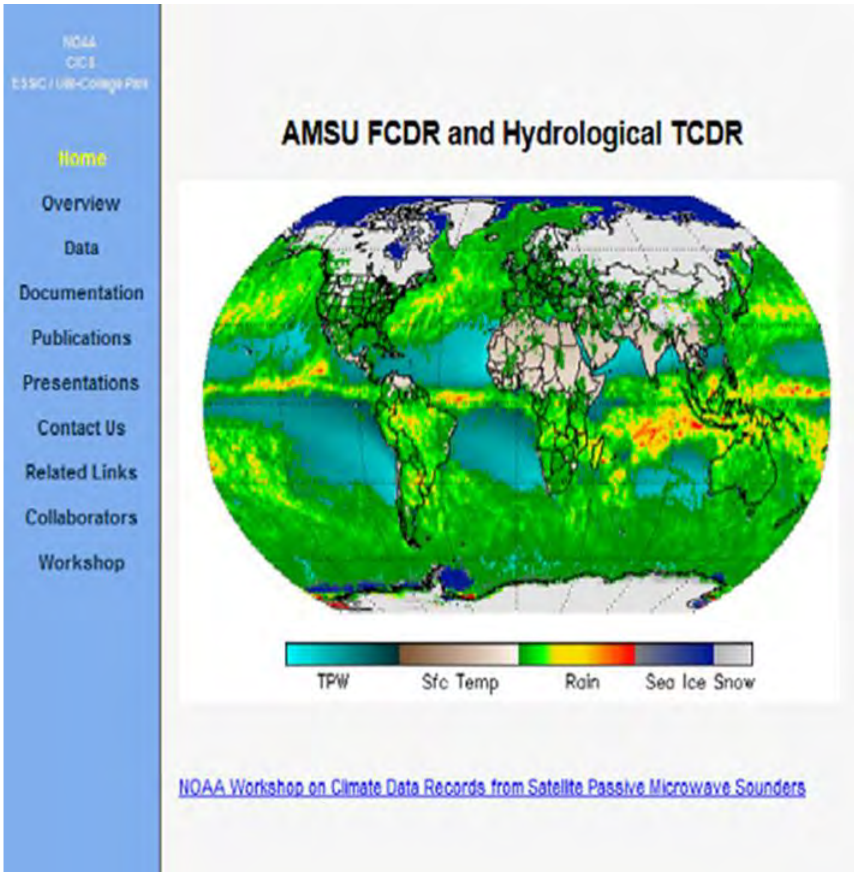


Figure 2. Snapshot of the home page of CICS-MD AMSU CDR website.

C. Various Improvements of the Beta Datasets

Endeavors have been made to make various improvements of the beta datasets during the report year, including:

1. Updated quality flags of AMSU-A FCDR and TCDR;
2. AMSU-B/MHS TCDR has been made available;
3. Better temporal coverage of AMSU-B/MHS TCDR;
4. Updated header files and meta-data of the data sets;
5. All beta data are made online.

D. Impact of AMSU Precipitation Climate Data Records (CDR)

A final report was delivered to NCEI as part of an impact study demonstrating the importance of AMSU derived precipitation CDR's, including the private sector. Working closely with J. McCollum of FM Global Insurance (Boston, MA; note Dr. McCollum was a former CICS-MD researcher!) and G. Huffman (NASA/GSFC), two versions of the TRMM 3B42RT merged precipitation product were made available to FM Global - one that did not include AMSU, and one that did. FM Global than used a five year record (2005-09) of 3B42RT as input to it's hydrological model, focusing on the Susquehanna River Basin, and found that the rain product with AMSU improved the river discharge estimates by 5%. *Importance*: NCEI's Climate Data Record program provides high quality satellite time series products that are not only useful for in-house NOAA climate monitoring, but also contain societal benefits.

Planned work

Migration of the data to NCDC is expected in FY2016 to sync with their transition schedule.

Publications

Yang, W., H. Meng, and R. Ferraro, 2016, Inter-Calibration of AMSU-A Window Channels, IEEE Trans. Geosci. Remote Sens. (to be submitted).

Products

AMSU-A window channels FCDR and TCDR;
AMSU-B/MHS water vapor channels FCDR and TCDR.

Presentations

Yang, Wenze, Ralph Ferraro, Phillip Arkin, and Gary Wick, Comparison of Global Atmospheric Rivers Depicted from Satellite and NWP Reanalysis, AGU Fall Meeting, San Francisco, CA, Dec 14-18, 2015.

Ferraro, Ralph, Huan Meng, Wenze Yang, Isaac Moradi, Tom Smith and Jim Beauchamp,
An Improved Microwave Satellite Data Suite for Hydrological and Climatological Applications, PI meeting, Asheville, NC, Aug 4-6, 2015.

Yang, Wenze, Huan Meng, Ralph Ferraro, An Improved Microwave Satellite
Data Set for Hydrological and Climate Applications, 95th American Meteorological Society Annual Meeting, Phoenix, AZ, Jan 4-8, 2015.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer reviewed papers	**1**
# of non-peered reviewed papers	**0**
# of invited presentations	**3**
# of graduate students supported by a CICS task	**N/A**
# of graduate students formally advised	**N/A**
# of undergraduate students mentored during the year	**N/A**

CUNY Completing the ISCCP Research-to-Operations Transition: Wrapping Up

Task Leader William B. Rossow
Task Code WRWR_ISCCP_15
NOAA Sponsor Xuepeng (Tom) Zhao
NOAA Office NESDIS/NCEI
Contribution to CICS Research Themes (%) Theme 1: 100%
Main CICS Research Topic Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%) Goal #1: 100%
Highlight The entire ISCCP processing system is running at NCEI
Link to a research web page

Background

This particular grant continued funding from NOAA to complete the transition of the ISCCP processing system to NOAA NCEI to become operational. All processing codes, including QC procedures, calibration, ancillary data and main cloud product production, have been delivered and documented. The Ancillary Data products were produced and delivered for 1979-2013; subsequent years will be produced operationally. Radiance calibration for 1983 – 2009 has been delivered; subsequent calibrations will be done operationally. The main Cloud Data products will be produced operationally. Final documentation will be delivered within a month.

Accomplishments

The complete ISCCP production system, which produces 6 main Cloud Data Products and 4 Ancillary Data Products (there are also 2 fixed data products as part of the system), has been delivered to NCEI. For the past year, the CREST group has been training the NCEI people and helping fix some computer incompatibilities. The system is running in “beta” mode but should be producing final products soon. Eventually the ISCCP products will cover the time period 1982-2015 and beyond.

Planned work

Although the ISCCP production system is not yet running routinely, this is a final report.

Publications

No peer-reviewed publications were supported by this grant. The complete Operations Guides have been delivered to NCEI for the main cloud product processing, for satellite radiance data QC and calibration, and for producing the Ancillary Data products. The Climate-Algorithm Theoretical Basis Document is in draft form (mostly requiring addition of references, tables and figures).

Products

Six Ancillary global data products for 1979-2013 were delivered for 3-hourly atmospheric temperature-humidity profiles, daily ozone abundance, monthly aerosol optical properties, daily snow and sea ice, a land-water mask with topographic and land surface types information. Test datasets for the main ISCCP Cloud Products were also delivered.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**12**
# of products or techniques submitted to NOAA for consideration in operations use	**5**
# of peer reviewed papers	**0**
# of non-peered reviewed papers	**3**
# of invited presentations	**0**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

The 12 data products developed are 6 Cloud products (differing details and space-time resolutions from 10-100 km and from 3 hr to monthly), 3-hourly atmospheric temperature-humidity profiles, daily ozone abundance, monthly aerosol optical properties and daily snow and sea ice cover. The 5 Procedures constitute the ISCCP processing system, which produces 4 Ancillary Data products and 6 main Cloud Data products. The non-peer-reviewed "papers" are the Operations Guides for the ISCCP processing system, including satellite radiance QC and calibration, Ancillary Data production and Cloud Product production.

7 Land and Hydrology

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

Task Leader	Naira Chaouch
Task Code	NCNC_IJAM_15
NOAA Sponsor	Mitch Goldberg
NOAA Office:	NOAA/NESDIS/STAR
Contribution to CICS Research Themes (%)	Theme 1: 70%; Theme2: 30%; Theme 3:0%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3:0%;

Highlight: An enhanced operational river ice mapping system using VIIRS is developed. It supports NWS RFCs with timely information on river ice extent and concentration over wide river sections.

Link to a research web page

Background

This project builds upon previous efforts in the field of river ice detection and mapping that started with the use of MODIS imagery to map ice on the Susquehanna River 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). This 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 of the project. The challenges that will be addressed in this phase of the project include a) cloud shadow, b) relief shade, c) narrow rivers, d) low ice concentration cases where ice reflectance is very low and sensitive to atmospheric corrections, and e) changes in solar angle that were faced during the first phase of the project especially in the Alaska RFC domain. The enhanced version of the product will deliver ice concentration values which is an improvement over the ice product generated in the phase 1 of the project. We also propose to enlarge the scope of the operational product by a) intergrading imagery from MODIS, b) covering new rivers and tributaries, c) study the causality between ice jam occurrence and other variable like Freeze/thaw, snow cover, and ambient weather conditions, and c) investigate the assimilation of the inferred information in river hydraulic models. The proposed study includes a strong validation component supported by the input from five RFCs and flyovers from GINA during specific periods of the year. We will also maintain a strong outreach impact by engaging graduate and undergraduate level students. The assessment will also include the use of active microwave data from new sensors that were recently put in orbit.

Accomplishments

The first goal of this work is focusing on enhancing the performance of the operational river ice product and on proposing solutions to the issues that were faced in the first phase of the JPP PGRR project and raised by NOAA's RFCs experts. The proposed enhancement is focusing first on developing a classification technique with adaptive thresholds that account for the seasonality of the reflectance and changes in sun angle and viewing geometry which are very significant especially in Alaska.

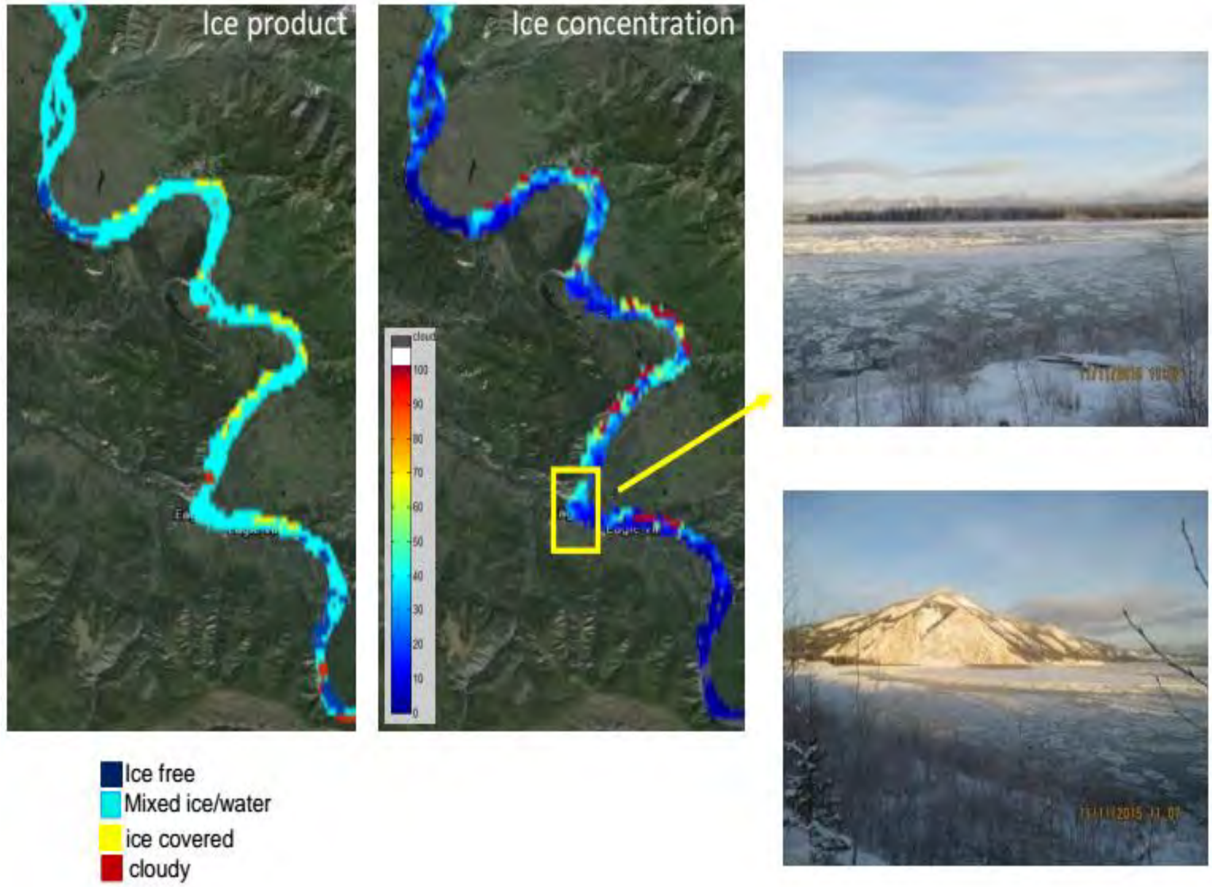


Figure 1: comparison of the ice product with the Neural Network simulated ice concentration and aerial photos, Eagle, Yukon River, 11/11/2015

In order to implement the adaptive river ice technique, training samples of both ice and water pixels were collected in addition to the observation geometry parameters that include the Satellite Zenith Angle, Satellite Azimuth Angle, Solar Zenith Angle, and Solar Azimuth Angle. These training samples are collected based on the analysis of in situ observations (flyovers), Landsat images and RFCs reports used for the validation of the previous version during previous winter and breakup periods. The implementation of the adaptive technique depends mainly on the quality and the number of the training samples. A relationship between the observed near infrared reflectance and the observation geometry parameters and the sine and cosine of the angles is established.

The artificial neural network (ANN) technique was tested to establish the relationship between the change in the observation geometry and the ice and water reflectance. The collected reflectance values are used to train the ANN and then to verify the model with a different set of observations. The proposed ANN-based method allows to simulate the reflectance of each pixel for both water and ice pixels. The actual observed reflectance with the same observation geometry parameter is then compared to the simulated reflectance values. Obviously, if the pixel reflectance is closer to the simulated water then the pixel is classified ad water and vice-versa for the ice case.

The simulated ice and water reflectance values that are dependent on the sun and viewing angles are used as tie-points in a linear mixed model for the determination of the ice concentration within the pixel. The neural network technique was tested for the determination of the ice concentration especially for the pixels that were classified as mixed water/ice pixels. Figure 1 shows an example of the comparison between the ice map obtained from the latest version of the ice product, ice concentration map and aerial photos for a section of the Yukon River. Ice concentration maps was also validated using MODIS RGB and Landsat images. The determination of the ice concentration according to the proposed approach constitutes an improvement over the current version of the operational system that only distinguish between pure water, pure ice and mixed water/ice pixels.

Planned work

- Validation of the River ice concentration product during 2016 onset and breakup periods
- Identification of cloud and cloud shadow using spectral analysis method and geometry method
- Expanding the geometric coverage of the product to include narrower rivers and upstream locations
- Implement the adaptive threshold technique for narrow rivers
- Determination of the ice concentration over narrow rivers

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

Daily River ice product and ice concentration maps are generated over Yukon, Kuskokwim, Missouri, Mississippi, Hudson Rivers and Lake Champlain (1). The ice product is running operationally over Alaska, north Central and north eastern US 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 Algorithm

Task Leader **Ismail Yucel**
Task Code **RKIY_GOESR_15**
NOAA Sponsor **GOES-R AWG**
NOAA Office **NESDIS**
Contribution to CICS Research Themes (%)
Main CICS Research Topic **Land and Hydrology**
Contribution to NOAA goals (%)
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.**

Link to a research web page

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 errors versus updraft bins are obtained for rainfall pairs 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 and 2004 years. Contrast to summer time analysis the relationship between SCaMPR errors and updrafts developed using winter data showed significant trend for all positive vertical wind speed values (updraft values). This means that orographic lifting is better represented with winter data which promises significant correction for SCaMPR rainfall values and thus, improved rainfall estimates. 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.

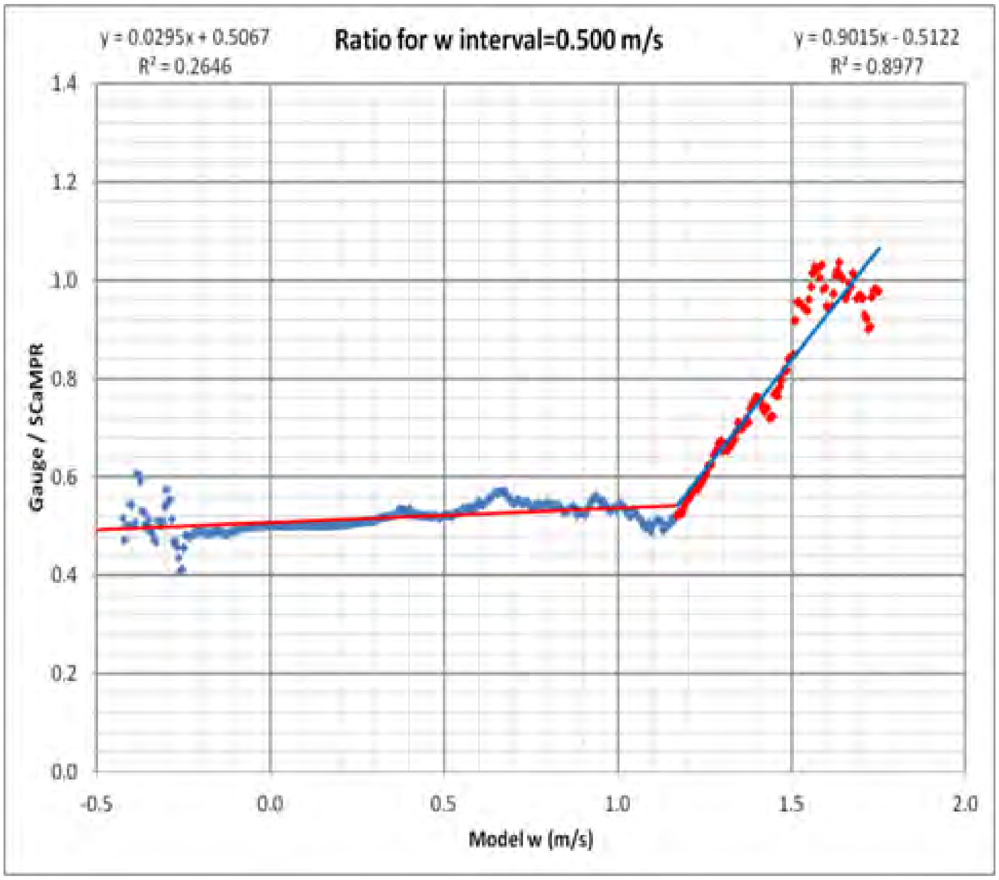


Figure 1: A relationship between updraft and errors in SCaMPR rain is shown for summer period.

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. In addition, instead of using the station values of rainfall, interpolated/gridded rainfall observation will be used in correction algorithm to reduce rainfall related uncertainties. 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 (please identify below the table)	
# of products or techniques submitted to NOAA for consideration in operations use	
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	
# of graduate students supported by a CICS task	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	

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

Validation and Application of JPSS/GCOM-W Soil Moisture Data Product for operational flood monitoring in Puerto Rico

Task Leaders	Tarendra Lakhankar and Jonathan Muñoz-Barreto
Task Code	TLTL_GCOM_16
NOAA Sponsor	Mitch Goldberg
NOAA Office	NESDIS/JPSS
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%;
Highlight	
Link to a research web page	

Background

This project targets to use 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 product. During the performance period, the CREST L-band microwave observation is being use at three temporal sites for the soil moisture monitoring. The observations include spatiotemporal measurements of L-band brightness temperatures, surface temperature, and soil moisture. These observations are being collected on soils under variable conditions like bare soil and soil under a variation of crops. Early results quantify the effect of surface vegetation on the soil moisture retrievals from L-band microwave radiometer. Irrigation patterns and the vegetation fraction under the observed area; results in variation in soil moisture is being assessed. In parallel, a development of a conceptual model for the Río Grande de Añasco watershed, a tropical watershed in Puerto Rico using a semi-distributed, integrated and physical hydrological model is being tested for hydrological simulation.

Accomplishments

Soil moisture field experiment (Figure 1) carried out during Feb 2016 at Western part of Puerto Rico in collaboration with scientists (Clint Smith and AndMorgan Fisher) from GRL/ ERDC, US. Army Corps of Engineers. During the field experiment microwave brightness temperature and soil moisture were observed for different irrigation pattern and vegetation conditions including: bare soil, short grass, tall grass, beans field, banana and avocado field. Two students Jonathan Nuñez (Graduate) and Karla M. Negron (Under Graduate) is being trained for using radiometer and soil moisture measurements and data processing and modeling.

In collaborative activity, parallel soil moisture observations are being conducted with GRL/ERDC/USACE using Cosmic-ray Soil Moisture Observing System (COSMOS). It is planned to permanently establish a COSMOS unit by GRL/ERDC at the Isabela Agricultural Station of UPRM, Puerto Rico. The variation in scales between the observing systems (in-situ soil moisture, L-band Observations and COSMOS) represent a unique opportunity for the validation of satellite (G-COM) soil moisture. Currently, we are in the process to generate a high resolution soil moisture map of western Puerto Rico.

The results presented (Figure 2) represents early results of the development, calibration and validation of a conceptual model for the Río Grande de Añasco watershed, a tropical watershed in Puerto Rico using a semi-distributed, integrated and physical hydrological model. For the calibration/validation of the satellite data, ground based radiometric and meteorological observations are being collected at watershed level. At this phase, the simulate streamflow, shows disagreement in terms of magnitude with the observed streamflow, the coarse resolution of the initialization parameters (Satellite Data whenever available) and the National Land Data Assimilation System (NLDAS) 0.25 degree x 0.25 degree) is hampering the model simulations. The next phase is to integrate downscaled satellite the data into de model.

Figure 1: Soil moisture field experiment carried out during Feb 2016 at Western part of Puerto Rico in collaboration with scientist from GRL/ ERDC, US. Army Corps of Engineers

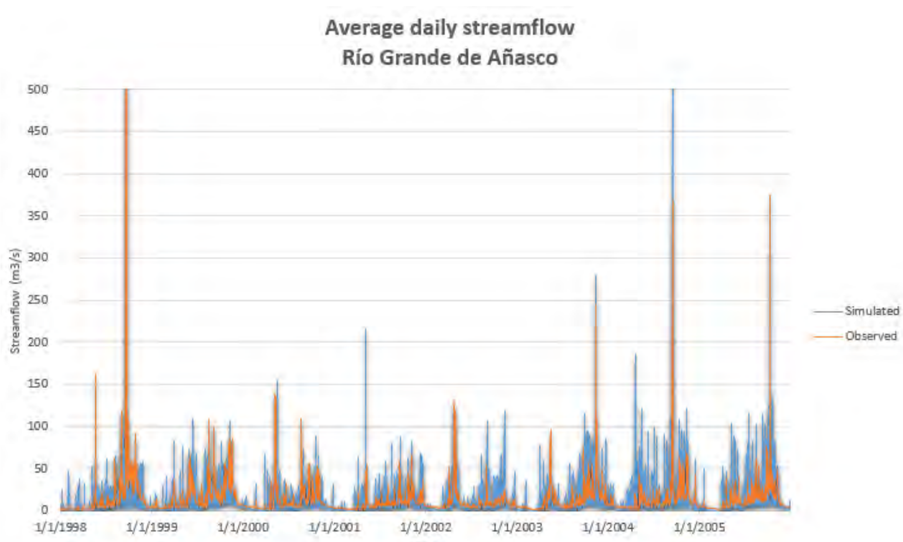


Figure 2: Simulation of streamflow using a conceptual empirical model for the Río Grande de Añasco watershed, PR

Planned Work

- Validation of GCOM-W soil moisture data using in-situ soil moisture data in Puerto Rico
- Continuous microwave observations using L-band radiometer and soil moisture measurements is being carried out Western part of Puerto Rico.

- We are processing of physical controls parameters sand fraction, NDVI and elevation for simulation of hydrological models for Puerto Rico.
- Identification of framework for GCOM-W soil moisture in Flash Flood Guidance System in Puerto Rico
- Second round of field experiment will be carried out for quantification of the effect of land cover heterogeneity on GCOM-W soil moisture retrievals on summer 2016.
- Currently, being with discussion 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

Presentations

1. Jonathan Muñoz-Barreto and Tarendra Lakhankar (2016) "Microwave remote sensing of soil moisture for hydrological and agriculture applications", presented at Congress of Engineering, Surveying and related disciplines (COINAR 2016), College of Engineers and Surveyors of Puerto Rico, San Juan, P.R – March 8th, 2016.
2. Jonathan Muñoz-Barreto (2015) "Satellite Data for Hydrological Applications – Study Case Puerto Rico", presented at Meeting of The Committee on Radio Frequencies – National Academy of Science, Engineering and Medicine, Arecibo Observatory, Arecibo, P.R – October 15th, 2015
3. Jonathan Muñoz-Barreto (2015) "Mapping Field-Scale Soil Moisture Using Ground-Based L-Band Passive Microwave Observations in Western Puerto Rico", presented at III Congress in Remote Sensing and Geographic Information Systems, Hotel La Habana Libre, La Habana, Cuba – September 24th, 2015.

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

Sediment and Coastal Organic Carbon Research and Applications Using Satellite Remote Sensing Data

Task Leader Sujay Kaushal
Task Code SKSK_CWQM_15
NOAA Sponsor: Paul DiGiacomo
NOAA Office: STAR/SOCD
Percent contribution to CICS Themes Theme 1: 100%; Theme 2: 0%; Theme 3: 0%.
Main CICS Research Topic Climate Research, Data Assimilation & Modeling
Percent contribution to NOAA Goals Goal 1: 20%; Goal 2: 80%

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.

Research Website:

Background

Despite substantial public and private expenditures on nutrient management, reports of recent record-sized hypoxic zones in the Chesapeake Bay and many other coastal waters have raised concerns about sources and transformations of nutrients and carbon. Compared with agricultural sources, urbanizing watersheds are a more rapidly growing source of coastal nutrient pollution and carbon inputs and more complicated. Urban nutrient and carbon sources can originate from wastewater treatment plants, sewage leaks, urban storm water, atmospheric deposition (e.g., NOx from combusted air), and fertilizers from lawns. 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; Deng et al. in press). 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 (e.g., bacteria, viruses, nutrients, heavy metals et al.), 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.

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.

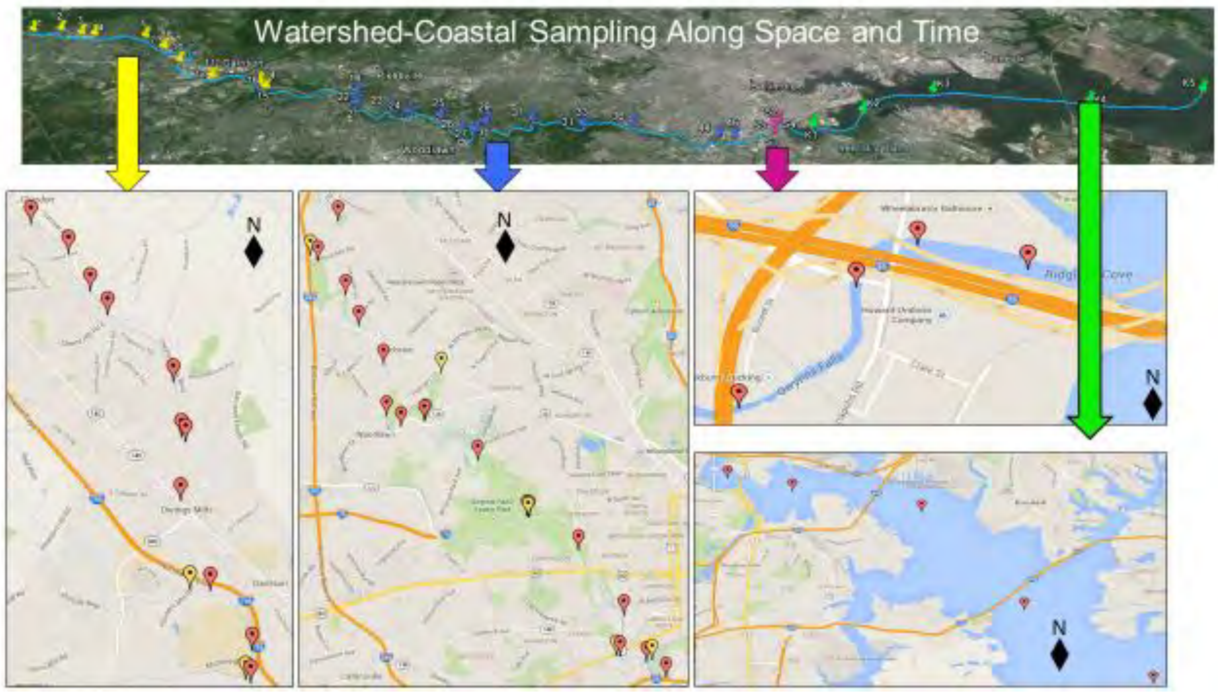
Field work and chemical analyses have been conducted by a technician of the Biogeochemistry Lab at the University of Maryland, Shahan Haq. *Shahan is now enrolled as a graduate student in the Department of Geology at UMD under the supervision of Dr. Sujay Kaushal.* Dr. Kaushal will continue help to advise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

Planned Work

* Finish analyses of carbon, nutrients, and greenhouse gases, and work on papers from the project.

Presentations

Urban Evolution: the Role of Water. USGS Reston (INVITED)


Watershed-Coastal Sampling Along Space and Time
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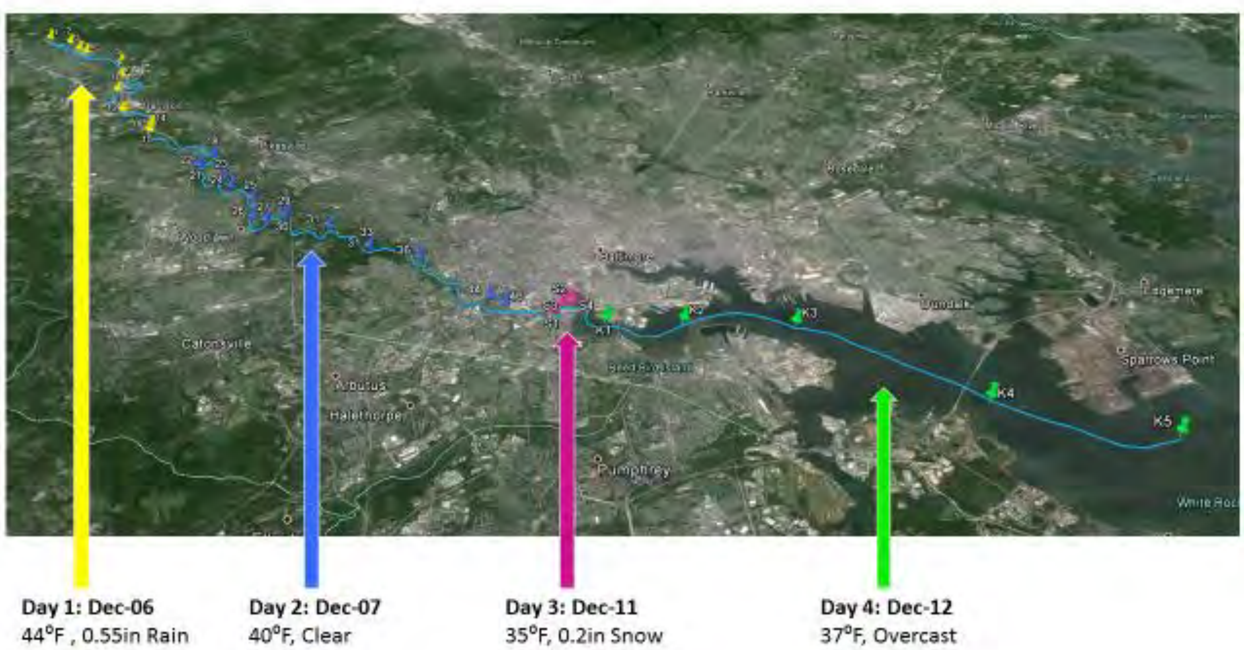

Catonsville
Arbutus
Halethorpe
Dundalk
Edgemere
Sparrows Point
K1
K2
K3
K4
K5
Day 1: Dec-06
44°F , 0.55in Rain
Day 2: Dec-07
40°F, Clear
Day 3: Dec-11
35°F, 0.2in Snow
Day 4: Dec-12
37°F, Overcast

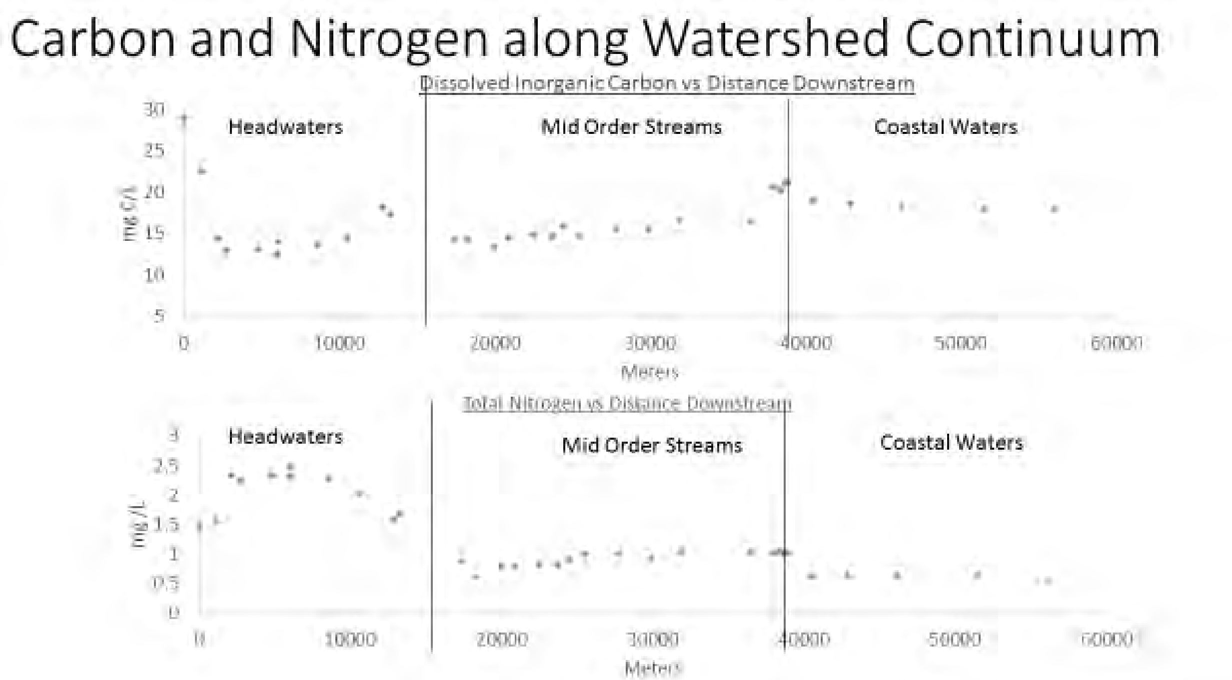


Figure 1: Examples of sampling locations from synoptic surveys on land and in coastal waters. Typology of carbon and nitrogen distributions along the watershed and coastal zone of Baltimore.

Performance Metrics	FY 16
# of new or improved products developed	
# of products or techniques transitioned from research to ops	
# of peer reviewed papers	
# of non-peered reviewed papers	
# of invited presentations	1
# of graduate students supported by a CICS task	1
# of graduate students advised under a CICS task	
# of undergraduate students supported by a CICS task	N/A

8 Earth System Monitoring from Satellites

Towards Operational Arctic Snow and Sea ice Thickness Products

Task Leader Sinéad Louise Farrell
Task Code SFSF_IOAS_14
NOAA Sponsor Laury Miller
NOAA Office NOAA/NESDIS/STAR/SOCD/OPB Laboratory for Satellite Altimetry
Contribution to CICS Research Themes (%) Theme 1: 30%; Theme 2: 60%; Theme 3: 10%
Main CICS Research Topic Earth System Monitoring from Satellites
Contribution to NOAA goals Goal 1: 50%; Goal 2: 50%
Highlight Multi-year sea ice continues to dominate the central Arctic Ocean, where mean ice thickness was ~3.5 m in winter 2015, while sea ice in the Beaufort/Chukchi Seas was a mix of multi- and first-year ice and mean thickness was ~ 2.4 m in winter 2015.
Link to a research web page http://ibis.grdl.noaa.gov/SAT/SeaIce/index.php

Background

Improving our knowledge of the nature, and variability, of the sea ice cover is critical in order to advance our capabilities to predict future Arctic state, on seasonal to decadal time-scales. The thickness and volume of the Arctic sea ice pack are key components of the polar climate system. Ongoing loss of the ice pack has serious implications for climate change, but also has ecological and socio-economic impacts on the Arctic region. Satellite altimetry observations from ICESat and CryoSat-2 indicate a decline in the thickness of the ice pack over the last decade. The latest results from NASA's IceBridge mission show that following the precipitous drop in multi-year ice in 2007-2008, the central Arctic remains dominated by multi-year ice just over 3 m thick, while ice thickness in the Beaufort and Chukchi Seas continues to decline. Extensive, and continued, monitoring of the Arctic sea ice pack using satellite altimetry is necessary to determine whether recent observations are part of a sustained negative trend, or a reflection of the natural, interannual variability of the system. Altimetry data from the Envisat, ICESat, CryoSat-2, IceBridge and ICESat-2 missions provide almost two full decades of measurements of the Arctic ice pack. The goal of this investigation is to assess how well Arctic sea ice elevation, ice freeboard, snow depth, and ice thickness can be mapped using satellite and airborne altimeters. We validate the capabilities of the various altimeter systems, using independent aircraft and field measurements.

Accomplishments

CICS-MD scientists, Dr. Sinéad L. Farrell, Dr. Thomas Newman and Mr. Kyle Duncan, along with scientists at the NOAA Lab. for Satellite Altimetry (LSA), participated in three NASA Operation IceBridge (OIB) Missions in 2015 including the Arctic Spring Campaign, the Arctic Summer Campaign and the Fall Campaign in the Southern Ocean. Ten of the seventeen planed Arctic 2015 sea ice surveys were successfully conducted from Thule, Greenland and Fairbanks, AK during March and April 2015 (Figure 1). CICS-MD and NOAA-LSA sea ice scientists collaborate closely with the NASA OIB Science Team on flight planning to acquire an optimal set of sea ice thickness and snow depth measurements across the ice pack of the western Arctic. Specifically the CICS-MD/NOAA-LSA sea ice team designed airborne survey lines, provided advice on the collection of cal/val data below altimetry satellites (e.g. ESA's CryoSat-2 and SARAL/AltiKa), and assisted in designing OIB flights above in situ field sites to better quantify the accuracy of the airborne instrumentation.

Figure 1 shows consistency between independent estimates of Arctic sea ice thickness in March/April 2015, derived from CryoSat-2 and OIB measurements. The oldest ice north of Greenland and the Canadian Arctic Archipelago was on average 3.5 m thick, while there is a strong gradient to thinner, seasonal ice in the Canada Basin and the eastern Arctic Ocean, where mean ice thickness was 2.4 m in winter 2015. Ice-Bridge also provides details of the inter-annual variability in the sea ice thickness distribution over a seven-year period spanning March/April 2009 to March/April 2015. Sea ice in the central Arctic is predominantly multi-year in nature, where mean and modal ice thickness remains stable at around 3.2 m and 2.5 m, respectively, over the 7-year observation period (Figure 1b). Sea ice in the Beaufort and Chukchi Seas region is more seasonal in nature and is a mix of multi-year (~25 %) and first-year ice (~75 %). Here, the interannual variability of the ice thickness distribution over the last seven years has been more variable (Figure 1c) with mean and modal ice thickness around 2.1 m and 1.8 m, respectively. Year-to-year variability is primarily related to the presence and location of a band of multi-year sea ice in the southern Beaufort Sea. These results were reported in the "Sea Ice" chapter of the NOAA *Arctic Repot Card 2015* (*Perovich et al.*, 2015).

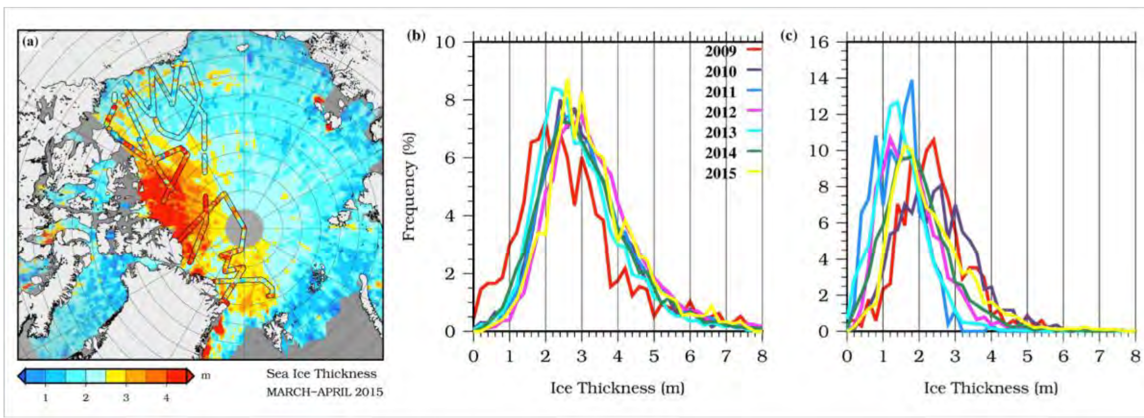


Figure 1: (a) Winter Arctic sea ice thickness from the OIB Quick Look product spanning 19 March - 3 April, 2015 overlaid on the CryoSat-2 near real time (NRT) product spanning 18 March - 14 April, 2015 (Tilling et al., 2016 and http://www.cpom.ucl.ac.uk/csopr/seaice.html). Sea ice thickness distributions for ice in (b) the central Arctic and (c) the Beaufort and Chukchi Seas at the end of the winter growth period between 2009 and 2015 (adapted from Perovich et al., 2015 and references therein).

During the OIB 2015 Arctic Spring campaign the Digital Mapping System (DMS) captured a photo of sea ice in the Beaufort Sea (Figure 2). DMS is a camera system that looks straight on the sea ice below the aircraft. Green laser light emitted by the Airborne Topographic Mapper (ATM) laser altimeter system is visible while it profiles the sea ice below the aircraft. This OIB image was selected as the "Image of the Day" on the NASA Earth Observatory webpage on April 5, 2015. The full story is available at: http://earthobservatory.nasa.gov/IOTD/view.php?id=85642&eocn=home&eoci=iotd_previous

CICS-MD Scientists Newman and Farrell, the OIB sea ice team, and collaborators, identified that the OIB snow radar dataset contained radar system artifacts including coherent noise and range sidelobes, which obscured interfaces and resulted in ambiguities in derived snow depths. During 2015 Drs. Newman and Farrell worked closely with the University Kansas/CReSIS team, through the 'NASA Snow

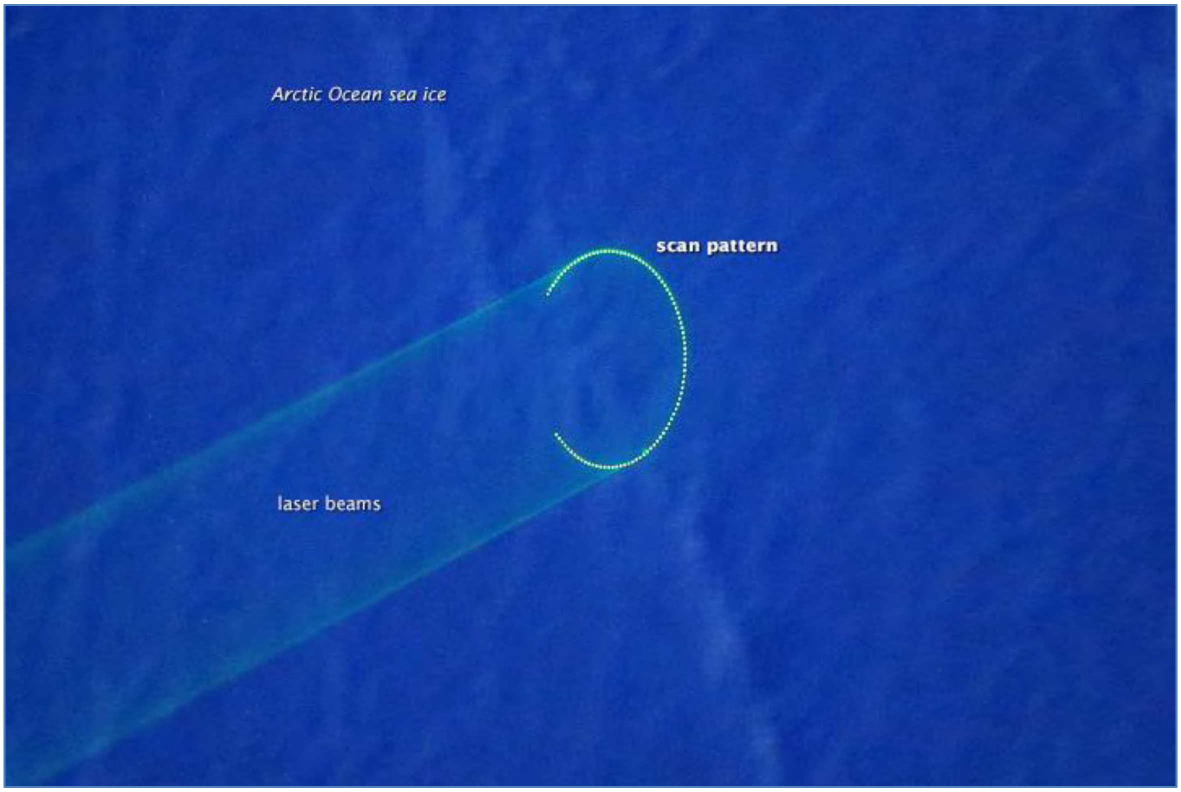


Figure 2. Green laser light emitted by OIB's ATM laser altimeter captured in a DMS photograph of Arctic sea ice.

Thickness on Sea Ice Working Group', to improve the quality of snow radar data. Newman was directly responsible for the quality control of over 25,000 individual radar echograms.

A comprehensive data quality flagging system was devised to indicate the utility of radar echograms collected over sea ice during OIB Arctic Spring campaigns between 2009 and 2015. The reprocessed echograms, with their specific quality flags, were delivered to the National Snow and Ice Data Center (NSIDC) in January 2016 and are now available to the entire research community. These reprocessed data represent a vast improvement in data quality, allowing for improved derivation of snow depth on sea ice and assessment of its inter-annual variability. The reprocessed data will also permit more detailed investigations of ice surface topography effects on airborne derived snow depths and will allow us to refine the existing Arctic snow climatology.

The CICS-MD and NOAA-LSA sea ice team presented their recommendations and recent research at the OIB Sea Ice Working Group and Science Team Meetings, 20-21 Jan. 2016, held at the NASA Goddard Space Flight Center (GSFC), Greenbelt, MD. CICS-MD/NOAA-LSA sea ice team research was featured on the NOAA/NESDIS website on August 11, 2015 as part of a NESDIS "Arctic Week" event. The article describes the team's work, which focuses on improving precision in measurements in Arctic sea ice thickness. http://www.nesdis.noaa.gov/news_archives/changing_climate.html. CICS-MD Scientist Sinéad Farrell was quoted in a PBS NewsHour article on September 11, 2015 regarding the upcoming NASA ICESat-2 mission. Dr. Farrell discussed the utility of ICESat-2 measurements for sea ice studies http://www.pbs.org/newshour/updates/nasa-icesat2-glacier-death/.

Planned work

- Support implementation and flight-line design for the NASA Operation IceBridge Summer 2016, Antarctic 2016 and Arctic 2017 airborne campaigns: assist with definition of science objectives and flight-planning for successful completion of each campaign.
- Extend results of Arctic snow depth validation to include rough/ridged sea ice surfaces via comparison of NASA OIB airborne snow radar data with multiple validation data sets gathered in situ across a range of ice conditions in March /April 2014 and 2016.
- Integrate OIB Arctic snow depth estimates with the NOAA-LSA sea ice freeboard product for improved characterization of changes in Arctic sea ice thickness.
- Examine sea ice dynamical change through assessment of the roughness and morphology of Arctic sea ice during the OIB era (2009-present).
- Continue collaborations with the NOAA Laboratory for Satellite Altimetry, NASA GSFC, the Naval Research Laboratory (NRL), CRREL, University College London, and the European Space Agency on the assessment and inter-comparison of IceBridge and CryoSat-2 data products over Arctic sea ice.

Publications

Perovich, D. K., W. Meier, M. Tschudi, S. Farrell, S. Gerland and S. Hendricks (2015), Sea ice, *Arctic Repot Card 2015*, peer-reviewed (http://www.arctic.noaa.gov/reportcard/sea_ice.html).

Blanchard-Wrigglesworth, E., S. L. Farrell, T. Newman and C. M. Bitz (2015), Snow cover on Arctic sea ice in observations and an Earth System Model, *Geophys. Res. Lett.*, doi: 10.1002/2015GL066049.

Farrell, S. L., K. M. Brunt, J. M. Ruth, J. M. Kuhn, L. N. Connor and K. M. Walsh (2015), Sea Ice Freeboard Retrieval using Digital Photon-counting Laser Altimetry, *Ann. Glaciol.*, *56*(69), 167–174, doi: 10.3189/2015AoG69A686.

Petty, A., M. Tsamados, N. Kurtz, S. Farrell, T. Newman, J. Harbeck, D. Feltham and J. Richter-Menge, Characterizing Arctic sea ice topography using high-resolution IceBridge data, *The Cryosphere*, under review, submitted Nov. 2015.

Presentations

Farrell, S. L. (2016), Validation Experiments to Assess ICESat Freeboard Accuracy, ESA CryoVal Sea Ice Project Meeting #5, Inst. Environmental Physics, University of Bremen, Germany, 9-10 February 2016.

Farrell, S. L. and J. Richter-Menge (2016), Update on IceBridge Arctic 2016 Sea Ice Campaign, ESA CryoVal Sea Ice Project Meeting #5, Institute of Environmental Physics, University of Bremen, Germany, 9-10 February 2016.

Connor, L., S. L. Farrell, T. Newman and D. McAdoo (2016), Sea ice parameters from IceBridge measurements over ice in the Canada Basin, Operation IceBridge Sea Ice Science Team Meeting, NASA GSFC, Greenbelt, MD, 21 January 2016.

Leuliette, E., L. Connor, S. Farrell and the NOAA Validation Team for Sentinel-3A Altimetry (2016), Inter-satellite, sea ice, and tide gauge validation plans of the NOAA S-3A Validation Team, Operation IceBridge Sea Ice Science Team Meeting, NASA GSFC, Greenbelt, MD, 21 January 2016.

Dattler, M. E., S. L. Farrell and T. Newman (2016), In-situ snow depth measurements over Arctic sea ice types, poster presented at the American Meteorological Society (AMS) 96th Annual Conference, New Orleans, LA, 10-14 January 2016.

Farrell, Sinéad L. (Co-convener & Chair) Advances in Altimetry of the Polar Regions Session (I & II) American Geophysical Union 2015 Fall Meeting, San Francisco, CA, 14-18 December 2015.

Farrell, S. L., J. Richter-Menge, J. Hutchings, C. Jackson, T. Newman and L. Connor (2015), Mapping the Changing Extent and Thickness of Arctic Multiyear Sea Ice, Abstract C43D-04, presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 December 2015.
Richter-Menge, J. and S. L. Farrell (2015), NASA IceBridge: Scientific Insights from Airborne Surveys of the Polar Sea Ice Covers (*invited*), Abstract C43D-01, presented at 2015 Fall Meeting, AGU, San Francisco, CA, 14-18 December 2015.
Petty, A., M. Tsamados, N. Kurtz, S. L. Farrell, T. Newman, J. Harbeck, D. Feltham and J. Richter-Menge (2015), Characterizing Arctic sea ice topography and atmospheric form drag using high-resolution IceBridge data, Abstract C52A-03, presented at 2015 Fall Meeting, AGU, San Francisco, CA, Dec. 2015.
Farrell, S. L. (2015), ICESat-2 Mission Update (*invited*), presentation at the Inter-agency Altimetry Summit, NOAA Center for Weather & Climate Prediction (NCWCP), College Park, MD, 28 September 2015.

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 serves as a member of the NASA IceBridge Science Team (2009-present)

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 CICS-MD Scientists Farrell, Newman and Duncan are members of the NOAA/NESDIS/STAR Sea Ice Team

ESSIC Affinity Groups: Cryosphere CICS-MD Scientist Sinéad Farrell chaired the ESSIC Cryosphere Affinity Group (2015) and CICS-MD Scientists Newman and Duncan are members of the ESSIC Cryosphere Affinity Group.

Mentoring, Advising, Teaching and Outreach CICS-MD Scientist Sinéad Farrell mentored Post-Doctoral Associate Dr. Newman (2011-present), Post-Doctoral Associate Dr. Petty (2014-2015) and Faculty Specialist Mr. Duncan (2015 – present).

CICS-MD Scientist Sinéad Farrell advised CICS Summer Student Intern Ms. Marissa Dattler (July 2015).
CICS-MD Scientist Farrell also delivered guest lectures for the AOSC 401: Global Environment Course, entitled "Aspects of the Cryosphere", on behalf of Prof. Z. Li (March 2015).
CICS-MD Scientist Sinéad Farrell served as a liaison and judge for the AGU Fall Meeting 2015 Outstanding Student Paper Awards (December 2015).

Performance Metrics	
# of new or improved products developed (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**3**
# of non-peered reviewed papers	**0**
# of invited presentations	**2**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**1**

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. The results of our studies were published in three (3) peer-review articles, and one (1) additional article has been submitted to a peer-reviewed journal. We presented our results at numerous national and international meetings, of which two (2) were invited. CICS-MD Scientist Sinéad Farrell mentored one (1) University of Maryland undergraduate student.

Utilization of M-T SAPHIR to monitor S-NPP ATMS and MiRS products

Task Leader Isaac Moradi
Task Code IMIM_ATMS_15
NOAA Sponsor Fuzhong Weng
NOAA Office: NOAA/STAR
Contribution to CICS Research : Theme 1 -20% Theme 2 - 60% Theme 3 - 20%
Main CICS Research Topic : Earth System Monitoring from Satellites
Contribution to NOAA goals (%): Goal 1 (100%)
Highlight: ATMS and SAPHIR data were intercompared and validated using radiosonde and GPS-RO data
Link to a research web page

Background

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

Measurements from low earth orbiting (LEO) satellites, in particular, microwave sensors, offer a unique dataset to develop global precipitation retrievals. These data are subject to errors and uncertainties after launch due to several reasons including drift in calibration. However, there is a lack of a perfect ground-based method to validate and monitor the accuracy of these observations. This project focuses on monitoring the accuracy of ATMS and SAPHIR observations with respect to each other as well as ground based radiosonde data. SAPHIR is a microwave humidity sounder onboard Megha-Tropiques (M-T) – a joint research mission between India and France (launched in October 2011) – and ATMS is the microwave instrument onboard S-NPP and future JPSS satellites.

The SAPHIR sensor on the M-T satellite has shown to be very accurate and can be utilized to cross-validate ATMS measurements in the 183 GHz water vapor bands. MiRS will also be generating TPW and rain rate products from SAPHIR.

Accomplishments

We have continued validation of both ATMS and SAPHIR observations using inter-comparison of measurements from similar channels as well as validation using simulated brightness temperatures from radiosonde data. The following website is developed where the intercomparison results are provided to the users of both instruments: http://www.star.nesdis.noaa.gov/star/mw-calval.php. Figure 1 shows an example of the images provided on the website.

The main accomplishments of the project which have continued from the pas fiscal year include:

- Inter-comparing similar channels from ATMS and SAPHIR
- Validating SAPHIR channels using observations simulated from radiosonde data

- Validating mid-upper tropospheric and lower stratospheric ATMS temperature sounding channels using simulated observations from radiosonde data
- Validating ATMS water vapor channels using simulated observations using radiosonde data
- Validating ATMS temperature sounding channels using observations simulated using a RT model and GPS-RO profiles

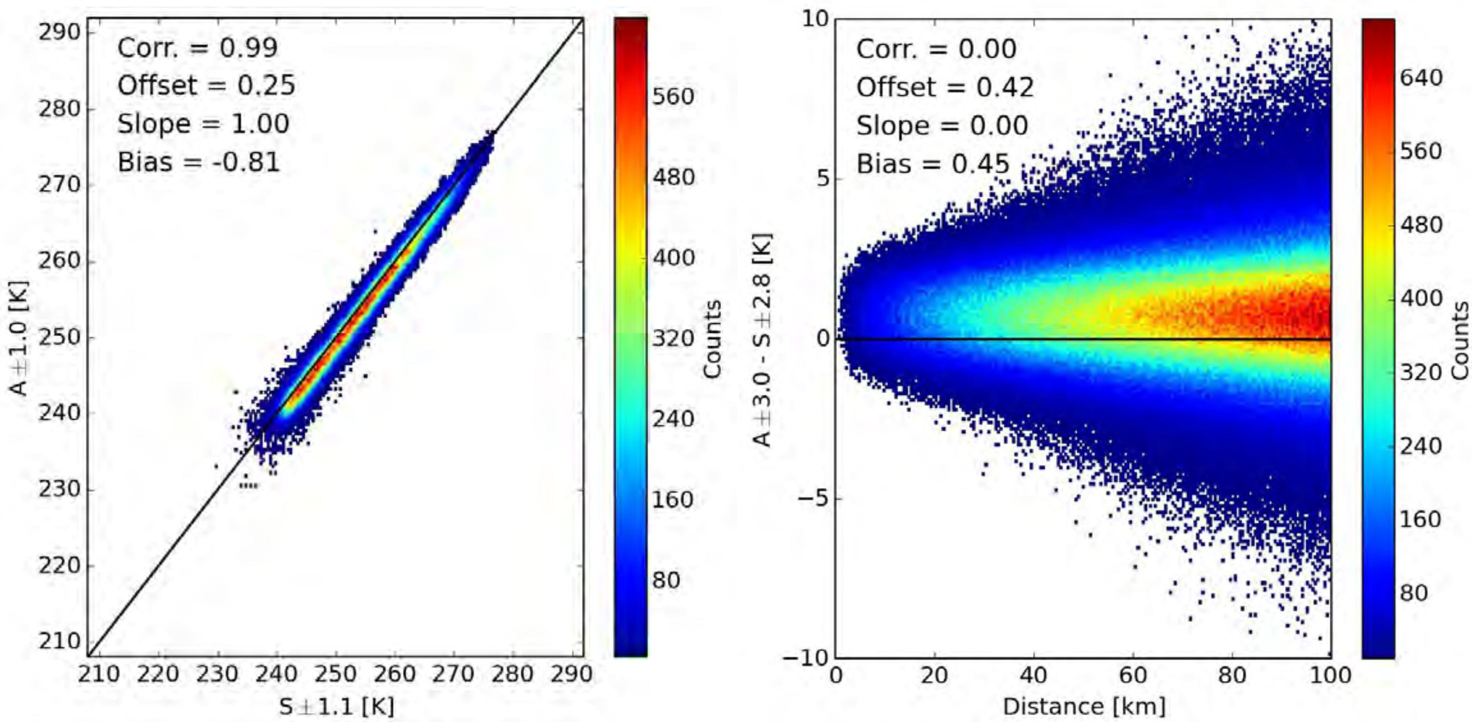


Fig. 1. (left): Collocated SAPHIR and ATMS observations, (right) relation between the difference between the collocations and the distance between the collocations.

Planned Work

- Continue inter-comparison of the collocated observations from SAPHIR and ATMS
- Update the website periodically
- Validation using radiosonde data from GRUAN

Publications

- Moradi, Isaac, **Ralph Ferraro**, Patrick Eriksson, and Fuzhong Weng, 2015: Inter-calibration and validation of observations from ATMS and SAPHIR microwave sounders, *IEEE Trans. Geosci. Remote Sens.*, **53**, 5915–5925, http://dx.doi.org/10.1109/TGRS.2015.2427165
- Moradi, I., **Ferraro, R.**, Soden, B., Eriksson, P., Arkin, P., 2015: Retrieving layer averaged tropospheric humidity from Advanced Technology Microwave Sounder (ATMS) water vapor channels, *IEEE Trans. Geosci. Remote Sens.*, **54**, 6675–6688, http://dx.doi.org/10.1109/TGRS.2015.2445832

- Moradi, I., Arkin, P., Ferraro, R., Eriksson, P., and Fetzer, E.: Diurnal variation of tropospheric relative humidity in tropical region, Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2015-1008, in review, 2016.

Products

The main products include interomparison results for ATMS and SAPHIR water channels provided on the website.

Presentations

- Moradi, Isaac and Ralph Ferraro: Inter-calibration and validation of observations from modern satellite microwave humidity and temperature sounders. AMS Annual Meeting Phoenix, AZ 1/4/2015 to 1/8/2015
- Moradi, Isaac, Ralph Ferraro, James Beauchamp, Huan Meng, and Tom Smith: Developing Climate Data Records from Microwave Water Vapor Channels. AMS Annual Meeting, Phoenix, AZ 1/4/2015 to 1/8/2015
- Moradi, Isaac and Ralph Ferraro: Inter-calibration and validation of observations from SAPHIR and ATMS instruments. AGU Fall Meeting San Francisco, CA 12/14/2015 to 12/18/2015

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

We are now providing the calibration status of SAPHIR and AMTS to NOAA. Besides, new techniques are developed that can be used to derive layer-averaged humidity from both ATMS and SAPHIR observations. After this extensive validation of SAPHIR and ATMS observations, now SAPHIR data are operationally used for NOAA MIRS system.

Leveraging Observations and Models to Improve Predictions of Convective Initiation

Task Leader **John R. Mecikalski**
Task Code **JMJM_CISN_15 & JMJM_DDCG_15**
NOAA Sponsor: Dr. Tilden Meyers
NOAA Office: NOAA ATDD, Oak Ridge, TN.
Contribution to CICS Research Themes (%): **Theme 1: 100%**
Main CICS Research Topic: **Earth System Monitoring from Satellites**
Contribution to NOAA goals (%): **Goal 1: 100%**
Highlight Development of 1-4 hour product for predicting new thunderstorm development.
Link to a research web page **None at this time.**

Background

The goal project was to develop a probabilistic 1-4 h convective initiation (CI) nowcast product using machine-learning approaches operating on real-time observations that describe the initial/background conditions within the pre-thunderstorm environment, with an emphasis on the Southeastern U.S. For this effort, there was a heavy reliance on data from NASA and NOAA satellite remote sensing fields including sea and lake/river surface temperatures, cloud products (optical depth, effective radius), land use, elevation, topography, derived fields like Normalized Difference Vegetation Index, Leaf Area Index, 0-1 hour CI nowcasts from the real-time algorithm of Mecikalski et al. (2015), and within established algorithms that retrieve sensible heating, evapotranspiration and soil moisture. Locations of CI were determined from Weather Surveillance Radar–1988 Doppler (WSR-88D) reflectivity observations. All NOAA and NASA data and other fields will be formed into a training database of many 1000s of CI events to be operated on by machine learning statistical methods after association rules are formed outward of high-resolution (~200 m) simulations are performed. The outcome of this project includes a 30-min update ~5 km resolution gridded product that provide significantly improved prediction accuracy for CI within the 1-4 h timeframe. The close relationship the UAH and the NASA Short-term Prediction Research and Transition Center will facilitate transition of improved forecasting techniques to the National Weather Service, which is already occurring with the 0-1 h CI nowcast products. In addition to benefitting the general public, enhanced prediction of convective storms will be useful for the aviation industry which suffers substantial cost due to delayed, cancelled and re-routed flights.

Accomplishments

The following section presents the main results from this research project, while follow-on work will be to define our accuracy of the methods used. We generated forecast maps for visual inspection and qualitative assessment of 1-, 2- and 3-hour CI probability using the Random Forest model presented in Fig. 1. Based on the result of attribute selection, we manually select 59 out of 234 features from the datasets listed above, using domain knowledge to train a number of classifiers in WEKA and compare their performance. The WEKA package contains implementation of many state-of-art machine-learning algorithms, including classifiers, clustering algorithms, association rules, attribute selection and visualization. We used full August 2014 feature data (59 features) as training data to train each of the following seven classifiers, with 10 cross validation. Each trained model was used evaluated on July feature data for the performance of the classifier. In order to obtain the maximum possible accuracy of classification, we investigated the ensemble classifier where in combination of the seven algorithms was evaluated to see if it produces better performance as compared to individual classifiers. Final CI event probability is the weighted average of 7 individual classification results. The weights are the overall accuracies for these classifiers. For instance, for 1-hour prediction, the logical model trees overall accuracy (from 10 cross-validation on training set) is 61.4%. If logical model trees labels/classifies a sample as yes (CI event), we consider a probability of 61.4% a CI event will occur 1 hour later. Then the ensemble probability a CI event occurrence is the weighted sum of the probability from each classifier with probability assigned as overall accuracy. In this way, a probability of 100% for CI occurrence is assigned to a sample if all the seven classifiers predict the occurrence of CI event. Probability of 0% is assigned to a sample if none of the classifier predicts CI occurrence for the sample.

Figure 1 demonstrates the initial CI nowcasts, over 1-3 hour timeframes from present (at 2300 UTC on 24 July 2014). Figure 1 shows that areas in which CI eventually occurs have gradually increasing CI probabilities, as for example over south-central Alabama and southeastern Mississippi. The CI-probability regions are consistent over time, and as the Random Forest method uses real-time satellite fields, the algorithm appears to be helping train the forecaster to view regions that are: (a) becoming increasingly unstable, (b) possess convective clouds that are growing in size (as a capping inversion is weakening), and therefore, (c) are increasingly supportive of convective storm development. What these figures do not depict, which is encouraging, are more random CI probabilities that change dramatically from forecast time to forecast time. Regions where storms already are occurring possess CI probabilities <50% or have 0% CI probability.

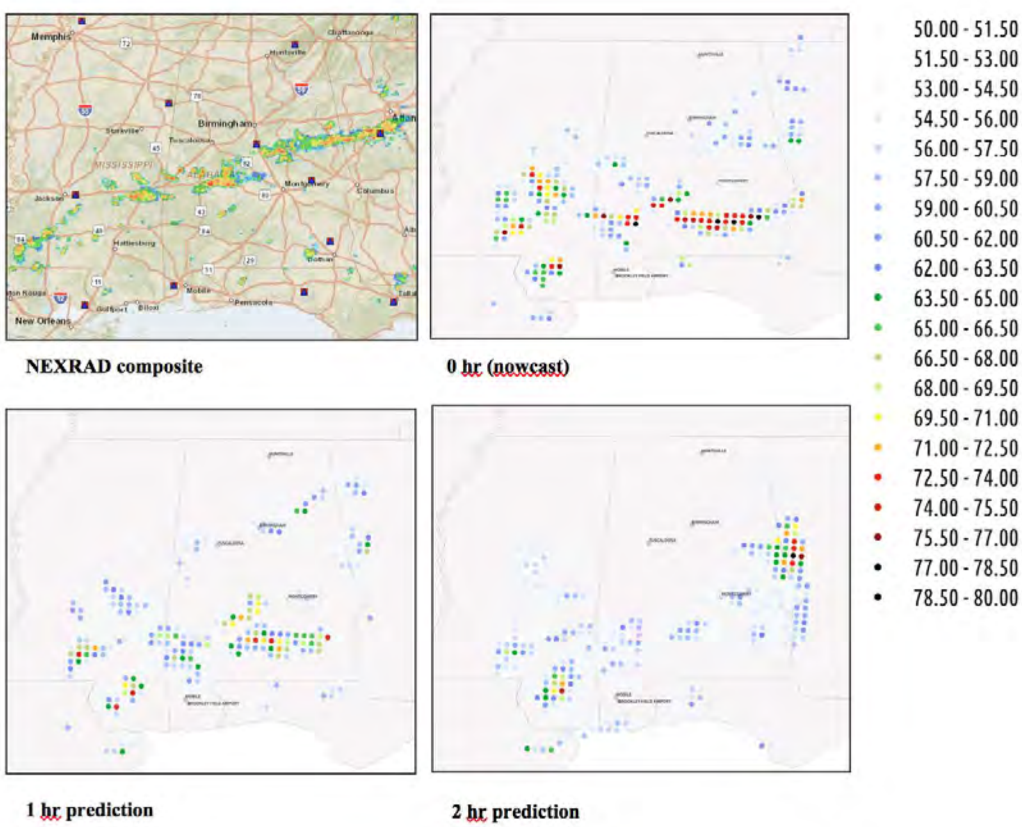


Figure 1: CI activity as seen on radar and CI nowcast, 1 and 2 hour forecast for 2300 UTC on 24 July 2014. Note that CI probabilities <50% are not shown.

Planned Work

- Project is complete as of April 2016. The main planned work is to make the 1-4 hour CI nowcasting algorithm operational, or to run in real-time. Depending on the availability of our main programmer, this real-time implementation would be completed in summer 2016.

Publications

Narayan, U., J. R. Mecikalski, and C. P. Jewett, 2016: A spatial data infrastructure for thunderstorm prediction using machine learning. *Comp. Geosci.*, In preparation.

Mecikalski, J. R., U. Narayan, and C. P. Jewett, 2016: Development and evaluation of a 1-4 hour machine learning approach to predict convective storm initiation. *J. Appl. Meteorol. Climatol.*, In preparation.

Products

A real-time 1-4 hour Convective Initiation product was developed form this project, which is appropriate for short-term weather prediction across the Southeastern U.S. The product uses ~59 observational, satellite-based, numerical weather prediction, and land-surface model-based fields. ***This 1-4 hour CI nowcast product provides National Weather Service forecasters with guidance to improve upon the typical, broad-brush 30-40% rain forecasts that dominate summer weather forecasts. Forecast accuracies from our product are ~65-70%.***

Presentations

Mecikalski, J. R., C. Jewett, U. Narayan, T. Berendes, and X. Li, 2015: Leveraging observations and NWP models to improve 1-4 hour forecasts of convective initiation. *2015 EUMETSAT Satellite Conference*, Toulouse, France, 21-26 September.

Mecikalski, J. R., C. Jewett, U. Narayan, X. Li and T. Berendes: A statistical methodology for coupled observational and NWP based 1-4 hour forecasts of convective storm initiation. *18th Symposium on Meteorological Observations and Instrumentation*, American Meteorological Society 96th Annual Meeting, New Orleans, LA, 10–14 January 2016.

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

A real-time 1-4 hour Convective Initiation product was developed form this project, which is appropriate for short-term weather prediction across the Southeastern U.S. The product uses ~59 observational, satellite-based, numerical weather prediction, and land-surface model-based fields. The plan is to develop a web site that presents these materials in real-time to the general public and to NOAA National Weather Service forecasters.

Given that the start of our funding time period was delayed by ~12 months, and yet we only had then a 1-year period of performance, there was no time to engage an undergraduate or graduate student in the project.

A New Technique for VIIRS Detection and Delineation of *Karenia brevis* Harmful Algal Blooms (HABS) in the West Florida Shelf without the Need for a Fluorescence Channel

Task Leader: Prof Sam Ahmed, NOAA CREST CCNY
Task Code: SASA_HABS_15
NOAA Sponsor: Dr. Mitch Goldberg
NOAA Office: NESDIS/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 %
Highlight: VIIRS Neural Network Detection of Karrenia Brevis harmful algal blooms in the West Florida Shelf.

Background

This work is the application of a Neural Network (NN) approach, previously developed by us, to the detection and tracking, of *Karenia brevis* Harmful Algal Blooms (*KB* HABs) that plague coasts of the West Florida Shelf (WFS) from satellite observations. Previous approaches primarily used observations from the Moderate Resolution Imaging Spectroradiometer Aqua (MODIS-A) of chlorophyll fluorescence at the 678 nm band. This fluorescence signal is a key element in normalized flurescence height (nFLH) algorithms, or in the Red Band Difference algorithms (RBD) that are used to detect *KB* HABs in the WFS. The Visible Infrared Imaging Radiometer Suite (VIIRS) which has replaced MODIS-A, unfortunately does not have a 678 nm fluorescence channel. The alternative NN approach described here, retrieves values of phytoplankton absorption at 443 nm (a_{ph443}) using measurements from existing VIIRS channels at 486, 551 and 671 nms, without the need for the fluorescence channel. The a_{ph443} values in these retrieved VIIRS images are in turn correlated to chlorophyll concentrations [*Chla*] and *KB* cell counts. To retrieve *KB* values, the NN VIIRS retrieved a_{ph443} images are filtered by applying limiting constraints, defined by (i) the low backscatter at *Rrs* 551nm and (ii) the a minimum [*Chla*] threshold, and hence equivalent minimum a_{ph443} value known to be associated with *KB* HABS in the WFS. The resulting residual images, are then used to delineate and quantify the existing *KB* HABS. Comparisons with *KB* HAB satellite retrievals using other techniques, including nFLH, as well as with in-situ meaurements reported over a four year period, confirm the viability of the combined NN together with our filtering constraints devised here for detection of *KB* HABS.

Accomplishments

Detection of *KB* HABS in the WFS were aided in the past by use of the 678 nm MODIS-A fluorescence for retrievals using nFLH and RBD techniques. The lack of a fluorescence channel on the successor VIIRS satellite provided the impetus for the NN work reported here. In this approach, NN algorithms using *Rrs* values from the 486, 551 and 671nm VIIRS bands as are used to retrieve an image of a_{ph443} values in the WFS. Then, as detailed above limiting criteria 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 specific limiting values for maximum Rrs551 and minimum a_{ph443} used in the filter processes were based on published data, reinforced and refined by inspections of retrieval results against available in-situ data. The retieved values of a_{ph443} and equivalent [*Chla*] retrieved using these filter limits, were then compared both qualitatively and quantitatively both against other techniques and in-situ measurements.

Comparisons of the NN technique were made first with the nFLH technique, which was the established technique for *KB* retrievals in the WFS from MODISA, prior to the advent of VIIRS. These comparisons showed good corelations between nFLH retrievals and the NN technique for open ocean waters. However, the nFLH technique requires the availability of a fluorescence band at 678nm, available on MODISA, but absent on VIIRS, the successor satellite.

Furthermore, KB retrieval capabilities with the nFLH technique are severely limited for in-shore retrievals, where the complex waters with increased non-algal particulate scattering interfere with the fluorecence signal making its interpretation more difficult. Further work on our NN KB retrieval technique is necessary before we can properly evaluate its capabilities for in-shore retrieval and compare them with those of MODISA nFLH. with MODISA. Comparisons were also made between the NN technique and retrievals using the NASA OCI product for [*Chla*] retrievals. Again, these comparisons showed reasonably corelations in open ocean waters, but confirmed difficulties with OCI retrievals in more complex inshore waters. with inshore retrieval

Finally, the ultimate test for the viability of *KB* HABs satellite retrieval techniques is the comparison of their ability to match retrieved values with concurrent in-situ measurements. We therefore sought to extend the range of available in-situ comparisons. This was done by seeking all available match-ups between VIIRS NN a_{ph443} (and equivalent [*Chla*] retrievals and in-situ *KB* cell count measurements for the period 2012-2015. These comparisons showed that when the window between in-situ observations and satellite measurements was reduced from daily, to 2, 1 and ½ hors, the correlations greatly improved for the VIIRS NN retrievals against in-situ match-ups. These showed a respectable $R^2 = 0.79$ for the ½ hour window. The comparisons also supported the choice of values for the F1 and F2 filter processes. Comparisons were also made comparing VIIRS NN retrievals identifying *KB* HABs, and and in-situ *KB* cell counts measured on the same date for 3 specific specific bloom events. All three confirmed the viability of the VIIRS NN retrieval approach, with very low errors of false negatives or positives.
In conclusion, results to date with the VIIRS NN technique appear promising. However, more match-ups, including more detailed considerations of observation times and their connections to false positives or negatives, sample depths, distance to observation pixel centers and sub-pixel variability and impact of comples in-shore waters need to be studied before more comprehensive statistics can be obtained on the overall efficacy of the approach.

Planned Work:

- Examine NN VIIRS KB HABs retrievals against location specific in-situ measurements - for both offshore and in-shore regions
- Examine time dependent correlations obtained for both in-shore and off –shore areas,
- Evaluate against specific normalized fluorescence height retrievals – in terms of time windows and for offshore and in-shore areas
- Evaluate against Red Band Difference retrievals – in terms of time windows and locations
- Evaluate against OCI/OC3 retrievals—again in terms of temporal and special conditions.
- Develop statistics of false positives and negative for VIIRS KB HABs specific HAB bloom retrievals.
- Compare retrievals for specific VIIRS NN KB HABs against other retrieval techniques.

Publications:

El-habashi and S. Ahmed "Neural Network Algorithms for Retrieval of Harmful Algal Blooms in the West Florida Shelf from VIIRS Satellite Observations and comparisons with other techniques, *Proc. of SPIE*, **9638, 2015**

Presentations

El-habashi and S. Ahmed "Neural Network Algorithms for Retrieval of Harmful Algal Blooms in the West Florida Shelf from VIIRS Satellite Observations and comparisons with other techniques, without the need for a fluorescence Channel", SPIE Remote Sensing, France, Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions, September 2015

Criteria for effective satellite detection of harmful algal blooms in the West Florida Shelf using neural networks and other techniques. A. El Habashi, Sam Ahmed, , CCNY NOAA CREST and Vince Lovko, Mote Marine Labs, Sarastota Fl. AGU Ocean Optics, New Orleans, February 2016.

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

Understanding the impact of AMSU derived FCDR's – Application to Hail Climatology

Task Leader: Wenze Yang & James Beauchamp
Task Code: WYWY_Hail_15
NOAA Sponsor: NCEI
NOAA Office
Contribution to CICS Research Themes (%) Theme 1: 100 %
Main CICS Research Topic: Earth System Monitoring from Satellites
Contribution to NOAA goals (%) Goal 1: 50%; Goal 2 50%
Highlight
Link to a research web page

Background

Previous studies have shown a strong relationship between hail and microwave brightness temperature (Tb) depression in convective clouds. Many of these were limited by the poor temporal and/or spatial coverage of the particular satellite. In our earlier study (Ferraro et al, 2014) the much improved spatial/temporal coverage afforded by AMSU-B/MHS microwave sensors aboard NOAA (NOAA-15 to NOAA-19) and EUMETSAT (MetOp-A and –B) satellites was utilized. This previous study used a gridded (HMAP) product, based on uncalibrated, level 1B satellite Tb's. These level 1B data have since been satellite inter-calibrated and Fundamental Climate Data Records (FCDR's) have been generated, which are better suited for climatological studies because there is improved Tb consistency between different satellites and some long-term trends can be corrected. In the current study, using inter-calibrated CDR's, we hope to demonstrate the utility of this improved product to create hail frequency climatologies. The hail detection algorithm for this study is the same as that used in Ferraro et al (2014), so it should not be surprising that results will be rather consistent with the previous study. After all, Tb corrections from inter-calibration tend to be small compared to Tb depressions due to the presence of hail.

Accomplishments

A. Software was developed to read through each satellite-year's CDR's (files) and using the same hail-detection threshold algorithm described in Ferraro et al (2014) hail climatologies were produced over the continental United States (CONUS) for the months of March to September, for the period calibrated AMSU/MHS data were available, 2000 – 2010.
B. Climatology maps (no. of hail events per 1 deg. grid) were produced for these 7 months separately and combined. Similar maps had already been completed based on HMAP and SPC data. Figure 1 shows these 7-month aggregate climatologies.
C. Similar to what was done in the Ferraro et al (2014) study, scatterplots (with correlation values) of satellite-detected hail events vs. ground observed hail events were made for each month, each year, and for all years and months combined.
D. To get a sense of diurnal variability in hail detection, hail climatology maps were generated dividing each day into four, six-hour periods. Figure 2 shows hail events for 00h to 06h local time. Note the relatively low number of hail events based on ground observations.
E. Probability of detection (POD) and false alarm rate (FAR) statistics were also done for each year separately and all years combined. Use of CDR data instead of HMAP data tended to improve POD values but degraded FAR's. These statistics will require further analysis.

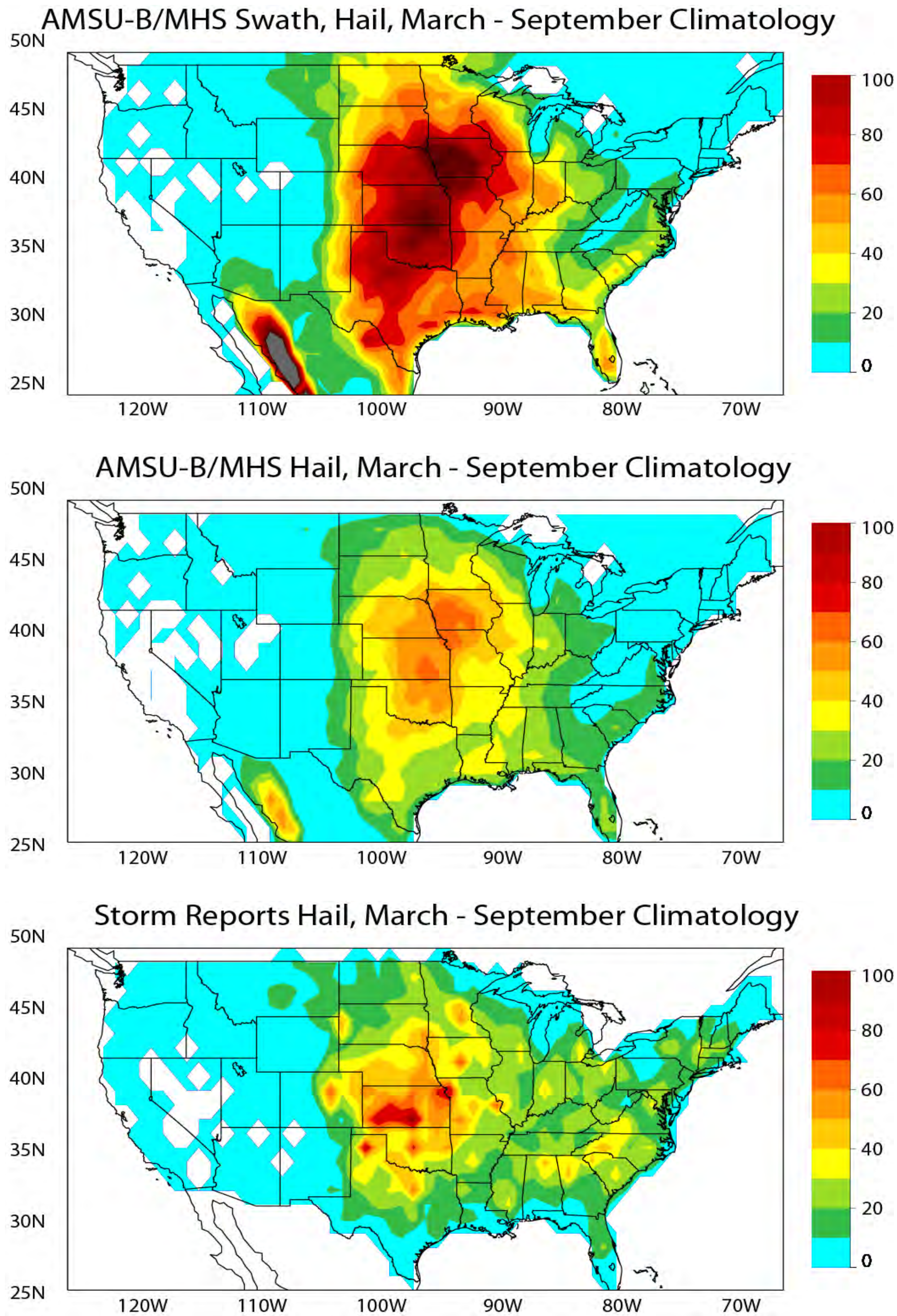


Fig. 1) Hail frequency climatology maps for the months March to September combined. Climatologies were based on the years AMSU-B/MHS were available, 2000 – 2011. Top panel is from the CDR data, middle panel from HMAP (uncalibrated, gridded) product, and the bottom panel from ground based spotter reports.

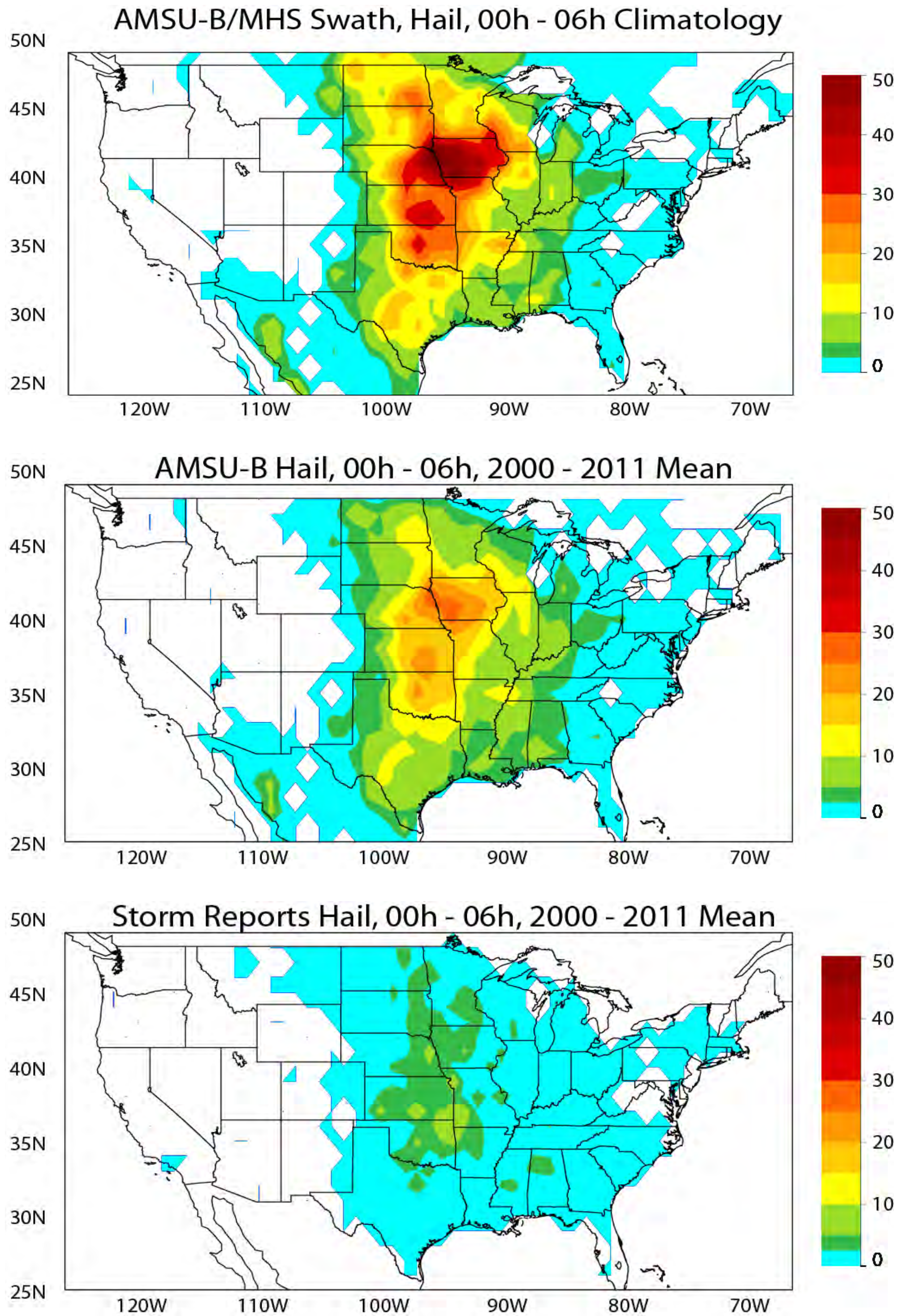


Fig. 2) Hail frequency climatology maps for the months March to September combined, but segregated into four separate periods during the day. These panels depict 00h – 06h local time and climatologies were based on the years AMSU-B/MHS were available, 2000 – 2011. Top panel is from the CDR data, middle panel from HMAP (uncalibrated, gridded) product, and the bottom panel from ground based spotter reports. Note the relatively few number of hail events from the ground based observations.

Planned Work

- Produce global hail climatologies for at least one year comparable to what had been done with non-calibrated HMAP data.
- Generate interannual time-series of hail events over central United States to assess the impact of using CDR data vs. HMAP data. Also to see if year-to-year changes might be related to ENSO or some other climate index/factor.
- Examine POD/FAR statistics only in the vicinity of one major metropolitan area, where there would be a greater likelihood of nearly all hail events being observed by a human spotter.
- Experiment with different methods of binning ground-observed and satellite detected hail events that are more consistent with other published hail climatology studies.
- Develop and submit a journal publication describing results of this study.
- Give an oral or poster presentation of results at a relevant scientific venue.

References

Ferraro, R., J. Beauchamp, D. Cecil and G. Heymsfield, 2014: A prototype hail detection algorithm and climatology developed with the Advanced Microwave Sounding Unit (AMSU). http://dx.doi.org/10.1016/j.atmosres.2014.08010

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

Development of SAR Altimeter capability

Task Leader: Alejandro Egido
Task Code: EBEB_DSAC_14
NOAA Sponsor: Walter HF. Smith
NOAA Office: STAR/SOCD/OPB Laboratory for Satellite Altimetry
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%
Highlight
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.

Accomplishments

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.

As a proof for that, we applied the delay/Doppler and fully-focused SAR processing techniques to CryoSat-2 SAR mode radar echoes from a small irrigation pond, circled in Fig. 1(a). The grey line in the image shows the sub-satellite track. In Fig. 1(b) we overlaid the delay-Doppler response for the pond, showing a 300 m along-track and a 1500 m across-track resolution. Fig. 1(c) shows the fully-focused response. As observed, the location of the pond is much better resolved than in the delay/Doppler case, however, there are still some side-lobes in the along-track response due to CryoSat's closed burst operation. Applying a simple deconvolution technique can compensate this, leading to a single stripe on the surface that perfectly defines the pond location, as shown in Fig. 1(d).

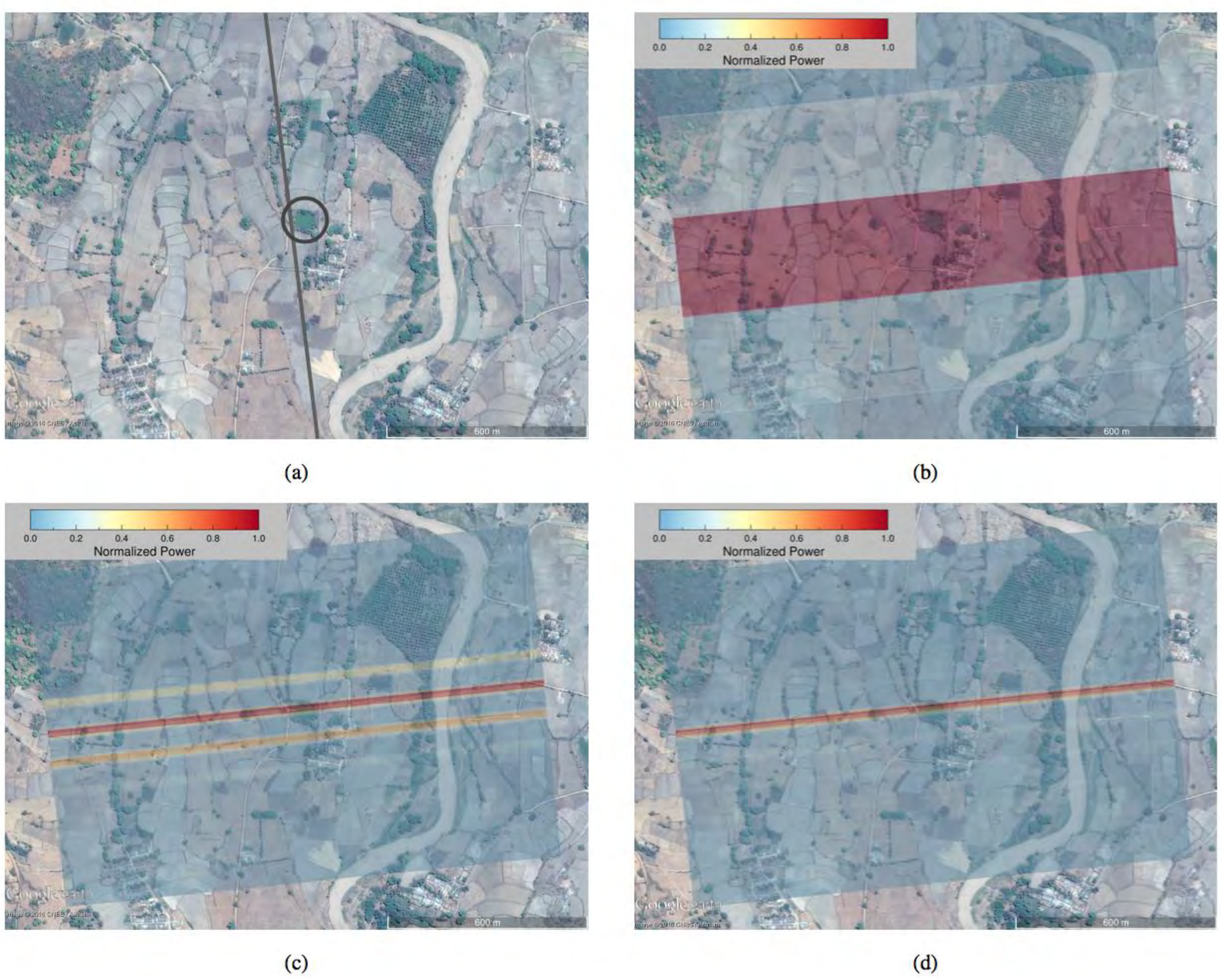
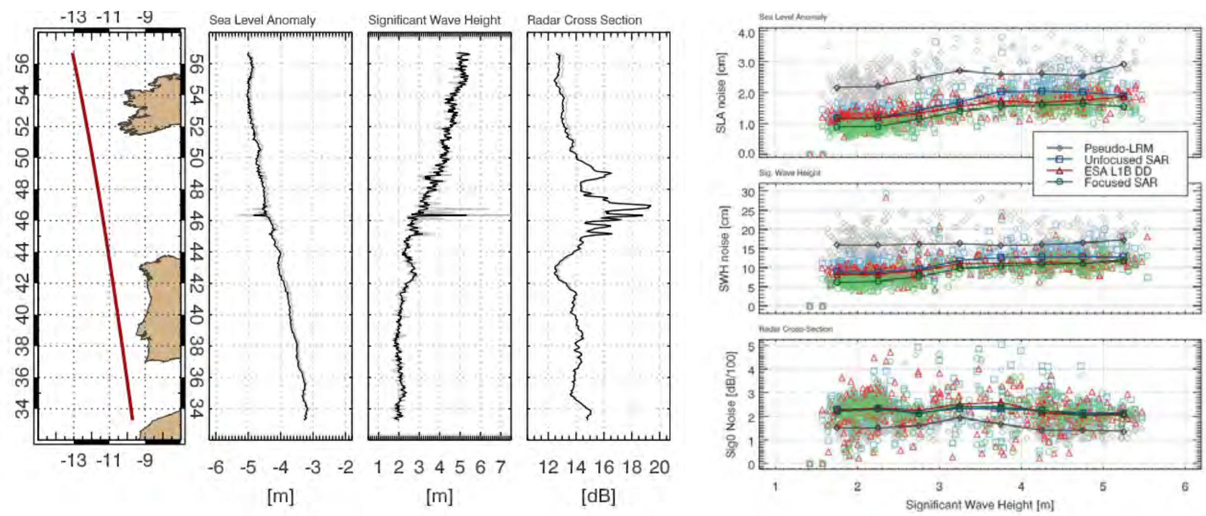


Figure 1: (a) Google Earth image showing the small irrigation pond, encompassed by a circle, and the sub-satellite track, depicted as a grey line; (b) delay/Doppler response; (c) fully focused SAR response; (d) fully focused SAR response after deconvolution.

Over the open ocean, the fully-focused SAR technique can also provide significant improvements with respect to the other radar altimeter techniques. Fig. 2(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.2 (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 25: (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.

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.

Sea Surface Height Applications

- Development of an improved waveform retracker to furnish estimates of sea surface height, significant wave height, and wind speed from CryoSat SAR-mode Level1b multi-looked waveforms.
- Processing of extended datasets of SAR Altimeter data to verify the performance of the technique
- Develop an improved averaging strategy for the coherent and incoherently processing of SAR FBR waveforms.

Sea Ice Applications

- Develop automatic leads/sea ice freeboard detection for SAR L1b Stack data.
- Develop improved SAR waveform re-tracker for the determination of sea level over coherent echo returns.
- Processing of extended datasets of CryoSat-2 data to verify the performance of the focused SAR processing technique with respect to the L1b and/or L2 ESA conventional sea ice thickness products.

- Validation and Calibration of results by comparison of CryoSat-2 outputs with freeboard estimates from IceBridge underflights.

Publications

(1) A. Egido, W. H. F. Smith, "Fully Focused SAR Altimetry: Theory and Applications", submitted to *IEEE Transactions on Geoscience and Remote Sensing, Feb. 2016*

Products

Sea Surface Height experimental product.

Presentations

(i) A. Egido, C. Martin-Puig, W. Smith, E. Leuliete, R. Scharoo, "NOAA Validation of FDM and LRM ocean product", CryoSat Quality Working Group 6. MSSL, Dorking, UK, March 17-19 2015

(ii) A. Egido, W. Smith, "Separation of Coherent and Incoherent Scattering Components from Delay/Doppler Altimeter Waveforms", Ocean Surface Topography Science Team Meeting; Reston, VA, USA; October 20th – 23rd, 2015

(iii) A. Egido, W. Smith, "Fully-focused SAR Altimetry, Theory and Applications", CICS-MD Science Meeting, College Park, MD, USA; Nov 23-24, 2015, poster

(iv) A. Egido, W. Smith, "Separation of Coherent and Incoherent Scattering Components from Delay/Doppler Altimeter Waveforms over Sea-Ice", AGU Fall Meeting 2015, San Francisco, CA, USA; Dec 14-18, 2015, poster

Accepted for Oral presentation:

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

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

Real-Time Monitoring and Short-term Forecasting of Phenology from GOES-R ABI for the Use in Numerical Weather Prediction Models

Task Leader	Xiaoyang Zhang (South Dakota State University)
Task Code	XZXZ_GOESR_15
NOAA Sponsor	Yunyue Yu
NOAA Office	**STAR**

Contribution to CICS Research Themes (%): Theme 1: 20%; Theme 2: 40%; Theme 3: 40%.

Main CICS Research Topic Earth System Monitoring from Satellites

Percent contribution to NOAA Goals Goal 1: 60%; Goal 2: 40%

Highlight: We generated phenological datasets using SEVERI EVI2 from 2006-2013. Further, we conducted a detailed comparison between phenological detections from SEVERI EVI2 and MODIS EVI2 in the Congo Basin where cloud cover frequently occurs. The results show that SEVERI EVI2 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 developed an algorithm for simulating trajectory of vegetation greenness development. We generated seasonal progress of vegetation greenness across Africa using hybrid piecewise logistic models. The green vegetation fraction from the phenological model presents gradually and continuously temporal and spatial variation while the green vegetation fraction from the approach of GOES-R product shows irregularly temporal variations and large gaps caused by cloud obstructions in the raw data (Figure 1).

- We established climatology of vegetation greenness development from MODIS/SEVERI data. The climatology of vegetation greenness in North America will be used for monitoring phenological development from GOES-R observations. Before the launch of GOES-R, we used the SENVERI greenness climatology in Africa and MODIS greenness climatology in North America to test the algorithms of real time monitoring of greenness. In doing this, we improved our algorithms in detecting phenological metrics from MODIS/SEVERI data: (a) using good quality observations in preceding and following years to represent the persistently missing (or cloud cover) observations (large gaps) in the given year and (b) selecting minimum vegetation index (VI) during a vegetation growing season and maximum VI during vegetation dormant period to enhance background VI estimation. After investigating the phenological metrics from 2001-2013, the climatological phenological metrics were generated (Figures 2 and 3).

- We compared the phenology development observed from MODIS and SEVERI across the Congo Basin (Figure 4). The results indicate that diurnal SEVIRI observations greatly increased the probability of capturing cloud-free daily EVI2 in the tropical rainforests across the Congo Basin, where the proportion of good quality (PGQ) observations during a canopy greenness cycle was up to 80% higher than that from MODIS. As a result, two canopy greenness cycles within a year were well identified from SEVIRI data but sparsely detected from MODIS data. In contrast, one greenness cycle annually was successfully retrieved from both MODIS and SEVIRI in the savanna-dominated northern and southern Congo Basin. Moreover, the decreases of PGQ observations in an annual time series significantly increased the uncertainties of phenological timing detections and the missing detections of the canopy greenness cycles.

- We investigated the influence of wildfire on GVF development (Figure 5). In Africa, wildfires occur frequently, which burn a large amount of plants. We collected MODIS active fires (with fire radiative power) from 2010-2013 to determine the location and time of fire occurrences and to define the fire intensity. Our preliminary results indicate that greenness (GVF) at a SEVERI pixel was slightly impacted by fire occurrences in most cases although greenness reduced sharply in a few cases. This is likely associated with the facts that fires mostly appear during the dry season when plants are at the dormant phase with limited green vegetation cover and that SEVERI pixel footprint is too large to distinguish the small portion of vegetation burned by fires. To understand well the fire impacts on GVF, further investigation is needed.

- We developed an algorithm for monitoring and forecasting phenological metrics. We developed the algorithm and computer codes for monitoring the seasonal dynamics of green vegetation fraction in real time and forecasting in short-term. We tested the approach using MDOIS and VIIRS data in North America. The results show the algorithms are able to produce the GVF reasonably although the detailed evaluation is needed.

- We generated a set of global GVF data from 2001 to 2013 using phenology algorithms and sent to NOAA EMC for model testing.

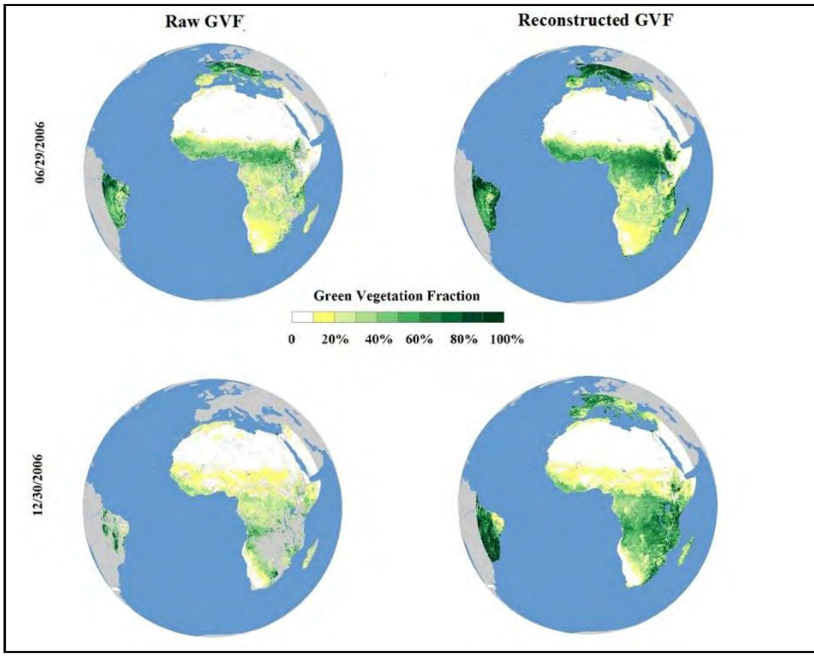


Figure 1. Comparison of spatial pattern between green vegetation fraction generated from phenological model and that from the approach of GOES-R GVF product (raw GVF). The grey color indicates GVF was not detected. The raw GVF maps (left) present large area with missing detections while the reconstructed GVF maps provide continuous variation. The latter are suitable to land model application.

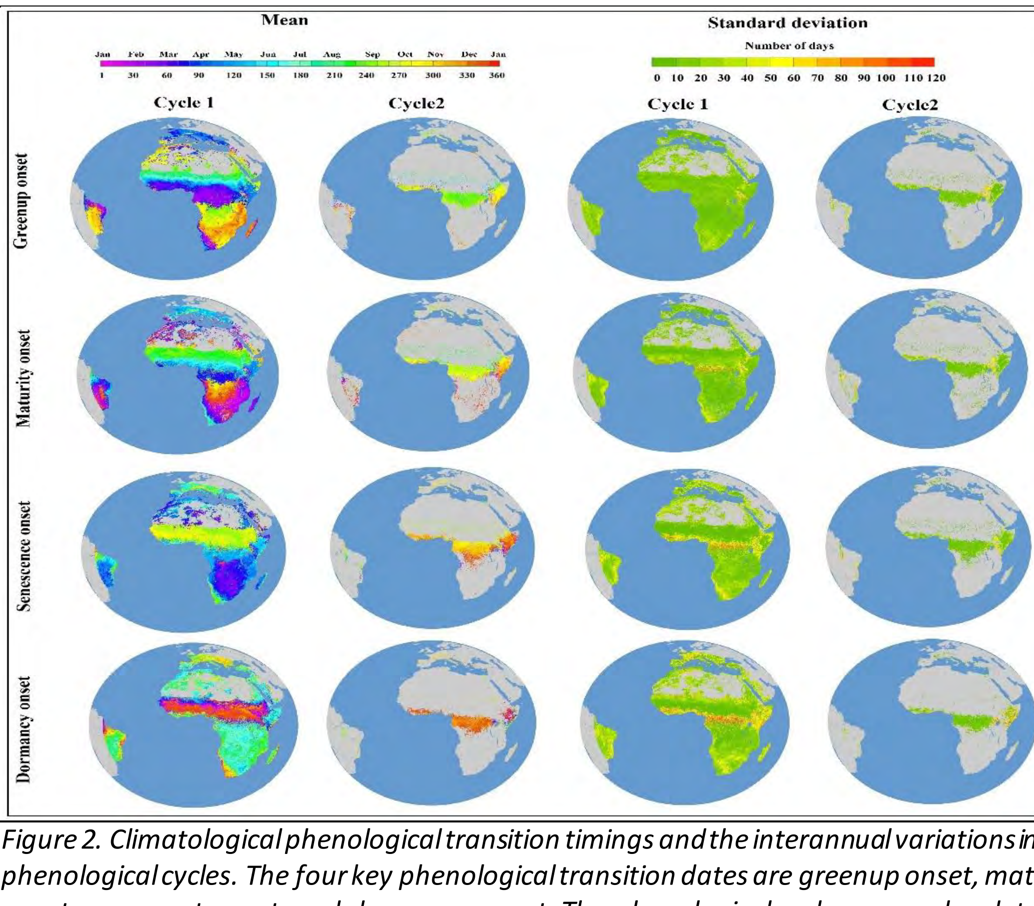


Figure 2. Climatological phenological transition timings and the interannual variations in two phenological cycles. The four key phenological transition dates are greenup onset, maturity onset, senescent onset, and dormancy onset. The phenological cycles were also detected across the Congo Basin and the Sahara Desert.

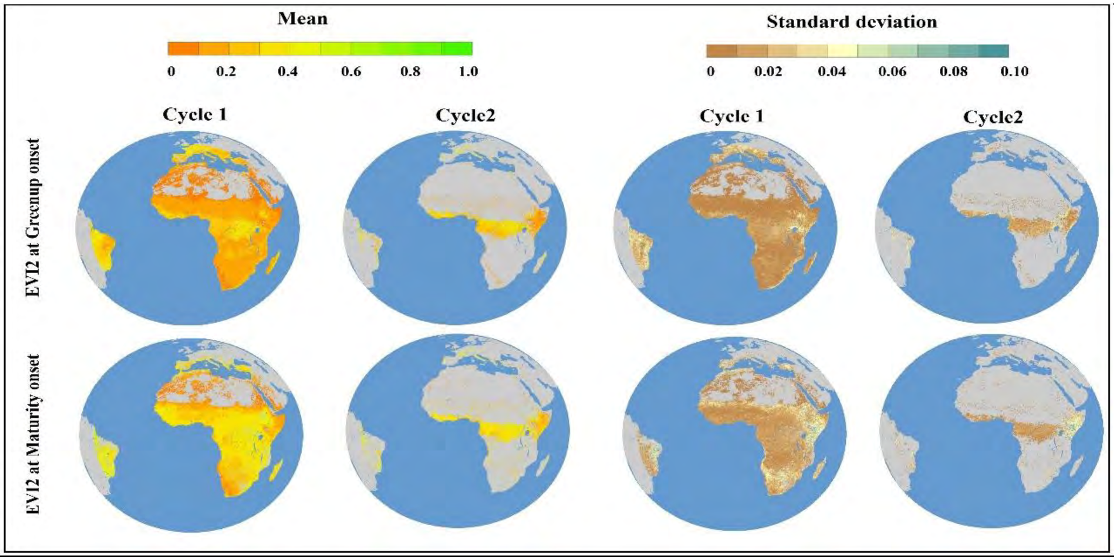


Figure 3. Climatology of maximum and minimum greenness (GVF) from SEVERI data (2006-2013). The maximum greenness was calculated at the time of greenness reaching maximum (maturity onset) and the minimum greenness were determined at the time when greenness starts increasing (greenup onset).

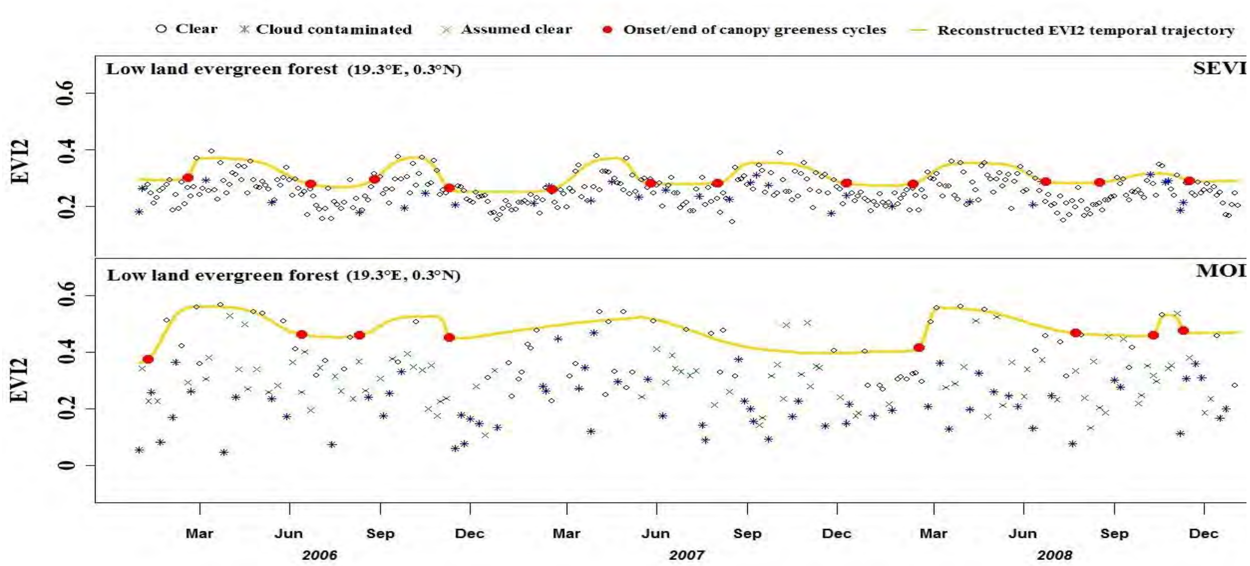


Figure 4. Comparison of the enhanced vegetation index (EVI2) between SEVIRI and MODIS observations. There is only one good MODIS observation during the greenness cycles from August-December in 2006 and from September- December in 2008 and no good MODIS observation from September-December in 2007. This leads the failure of proper detections of green vegetation fraction. In contrast, SEVERI EVI2 provides a set of good observations which allow us to calculate GVF variation.

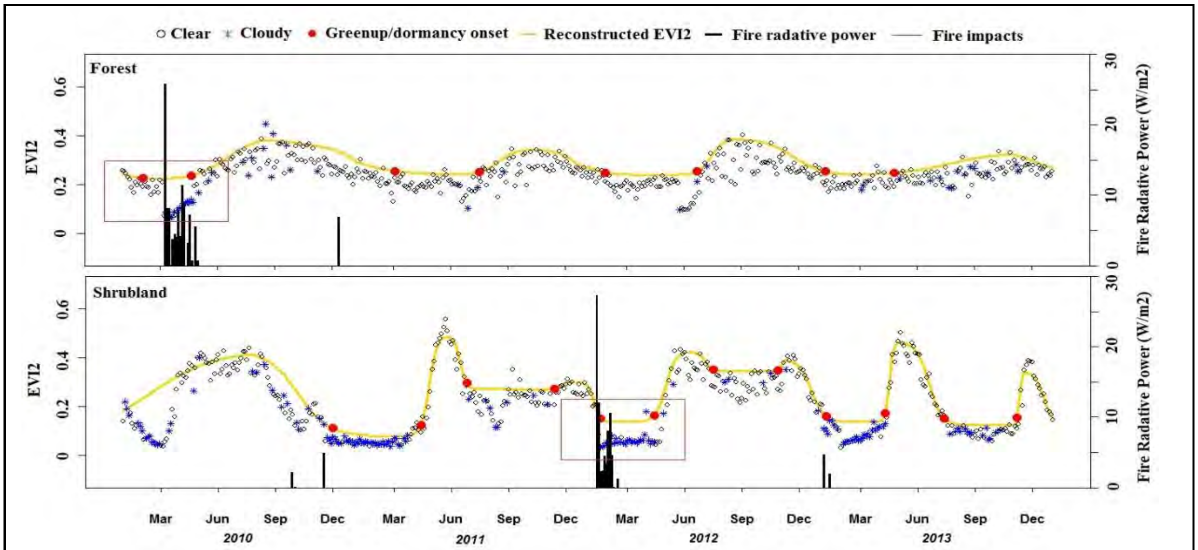


Figure 5. Temporal vegetation greenness impacted by fire occurrences. The fire intense was represented using fire radiative power (FRP).

Planned Work

- Investigate fire effects on GVF estimates.
- 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

Yan, D., Zhang, X., Yu, Y. Guo, W. 2016, The Influences of Data Quality on the Retrievals of Tropical Rainforest Phenology from Geostationary (SEVIRI) and Polar-orbiting (MODIS) Sensors across the Congo Basin, *IEEE Transactions Geoscience and Remote Sensing* (under revision, minor revision was requested).

Zhang, X., and Zhang, Q. 2016, Monitoring interannual variation in global crop yield using long-term AVHRR and MODIS observations, *ISPRS Journal of Photogrammetry and Remote Sensing* 114, 191-205.

Liu, L., Zhang, X., Donnelly, A. and Liu, X. ,2016, Interannual variations in spring phenology and their response to climate change across the Tibetan Plateau from 1982 to 2013, *Int. J. Biometeorol.*, doi:10.1007/s00484-016-1147-6

Wu, M., Zhang, X, Huang, W., Niu, Z., Wang,C., Li, W. and Hao, P., 2015, Reconstruction of Daily 30 m Data from HJ CCD, GF-1 WFV, Landsat, and MODIS Data for Crop Monitoring, *Remote Sensing*, http://dx.doi.org/10.3390/rs71215826.

Liang, L., Zhang, X., 2015, Coupled Spatiotemporal Variability of Temperature and Spring Phenology in the Eastern U.S., *International Journal of Climatology,* http://dx.doi.org/10.1002/joc.4456.

Yue, X., Unger, N., Keenan, T. F., Zhang, X., and Vogel, C. S. 2015, Probing the past 30-year phenology trend of US deciduous forests, *Biogeosciences*, http://dx.doi.org/10.5194/bg-12-4693-2015.

Zhang, X., 2015, Reconstruction of a Complete Global Time Series of Daily Vegetation Index Trajectory from Long-term AVHRR Data, *Remote Sensing of Environment*, http://dx.doi.org/10.1016/j.rse.2014.10.012.

Zhang, Q., Cheng, Y.B., Lyapustin, A.I., Wang, Y., Zhang, X., Suyker, A., Verma, S., Shuai, Y., Middleton, E.M., 2015, Estimation of crop gross primary production (GPP): II. Do scaled MODIS vegetation indices

improve performance? *Agricultural and Forest Meteorology,* http://dx.doi.org/10.1016/j.agrformet.2014.09.003.

Presentations

Zhang, X., Yu, Y., Liu, L., 2015, A System for Monitoring and Forecasting Land Surface Phenology Using Time Series of JPSS VIIRS Observations and Its Applications, AGU *Fall Meeting*, 14–18 December, San Francisco, California, USA.

Liu, Y., MacKenzie, C.M., Primack, R., Zhang, X., Schaaf, C., Sun, Q., and Wang, Z., 2015, Phenological monitoring of Acadia National Park using Landsat, MODIS and VIIRS observations and fused data, *AGU Fall Meeting*, 14–18 December, San Francisco, California, USA. (10% effort)

Yan, D., Zhang, X., Yu, Y., and Guo, W., 2015, Rainfall Controls on Land Surface Phenology over "Never-green" and "Ever-green" Lands in Africa, *AGU Fall Meeting*, 14–18 December, San Francisco, California, USA.

Zhang, X., Yu, Y., Liu, L., Henebry, G., Friedl, M., Joshua Gray, J., Schaaf, C., Liu, Y., and Wang, Z., 2015, VIIRS Land Surface Phenology: from Climate Date Record to Real Time Monitoring, *Third International Conference on Phenology*, 5-8 October, Kusadasi, Turkey.

Liu, Y., Schaaf, C., Zhang, X., Wang, Z., Erb, A., Saenz, Z., Sun, Q., Paynter, I., 2015, Monitoring tree and understory grass phenological development in California Savannas using daily MODIS and VIIRS NBAR, *Third International Conference on Phenology*, 5-8 October, Kusadasi, Turkey.

Zhang, X., Yu, Y., Liu, L., Wu, Y., and Ek, M., 2015, Operational Monitoring and Forecasting of Land Surface Phenology from JPSS VIIRS Observations and its Applications, *JPSS 2015 Annual Science Meeting,* 24-28 August, *College Park, MD.*

Zhang, X., 2015, Satellite Monitoring of the Green Wave and Brown Wave on the Earth's Land Surface in Response to Global Climate Change, *South Dakota State Geography Convention*, 19-20 March, South Dakota State University, SD.

Zhang, X., Liu, L., Yan, D., 2015, Long-term Land Surface Phenology: Climatology, Trend, Variability, and Climate Impacts, *AAG 2015*, 21-26 April, Chicago, IL.

Liu, L, Zhang, X., 2015, The response of spring phenology to climate change on the Tibetan Plateau from 1982 to 2013, *AAG 2015*, 21-26 April, Chicago, IL.

Zhang, X., Liu, L., Yu, Y., 2015, Real-time Monitoring Land Surface Vegetation Phenology from VIIRS Observations, *2015 NOAA Satellite Conference*, April 27-May1, Greenbelt, MD.

Zhang, X., Friedl, M., Henebry, G., Jayavelu, S., Gray, J., Schaaf, C., Liu, Y., 2015, Comparison of Land Surface Phenology Retrieved from MODIS and VIIRS Data, *2015 NASA MODIS and VIIRS Science Team Meeting*, 18-22 May, Silver Spring, MD.

Henebry G, de Beurs, K, Krehbiel, C, Nguyen, L, Owsley, B, Zhang, X, Zheng, B, 2015, Change in our MIDST: Toward detection and analysis of urban dynamics in CONUS, *NASA Carbon Cycle & Ecosystems Joint Science Workshop,* 20–24 April, College Park, MD.

Henebry GM, Zhang, XY, de Beurs, KM, Kimball, JS, Small, C, 2015, Change in our MIDST: Toward Detection and Analysis of Urban Land Dynamics in North and South America Joint Urban Remote Sensing Event, *2015 Joint Urban Remote Sensing Event (JURSE),* 30 March–01 April, Lausanne Switzerland.

Performance Metrics	FY14
# of new or improved products developed	0
# of products or techniques transitioned from research to ops	0
# of peer reviewed papers	8
# of non-peered reviewed papers	0
# of invited presentations	13
# of graduate students supported by a CICS task	N/A
# of undergraduate students supported by a CICS task	N/A

Monitoring Land Surface Vegetation Phenology from VIIRS

Task Leader Xiaoyang Zhang (South Dakota State University)
Task Code XZXZ_VIIRS_15
NOAA Sponsor Yunyue Yu
NOAA Office **STAR**
Contribution to CICS Research Themes(%): Theme 1: 20%; Theme 2: 40%; Theme 3: 40%.
Main CICS Research Topic Earth System Monitoring from Satellites
Percent contribution to NOAA Goals Goal 1: 60%; Goal 2: 40%

Highlight: We developed algorithms and operational computer codes to monitor spring and fall foliage development from VIIRS data. The algorithms were tested using VIIRS data in 2014 across CONUS and extended to entire North America in 2015. 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. 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 modified the computing code to trace the spring green vegetation development. To distinguish the leaf phenology from background, only the spring dynamics of green leaves was identified but the green leaves remaining at dormant phases (evergreen vegetation during winter) were calculated separately. We routinely produced the spring green leaf progress every 3 days and made the prediction in 10 days ahead (Figure 1).

We enhanced algorithms and computing codes for near-real time monitoring of phenology development. Specifically, we modified the computer codes to calibrate the MODIS and VIIRS data in order to improve the quality of climatological phenology datasets. We compared fall foliage detections from NDVI and EVI2 data and selected EVI2 for the fall foliage monitoring. As a result, both spring and fall foliage developments are consistently monitored using EVI2. Further, we combined the models for monitoring the spring green leaf progress and fall foliage coloration into a single computer code, which was tested using VIIRS data over CONUS in 2014. Moreover, we prepared a code to automatically obtain VIIRS inputs and send outputs result to JPSS Environmental Data Records.

We extended the algorithm of near-real time monitoring of phenology to entire North America at a spatial resolution of 4km. In doing this, we first generated climatology of phenology during spring and senescent phases based on MODIS observations from 2001-2012 in North America (Figure 2). The phenological metrics for individual years were detected from daily MODIS observations. The MODIS-based climatology was then calibrated to be equivalent to VIIRS observations by establishing models between VIIRS EVI2 and MODIS EVI2 for individual pixels using data in 2014. Finally, the daily VIIRS observations during fall in 2015 were applied to conduct the monitoring and forecasting of fall foliage coloration across the North America (Figure 3). The foliage progress product was delivered to NOAA NESDIS STAR every three days in 2015 (http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Foliage.php).

We prepared and delivered the green vegetation cover (GVF) data over North America for Land Model in EMC (Figure 4). The GVF was derived from phenology algorithms from VIIRS observations. If snow occurs in a pixel, it was assumed that snow covered 60% of green leaves in forests and 85% of green leaves in non-forests. It is due to the fact that evergreen vegetation always exists in individual pixels. Thus, the VIIRS GVF provides many details than climatology which is currently used for Land Model simulation. We further generated the global 1km green vegetation cover (GVF) data in 2014 for Land Model in EMC although it was challenging to process the large dataset. This dataset was used for investigating land model processing in EMC.

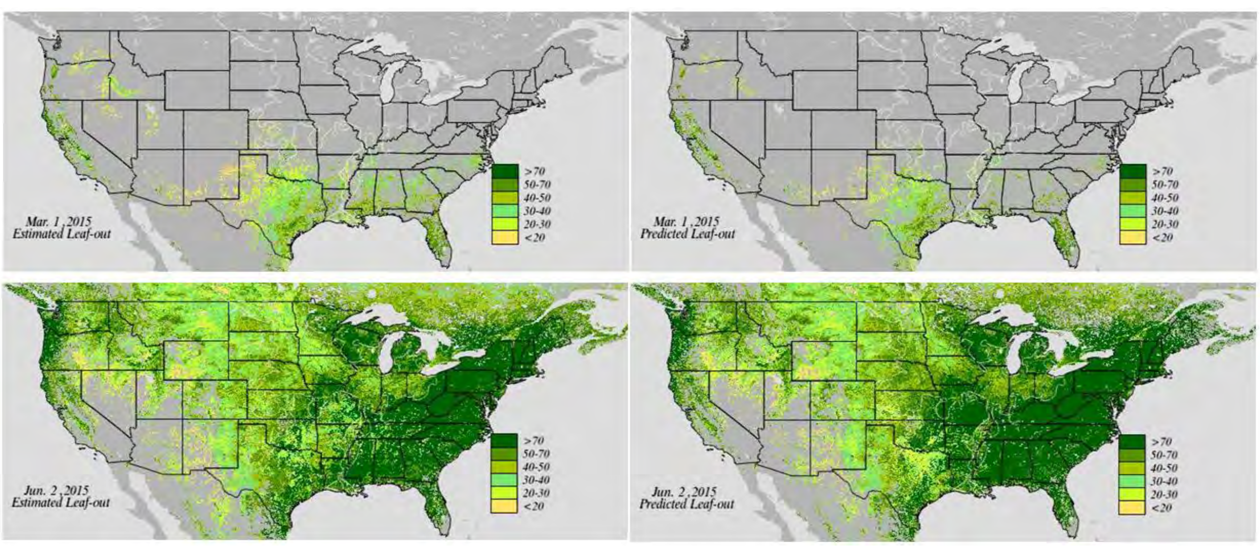


Figure 1. Real-time monitoring and short-term forecasting of the progress of spring green vegetation fraction (4km). The "Estimated Leaf-out" indicates the green vegetation fraction monitored in real time while the "Predicted Leaf-out" represents the values predicted 10 days ahead.

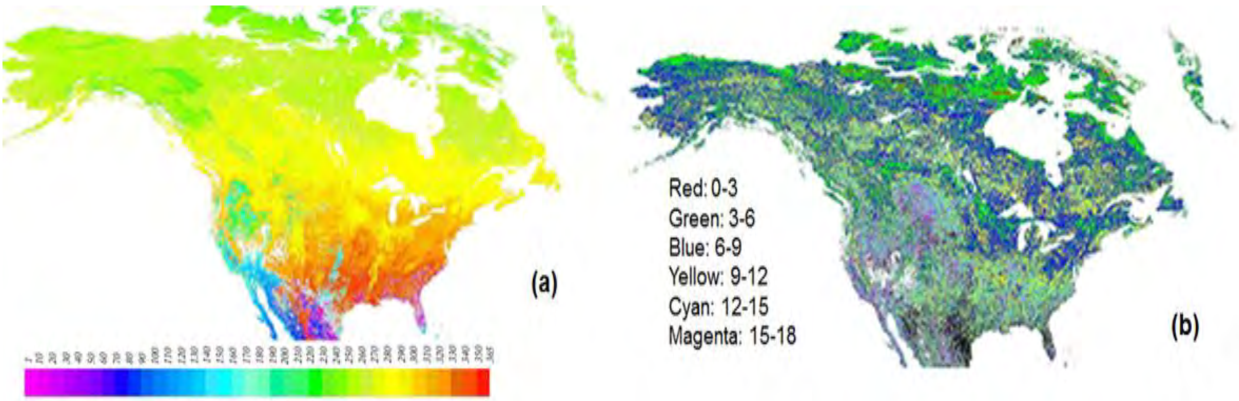


Figure 2. Climatology of dormancy onset and standard variation from MODIS phenology data from 2001-2012. (a) the mean timing of dormancy onset and below panel and (b) the standard deviation of dormancy timing from 2001-2012.

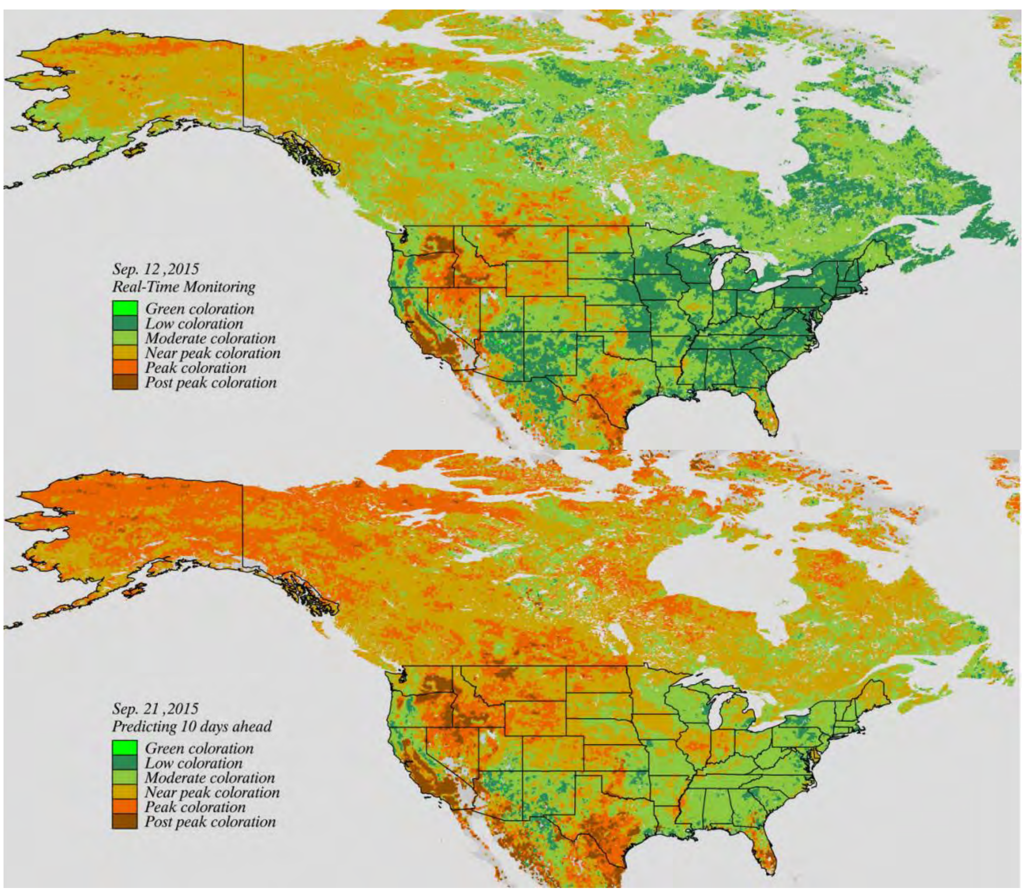


Figure 3. Real time monitoring and short term forecasting of fall foliage coloration over North America in 2015.

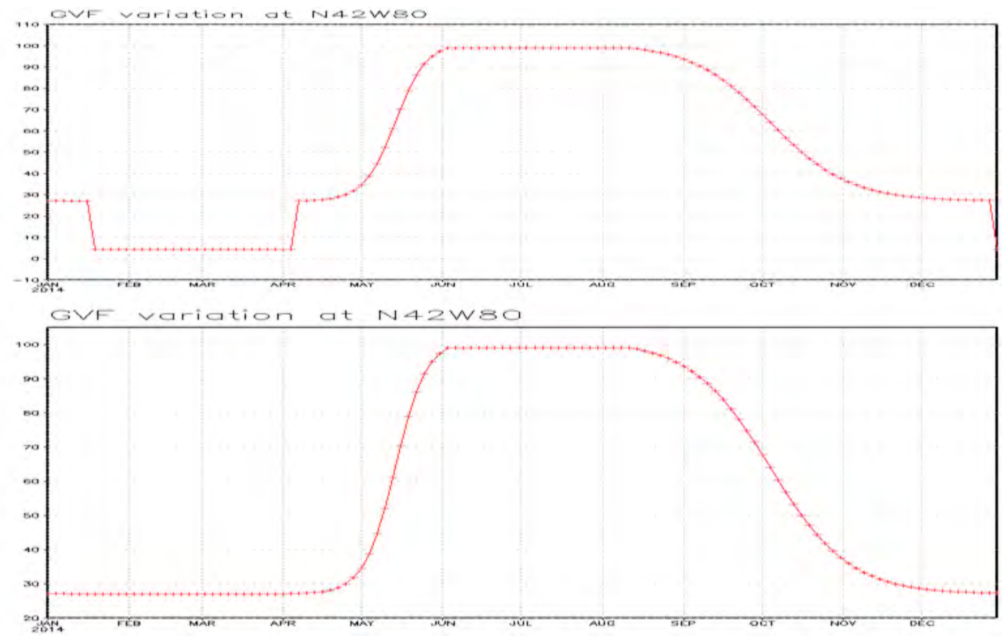


Figure 4. The green vegetation cover (%) calculated from the phenological model for Land Model in EMC. Upper panel represents that the green leaves covered by snow was considered as no green vegetation while the bottom panel indicates the green leaves under snow was included in an example pixel.

Planned Work

- Refine the algorithms and computer codes and extend the foliage monitoring to Eurasia and south hemisphere.
- Validate the results using field observations and PhenoCam time series.
- Prepare phenological data for land model

Publications

Zhang, X., and Zhang, Q. 2016, Monitoring interannual variation in global crop yield using long-term AVHRR and MODIS observations, *ISPRS Journal of Photogrammetry and Remote Sensing* 114, 191-205.

Liu, L., Zhang, X., Donnelly, A. and Liu, X. ,2016, Interannual variations in spring phenology and their response to climate change across the Tibetan Plateau from 1982 to 2013, *Int. J. Biometeorol.*, doi:10.1007/s00484-016-1147-6

Wu, M., Zhang, X, Huang, W., Niu, Z., Wang,C., Li, W. and Hao, P., 2015, Reconstruction of Daily 30 m Data from HJ CCD, GF-1 WFV, Landsat, and MODIS Data for Crop Monitoring, *Remote Sensing*, http://dx.doi.org/10.3390/rs71215826.

Liang, L., Zhang, X., 2015, Coupled Spatiotemporal Variability of Temperature and Spring Phenology in the Eastern U.S., *International Journal of Climatology*, http://dx.doi.org/10.1002/joc.4456.

Yue, X., Unger, N., Keenan, T. F., Zhang, X., and Vogel, C. S. 2015, Probing the past 30-year phenology trend of US deciduous forests, *Biogeosciences*, http://dx.doi.org/10.5194/bg-12-4693-2015.

Zhang, X., 2015, Reconstruction of a Complete Global Time Series of Daily Vegetation Index Trajectory from Long-term AVHRR Data, *Remote Sensing of Environment*, http://dx.doi.org/10.1016/j.rse.2014.10.012.

Zhang, Q., Cheng, Y.B., Lyapustin, A.I., Wang, Y., Zhang, X., Suyker, A., Verma, S., Shuai, Y., Middleton, E.M., 2015, Estimation of crop gross primary production (GPP): II. Do scaled MODIS vegetation indices improve performance? *Agricultural and Forest Meteorology,* http://dx.doi.org/10.1016/j.agrformet.2014.09.003.

Produts

- Algorithm and computer codes for global phenology detection from VIIRS across North America.

Presentations

Zhang, X., Yu, Y., Liu, L., 2015, A System for Monitoring and Forecasting Land Surface Phenology Using Time Series of JPSS VIIRS Observations and Its Applications, AGU *Fall Meeting*, 14–18 December, San Francisco, California, USA.

Liu, Y., MacKenzie, C.M., Primack, R., Zhang, X., Schaaf, C., Sun, Q., and Wang, Z., 2015, Phenological monitoring of Acadia National Park using Landsat, MODIS and VIIRS observations and fused data, *AGU Fall Meeting*, 14–18 December, San Francisco, California, USA. (10% effort)

Yan, D., Zhang, X., Yu, Y., and Guo, W., 2015, Rainfall Controls on Land Surface Phenology over “Never-green” and “Ever-green” Lands in Africa, *AGU Fall Meeting*, 14–18 December, San Francisco, California, USA.

Zhang, X., Yu, Y., Liu, L., Henebry, G., Friedl, M., Joshua Gray, J., Schaaf, C., Liu, Y., and Wang, Z., 2015, VIIRS Land Surface Phenology: from Climate Date Record to Real Time Monitoring, *Third International Conference on Phenology*, 5-8 October, Kusadasi, Turkey.

Liu, Y., Schaaf, C., Zhang, X., Wang, Z., Erb, A., Saenz, Z., Sun, Q., Paynter, I., 2015, Monitoring tree and understory grass phenological development in California Savannas using daily MODIS and VIIRS NBAR, *Third International Conference on Phenology*, 5-8 October, Kusadasi, Turkey.

Zhang, X., Yu, Y., Liu, L., Wu, Y., and Ek, M., 2015, Operational Monitoring and Forecasting of Land Surface Phenology from JPSS VIIRS Observations and its Applications, *JPSS 2015 Annual Science Meeting,* 24-28 August, *College Park, MD.*

Zhang, X., 2015, Satellite Monitoring of the Green Wave and Brown Wave on the Earth’s Land Surface in Response to Global Climate Change, *South Dakota State Geography Convention*, 19-20 March, South Dakota State University, SD.

Zhang, X., Liu, L., Yan, D., 2015, Long-term Land Surface Phenology: Climatology, Trend, Variability, and Climate Impacts, *AAG 2015*, 21-26 April, Chicago, IL.

Liu, L, Zhang, X., 2015, The response of spring phenology to climate change on the Tibetan Plateau from 1982 to 2013, *AAG 2015*, 21-26 April, Chicago, IL.

Zhang, X., Liu, L., Yu, Y., 2015, Real-time Monitoring Land Surface Vegetation Phenology from VIIRS Observations, *2015 NOAA Satellite Conference*, April 27-May1, Greenbelt, MD.

Zhang, X., Friedl, M., Henebry, G., Jayavelu, S., Gray, J., Schaaf, C., Liu, Y., 2015, Comparison of Land Surface Phenology Retrieved from MODIS and VIIRS Data, *2015 NASA MODIS and VIIRS Science Team Meeting*, 18-22 May, Silver Spring, MD.

Henebry G, de Beurs, K, Krehbiel, C, Nguyen, L, Owsley, B, Zhang, X, Zheng, B, 2015, Change in our MIDST: Toward detection and analysis of urban dynamics in CONUS, *NASA Carbon Cycle & Ecosystems Joint Science Workshop,* 20–24 April, College Park, MD.

Henebry GM, Zhang, XY, de Beurs, KM, Kimball, JS, Small, C, 2015, Change in our MIDST: Toward Detection and Analysis of Urban Land Dynamics in North and South America Joint Urban Remote Sensing Event, *2015 Joint Urban Remote Sensing Event (JURSE),* 30 March–01 April, Lausanne Switzerland.

Performance Metrics	**FY14**
# of new or improved products developed	1
# of products or techniques transitioned from research to ops	0
# of peer reviewed papers	7
# of non-peered reviewed papers	0
# of invited presentations	13
# of graduate students supported by a CICS task	N/A
# of undergraduate students supported by a CICS task	N/A

Support transition of GSIP LST products to the Enterprise Processing System

Task Leader Yuling Liu
Task Code YLYL_GSIP_15
NOAA Sponsor Yunyue Yu
NOAA Office NESDIS/STAR/SMCD
Contribution to CICS Research Themes (%) Theme 1: 70%; Theme 2: 30%; Theme 3: 0%.
Main CICS Research Topic Earth System Monitoring from Satellites
Contribution to NOAA goals (%) Goal1:20%; Goal 2: 80%; Goal 3: 0%
Highlight
Link to a research web page

Background

This report summarizes the work of year 3 of the ongoing project entitled “supporting the transition of GOES LST product to the enterprise processing system”. Information on land surface temperature (LST) is important for understanding climate change, modeling the hydrological and biogeochemical cycles. The LST product from U.S. Geostationary satellite series is an important component of the global LST production at NOAA NESDIS. Current GOES LST is an independent product at OSPO which is proposed to be integrated into an enterprise operational system. This task is a part of the enterprise product development project with the objective of providing support for the transition of GOES LST product to the enterprise system.

Accomplishments

Emissivity update

The emissivity data used as input for GOES LST retrieval are updated annually. The emissivity in 2015 has been included in the latest update.

- Provided input related to GLST product for the enterprise PS GSIP and CLAVRx CDR review.
- Provided the list of parameters extracted from GSIPL2 files for GLST generation upon the request from OSPO.
- Corrected the error in the GLST code for generating grib2 output.
- Fixed the error in the software code. Performed the code test in the local environment.
- Delivered the code package and verified the output from OSPO.
- Attended project progress meeting and provide support for scientific and engineering review

A verification report has been delivered to summarize the modifications and test results. Software tools including Panoply, Wgrib2 and Grads are used to verify the Grib2 LST output. Figure 1 shows the grib2 LST output in Panoply and Figure 2 shows the grib2 LST output in Wgrib2 and Grads tools. The tests results indicate that the GLST grib2 output is correctly generated.

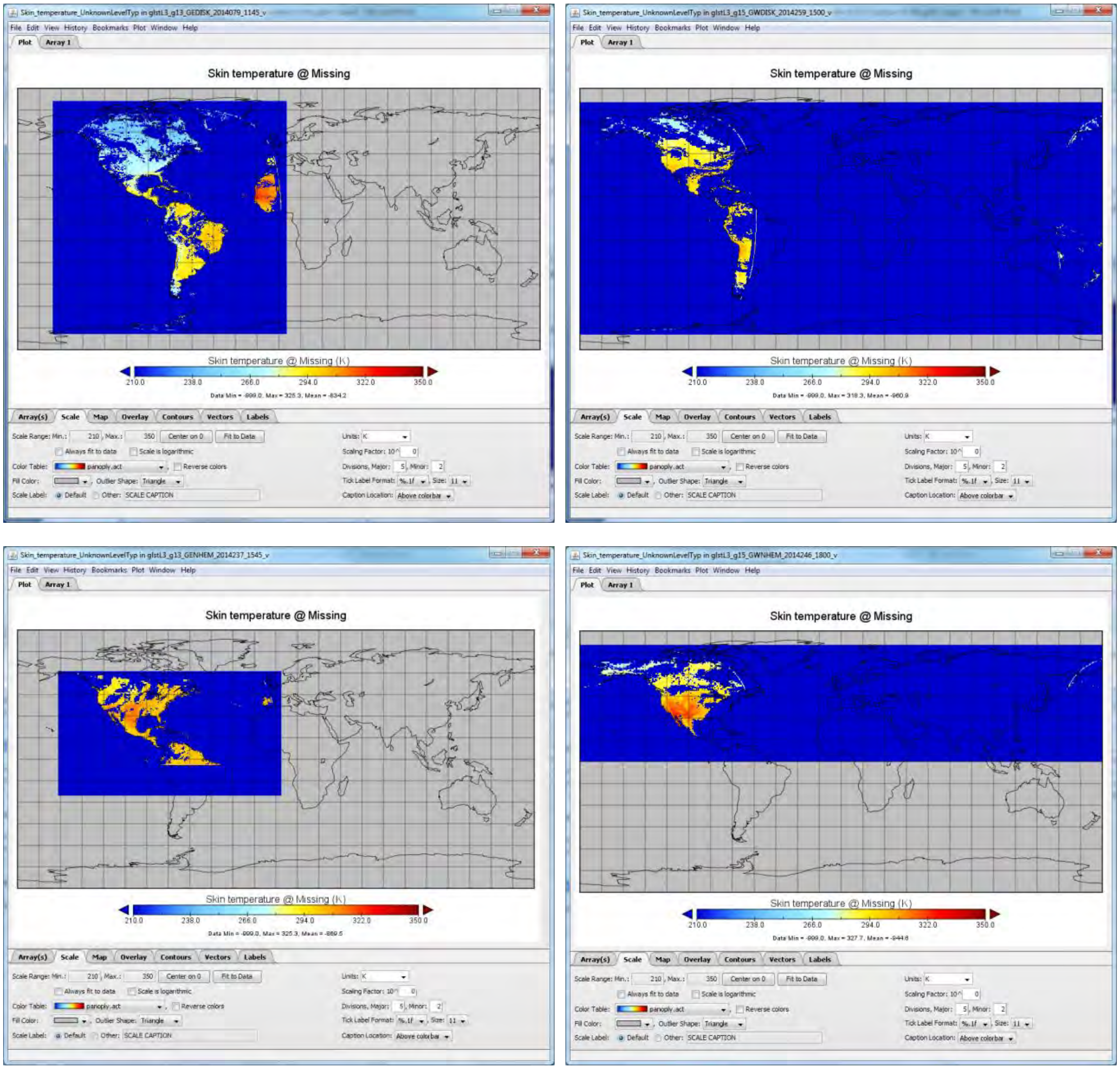


Figure 1. Grib2 LST output map in Panoply software over four spatial domains after the error fix: GEDISK(top left), GWDISK(top right) and GENHEM(bottom left) , GWNHEM(bottom Right)

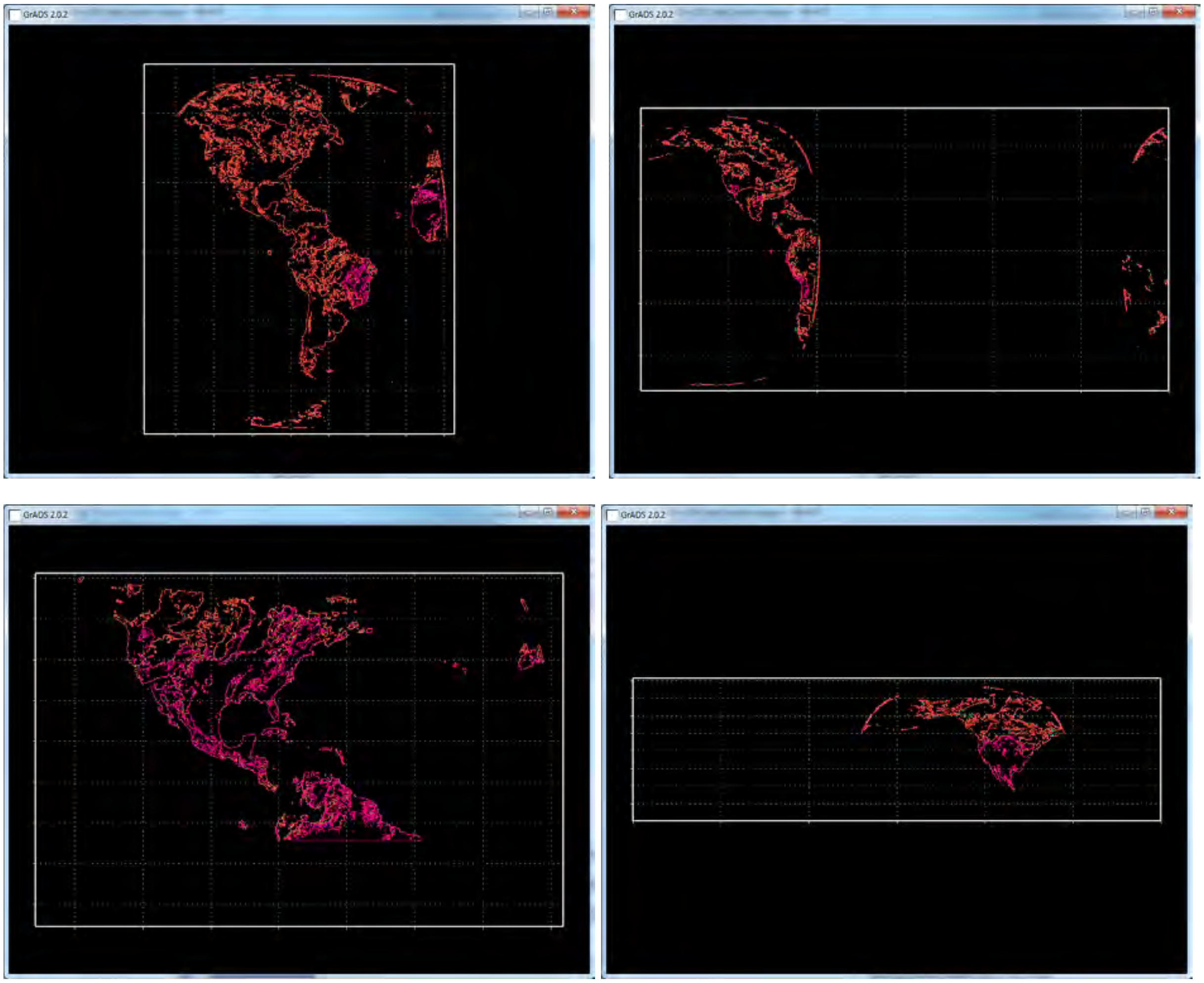


Figure 2. Grib2 LST output map in grads tool over four spatial domains after the error fix: GEDISK(top left), GWDISK(top right) and GENHEM(bottom left) , GWNHEM(bottom Right)

Planned Work

- Provide support for the LST software package
- Provide support for related scientific or engineering review of the project
- Provide support for the test related to transition, e.g. verification of the output before and after the transition

Products

- GOES LST product.

Presentations

Presentation for GLST part in the enterprise PS GSIP and CLAVRx CDR review meeting.

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

GMU Development of Version 2.0 SNPP Flood Detection Package

Task Leader: Donglian Sun
Task Code: ZLDS_GMU_15
NOAA Sponsor: JPSS Proving Ground and Risk Reduction
NOAA Office: JPSS Program Office
Contribution to CICS Research Themes (%): Theme 2:100%
Main CICS Research Topic: Earth System Monitoring from Satellites
Contribution to NOAA goals (%): Goal 1 (100%)
Highlight
Link to a research web page: rs.gmu.edu

Background

Floods are the most frequent natural disasters over the globe impacting human lives and infrastructure. During the 20th century, floods were the highest ranking natural disaster in the United States in terms of number of lives lost and property damage (Charles Perry, http://ks.water.usgs.gov/pubs/fact-sheets/fs.024-00.html). Satellite-derived flood maps in near-real time are invaluable to stake holders and policy makers for disaster monitoring and relief efforts.

With the continuous support from the PGRR Program Office since 2012, Dr. Donglian Sun and Dr. Sanmei Li from George Mason University have released the first version of VIIRS flood detection package which has been successfully applied in VIIRS daily flood product derivation for NWS-River Forecast Centers in the USA, after a demonstrating application initialized by the JPSS PGRR Program Office. To further improve the quality of flood product and explore new flood detection capabilities, we continue developing the second version of VIIRS flood detection package.

Accomplishments

With the support from the JPSS (Joint-Polar Satellite System) Proving Ground and Risk Reduction Program (JPSS/PGRR), a flood detection package has been developed using SNPP/VIIRS (Suomi National Polar-orbiting Partnership/ Visible Infrared Imaging Radiometer Suite) imagery to generate daily near real-time flood maps automatically for National Weather Service (NWS)-River Forecast Centers (RFC) in the USA. In this package, a series of algorithms have been developed including water detection, cloud shadow removal, terrain shadow removal, minor flood detection, water fraction retrieval and flooding water determination. The package has been running routinely with the direct broadcast SNPP/VIIRS data since 2014. Flood maps were carefully evaluated by river forecasters using airborne imagery and hydraulic observations. Offline validation was also made via visual inspection with VIIRS false-color composite images on more than 10,000 granules across a variety of scenes and comparison with river gauge observations and NOAA flood outlook and warning products year-round. Evaluation of the product has shown high accuracy and the promising performance of the package has won positive feedback and recognition from end-users.

Planned Work

We continue developing the algorithm for 3-d flood products. Based on the previous work, the algorithm is re-designed with external network and internal network analysis included.

1) Neighboring water polygon clustering: Neighboring water pixels with the same river levels and similar surface elevations are clustered into polygons. This is a recursion step, so the search distance is limited to less than 100 VIIRS pixels in horizontal and vertical directions. Starting with a river pixel, adjacent water pixels are clustered if any of the following conditions are met:
   a) adjacent river pixels with the same river level
   b) adjacent non-river water pixels with surface elevation larger than river level
   c) adjacent non-river water pixels with surface elevation no more than 3 m below river level
2) Merge water polygons: polygons with the same river levels are merged into one polygon.
3) Polygon water surface level calculation: Average water surface level in a water polygon is calculated using all the flood pixels. River/lake pixels are not used because their elevations could not reflect the relationship between water surface level and water fraction.
4) External network analysis: Polygons are further merged into rivers based on network analysis. Upstream river section is always with water surface level no less than that of downstream river section.

Publications

Sanmei Li, Donglian Sun, Mitchell E. Goldberg & Bill Sjoberg (2015): Object based automatic terrain shadow removal from SNPP/VIIRS flood maps, International Journal of Remote Sensing, 36:21, 5504-5522

Products

Near real-time flood product from VIIRS imagery data.
http://rs.gmu.edu/sites.html
http://realearth.ssec.wisc.edu/?products=RIVER-FLOOD-NC.100&center=42.45588764197166,-84.814453125&zoom=5&width=1238&height=912&timeproduct=RIVER-FLOOD-NC&timespan=-172800s

Presentations

Sanmei Li, Donglian Sun, Mitchell E. Goldberg, Bill Sjoberg, Scott Lindsey, Eric Holloway, Edward Plumb, and Melissa Kreller (2015): Application of SNPP/VIIRS data in Near-Real-Time Supra-Snow/Ice Flood Detection. AGU 2015, San Francisco, 14-18 December 2015.

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

9 Education, Training, and Outreach

CICS-MD Summer Research Initiative	
Task Leader	Hugo Berbery
Mentors	Hugo Berbery, Charon Birkett, Sinead Farrell, Ralph Ferraro, Melissa Kenney, Cezar Kongoli, Scott Rudlosky, Pat Meyers, Daniel Tong, Yalei Zhou

Background

The CICS-MD Summer Initiative (CSI) series provides training and outreach opportunities for both graduate and undergraduate students. It pairs students with mentors to conduct original scientific research and help train future NOAA scientists. Students not only learn new tools but are already contributing to generate products with value for NOAA. The summer initiative is a framework that includes software tutorials, informal student presentations, weather/climate discussions, and interactions with other institutions/organizations to maximize the student experience.

Climate Outreach and Education at the Climate Program Office

Task Leader	Hugo Berbery
Primary Scientist	Will Chong
Task Code	DBWC_CPO_15 & DBDB_COEC_15
NOAA Sponsor	Eric Locklear
NOAA Office	OAR/CPO/ASD
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Education, Climate Literacy and Outreach
Contribution to NOAA Goals (%)	Goal 1: 10%; Goal 2: 90%; Goal 3: 0%

Highlight CICS-MD Scientist Will Chong increased collaboration and cooperation among scientists from NOAA, other agencies, Cooperative Institutes, and the external community to foster the net output of research for the general public. Outreach using web interface and communicative materials has helped maximize the promotion of scientific stewardship of climate related information.

Link: http://cpo.noaa.gov/MAPP

Background

The Climate Program Office (CPO) focuses on developing a broader user community for climate products and services, provides NOAA a focal point for climate activities, leads NOAA climate education and outreach activities, and coordinates international climate activities. To achieve these goals, CPO will benefit significantly from a strong partnership with outside investigators. Building this partnership requires the involvement of personnel with computational and organizational skills to assist with program management activities.

Accomplishments

In FY15, the primary scientist continued to manage the website on the web interface content management system (CMS). The old website was structured using basic HyperText Markup Language (HTML), something that limited how much information and the type of information that could be effectively communicated online. The previous migration and creation of the new CMS allowed for a more efficient way to display and communicate climate related research results to the public. This year, the primary scientist continued to manage and develop new content for the website to better communicate and distribute the program's research outcomes with the public. New pages and sections were created to represent new task forces, providing a space for the public to view descriptions, missions, participants, news items, publications, reports and other resources. Articles were continually developed throughout the year to highlight newsworthy program news and events. This work enabled scientists from NOAA, other agencies, Cooperative Institutes, and the external community to increase their collaboration and improve the public's knowledge of research activities across multiple sectors.

The primary scientist collaborated with the Climate Program Office's Communication and Education division and public sector communities for the development of material for the website and communication materials. Material for the website including images and graphics were used to increase the communication and distribution of research results reflected on the website. Physical materials such as informational business cards and program brochures were co-created by the physical scientist for the distribution at meetings and conferences, such as the 2015 American Geophysical Union Fall Meeting in San Francisco, California and the 2016 American Meteorological Society Annual Meeting in New Orleans, Louisiana. Those materials allowed for more outreach to promote scientific stewardship of climate related information.

The primary scientist interacted with investigators funded by the grants program to better promote and communicate their research and to facilitate the integration of their research results into NOAA activities and products. A webpage was created on the website that displays the projects in an informal profile for those of the general public who are interested in learning more about current and past NOAA research activities. The primary scientist also archives progress reports and publications submitted by investigators throughout the year for program management to review.

The involvement of the primary scientist with computational and organizational skills to assist with program management activities has been essential to the success of his ability to provide climate outreach and education activities at CPO. The primary scientist has provided logistical and technical support for organized groups of federal, state, non-governmental organizations, and the broader academic research community. Examples of this include successfully scheduling and organizing monthly teleconferencing events, virtual meetings, in-person meetings and workshops to connect and engage research activities across sectors. The primary scientist also provides IT support during meetings to help ensure they run smoothly. Technical support includes running test on computers and software prior to meetings to ensure timely efficiency. Web conferencing tools have been utilized to allow for program management and scientist to more effectively communicate during virtual meetings. This has resulted in improved meeting engagement with participants.

Planned Work

- Continue to manage and develop content for the website
- Continue to serve as the logistical organizer for groups, meetings, and workshops
- Continue to develop communicative tools for outreach and education

PERFORMANCE METRICS	FY14
# of new or improved products developed (please identify below the table)	5
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	N/A
# of non-peered reviewed papers	N/A
# of invited presentations	N/A
# of graduate students supported by a CICS task	N/A
# of graduate students formally advised	N/A
# of undergraduate students mentored during the year	N/A

Performance Metrics Explanation

New and improved products are described in the accomplishments section. Papers and graduate students are not applicable to the task.

GOES-R/JPSS Visiting Scientist Program: Forecaster Training

Task Leader: Michael J. Folmer

Task Code: EBMF_GOESR_15/ EBMF_JPSS_15 (GOES-R/JPSS Proving Ground Scientist)

Main CICS Research Topics: Future Satellite Programs (GOES-R and JPSS)

Percent contribution to CICS Themes: Theme 1: 20%; Theme 2: 80%; Theme 3: 0%.

Percent contribution to NOAA Goals: Goal 2: 50%; Goal 3: 50%

Highlight: A CICS visiting scientist (VS) plays a critical role in training forecasters to use the new products that will be available from GOES-R and JPSS.

Background

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

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

Accomplishments

Michael Folmer did Forecaster Training at Weather Forecasting Offices (WFO) this year on “GOES-R Series Program Update and User Readiness.” His on-site training included:

1. Eureka, CA WFO
2. Juneau, Anchorage, and Fairbanks, AK WFOs
3. Raleigh, Newport/Morehead City, and Wilmington, NC WFOs:
4. Forecasters at NCWCP, College Park, MD
5. Sterling, NWS WFO (LWX), Sterling, VA
6. Forecasters at the National Hurricane Center, Miami, FL

Planned Work

- Train forecasters on Himawari imagery and prepare for GOES-R/JPSS

Outreach

- Visiting WFOs when possible to update on GOES-R and introduce the MPS PG

Grooming the Next Generation Cadre of JPSS Scientists through Pragmatic Education and Training

Task Leader **Shakila Merchant**
Task Code
NOAA Sponsor **Mitch Goldberg**
NOAA Office **JPSSO**
Contribution to CICS Research Themes (%) NA
Main CICS Research Topic NA
Contribution to NOAA goals (%) NOAA Education Goal #4 (Workforce Development)
Highlight: Created Education Proving Ground Initiative for JPSS
Link to a research web page

Background

Through this proposal a unique education & training initiative has been designed and being implemented to train, mentor and provide targeted experiential learning opportunities in NOAA JPSS related technological and scientific advances in environmental monitoring to advance weather, climate, environmental and oceanographic science.

Accomplishments

- Four students have been recruited and interviewed for the upcoming JPSS Summer internship June 2016
- The JPSS Education Proving Ground Paper was presented at the AMS 2016 25th AMS Education Symposium held in New Orleans, January 2016

Planned work

- JPSS interns will be interning this summer 2016
- They will be mentored by JPSS program managers at NOAA and IMSG
- There will be group seminars and classroom training
- The interns will also interact with summer interns/students and scientists at our partner Institution CICS, UMD, MD
- The summer program will be evaluated and assessed for its effectiveness and best practices

Publications

Merchant, S, Goldberg, M, and Khanbilvardi, R. (2016) A Novel Approach to Prepare the Next Generation Cadre of JPSS Scientists through Pragmatic Education and Training, 96th Annual AMS Meeting, 25th Education Symposium., New Orleans, LA., January 2016.

Other

JPSS interns attended the Annual CoRP Symposium that was hosted by CICS, MD in September 2015. The also attended the CREST meetings and presented their research work.

Performance Metrics	
# of new or improved products developed (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	4
# of graduate students formally advised	4
# of undergraduate students mentored during the year	0

GOES-R Training for NOAA Meteorologists

Task Leader	Jim Gurka
Task Code	EBJG_GOESR_15
NOAA Sponsor	LeRoy Spayd
NOAA Office	NWS/OCWWS/TD
Contribution to CICS Research Themes (%)	Theme 1: 100%
Main CICS Research Topic	Education, Training and Outreach
Contribution to NOAA goals (%)	Goal 1: 10%; Goal 2: 80%; Goal 3: 10%

Highlight: Jim Gurka organized and presented an AMS Short Course on Geostationary Operational Environmental Satellite (GOES)-R and Joint Polar Satellite System (JPSS)

Link to a research web page: N/A

Background

NOAA is conducting extensive preparations prior to the launch of the new GOES-R satellite late in 2015 or early 2016. NOAA has invested billions of dollars in developing the GOES-R series of satellites. The recent NAPA report on the NWS recommends significant reinvestment in training for the NWS. A major component of the preparations for GOES-R is user readiness that includes a comprehensive training program for NOAA staff and its partners in the media, academia, private sector and other government agencies.

Accomplishments

Among other trainings, Jim Gurka organized and presented an AMS Short Course on Geostationary Operational Environmental Satellite (GOES)-R and Joint Polar Satellite System (JPSS). This course was held on January 9–10 in conjunction with the American Meteorological Society's (AMS) Annual Meeting in New Orleans, LA. The other instructors were Steve Goodman and Tim Schmit.

Overviews were following with hands-on exercises for the operational products of GOES-R/JPSS with special emphasis following instruments packages:

- Advanced Baseline Imager (ABI);
- Geostationary Lightning Mapper (GLM); and
- Visible/Infrared Imager Radiometer Suite (VIIRS).

Planned Work

This project will continue to establish, develop, conduct, assess and update a user readiness GOES-R Training program for NOAA staff and partners. Training program will include web based modules, residence courses, simulations exercises and real-time webinar based weather briefings. A special additional feature will be GOES-R realtime help desk support for users done through blogs, chat, and various social media applications.

10 Decision Support Science

International Decision Support Systems for Food Security	
Task Leader	E. Hugo Berbery
Task Code	EBMR_CIDT_15
NOAA Sponsor	Mike Halpert
NOAA Office	NWS/CPC
Contribution to CICS Research Themes (%)	Theme 1 (100%)
Main CICS Research Topic	Environmental decision support science; Climate research, data assimilation and modeling
Contribution to NOAA goals (%)	Goal 2 (100%)

Highlight Produced roughly twenty four weather and climate hazards outlooks over Africa, Central America and Hispaniola, and Central Asia and disseminated these climate information documents to the Famine Early Warning Systems Network partners and users. Presented preliminary results on the investigation of recent droughts over Central America at the 40th Climate Diagnostics and Prediction Workshop in Denver, CO during late October 2015. Trained seven visiting scientists at the Climate Prediction Center's International Desks on the QGIS computer software application.

Link to a research web page http://www.cpc.ncep.noaa.gov/products/international/index.shtml

Miliaritiana Robjhon
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Background

The Cooperative Institute for Climate and Satellites-Maryland plays an integral part of the Famine Early Warning Systems Network, also known as, FEWS NET. The FEWS NET is led by the United States Agency for International Development and was created in 1984 as a direct response to the severe famines in West Africa and East Africa in the 1980's. The FEWS NET goals include providing with vital environmental and socioeconomic information to decision makers to help guide humanitarian activities over food insecure nations. The FEWS NET is a multi-agency program and comprises of five United States Government agencies, including the National Oceanic and Atmospheric Administration or NOAA. To support the NOAA Climate Prediction Center, or CPC's goal to providing access with timely and accurate weather and climate information to FEWS NET partners and users, weather and climate, environmental variables such as remotely-sensed land surface information, and model-derived hydrometeorological prognostics are routinely analyzed to develop weekly weather and climate hazards documents over Africa, Central America and the Caribbean, and Central Asia. Commonly-used tools as drought monitors are developed and improved upon to detect, monitor, evaluate, and classify the severity of extreme climatic conditions such as floods and droughts. Climate research is also conducted to shed light on the governing mechanisms and characteristics of recent extreme events such as the 2014 and 2015 droughts over Central America to help improve prediction and the regional hazards process.

Accomplishments

Accomplishments made during the period of performance are divided into two general categories, i.e., operation and research.

For operation, roughly twenty four weekly weather and climate hazards outlooks were produced for the four regions of the FEWS NET. These regions are Africa, Central America and Hispaniola, and Central Asia. A rigorous analysis process was followed. Weather and climate for the region of interest were analyzed to assess current climatic conditions. Environmental variables, including the NOAA Center for Satellite Applications and Research's Vegetation Health Index and United States Geological Survey Earth Resources Observation and Science's Normalized Difference Vegetation Index were used to assess the response of the biomass and land surface information to climate anomalies. Short and medium-range weather forecasts were analyzed to provide with guidance on the potential evolution of hazards. Prior to the releasing of final documents, weekly weather briefings were delivered to partners via teleconference. In-situ field reports and email correspondence were also taken into account. Some of the highlights of the regional hazards outlooks featured developing droughts across Southern Africa (Figure 1).

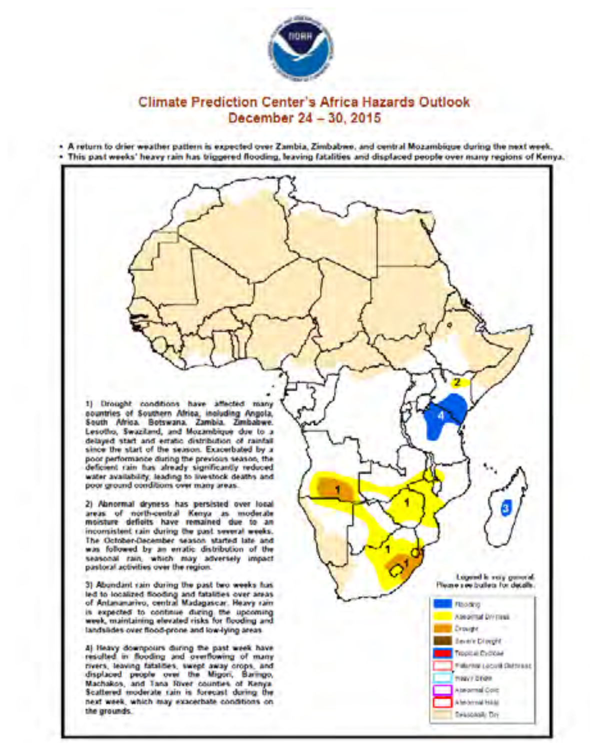


Figure 1 The first page of the Africa hazards outlook for December 24-30, 2015.

The Inter-tropical Front, also abbreviated as ITF, is a major rain-bearing system over Africa. The NOAA CPC International Desks monitor its poleward advancement and equatorward retreat across the Sahelian and Guinean-Sudanian regions of Africa from April to October. The latitudinal positions of the ITF were determined daily by analyzing near-surface wind and surface dew point temperature maps. Although many methods exist to determining the position of the ITF, the NOAA's methodology is frozen to ensure consistent climatology since the late 1970's.

Drought monitors such as the standardized precipitation index, soil moisture percentiles, and runoff percentiles are commonly-used tools to monitor and measure the severity of droughts. Computer scripts that calculate and post the associated graphics on the NOAA webpages were maintained to make sure these drought monitors are available for the regional hazards process. Some updates were made on these scripts due to compliance requirements from the NOAA Central Operation.

For research, preliminary results on the investigation of the drought over Central America during the summer of 2014 were presented at the 40th Climate Diagnostics and Prediction Workshop in Denver, CO during late October 2015. Empirical orthogonal function analysis was applied to global sea-surface temperatures and linear regressions of seasonal rainfall onto the principal components of sea-surface temperatures were performed (Figure 2). Atmospheric fields and moisture transport were also analyzed. We showed sea-surface temperature anomalies over both the surrounding Pacific and Atlantic oceans influence summer rainfall over Central America. Specifically, warmer Pacific and relatively cold Atlantic, drive a vertical circulation, with its ascending branch over the northeastern Tropical Pacific and associated descending branch over much of Central America and is associated with drier than average conditions over Central America. We found a westward extension of the subtropical high onto the Gulf of Mexico and amplified Caribbean low-level jet, consistent with features associated with the mid-summer drought over Central America and southern Mexico in the literature. An extended abstract was submitted to and posted on the Climate Prediction Science and Technology Digest webpage.

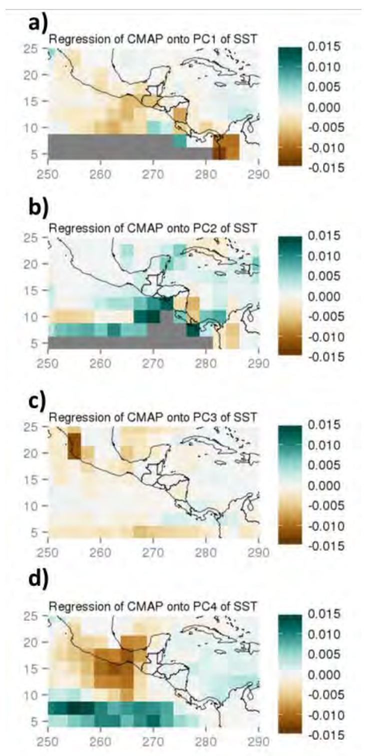


Figure 2 Regression of the May-August CMAP rainfall onto the each of the first four (a-d) PCs of SST.

Planned Work

- Continue to perform operational tasks, including the regional hazards outlooks, ITF analysis, training on Geographical Information Systems, or GIS, for visiting scientists, and special assignment projects by the NOAA CPC International Desks Team Lead to support the center's international commitment efforts;
- Improve upon the already-developed drought monitors by adding new products that could have significant impacts on the regional hazards process and removing others that do not have much so. New addition would be standardized precipitation index at 1, 3, 6, 12-month time scales;
- Secure CFSv2 experimental runs to isolate the role played by sea-surface temperatures over the Pacific, Atlantic, and other regions and influence on summer rainfall over Central America.
- Continue analysis of the characteristics of the 2014 and 2015 summer rainfall over Central America, present findings at meetings and workshops, and publish results in a journal article.

Publications

Non-peer-reviewed

Robjhon, M., and W. Thiaw, 2015: The 2014 Primera Drought over Central America. *Science and Technology Infusion Climate Bulletin. NOAA's National Weather Service 40th NOAA Annual Climate Diagnostics and Prediction Workshop Denver, CO, 26-29 October 2015.* Available at the URL: http://www.nws.noaa.gov/ost/climate/STIP/40CDPW/40cdpw-MRobjhon.pdf

Presentations

Robjhon, M., and W. Thiaw (2015), The 2014 Primera Drought over Central America, 40th NOAA Annual Climate Diagnostics and Prediction Workshop, 26-29 October 2015, Denver, CO.

Products

A basic tutorial document on the QGIS software application was developed to serve as a quick reference manual on GIS for the visiting scientists at the NOAA CPC International desks.

Other

As part of capacity building for visiting scientists at the CPC International Desks, seven scientists from Africa and Indonesia were trained on GIS using the open source QGIS software. Emphasis was placed upon use and capabilities of GIS in meteorology, with hands-on exercises.

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

New product developed included a basic tutorial manual on QGIS for visiting scientists at the NOAA CPC International Desks.

Strengthening Coastal Community Resilience in the face of Climate Change: Science to Better Understand, Measure, and Value Coastal Ecosystem Services

Task Leader Ariana Sutton-Grier
Task Code ASAS_SCCR_15
NOAA Sponsor: Russell Callender
NOAA Office: NOS/HQ
Contribution to CICS Research Themes (%): Theme 1: 5% Theme 2: 0% Theme 3: 95%
Main CICS Research Topic: Climate Science to Support Policy
Contribution to NOAA goals (%): Goal 1: 10%, Goal 2: 0%, Goal 3: 90%
Highlight: The second year of this project has resulted in the publication of 5 papers on aspects of coastal resilience and the incorporation of ecosystem services into federal policy and decision making and has also contributed to significant progress in natural resource policy and climate policy goals for the U.S.
Link to a research web page : www.suttongrier.org

Background

This report summarizes the second year of the NOAA project entitled, "Strengthening Coastal Community Resilience in the face of Climate Change." This project's goal is to provide science and science policy to support coastal resilience efforts with a particular focus on ecosystem services such as coastal blue carbon and the storm protection benefits provided by natural infrastructure (i.e., healthy coastal ecosystems), as well as the connections between ecosystems and human health.

Figure 1: The photos above are examples of natural infrastructure (top row) and built infrastructure (bottom row). This is from an article that discusses innovative opportunities to combine the two into hybrid approaches for coastal protection. Sutton-Grier, Ariana E., Kateryna Wowka, and Holly Bamford, 2015: Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems, Environ. Sci. Policy, 51, 137–148, http://dx.doi.org/10.1016/j.envsci.2015.04.006.

Accomplishments

This project has had a very productive second year. I do want to mention that for the last 3 months of the project I have been on maternity leave, so the progress reported here represents the effort of 9 months of full-time work. Five publications about ecosystem services were published (one is in press), and I gave ten talks (nine of which were invited presentations). This project has also advised 5 graduate student research projects and 2 undergraduate projects (1 Hollings Scholar at NOAA and one Socio-Environmental Synthesis Center (SESYNC) summer intern at UMD). I also designed and taught a course in the Environmental Science and Policy program at UMD (ENSP 399R: Climate Change – Coastal Resilience) focused on teaching students science policy skills and the science and policy challenges of helping coastal ecosystems and communities become more resilient in the face of climate change. I also developed and taught a teaching workshop at the annual Ecological Society of America (ESA) conference. The research articles published from year 2 of this project have already been cited 11 times since their publication a few months ago.

This project has also contributed to significant natural resource policy and climate policy goals for the U.S. federal government including climate policy as well as U.S. coastal resilience efforts. One publication from this project that has had a particularly important policy impact was the "Future of Our Coasts" publication in the journal Environmental Science and Policy. This publication helped inform the "Ecosystem Service Assessment: Federal Research Needs for Coastal Green Infrastructure" report that was released in August, 2015. The publication also garnered me an invitation to speak at a Senate Hearing in Louisiana but I was unable to attend due to travel conflicts so I submitted written testimony based on the research instead. The publication also resulted in an invitation to participate in a Congressional Hill Briefing in October organized by COMPASS and the American Meteorological Society on coastal natural infrastructure. The symposium I organized at the annual ESA meeting about the societal benefits of healthy coastal ecosystems inspired a Science Magazine writer who published an article in November called, "Breaking the Waves" about living shorelines in which I was quoted.

In addition, my work on coastal blue carbon at NOAA has also had important policy outcomes. For example, in 2015 the U.S. government has been working to incorporate coastal wetlands into our national greenhouse gas inventory (as recommended in the IPCC 2013 Wetlands Supplement). Incorporating coastal wetlands into the U.S. national greenhouse gas inventory is a process that is taking two years to complete (the U.S. will have numbers included in our 2017 submission) and is being completed by a team that includes academic, nonprofit, and government participants including myself. Completing the inventory is one of the activities specified in the 2014 White House "Priority Agenda Enhancing the Climate Resilience of America's Natural Resources" released by the Council on Climate Preparedness and Resilience, and NOAA has been leading the effort for the US government to complete this task. My research and my expertise are helping achieve this important policy objective and the U.S. is being watched by other countries around the world as we are leading the effort to include coastal wetlands in our national greenhouse gas inventory.

Also, in October the Office of Management and Budget (OMB), the Office of Science and Technology Policy (OSTP), and the Council on Environmental Quality (CEQ) released a joint memorandum, "**Memorandum for Executive Departments and Agencies on Incorporating Ecosystem Services into Federal Decision Making" which will help guide federal agencies in the incorporation of ecosystem services into federal** decision making and planning. I helped write NOAA's official response to this memorandum which will be submitted shortly and NOAA's response was informed by my research over the past several years including references to my blue carbon research and my storm protection/coastal resilience research. So, it has been a very exciting second year of this project, especially given this represents 9 months of full-time work due to my maternity leave January-March of 2016.

Planned Work

- Complete and submit manuscript on storm protection services in the Natural Resources and Damage Assessment (NRDA) process (with colleagues from NOS OR&R)Complete revisions on a blue carbon ecosystems paper and resubmit
- Write a book chapter on how blue carbon can be incorporated into national policies
- Continue to help implement the baseline assessment for coastal wetland carbon emissions that NOAA is leading in order to incorporate coastal wetlands into the U.S. National Greenhouse Gas Inventory (Spring-Fall 2016)
- Continue to be part of NAS research team examining how disasters impact ecosystem services and human health in the Gulf in the grant, ""Modeling stress-associated health effects of multi-ple impacted ecosystem services in the Gulf of Mexico"
- Participate in a new Science for Nature and People Partnership (SNAPP) team out of the National Center for Ecological Analysis and Synthesis (NCEAS) (Spring 2016-Winter 2017)
- Present on natural infrastructure and coastal resilience at the Society of Wetlands Scientists meeting (June, 2016)
- Be one of the U.S. leads in the Commission on Environmental Cooperative Blue Carbon grant
- Continue to work with academic partners in the SAGE (Sustainable Adaptive Gradients in the Coastal Environment) to develop strategies for the Eastern U.S. and the Caribbean to be more resilient to extreme events
- Connect U.S. policy opportunities to the NASA-funded research project linking satellites to field measurements of coastal carbon
- Potentially host a SESYNC intern to work on coastal resilience science policy (Summer, 2016)
- Be a member of the Planning Committee for the "A Community on Ecosystem Services (ACES)" annual meeting in Decem

Publications

Peer-Reviewed

Sutton-Grier, A.E. and A. Moore. In Press. Leveraging Carbon Services of Coastal Ecosystems for Habitat Protection and Restoration. Coastal Management.

Wylie, L., **A.E. Sutton-Grier**, and A. Moore. 2016. Keys to Successful Blue Carbon Projects: Lessons Learned from Global Case Studies. Marine Policy. 65:76-84. DOI: 10.1016/j.mar-pol.2015.12.020.

Sutton-Grier, A.E., K. Wowk, H. Bamford. 2015. Future of Our Coasts: The Potential for Natural and Hybrid Infrastructure to Enhance the Resilience of Our Coastal Communities, Economies and Ecosystems. Environmental Science and Policy. DOI: 10.1016/j.envsci.2015.04.006.

Schaefer, M., E. Goldman, A. Bartuska, **A.E. Sutton-Grier**, and J. Lubchenco. 2015. Nature as Capital: Advancing and Applying Ecosystem Services in U.S. Federal Policies and Programs. Proceedings of the National Academy of Sciences. 112:7383-7389. DOI: 10.1073/pnas.1420500112.

*Sandifer, P., **A.E. Sutton-Grier**, and B. Ward. 2015. Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. Ecosystem Services. 12:1-15. DOI: 10.1016/j.ecoser.2014.12.007.*

Richarson, C.J., G. Bruland, M. Hanchey, and **A.E. Sutton-Grier**. 2015. Ch. 19. Soil Restoration: The foundation of successful wetland reestablishment. In Wetland Soils: Genesis, Hydrology, Landscapes, and Classification, 2nd Ed. Vepraskas and Craft (Eds).

Non-Peer-Reviewed

***Sutton-Grier, A. E.**, E. Rauschert and J. Momsen. 2016. Using Discussion to Promote Learning in Undergraduate Biology. Bulletin of the Ecological Society of America. 91(1):102-110.*

Presentations

Invited

Sutton-Grier, A.E. 2016. "Future of Our Coasts: The Potential for Natural and Hybrid Infrastructure in an Urbanizing World." Atlantic Estuarine Research Society Spring Meeting Keynote Address, Virginia Beach, Virginia.

Sutton-Grier, A.E. 2015. "Shoring Up: Natural and Hybrid Infrastructure for Coastal Resilience." Capitol Hill Briefing, October 21, 2015. Washington, D.C.

Sutton-Grier, A.E. 2015. "Innovative Policy Opportunities for Wetland Conservation." Inaugural Society of Wetland Scientist (SWS) Webinar.

Sutton-Grier, A.E. 2015. "Future of our coasts: Potential for natural and hybrid infrastructure to enhance ecosystem and community resilience." Council of State Governments Eastern Regional Conference, Wilmington, Delaware.

Sutton-Grier, A.E. 2015. Coastal "Blue Carbon" Benefits of Natural Infrastructure: One More Reason to Love the Coasts!" Ecological Society of America Annual Conference, Baltimore, Maryland.

Sutton-Grier, A.E. 2015. "Innovative Policy Opportunities for Wetland Conservation and Climate Mitigation and Adaptation." Society of Wetland Scientists Wetlands and Climate Change Expert Panel Discussion, Providence, Rhode Island.

Sutton-Grier, A.E. 2015. "National and International Blue Carbon Policy Opportunities." Society of Wetland Scientists Annual Conference, Providence, Rhode Island.

Sutton-Grier, A.E. and A. Moore. 2015. "Climate and Coastal Resilience National Policy Opportunities for Blue Carbon." Capitalizing on Coastal Carbon workshop, Massachusetts.

Sutton-Grier, A.E. 2015. "Blue Carbon, Green Infrastructure, Biodiversity and Human Health: Science to Support Coastal Resilience." Environmental Science and Technology Departmental Seminar, University of Maryland, College Park, Maryland.

Contributed

Sutton-Grier, A.E. 2015. "Future of our coasts: Potential for natural and hybrid infrastructure to enhance ecosystem and community resilience." Coastal and Estuarine Research Federation (CERF) Meeting, Portland, Oregon.

Other

I was awarded a prestigious award from the Ecological Society of America. I received their "Early Career Fellow" award (2015-2019). This award recognizes members "who have begun making and show promise of continuing to make outstanding contributions to a wide range of fields served by ESA. Such contributions include, but are not restricted to, those that advance or apply ecological knowledge in academics, government, non-profit organizations, and the private sector." This was a big honor to receive this award in its second year of awardees. This demonstrates that my peers value the scientific contribution I am making at the science policy nexus.

Performance Metrics	
# of new or improved products developed (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**5**
# of non-peered reviewed papers	**1**
# of invited presentations	**9**
# of graduate students supported by a CICS task	**0**
# of graduate students formally advised	**5**
# of undergraduate students mentored during the year	**2**

My NOAA grant does not focus on the generation of new products or new techniques so that is not an expectation of my work. It is expected that I will work to publish my work and I got five publications published since March 2015. I have one other publications in review currently. It is also part of my job to work on non-reviewed publications as appropriate and I had one of those.

Public speaking and science translation is a big part of my job. I gave nine invited talks this year. In addition, I gave an additional talk as contributed talks to scientific societies. And I also chaired a session at the Ecological Society of America annual meeting in August.

Last spring (Feb-June 2015) I advised 4 graduate students in Columbia University's International Research Institute for Climate and Society program. I advised them on their research project related to opportunities to incorporate blue carbon into international climate or conservation policies. This project informed the work that my Hollings Scholar did last summer which resulted in a peer-reviewed publication (Wylie et al. above). I also mentored a SESYNC scholar from UMD last summer and she developed 2 stories for NOAA's "Science on a Sphere" which is a way to three-dimensionally show global data. Her stories were very successful and were shown to NOS leadership in Fall 2015.

I finished advising 1 graduate student at University of Maryland in the Sustainability and Conservation Biology program. I was her adviser (CONS 798) her on her final project in which she prepared a literature synthesis of all the recent salt marsh data published in the last 15 years on carbon sequestration, storage, and emissions.

Research, Development and Implementation of National and Regional Physical, Ecological, and Societal Climate Indicators for the NOAA and the USGCRP National Climate Assessment

Task Leader Melissa Kenney

Task Code MKMK_RDIP_15
NOAA Sponsor Eric Locklear
NOAA Office OAR/CPO
Contribution to CICS Research Themes (%) Theme 1: 75%; Theme 2: 0%; Theme 3: 25% (estimated)
Main CICS Research Topic National Climate Assessments
Contribution to NOAA goals (%) Goal 1: 85%; Goal 2: 5%; Goal 3: 10% (estimated)

Highlight Kenney is leading the development and research of an interagency climate indicator system to bring together data, observations, and indicator products in innovative ways to better assess climate changes, impacts, vulnerabilities, and preparedness and move the research products into operations for decision support.

Link to a research web page http://tinyurl.com/melissakenney
http://www.globalchange.gov/what-we-do/assessment/indicators
http://indicators.umd.edu

Background

Research activities in Year 2 were marked by a major milestone with the release of the U.S. Global Change Research Program (USGCRP) pilot indicators, based on prototypes and processes developed by our research team, and a transition from activities that are more development focused to a CPO-directed focus on indicators and climate decision support research. Specific activities include: (1) knowledge transfer; (2) indicator prototype development; (3) indicators special issue in *Climatic Change*; (4) indicators and networked metadata as a boundary object; (5) understandability of indicators by non-scientists; and (6) synthesis of existing indicator efforts. Finally, we will present future research activities in progress.

Accomplishments

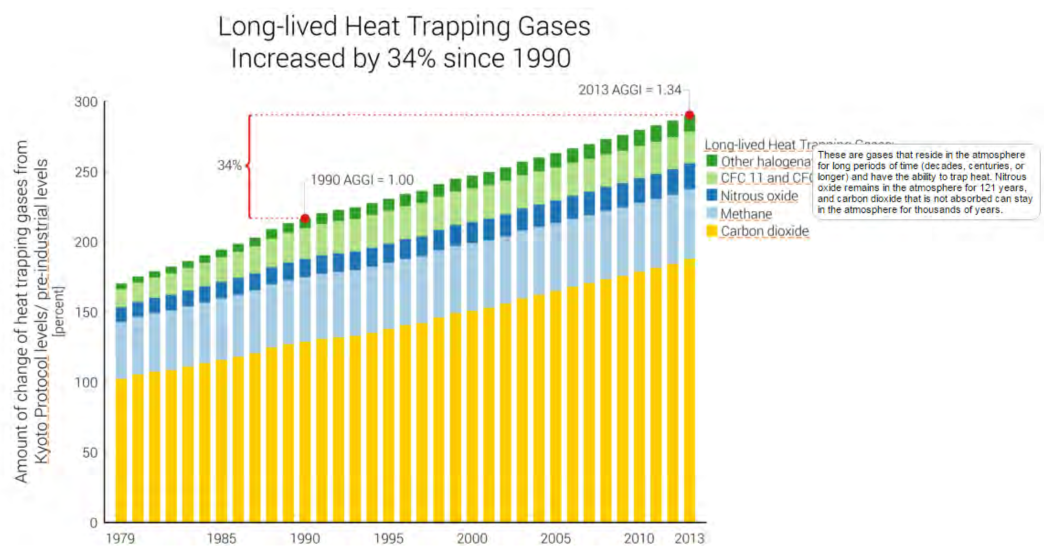
Knowledge Transfer

An early and notable milestone was the release of a proof-of-concept set of indicators by USGCRP based on the recommendations and prototypes developed by our team in May 2015. Part of these recommendations was the development of a transparent and repeatable process of development and documentation, which is described in Kenney et al., 2016. Specifically, with NEMAC we developed a graphic style guide for indicators development (supplementary materials to Kenney et al., 2016). This document details the standards for visual display that we used for the indicators system including: colors, typography, graph details, labeling conventions, and spatial reference. We also developed a form to aid teams in collecting the information or Federal scientists in articulating data and methods for inclusion in the Global Change Information System (GCIS). This documentation was used it to collect said information for each indicator or refined portrayal (see: https://drive.google.com/open?id=0B4RJXzWbJ1FYaj-ZYMmNjV2VObFE).

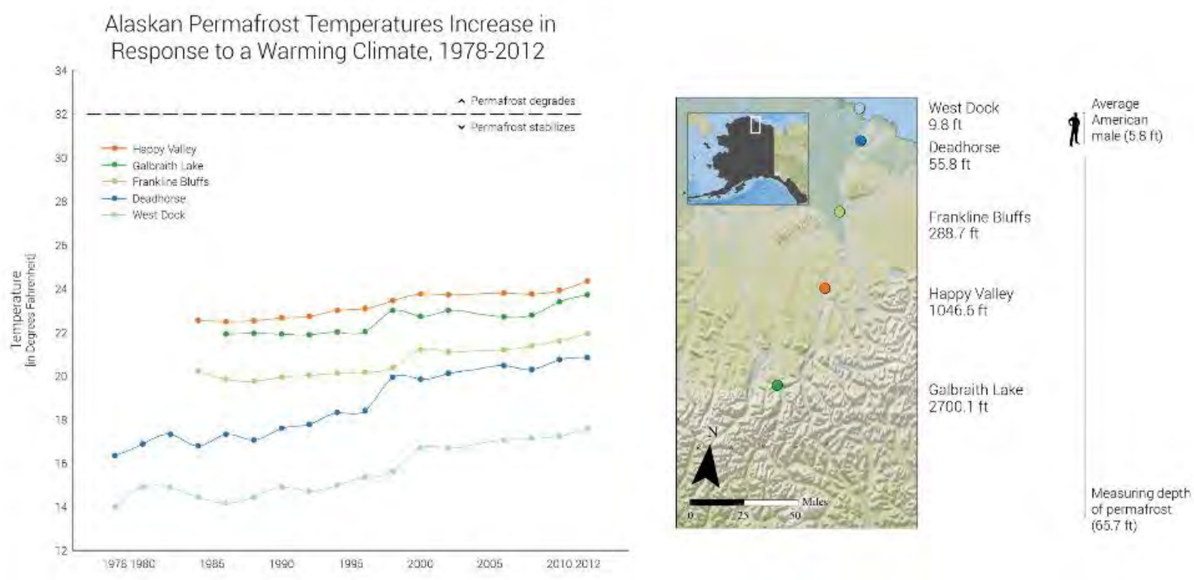
In addition to these tools, we also created a portal for USGCRP use in the future indicators creation process. This portal can be used to track progress and collection of input materials as well as revisions/versioning. It is based on the portal we created with NEMAC for our own use, and reflects changes we found helpful as we moved through the indicators prototyping process with the pilot indicators. We also made changes to the existing portal for indicator development including minor modifications to improve functionality and usability. In addition, we migrated the portal to a stable cloud-based hosting environment. This portal was transferred to USGCRP ownership (although this year our team used grant funds to support the maintenance of the portal).

Indicator Prototype Development

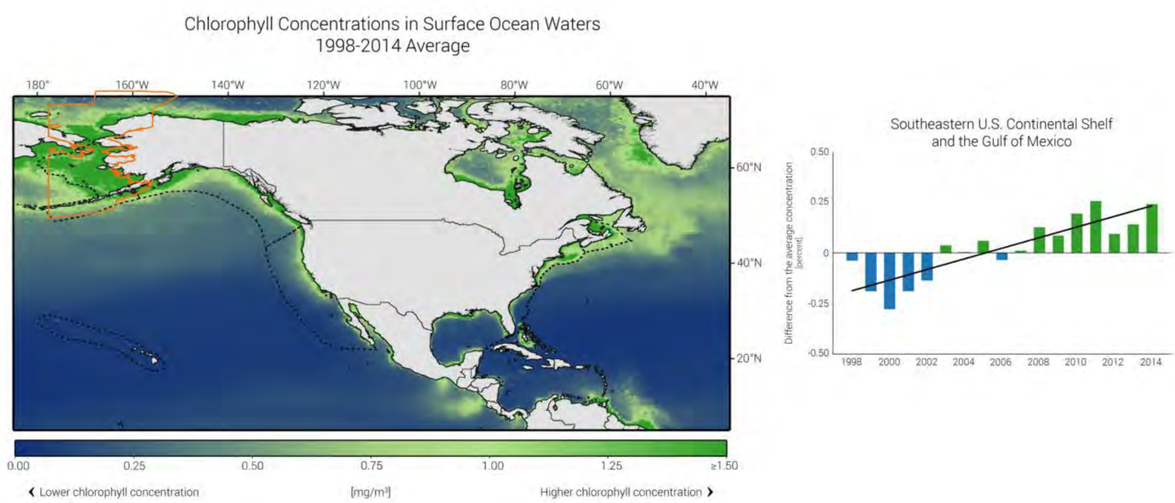
To meet the vision of the NCIS, additional indicators that have not been developed yet will need to be created. After the USGCRP indicators were released, the team spent time refining indicators that were in progress, developing prototype indicators, and developing animated and interactive indicators. Indicators for which we developed graphics/metadata but were not included in the pilot included: Permafrost, Coral Thermal Stress, Ocean Chemistry and Acidification, Crop Yields, Snow Cover, and Heavy Precipitation. Additionally, animated and interactive indicator graphics for Incidences Lyme Disease, Arctic Sea Ice, Ocean Chlorophyll, and an interactive version of the Annual Greenhouse Gas Index indicator. Examples of these indicators are below. Because of clear feedback that we received that additional prototype indicators would not be useful at this stage, our team reprioritized in fall 2015 to focus more on the special issue and developing indicator research, described in this report.



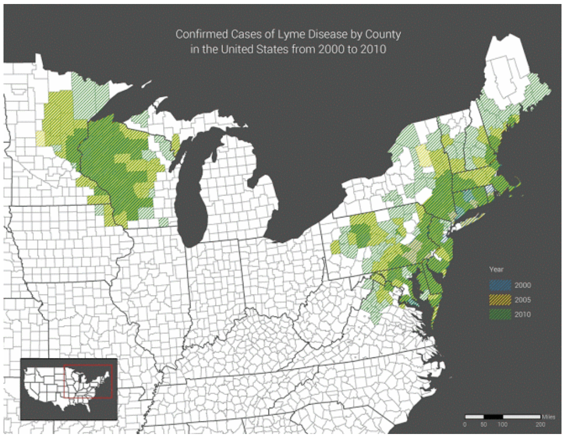
Interactive Aggregated Greenhouse Gas Index (AGGI). To view interactive version, see http://cmy2k.github.io/aggi/



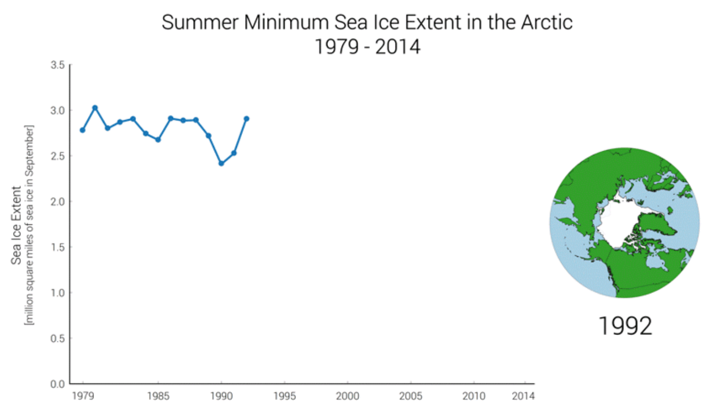
Prototype Permafrost indicator submitted to USGCRP with metadata in adopted format.



Ocean Chlorophyll Concentrations. Designed as an interactive indicator with mouse-over regions to show detailed regional graph. To view, see http://cmy2k.github.io/chlorophyll-map/orange.html



Animated graphic of spread of Lyme disease over time, a new indicator developed in collaboration with researchers from Centers of Disease Control.

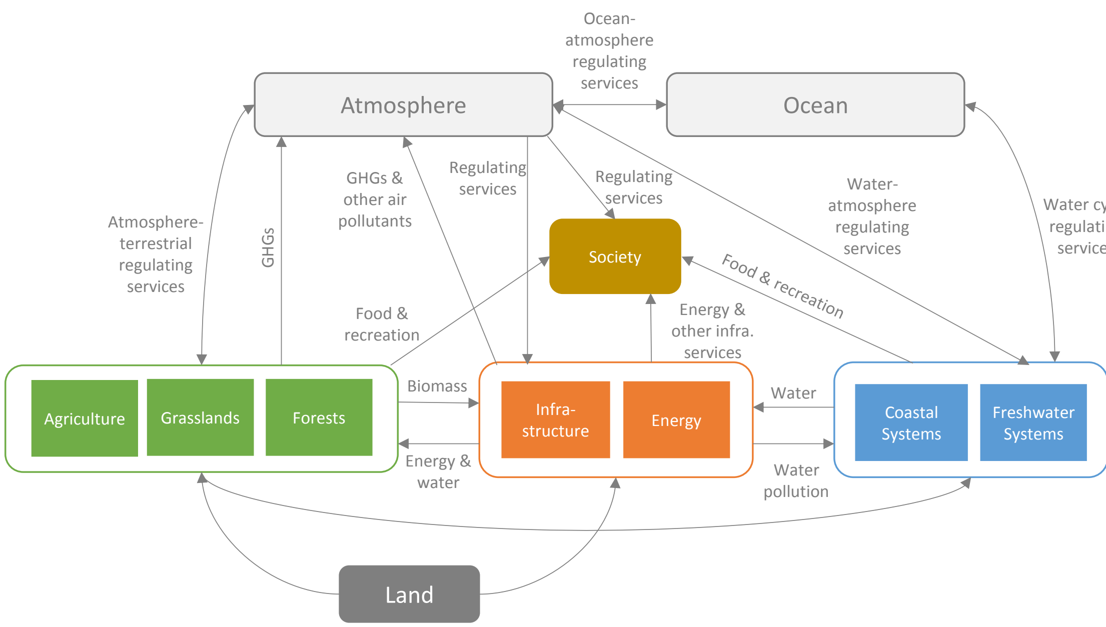


Sea ice extent – globe image that shows sea ice extent animated over time as line progresses

Special Issue on Indicators in *Climatic Change*

During the summer of 2015 Kenney and Janetos successfully negotiated to guest edit a special issue in the journal *Climatic Change*, which we anticipate will include ~15 papers and be published in early 2017. The special issue will include a scientific article from 12 technical teams, providing the scientific basis for indicator recommendations and highlights knowledge gaps and future directions for indicator development. In addition, four articles will be included on other indicator efforts, which include indicators developed for New York City, Canadian forest indicators, Arctic sea ice, and net primary productivity indicators.

A summary article in progress – authored by Kenney, Janetos, and Gerst -- will tie the special issue together. It will provide a built out version of the an overarching conceptual framework for the indicator system, which describes how the various sectors are linked in the broader system, and a synthesis of the comprehensiveness of the indicators chosen by the teams. In addition, discussion will be included on future directions of the system, including leading indicators.



Overall indicators conceptual model (draft)

After an extensive review of the literature on conceptual models of socio-environmental systems and indicators, we chose to ground the overarching conceptual model in an ecosystem services framing that provides a common language for describing the links between human and natural systems. This was used to guide the 12 author-teams in re-visiting the conceptual framing of their recommendations. This meant that in many cases we developed prototype conceptual models to facilitate the translation of previous work with the framing needed to create cohesion, consistent with our long-term research plan, for the recommendations across the teams. In addition, Kenney, Janetos, and Gerst have provided extensive internal review to the teams as they have prepared their papers for submission to *Climatic Change.* The special issue is prioritized and timed to support the 4th National Climate Assessment and strengthen the scientific basis for the indicator system.

Indicators and Networked Metadata as a Boundary Object

This study proposes to examine how researchers from different disciplines and practical contexts use information about the sources and analysis of data, also known as provenance, when presented with indicators, addressing the research question: Can coupling climate-related indicators with data provenance support scientific innovation and science translation?

To address this question, we will draw on and expand upon boundary object theory, which focuses on the role of artifacts (such as images) in translation and communication across the boundaries of social groups, as a theoretical lens to inform and direct our inquiry. Leveraging seed grant funding from the University of Maryland ADVANCE program (collaborator A. Wiggins, co-mentored postdoc A. Young), the team, including several undergraduate researchers, conducted in-depth semi-structured interviews with scientists and 5-minute intercept interviews at the Ecological Society of America meeting and the annual American Geophysical Union (AGU) conference.

Responses to the indicator and metadata mockup were generally positive and met participant expectations. Some suggestions for improvement included describing uncertainty, defining key terms, and providing authorship information on the indicator page or via a quick link from that page, rather than in the metadata pop-up. Many participants also felt that the text was dense and scientific, and expressed the opinion that the general public may have trouble with interpreting the information. Data analysis is ongoing, and the researchers expect to submit a manuscript this summer reporting the outcomes of the study.

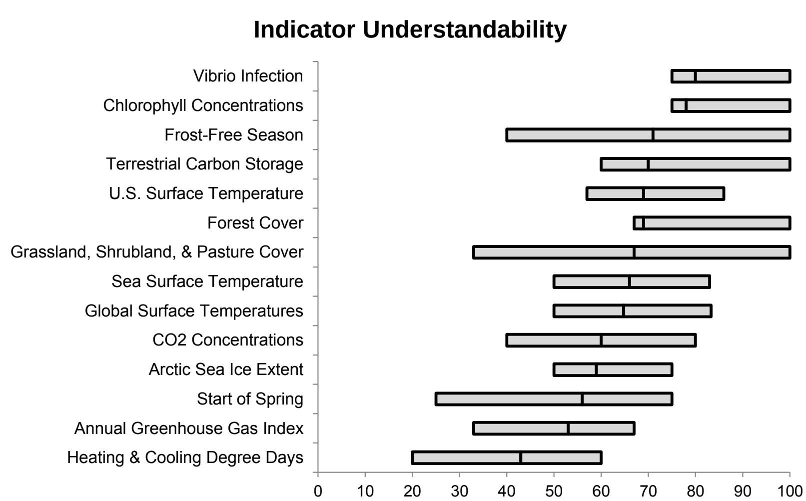
Understandability of Indicators by Non-scientists

In order for indicators to effectively convey information target audiences must easily understand them. Indicator understandability is a mix of the abstractness of the indicator, the complicatedness of the patterns portrayed by the indicator, and visualization techniques. We have initially chosen to focus on visualization techniques, as this is often the easiest lever to use in efforts where indicators have been co-produced with experts and stakeholders. The experimental design proceeded in two stages. First we gauge understandability across the pilot indicators. Then for poorly understood indicators we made visualization design changes and tested for improvement in understandability.

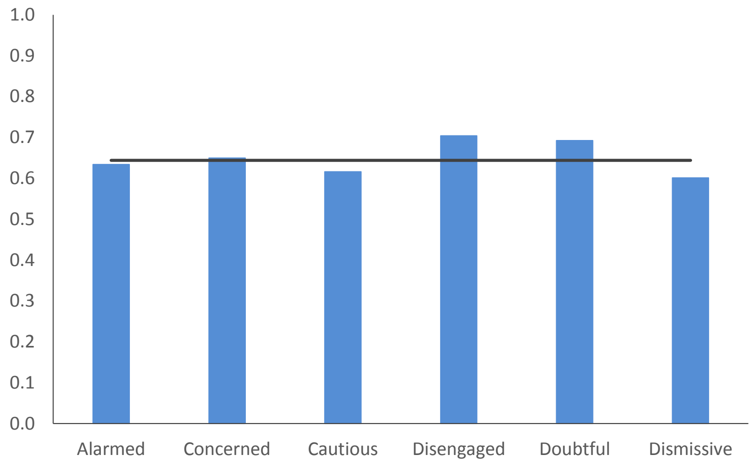
In order to gauge understandability, we wrote a few questions for each indicator that were answered through an online survey. The sample size was balanced to roughly represent the US adult population. Importantly, we also included questions that categorized beliefs about climate change according to the well-known Six Americas classification of climate beliefs.

The results indicate that understandability varies across indicators somewhat along expectations. Easy to understand visuals, such as vibrio infections, are well understand while more difficult concepts such as heating and cooling degree days and AGGI are more difficult. In addition, we found that understandability across beliefs in climate change does not vary widely.

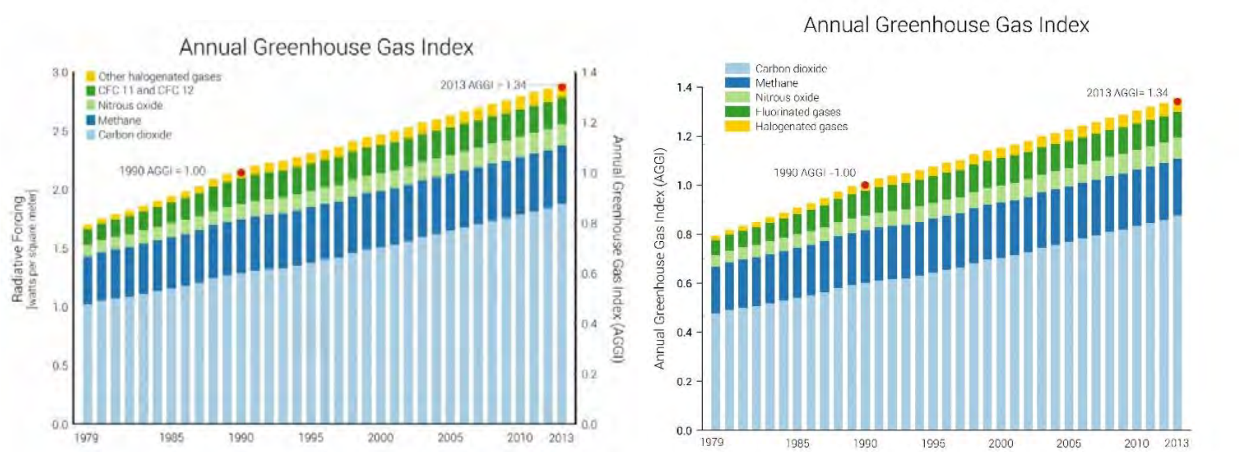
Drawing from the visualization literature, we tested whether understandability of heating and cooling degree-days and AGGI suffered from what is called superposition overload. As can be seen from the redesign of these figures, this refers to superposition of too much information in one graph when two or more might allow for easier interpretation. Not overloading one graph has a surprisingly large effect on understandability, improving scores by 12 and 14 points for AGGI and degree-days, respectively. This puts the overall understandability of these indicators more in-line with the results of the other pilot indicators. A paper is in progress and is slated for submission in June 2016.



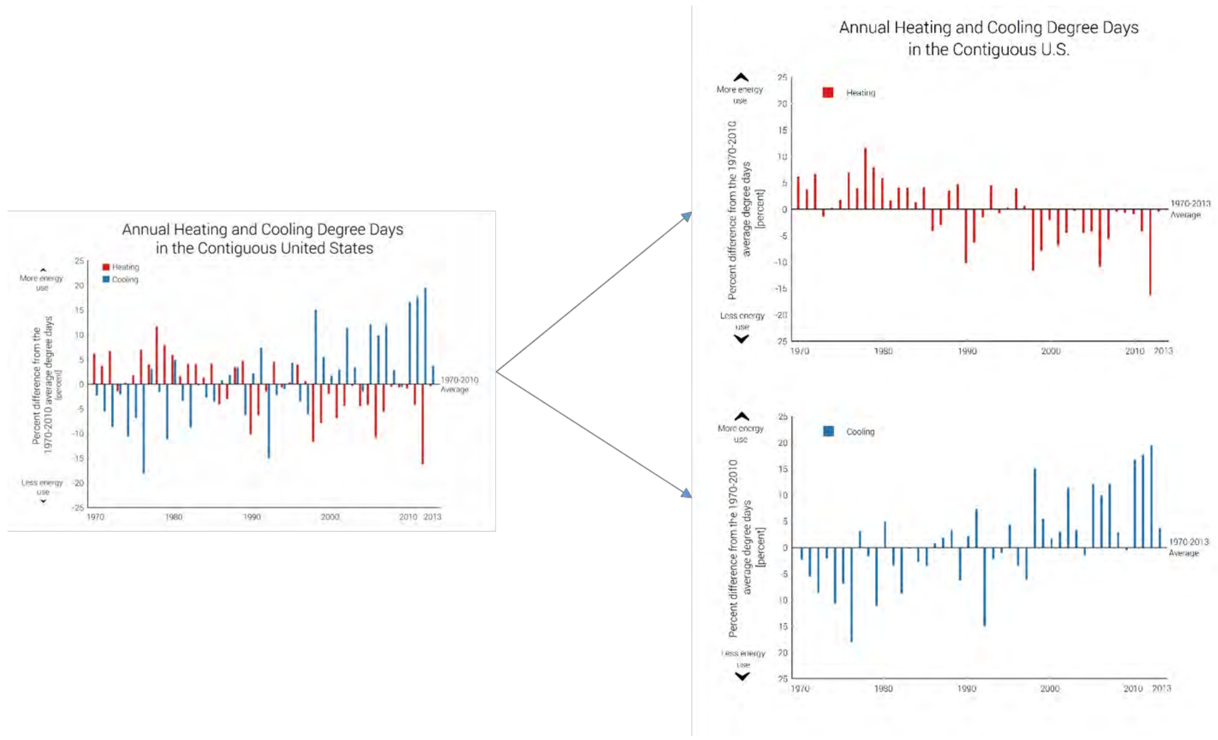
Understandability scores of indicators. Shaded areas are the interquartile range and vertical bars mark the median.



Understandability across Six America audience climate belief segmentations. Vertical line shows average across all beliefs, which run from left to right most to least in-line with scientific consensus on climate change.



Comparison of before and after graphs of AGGI indicator. Note the right panel has only one axis, which shows AGGI, instead of both radiative forcing and AGGI (left panel).



Comparison of USGCRP pilot indicator and potential modification of heating and cooling degree-day indicator used for testing understandability of different visualization schemes.

Synthesis of Existing Indicator Efforts

A major gap in the literature exists for review of indicator efforts. This gap is emphasized by the many Federal indicator workshops requesting indicator inventories, with slightly different emphases. Thus, there is a need to better understand the indicator efforts that measure what we care about and for what purposes the indicators are used, from small to large governance scales.

To develop the method and meet regional needs expressed by stakeholders in the Northeast states, we designed an indicators synthesis process by identifying indicator efforts in urban areas in the Northeast. With a small group of undergraduate research assistants, we are finalizing the analysis of a dataset developed of urban resilience indicators in the Northeast US (DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT), which involves a review of efforts for 114 cities. We have found that very few cities indicators systems that are either framed around resilience or contain all of the components of resilience (hazard, exposure, sensitivity, capacity, and impact) necessary to be used as a resilience indicator system. However, a large majority of cities do have indicators produced for other types of efforts, such as health, sustainability, prosperity, quality-of-life, and well-being. Many of these contain social and economic indicators that would be important in constructing a comprehensive resilience indicator system, especially with respect to sensitivity and capacity. This paper is drafted and is planned for submission to *Climatic Change* (at the verbal request of one of the editors) in April 2016. The methods developed as part of this research study are designed to be scalable to larger indicator review efforts, which are planned to commence after the submission of the regional paper.

Planned work

Research in Year 3 will finalize the special issue and see to its successful review and publication. The set of papers aims to give a clear set of recommendations that build out the white papers developed by each of the technical teams. Additionally, we will build out the synthesis research to areas throughout the U.S. and develop a publically accessible database to synthesize indicator efforts and how they are used. As part of the synthesis, we are hoping to get a better sense of the indicators that are used for adaptation and mitigation efforts. Such research, which would be published as a separate paper and to inform a number of indicator discussions involving the desire for adaptation indicators, would consider the ontology of response indicators (from accounting indicators to effectiveness indicators), examples from the synthesis, and recommendations for the development or adoption of response indicators to support the indicator system and sustained assessment efforts.

Furthermore, we have support from Boston University to support a leading indicators workshop, planned for Fall 2016, to examine the development of leading indicators to support a sustained assessment (meeting the goals of providing future information) and to meet the needs of supporting decisions, which require information about the potential consequences of future actions. This is work that was called for in Janetos and Kenney, 2015 and Kenney et al., 2016, and the focus of this effort will be to emphasize multi-stressor climate impacts, instead of the better understood and developed physical climate indicators.

Finally, through relationships built over the past several months in the Mid-Atlantic and Northeast regions, we are working to develop research to explore the scalability of indicators from local/sectoral scale indicator to a national scale effort, like the USGCRP indicators. The aim is to explore the role and relationship between indicators to support assessment and indicators that are useful for decision support – some of which may be the same, but some of which may be importantly different in component and form.

Publications

1. Kenney, M.A., A.C. Janetos, G.C. Lough. (2016) Developing a Sustained National Climate Indicators System. *Climatic Change*. doi:10.1007/s10584-016-1609-1 (invited article for special issue on Sustained Assessments guest edited by K. Jacobs, J. Buizer, and S. Moser)
2. Prava, V., R.T. Clemen, B.F. Hobbs, and M.A. Kenney. (2016) Partition Dependence and Carryover Biases in Subjective Probability Assessment Surveys for Continuous Variables: Model-based Estimation and Correction. *Decision Analysis.* 13(1): 1-17. doi:10.1287/deca.2015.0323
3. Janetos, A.C. and M.A. Kenney (2015) Developing better indicators to track climate impacts. *Frontiers in Ecology and the Environment.* 13: 403.
4. Kenney, M.A., M.D. Gerst, and J.F. Wolfinger (in press) Understandability of Indicators for Non-expert Audiences: Increasing their potential value for decision-making. Conference abstract for edited volume for workshop on the Socioeconomic Benefits of Geospatial Information.
5. Mallampalli, V.R., G. Mavrommati, J. Thompson, M. Duveneck, S. Meyer, A. Ligmann-Zielinska, C. G. Druschk, K. Hychka , M.A. Kenney, K. Kok, M.E. Borsuk (in revision) Methods for Translating Narrative Scenarios into Quantitative Assessments of Land Use Change. *Environmental Modelling and Software*.

Publications In Preparation

1. Kenney, M.A., A.C. Janetos, M. Gerst, A. Lloyd, J.F. Wolfinger. (in preparation) The National Climate Indicators System: A proposed integrated set of indicators for the U.S. *Climatic Change*. Capstone paper for Special Issue of *Climatic Change* guest edited by M.A. Kenney and A.C. Janetos.
2. Gerst, M., M.A. Kenney, A. Lloyd, J.F. Wolfinger, and 8 students. (in preparation) A synthesis of resilience indicators in Northeast U.S. cities. Planned for *Climatic Change.*
3. Kenney, M.A., M. Gerst, J.F. Wolfinger, and A. Lloyd. (in preparation) Improving the understandability of indicators for non-scientific audiences. Planned for *Weather, Climate, and Society.*

Products

1. Kenney and Janetos are guest editing a special issue of *Climatic Change* that will include articles from 12 indicator technical teams as well as local and international indicator efforts that are complementary to the NCIS. Papers are in draft form and Kenney and Janetos have internally reviewed most papers. Paper submission anticipated in late spring or early summer with publication of the special issue papers anticipated in early 2017.
2. Development and maintenance of an indicators portal to provide full transparency of the indicator production process.
3. Developed several prototype indicators including:
    - Permafrost
    - Coral Thermal Stress
    - Ocean chemistry and acidification
    - Crop Yields
    - Snow Cover
    - Heavy Precipitation
    - animated Lyme Disease
    - animated Arctic Sea Ice
    - animated Ocean Chlorophyll
    - interactive Aggregated Greenhouse Gas Index

Presentations

Invited Presentations

1. Janetos, A.C. and M.A. Kenney (2016) Developing a pilot indicator system for U.S. climate changes, impacts, vulnerabilities, and responses. Nonprofit Coordinating Committee of New York (NPCC) Indicators and Monitoring Working Group. New York City, NY.
2. Insert GEOValue Presentation
3. Kenney, M.A. (2015) Training Multidisciplinary Scholars in Science Policy for Careers in Academia, Private Sector, and Public Service, American Geophysical Union, San Francisco, CA.
4. Kenney, M.A. (Fall 2015) International Sigma Xi Conference, Young Investigator Award Keynote. Invited Keynote Speaker.
5. Kenney, M.A. (2015) Climate Decision Support and Prototype of National Climate Indicators System. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. College Park, MD. Invited Speaker.
6. Kenney, M.A. (2015) Indicators to Inform Sustainability Decisions: Prototype of National Climate Indicator System. National Academies of Sciences, Sustainability Roundtable. Washington, DC. Invited Speaker and panelist.

7. Kenney, M.A. (2015) Bridging the divide between science, public views, and policy. AAAS Science and Policy Forum. Washington, DC. Invited Speaker and panelist.
8. Kenney, M.A. (2015) Interdisciplinary Research to Support Climate Adaptation and Mitigation Decisions. Mid-Atlantic Regional Meeting of Sigma Xi, George Mason University, Fairfax, VA. Invited Keynote Speaker.
9. Kenney, M.A. (2015) Climate Science Policy Research: National Climate Indicator System. Earth System Science Interdisciplinary Center Review. College Park, MD. Speaker and panelist.
10. Kenney, M.A. (2015) TBD. Virginia Lakes and Watershed Association (VLWA), Richmond, VA. Invited Keynote Speaker.
11. Kenney, M.A. (2015) Supporting and Informing Decisions through Assessment and Indicators, American Association for the Advancement of Sciences, San Diego, CA.
12. Kenney, M.A. (2015) Demonstration of Proposed National Climate Indicator System, Presidential Innovation Fellows, Washington, DC.
13. Kenney, M.A. (2015) Supporting and Informing Decisions Through Assessments and Indicators: Multidisciplinary Science to Support Environmental Decisions, U.S. Geological Survey Patuxent Wildlife Research Center, Laurel, MD. Invited USGS Seminar.
14. Kenney, M.A. (2015) Climate Indicators? Or Farmer's Almanac? Weather -Water-Science-Policy, DC Chapter of Sigma Xi and Rockville Science Cafe, Rockville, MD. Invited Public Lecture.
15. Kenney, M.A. (2015) Indicators for the National Climate Assessment, Invited Presentation. American Meteorological Society, Phoenix, AZ.
16. Kenney, M.A. (Spring 2016) Climate Decision Support: Bridging the gap between scientifically interesting results and outputs needed for decisions. Boston University, Boston, MA. Earth and Environment.
17. Kenney, M.A. (Spring 2016) Climate Decision Support: Bridging the gap between scientifically interesting results and outputs needed for decisions. University of California, San Diego, La Jolla, CA. School of Global Policy and Strategy and Scripps Institution of Oceanography.
18. Kenney, M.A. (Spring 2016) Climate Decision Support: Bridging the gap between scientifically interesting results and outputs needed for decisions. Clark University, Worcester, MA. International Development, Community, and Environment (IDCE).
19. Kenney, M.A. (Fall 2015) Indicators: Are they useful for decision-making? University of Maryland, College Park. Program for Society and the Environment (PSE).
20. Kenney, M.A. (Fall 2015) Science for Policy: Communicating Science to Policymakers. University of North Carolina, Chapel Hill.
21. Kenney, M.A. (Fall 2015) Is Stream Restoration Worth It? Fairfield University.
22. Kenney, M.A. (Fall 2015) Multidisciplinary Insights to Solve Difficult Environmental Problems. Old Dominion University.
23. Kenney, M.A. (Spring 2015) Understandability and utility of climate indicators. Climate Change Communication Center, George Mason University.

Invited Workshop Presentations and Participation

1. Operational Ecological Forecast. (2016) Invited Speaker and Workshop Participant. Sponsored by the National Ecological Observatory Network (NEON, Inc.). Fort Collins, CO.
2. Convening on Evaluation of Public Engagement with Science. (2015) Invited Workshop Participant. Sponsored by American Association for the Advancement of Sciences. Washington, DC.
3. Northeast Climate Change and Streamflow Workshop. (2015) Invited Speaker. Sponsored by the U.S. Geological Survey. Catonsville, MD.

4. Food-Energy-Water Workshop. (2015) Invited Speaker and Panelist. Sponsored by University of Maryland, National Science Foundation, and the World Bank.
5. Ecosystem and Resilience Indicators and Metrics Workshop: Designing a framework for an ecosystem resilience decision support tool. (2015) Invited Participant. Sponsored by U.S. Federal Interagency Climate and Natural Resources Working Group, including Department of Interior, National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, Army Corps of Engineers, Department of Transportation, and Environmental Protection Agency. Washington, DC.
6. Sustainable Adaptive Gradients in the Coastal Environment (SAGE): Reconceptualizing the Role of Infrastructure in Resilience. (2015) Co-led by Haimin, E., D. DeGroot, **M.A. Kenney**, T. Sheahan. Sponsored by SAGE RCN. St. Ann, Jamaica http://www.resilient-infrastructure.org/
7. S^3 RCN Workshop II: Scenarios to Simulation. (2015) Invited Workshop Participant. Sponsored by Scenarios, Services, and Society Research Coordination Network (S^3 RCN). Dartmouth College, Hanover, NH. http://harvardforest.fas.harvard.edu/scenarios-simulation
8. Communicating Climate Science Workshop (2015). Invited Workshop Participant. Sponsored by Ecological Society of America and American Association for the Advancement of Sciences. Washington, DC.

Other Presentations

1. Kenney, M.A., M. Gerst (presenter), J.F. Wolfinger. (2016) Using Visualization Science to Evaluate Effective Communication of Climate Indicators. *American Meteorological Society*, New Orleans, LA.
2. Wiggins, A., M.A. Kenney, A. Young, C. Brody, M. Gerst, A. Lamoureux, A. Rice, J.F. Wolfinger. (2015) Climate-related Indicators and Data Provenance: Evaluating Coupled Boundary Objects for Science, Innovation, and Decision-Making, *American Geophysical Union*, San Francisco, CA.
3. Kenney, M.A. (Fall 2015) *INFORMS, Decision Analysis Society Cluster*. Philadelphia, PA. Session co-organizer.
4. Kenney, M.A. (accepted 2015) Is it Doing Any Good? Monitoring and Evaluating Climate Adaptation Activities. *National Adaptation Forum*. Saint Louis, MO. Session co-organizer.
5. Kenney, M.A. and A.C. Janetos (2015) Developing a pilot indicator system for U.S. climate changes, impacts, vulnerabilities, and responses. *North American Carbon Program*, Washington, DC.
6. Kenney, M.A. (2015) National Climate Indicator System: Utility of Information of Indicators. *American Meteorological Society*, Phoenix, AZ.
7. Kenney, M.A., M. Gerst, A. Lloyd, J.F. Wolfinger, R.V. Pouyat, S. Anderson, J. Reyes, and A.C. Janetos. (2015) A Prototype Indicators System for U.S. Climate Changes, Impacts, Vulnerabilities, and Responses. *American Geophysical Union*. San Francisco, CA.
8. Gerst, M., M.A. Kenney, M.A., A. Lloyd, J.F. Wolfinger, (2015) Using Visualization Science to Evaluate Effective Communication of Climate Indicators. *American Geophysical Union*. San Francisco, CA.
9. Kenney, M.A., M. Gerst, A. Lloyd, J.F. Wolfinger, R.V. Pouyat, S. Anderson, J. Reyes, and A.C. Janetos. (2015) A Prototype Indicators System for U.S. Climate Changes, Impacts, Vulnerabilities, and Responses. *Cooperative Institute for Climate and Satellites-Maryland Science Meeting*. College Park, MD
10. Kenney, M.A., A. Lloyd, M. Gerst, J.F. Wolfinger, R.V. Pouyat, S. Anderson, J. Reyes, A. Lamoureux, A. Bredder, M. Sharova, Y. Ding, A. Rice, C. Brody, and A.C. Janetos. (2015) A Prototype Indicators System for U.S. Climate Changes, Impacts, Vulnerabilities, and Responses. *Ecological Society of America*. Baltimore, MD.
11. Kenney, M.A., A.C. Janetos, D. Ardnt, R. Pouyat, R. Aicher, A. Lloyd, O. Malik, J. Reyes, and S. Anderson. (2015) Developing a Pilot Indicator System for U.S. Climate Changes, Impacts, Vulnerabilities, and Responses. *Earth System Science Interdisciplinary Center Review*. College Park, MD.

12. Kenney, M.A., A.C. Janetos, R.V. Pouyat, R.J. Alcher, A. Lloyd. (2015) Developing a U.S. Interagency Pilot Indicator System to Support Climate Resilience, *American Association for the Advancement of Sciences*, San Jose, CA.
13. Kenney, M.A. (2015). Citizen science can support development of physical, natural, and societal indicators for the U.S. National Climate Indicator System. *Citizen Science Association*. San Jose, CA.
14. Cloyd, E.T. and M.A. Kenney (2015). Tracking a changing climate: citizen science contributions to climate change indicator systems. *Citizen Science Association*. San Jose, CA.

Other

Honors to Kenney (largely resulting from the indicators work) include:

- 2015 Sigma Xi Young Investigator Award
- American Association for the Advancement of Sciences Leshner Leadership Institute for Public Engagement with Science Fellow focused on Climate Change (2016-2017)
- University of Maryland 8th Annual University-Wide Celebration of Scholarship and Research (2015)

Heath, Linda S.; Anderson, Sarah M.; Emery, Marla R.; Hicke, Jeffrey A.; Littell, Jeremy; Lucier, Alan; Masek, Jeffrey G.; Peterson, David L.; Pouyat, Richard; Potter, Kevin M.; Robertson, Guy; Sperry, Jinelle; Bytnerowicz, Andrzej; Jovan, Sarah; Mockrin, Miranda H.; Musselman, Robert; Schulz, Bethany K.; Smith, Robert J.; Stewart, Susan I. 2015. Indicators of climate impacts for forests: recommendations for the U.S. National Climate Assessment indicators system. Gen. Tech. Rep. NRS-155. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 143 p.
Report developed during research process led by Kenney research team to build recommendations for National Climate Indicator System, acknowledges Kenney's Indicator Research Team and NOAA funding

National Academies of Sciences. (2015) Measuring Progress Toward Sustainability: Indicators and Metrics for Climate Change and Infrastructure Vulnerability. Roundtable on Science and Technology for Sustainability. http://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_168935.pdf
Meeting summary that included invited presentation by Kenney on sustainability indicators

Bours, D. (September 2015) What would you do with 200 Million US Dollars? Climate-Eval Blog. https://www.climate-eval.org/blog/what-would-you-do-200-million-us-dollars

Wren, K. (May 2015) New online resource aims to arm decision-makers, public with science-based climate information. AAAS. http://www.aaas.org/news/new-online-resource-aims-arm-decision-makers-public-science-based-climate-information
From CICS-MD: CICS-MD Scientist Melissa Kenney is the focus of a new article on the website of the American Association for the Advancement of Sciences (AAAS). The article talks about her CICS-MD project on Climate Change Indicators, which "are intended to communicate how the environment is changing, spotlight risks, and inform decision-making on policy, planning, and resource management." It also included information on the recently released pilot web tool that makes years of climate data to more accessible to policymakers and the general public.

CPO Web Article Features CICS Indicators Task (August 2015) http://cpo.noaa.gov/AboutCPO/All-News/TabId/315/ArtMID/668/ArticleID/292084/USGCRP-releases-Prototype-Indicators-System-.aspx

"The USGCRP indicator effort, which NOAA significantly supported through a CICS grant, announced a pilot indicator release on May 6....CPO partially supported Melissa Kenney's time as a AAAS Science and Technology Fellow (2010-2012) to staff and lead the NCA indicators workshops and work with the NCADAC Indicator Work Group. Given the interest by the scientific and user communities and CPO's support of sustained assessment activities, they provided Kenney's research team grant funding via CICS-MD to develop recommendations (in collaboration with 200+ scientists) and a pilot for USGCRP to consider as part of foundational NCA sustained assessment activities." To explore the USGCRP indicators, visit: www.globalchange.gov/browse/indicators . Indicators of climate change communicate how the environment is changing, identify risks, and inform decisions about policy, planning, and resource management.

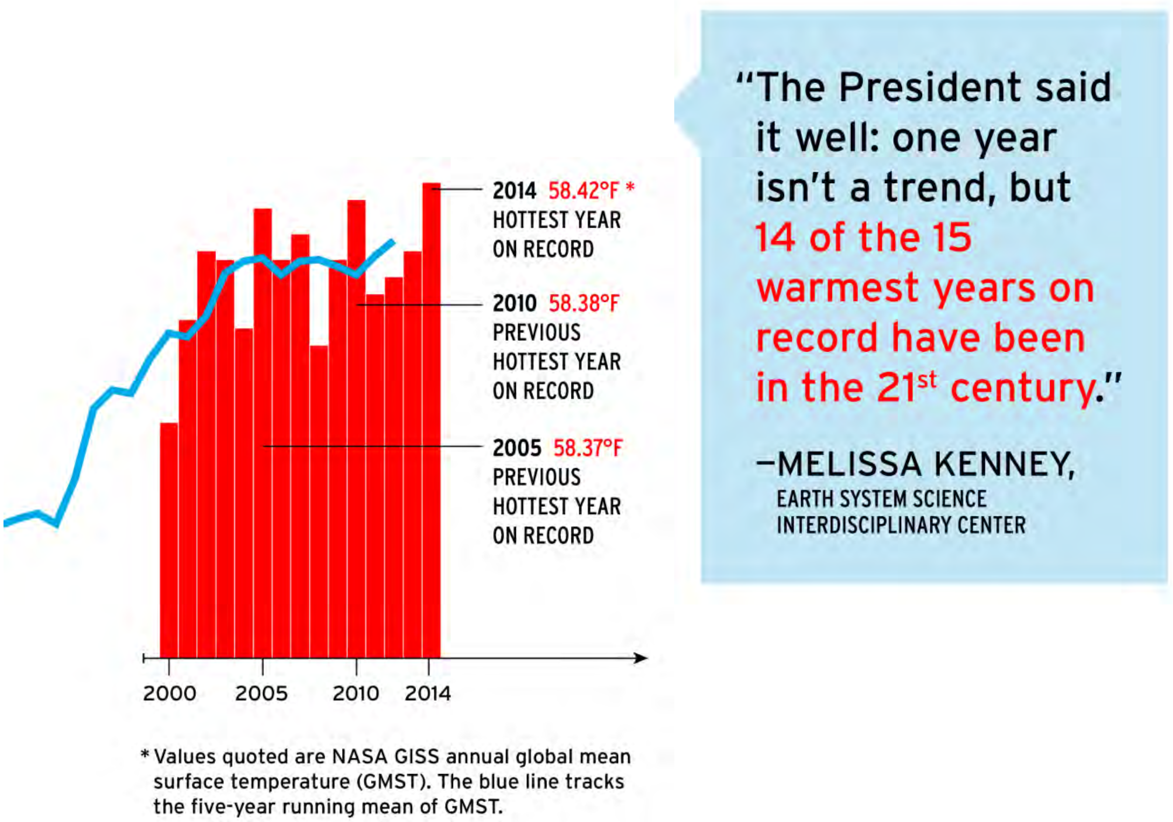
CICS-MD Summaries of Our Work

2-13-15 **Bias Correction for Expert Survey Data in Review** Melissa Kenney
CICS-MD Scientist Melissa Kenney has a new article in review with the journal Decision Analysis. It discusses bias correction for expert survey data. Prava, V., R.T. Clemen, B.F. Hobbs, and M.A. Kenney, 2014: Partition dependence and carryover biases in subjective probability assessment surveys for continuous variables: Model-based estimation and correction. Decis. Anal. (in review).

2-20-15 **Climate Indicators Featured on BU Website** Melissa Kenney
CICS-MD Scientist Melissa Kenney's task on Climate Indicators is the topic of a new article on the Boston University website. The article is titled, "Building a Better Barometer: Anthony Janetos leads a quest to quantify climate change." The story mentions NOAA as a major collaborator in the project. The entire article is available at http://www.bu.edu/research/articles/building-a-better-barometer/?utm_source=social&utm_medium=twitter&utm_campaign=prbuexperts.

2-20-15 **Kenney Quoted on Record-Breaking Temperatures** Melissa Kenney
CICS-MD Scientist Melissa Kenney was quoted by the in the web article UMD Climate Researchers React to 2014's Record-Breaking Global Temperatures. She was quoted as saying:

> "The 2014 announcement is a good reminder as to why we're making these important decisions. A single indicator like this can make a great story, but it is not enough by itself to support decisions. Folks will hear the news and then ask, 'How does this impact me and my community? How can I use this information to help make decisions?' My work is focused on how we can translate complex scientific information into a broader range of indicators that people can use to make decisions, without being policy-prescriptive."



The figure above from Kenney ran with the article. In addition, CICS-MD Scientists Antonio Bussalachi and Ross Salawitch were also quoted. The full article is available at https://cmns.umd.edu/news-events/features/2791.

2-20-15 **Kenney Participates in Invitation-Only Workshops** Melissa Kenney
CICS-MD Scientist Melissa Kenney's expertise has been in demand for several invitation-only workshops over the past year. She participated at:

- **Measurement Science for Sustainable Construction and Manufacturing**, in Reston, VA (12-13 Jun. 2014), sponsored by National Institute of Standards and Technology (NIST) and the University of Maryland (http://www.civil.umd.edu/news/news_story.php?id=8412);
- **Measures of Community Resilience: From Lessons Learned to Lessons Applied** in Washington, DC (5 Sept. 2014), sponsored by National Academy of Sciences (http://sites.nationalacademies.org/pga/resilientamerica/pga_152193); and
- **Economic and Financial Risks of a Changing Climate** in Washington, DC (12 Nov. 2014), sponsored by Resources for the Future and American Association for the Advancement of Sciences (http://www.rff.org/Events/Pages/The-Economic-and-Financial-Risks-of-a-Changing-Climate.aspx).

She will also be participating in two upcoming invitation-only workshops:

- **Scenarios to Simulation Workshop** at Dartmouth College, Hanover, NH (26-27 Feb. 2015), sponsored by the Scenarios, Services, and Society Research Coordination Network (S3 RCN) located at Harvard Forest (http://harvardforest.fas.harvard.edu/scenarios-simulation); and

- **Communicating Climate Science Workshop** at AAAS, Washington, DC (4 Mar. 2015), sponsored by Ecological Society of America and American Association for the Advancement of Sciences (http://www.esa.org/esa/public-affairs/communicating-climate-science-workshop/).

2-20-15 **Unmet Needs of Climate Assessment Article in Revision** Melissa Kenney
CICS-MD Scientist Melissa Kenney has a new article entitled "Indicators of Change and Consequence are Unmet Needs for Climate Change Assessments" in revision for publication by *Nature Climate Change*.

2-20-15 **Kenney Invited to Give Keynote for VLWA Conference** Melissa Kenney
CICS-MD Scientist Melissa Kenney will be the Keynote Speaker at the upcoming Virginia Lakes and Watershed Association Conference. This conference will be held 8-9 March 2015 in Richmond, VA. The title of her talk is "The Benefits of Water Quality Improvements and Restoration. More information on the conference is available at http://www.vlwa.org/VirginiaWaterConference.aspx .

2-27-15 **Kenney Spoke at Five Conferences in January and February** Melissa Kenney
CICS-MD Scientist Melissa Kenney spoke about the U.S. National Climate Indicator System at several different forums in the last few months:

- S3 RCN Scenarios to Simulation Workshop, Dartmouth College, Hanover, NH (2/26 to 2/27/2015)
- AAAS Annual Meeting, San Jose, CA (CA (2/12 to 2/16/2015)
- Citizen Science Association Conference, San Jose, CA (2/11 to 2/12/2015)
- DC Chapter of Sigma Xi and Rockville Science Café, Rockville, MD (1/20/2015)
- AMS Annual Meeting, Phoenix, AZ (1/4 to 1/8/2015)

She gave two presentations at the AAAS Annual Meeting, at Citizen Science Association Conference, and presented a poster along with an invited presentation at AMS.

4-3-15 **AAAS Science and Policy Forum** Melissa Kenney
CICS Scientist Melissa Kenney has been asked to speak at the AAAS Science and Policy Forum to be held on April 30th through May 1st in Washington, DC. She will be on the Public Opinion and Policy Making Panel and her talk is entitled "Bridging the divide between science, public views, and policy." For more information on the conference, see
http://www.aaas.org/page/forum-science-technology-policy .

4-10-15 **Kenney's Past Conference Presentations** Melissa Kenney
CICS Scientist Melissa Kenney recently spoke at three conference:.

- The first talk, "Developing a pilot indicator system for U.S. climate changes, impacts, vulnerabilities, and responses" was presented at the North American Carbon Program held in Washington, DC on January 26–29.

- The second talk, “Tracking a changing climate: Citizen science contributions to climate change indicator systems” was presented at the Citizen Science Association Conference in San Jose, CA on February 11–12.
- The third talk, “Supporting and Informing Decisions through Assessment and Indicators” was presented at the AAAS Annual Meeting held in San Jose, CA on February 12–16.

4-10-15 **Kenney’s Upcoming Conferences** Melissa Kenney
CICS-MD Scientist Melissa Kenney has been invited to be a panelist at the AAAS Science and Policy Forum, which will be held in Washington, DC on April 30–May 1. Her talk is part of the Public Opinion and Policy Making panel and is entitled “Bridging the Divide between Science, Public Views, and Policy.” This event draws 500 to 700 participants annually that are a mix of government and academic scientists, government staff and policy makers, and representatives from many scientific and engineering societies and organizations. For more information, see http://www.aaas.org/page/forum-science-technology-policy. Kenney is also a session co-organizer at National Adaptation Forum to be held in Saint Louis, MO on May 12–15. She will also be a speaker and her talk is called ““Is it Doing Any Good? Monitoring and Evaluating Climate Adaptation Activities.” For more information, see http://www.nationaladaptationforum.org/.

4-24-15 **Kenney to be honored at UMD** Melissa Kenney
CICS-MD Scientist Melissa Kenney will be honored for her work and accomplishments at the 8th Annual University of Maryland Celebration of Scholarship and Research on May 1st.This informal reception illustrates the breadth of UMD faculty results over the past year. She was nominated for this award by Jayanth Banavar, the Dean of the College of Computer, Mathematical and Natural Sciences.

4-24-15 **Kenney to Speak at STS Roundtable** Melissa Kenney
CICS Scientist Melissa Kenney has been invited to speak at the U.S. National Academies' Roundtable on Science and Technology for Sustainability (STS Roundtable). The meeting will be held on June 4-5, 2015 at the National Academy of Sciences building in Washington, DC. She has agreed to participate in the session on "Examples of Innovative Public Sector Sustainability Indicators and Metrics."

5-8-15 **USGCRP Indicators Pilot System Launched** Melissa Kenney
On May 8, USGCRP released a pilot set of 14 indicators that communicate some of the key aspects of the changing climate, such as temperatures over land and at sea, greenhouse gas levels in the atmosphere, the extent of Arctic sea ice, and related effects in sectors like public health and agriculture. Some of the indicators show climate-related trends over time, whereas others show the status of resources that may be affected by climate change in the future. Similar to the findings and figures in the 2014 National Climate Assessment, the indicators and their associated datasets are fully traceable and documented by detailed metadata in USGCRP’s Global Change Information System. This comes on the same day that NOAA announces that a bleak milestone was reached >400ppm global monthly CO_2. (Melissa Kenney, CICS, kenney@umd.edu, 301-734-1218).

5-8-15 **Kenney Speaks at Sigma Xi** Melissa Kenney
On May 2, CICS ScientistMelissa Kenney presented the keynote address at the regional meeting of Sigma Xi, the scientific research society. Her talk was entitled "Interdisciplinary Research to Support Climate Adaptation and Mitigation Decisions." After the keynote, a panel discussion on global and climate change was heldwith Dr. Jim Kinter, Dr. Tim Delsole, and Dr. Melissa Kenney, moderated by Dr. Paul

Schopf. For more information, see https://www.sigmaxi.org/news/article/2015/04/21/sigma-xi-mid-atlantic-regional-meeting-is-may-2 CO2 (Melissa Kenney, CICS, kenney@umd.edu, 301-734-1218).

6-26-15 **Kenney Featured in AAAS Website** Melissa Kenney
CICS-MD Scientist Melissa Kenney is the focus of a new article on the website of the American Association for the Advancement of Sciences (AAAS). The article talks about her CICS-MD project on Climate Change Indicators, which "are intended to communicate how the environment is changing, spotlight risks, and inform decision-making on policy, planning, and resource management." It also included information on the recently released pilot web tool that makes years of climate data to more accessible to policymakers and the general public.

Above is a photo of Kenney and her staff that appears in the article. Kenney was an AAAS Executive Branch Fellow from 2010 to 2012. Kat Song, U.S. Visualizes Data to Spur Action on Global Change, (posted 6-16-15) http://www.aaas.org/news/us-visualizes-data-spur-action-global-change?utm_campaign=2015-Summer+Fellowship+Focus&utm_medium=email&utm_source=constantcontact.com&utm_content=read+more&utm_source=Fellowship+Focus+Summer+2015&utm_campaign=Fellowship+Focus+Summer+2015&utm_medium=email (Melissa Kenney, CICS Reported by:Business Phone: melissa.kenney@noaa.gov 301-734-1218).

7-2-15 **New Article Coming Out on Bias Correction for Expert Survey Data** Melissa Kenney
CICS-MD Scientist Melissa Kenney has an article accepted with the journal *Decision Analysis*. It discusses bias correction for expert survey data. Prava, V., R.T. Clemen, B.F. Hobbs, and M.A. Kenney, 2015: Partition dependence and carryover biases in subjective probability assessment surveys for continuous variables: Model-based estimation and correction. *Importance*: Accurately assessing public preferences on key NOAA issues like "Is urban stream restoration worth it?" requires new methods to correct hidden survey biases. *POC*: M. Kenney

10-16-15 **Kenney Coauthors ESA Guest Editorial** Melissa Kenney

CICS-MD Scientist Melissa Kenney (supporting OAR/Climate Program Office) coauthored a guest editorial in the October issue of *Frontiers in Ecology and the Environment*, a publication of the Ecological Society of America (ESA). In it, she and her coauthor assert that the scientific community struggles to systematically document the magnitude and distribution of climate impacts and to establish whether the nation is effectively adapting because of a lack of indicators of change. *Importance*: NOAA is a leader in tracking changes in the physical climate system and already has its own climate indicators program. *POC*: M. Kenney

8-6-2015 **CPO Web Article Features CICS Indicators Task** Melissa Kenney
"The USGCRP indicator effort, which NOAA significantly supported through a CICS grant, announced a pilot indicator release on May 6....CPO partially supported Melissa Kenney's time as a AAAS Science and Technology Fellow (2010-2012) to staff and lead the NCA indicators workshops and work with the NCADAC Indicator Work Group. Given the interest by the scientific and user communities and CPO's support of sustained assessment activities, they provided Kenney's research team grant funding via CICS-MD to develop recommendations (in collaboration with 200+ scientists) and a pilot for USGCRP to consider as part of foundational NCA sustained assessment activities." http://cpo.noaa.gov/AboutCPO/AllNews/TabId/315/ArtMID/668/ArticleID/292084/USGCRP-releases-Prototype-Indicators-System-.aspx. To explore the USGCRP indicators, visit: www.globalchange.gov/browse/indicators. Indicators of climate change communicate how the environment is changing, identify risks, and inform decisions about policy, planning, and resource management.

10-12-15 **Kenney Elected to DAS Governing Board** Melissa Kenney
I was just elected to the governing board for one of my main professional societies, the Decision Analysis Society of INFORMS (operations research and analytics). https://www.informs.org/Community/DAS
I am also co-chairing the Decision Analysis Society cluster at the upcoming annual INFORMS meeting in November, with several excellent sessions focused on decision analysis and environmental applications

12-2-15 **SAGE Webinar** Melissa Kenney
I wanted to share with you a Webinar announcement for the Sustainable Adaptive Gradients in the Coastal Environment (SAGE) Webinar series. SAGE is an NSF RCN focused on grey, green, and cultural infrastructure resilience in the Northeast U.S. and Caribbean nations; I'm a co-PI on the grant. I hope you can join us on Friday, and please feel free to share this announcement with others.

2-1-16 **Kenney Pubs** Melissa Kenney
The paper describing the process and lessons learned from the development of the U.S. National Climate Indicators System -- written by me, Tony Janetos, and Glynis Lough -- was just released by Climatic Change! The article and supplementary online materials are all open access and available at: http://link.springer.com/article/10.1007/s10584-016-1609-1. Additionally, you may be interested in an editorial written by me and Tony Janetos calling for developing better indicators of climate impacts that was published in Frontiers in Ecology and the Environment in October 2015. You can access that paper at: http://onlinelibrary.wiley.com/doi/10.1890/1540-9295-13.8.403/epdf. Both articles were developed as a result of a NOAA Climate Program Office grants NA09NES4400006 and NA14NES4320003 (Cooperative Institute for Climate and Satellites-CICS) at the University of Maryland/ESSIC.

Performance Metrics	
# of new or improved products developed (please identify below the table)	12
# of products or techniques submitted to NOAA for consideration in operations use	11
# of peer reviewed papers	3 published, 1 in revision
# of non-peered reviewed papers	2
# of invited presentations	27
# of graduate students supported by a CICS task	1
# of graduate students formally advised	1
# of undergraduate students mentored during the year	14