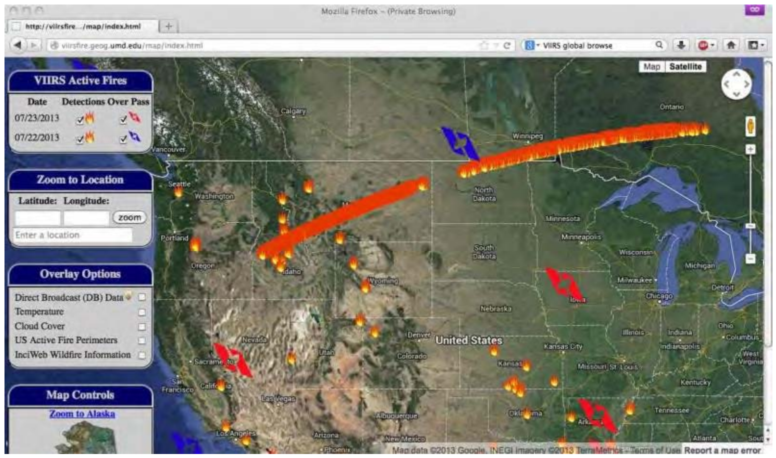


*Figure 1: Example of spurious line of fires present in the IDPS-based Active Fires EDR caused by an improperly calibrated M13 scan acquired on 23 July 2013.*

We continued our assessment of the VIIRS SDRs in mid-2013 and identified additional problems in several bands with respect to the conversion of radiance to brightness temperatures (Figure 2). Several DRs have been filed as a result of our efforts.

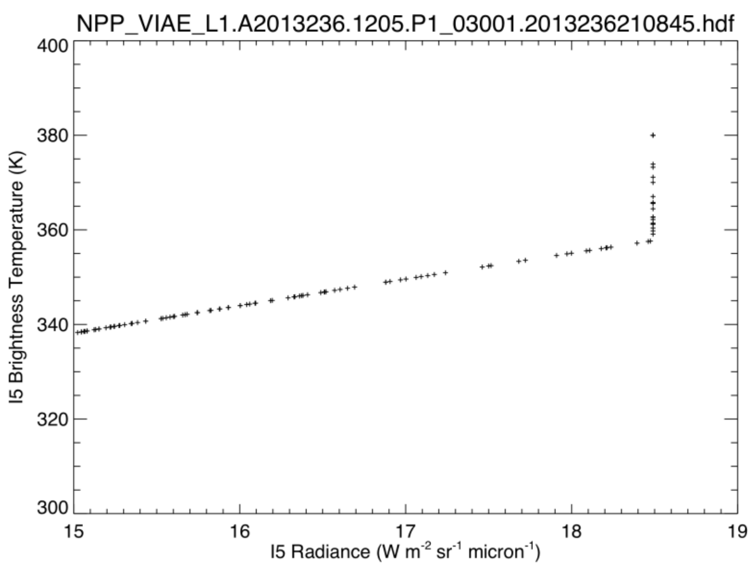


*Figure 2: Example of flawed band I5 brightness temperatures present in August 2013 VIIRS SDR. Unlike the pattern shown here, there should of course be just one brightness temperature associated with each radiance value.*

In August 2013 we attended the Suomi NPP EDR Product Review for Active Fires, Surface Reflectance, and Vegetation Indices. Based on our product development and validation results presented to the review panel, the VIIRS Active Fire (formerly Active Fires) EDR was assigned a maturity status of *provisional* in October.

In December 2013 we updated the *Joint Polar Satellite System (JPSS) Algorithm Specification Volume II: Data Dictionary for the Active Fires* at the request of our NESDIS lead.

**PLANNED WORK**

- Continue assessment of VIIRS SDR radiance, brightness temperature, and QF data used to generate the VIIRS Active Fire product.
- Continue work to refine the algorithm parameters and improve performance.
- Transition algorithm to operations (NDE or IDPS).

**PUBLICATIONS**

Csiszar, I., W. Schroeder, L. Giglio, E. Ellicott, K. P. Vadrevu, C. O. Justice, and B. Wind (2014), Active fires from the Suomi NPP Visible Infrared Imaging Radiometer Suite: Product status and first evaluation results, J. Geophys. Res. Atmos., 119, doi:10.1002/2013JD020453.

**DELIVERABLES**

- Replacement fire code implementing MODIS Collection 6 algorithm;
- Ongoing quality assurance of VIIRS Active Fire EDR and selected SDRs;
- Updates to assorted JPSS documentation, including the *Joint Polar Satellite System (JPSS) Algorithm Specification Volume II: Data Dictionary for the Active Fires*.

**PRESENTATIONS**

Csiszar, I., Schroeder, W., Giglio, L., Wind, B., Ellicott, E., and Justice, C. O., 2013: VIIRS Fire Products Update, *GOFC-Gold Land Monitoring Symposium*, 15-19 April 2013, Wageningen, Netherlands.

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

## Improvement of ATMS Snowfall Rate Algorithm

| | |
|---|---|
| **Task Leader** | Cezar Kongoli |
| **Task Code** | CKCK_ATMS_13 |
| **NOAA Sponsor** | Huan Meng |
| **NOAA Office** | NESDIS/STAR |
| **Percent contribution to CICS Themes** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0%. |
| **Main CICS Research Topic** | Future Satellites: Scientific Support for the JPSS Mission |
| **Percent contribution to NOAA Goals** | Goal 1: 20%; Goal 2: 80% |

**Highlight**: A prototype ATMS Snowfall Rate algorithm has been developed in a JPSS Proving Ground (PG) and STAR End of Year (EOY) co-sponsored project. The focus of this project is to investigate the possibility to improve the assumptions in the algorithm about Ice Water Content based on better understanding of cloud physics and its relationships with the environmental conditions.

**BACKGROUND**

Building on the operational AMSU/MHS Snowfall Rate (SFR) product, a prototype ATMS SFR algorithm has been developed in a JPSS Proving Ground (PG) and STAR End of Year (EOY) co-sponsored project. While the validation of the AMSU/MHS product has demonstrated that the product generally performs well compared to radar SFR and gauge measurements, some important assumptions and simplifications made in the algorithm are far from ideal due to various limitations. A critical assumption in the ATMS algorithm is that the ratio between the Ice Water Content (IWC) at the cloud base and the average IWC in the cloud column is a constant, . IWC is the amount of ice (converted to liquid) in unit volume of atmosphere. Ice crystals grow as they fall down the cloud column as a result of supercooled water vapor deposition, i.e. Bergeron process, and aggregation. This mechanism leads to higher IWC at the lower portion of the cloud than in the upper portion. In the current algorithm, the assumption of constant IWC and then compensating the non-uniform IWC distribution with a ratio, , allows SFR to be represented as an integral that can be solved numerically (Meng, et al., 2012). This assumption essentially modifies the initial SFR retrieval with a constant scaling factor. However, a previous study has revealed that a nonlinear relationship exists between radar snowfall rate and the satellite retrieved snowfall rate for most snowstorms. This observation could be an indication that instead of being a constant is actually a function of the unscaled snowfall rate.

The focus of this project is to investigate the possibility to improve the assumptions about IWC based on better understanding of cloud physics and the relationship between IWC and the environmental conditions such as temperature and water vapor. The project's federal partner is Huan Meng and the work has been carried out by CICS scientist Jun Dong.

**ACCOMPLISHMENTS**

To study the vertical distribution of IWC and its relationship to atmospheric conditions and microwave sensor measurements, a comprehensive data set has been developed that includes matching

Advanced Microwave Sounding Unit-A (AMSU-A) and Microwave Humidity Sounder (MHS) brightness temperatures, CloudSat IWC profiles, ECMWF temperature and specific humidity profiles, and other ancillary data. CloudSat is NASA's spaceborne cloud radar that operates at 94 GHz frequency. The radar is highly sensitive to small particles of liquid water and ice that constitute clouds, and can provide 3D information of the particles. A CloudSat-based IWC profile product (Austin et al., 2009) has been developed at Colorado State University and provides the IWC information for this study. ECMWF is one of the best numerical weather prediction (NWP) models currently available. The temperature and water vapor profiles from ECMWF will be used to study their impact on the IWP distribution in the cloud column.

Three sets of IWC profiles have been selected which respectively corresponds to light, medium, and heavy snowfall. Figure 1 shows one of the profiles from the heavy snowfall group. The IWC, temperature, and specific humidity are depicted in the plot against height. The green shaded area corresponds to the favorite snow production zone as indicated by the IWC profile. The blue shaded area denotes the temperature range that favors rapid dendritic ice growth (Fig. 2) (Auer and White, 1982). In Fig 1, the IWC gradient is the steepest where the ambient temperature reaches the dendrite favoring zone. Besides temperature, availability of moisture is also a necessary condition for ice particle to grow effectively. The specific humidity profile shown in Fig 1 reveals that there is indeed abundant water vapor in the clouds that can sustain the continuous growth of ice crystals. This case study demonstrates that water vapor and temperature profiles can potentially provide information on the distribution of IWC.

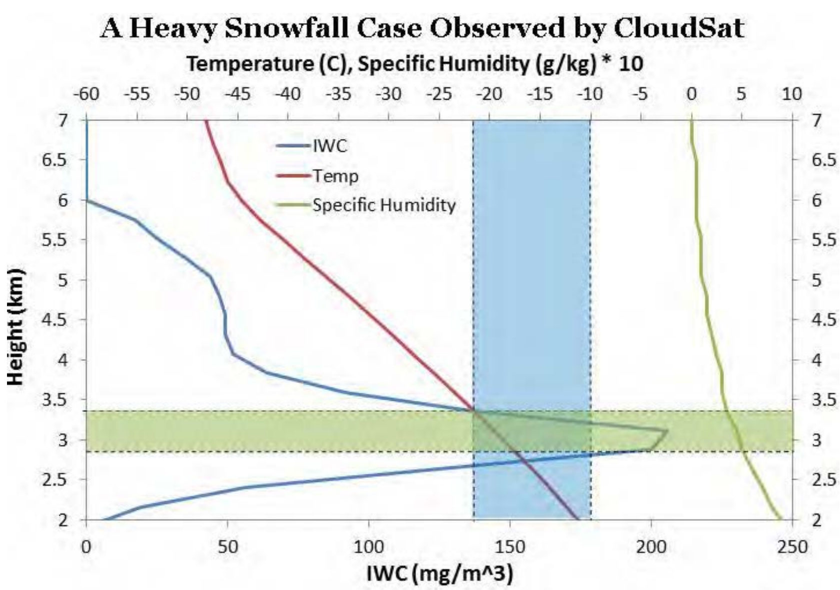


*Figure 1: CloudSat retrieved IWC profiles from a heavy snowfall case. Also included are the corresponding ECMWF temperature and water vapor profiles. The green shaded area corresponds to the favorite snow production zone as indicated by the IWC profile. The blue shaded area denotes the temperature range that favors rapid dendritic ice growth.*

In addition, the ice morphology diagram in Fig 2 illustrates the relationship between ice habit shape/size and temperature and supersaturation. Theoretically, the microphysics of the ice crystals can be determined, at least qualitatively, if temperature and the degree of supersaturation are known. This information will help to improve the parameterization of the SFR algorithm.

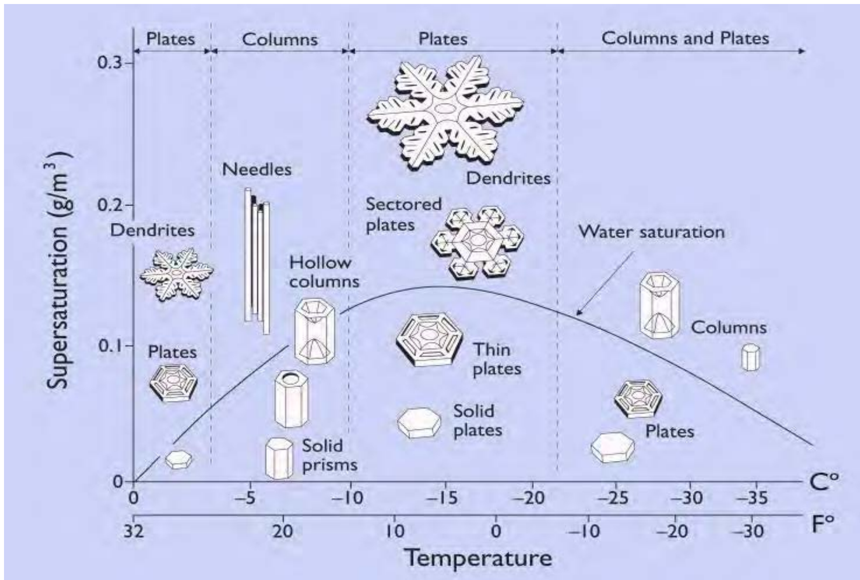


*Figure 2: The relationship between ice habit shape/size and temperature and supersaturation.*

**PLANNED WORK**

This is an on-going effort due to the late start of the project that was caused by staffing issue. The following work will be carried out in the next 3 months:

- Investigate IWC vertical structures under different snowfall intensities and their relationship with atmospheric conditions including temperature and water vapor profiles
- Based on the study on IWC, explore the possibility to improve the assumptions used in the current ATMS SFR algorithm

**REFERENCES**

Auer, A. H. Jr., and J. M White, 1982: The Combined Role of Kinematics, Thermodynamics, and Cloud Physics Associated with Heavy Snowfall Episodes*, J. Meteor. Soc. Japan*, 60, 591-597.

Austin, R. T., A. J. Heymsfield, and G. L. Stephens, 2009: Retrieval of ice cloud microphysical parameters using the CloudSat millimeter-wave radar and temperature*. J. Geophys. Res*., 114, D00A23, doi:10.1029/2008JD010049.

Meng, H., B. Yan, R. Ferraro, C. Kongoli. Snowfall rate retrieval using passive microwave measurements. *12th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment*, Frascati, Italy, 5-9 March, 2012.

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

**Validation of Cryospheric EDRs from GCOM**

| | |
|---|---|
| **Task Leader** | Cezar Kongoli |
| **Task Code** | CKCK_EDR_13 |
| **NOAA Sponsor** | Jeff Key |
| **NOAA Office** | NESDIS/STAR |
| **Percent contribution to CICS Themes** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0%. |
| **Main CICS Research Topic** | Future Satellites: Scientific Support for the JPSS Mission |
| **Percent contribution to NOAA Goals** | Goal 1: 20%; Goal 2: 80% |

**Highlight**: The Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument launched on May 18, 2012 onboard the Global Change Observation Mission 1st - Water "SHIZUKU" (GCOM-W1) satellite. A suite of AMSR2 operational algorithms have been developed for the retrieval of snow cover, snow depth and Snow Water Equivalent using heritage AMSR-E data as proxy.

**BACKGROUND**

A suite of operational snow algorithms have been developed for the new AMSR2 instrument and are being tested for operational implementation at NOAA as Option 2 products. The suite of snow products includes snow cover, snow depth and Snow Water Equivalent (SWE). The snow cover algorithm is a decision tree classification scheme originally developed for the SSM/I instrument. The algorithm is enhanced with a climatology test which applies snow cover climatology derived from the Interactive MultiSensor Snow and Ice Mapping Unit (IMS). The snow depth algorithm is based on the NASA AMSR-E empirical dynamical approach whereby algorithm regression coefficients are dynamically adjusted (computed from brightness temperatures). SWE is derived from the retrieved SD and climatologically determined snow density.

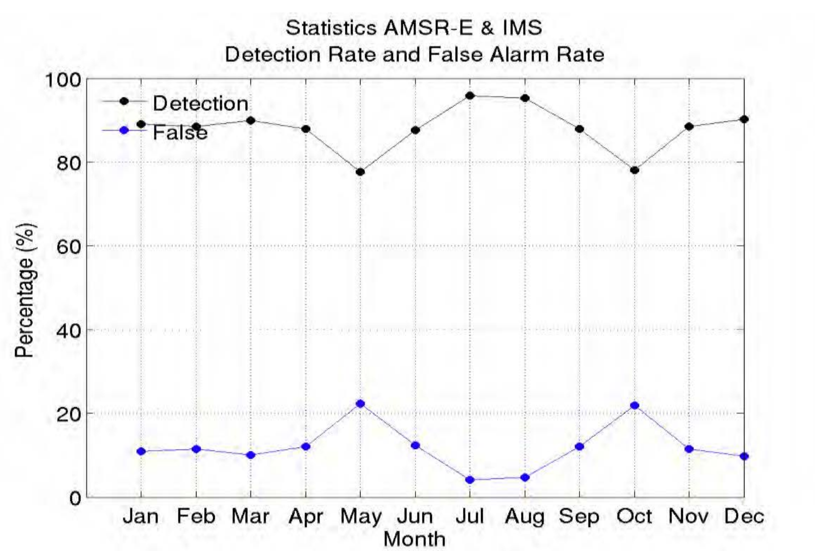


*Figure 1. Snow cover algorithm statistics with respect to IMS as reference ground truth.*

**ACCOMPLISHMENTS**

Snow cover algorithm and code have been developed and its performance tested against IMS snow cover as ground truth reference. Figure 1 presents statistical measures of accuracy with respect to IMS - detection rate and false alarm - which meet operational requirements.

Snow depth algorithm code has also been developed and preliminary testing performed, whereas SWE algorithm is underdevelopment. Table 2 below present performance statistics (standard deviation and bias) with respect to snow depth measurements from in-situ stations (table) and a map of retrieved Snow Depth distribution (right).

| | STD (cm) | Bias (cm) | Number of samples |
|---|---|---|---|
| All data | 17.97 | 0.39 | 130,036 |
| ff=0 | 17.20 | -3.69 | 69,139 |
| 0.0<ff<=0.5 | 18.26 | 6.14 | 35,232 |
| ff>0.5 | 16.78 | 3.46 | 25,665 |

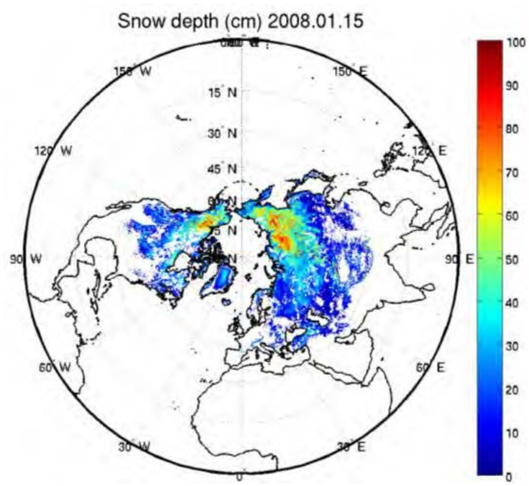


*Figure 2: Snow Depth algorithm statistics with respect to in-situ stations (left) and a map of retrieved Snow Depth (right)*

**PLANNED WORK**

- Continue work to test the SWE algorithm
- Optimize snow cover algorithm AMSR-E thresholds for improved performance
- Improve Snow Depth Algorithm performance for deeper snow
- Improve Snow Water Equivalent Algorithm

**PRESENTATIONS**

Lee, Y. C. Kongoli and J. Key, "Preliminary snow products from Global Change Observation Mission (GCOM) AMSR2 Instrument, (poster) 2014, AGU Fall Meeting, 15-19 September 2013, San Francisco, CA.

Lee, J-K., C. Kongoli, J. Key, 2013. "Preliminary snow products for the Global Change Observation Mission (GCOM) AMSR2 instrument", 2013 AGU Fall Meeting, San Francisco, CA, 3-7 December 2013 (poster).

Lee, J-K., C. Kongoli, J. Key, 2013. "Preliminary AMSR2 snow products", NASA Snow Remote Sensing Workshop, Boulder, Colorado, August 14-16, 2013 (oral).

**PUBLICATIONS**

Lee, Y. C. Kongoli and J. Key, 2014, Evaluation of NOAA's AMSR2 Snow Algorithms, submitted to *Remote Sensing of Environment*

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

**Extension of ATMS Snowfall Detection Algorithm to Colder Regions: AMSR2 for IMS V3 Snow Depth**

| | |
|---|---|
| **Task Leader** | Cezar Kongoli |
| **Task Code** | CKCK_JPSS_13 |
| **NOAA Sponsor** | Jeff Key |
| **NOAA Office** | NESDIS/STAR |
| **Percent contribution to CICS Themes** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0%. |
| **Main CICS Research Topic** | Future Satellites: Scientific Support for the JPSS Mission |
| **Percent contribution to NOAA Goals** | Goal 1: 20%; Goal 2: 80% |

**Highlight**: A new statistical algorithm for detection of snowfall over land from ATMS has been developed. The new algorithm computes the probability of snowfall using logistic regression from principal components of high frequency brightness temperatures at 89 GHz and above. Evaluation of the algorithm shows significant skill in capturing snowfall in colder weather. The IMS V3 Blended Snow Depth Analysis is being transitioned to operations. Work is on-going to ingest AMSR2 snow depth into the analysis for blending microwave with in-situ snow depth.

**BACKGROUND**

A new statistical algorithm for detection of snowfall over land from ATMS measurements have been developed that can detect snowfall in colder weather. The new algorithm computes the probability of snowfall using logistic regression from principal components of high frequency brightness temperatures at 89 GHz and above. To derive the algorithm, ground truth surface weather data including snowfall occurrence were collected during two winter seasons in 2012-2013 and 2013-2014. A two-step algorithm is developed that optimizes retrievals over two snow regimes – "warm" and "cold" snow - and the limb-corrected brightness temperature at the ATMS oxygen absorption channel 53.6 GHz is used as temperature proxy to define the regimes. Evaluation of the algorithm with several snowfall events over US shows significant skill and robustness in capturing snowfall in variable weather conditions including colder weather.

A new snow depth analysis product has been developed and integrated into IMS Version 3. The analysis is an optimal interpolation scheme blending microwave and in-situ data, as well as analyst estimates generated interactively to produce a daily 4-km snow depth product over Northern hemisphere. Work is on-going to ingest the new GCOM-W1 AMSR2 snow depth into the analysis.

**ACCOMPLISHMENTS/PLANNED WORK**

- New ATMS dataset collected: Collected hourly surface observations including snow fall occurrence for two consecutive snow seasons between 2012-1014 and matched these observations with ATMS.

- New Findings with important scientific and operational implications**:** Statistical analysis showed that in relatively warm weather, snowfall tends to be associated with significantly lower brightness temperatures than no snowfall. In colder weather conditions, however, snowfall tends to occur at warmer temperatures and higher microwave brightness temperatures at opaque channels than no snowfall. We hypothesize that the lower brightness temperatures for snowfall in warmer weather is attributed to scattering by ice particles that dominates the signal, which for colder weather is insignificant due to the predominance of light snowfall. Based on these results.

- <u>A New ATMS Algorithm for colder weather:</u> A New ATMS snowfall algorithm based on Principal Component + Logistic Regression that computes probability of snowfall in a wide range of weather conditions. Below is an example application of ATMS snowfall detection algorithm applied in concert with the new ATMS snowfall rate on February 13, on a significant snowstorm. Shown is also coincident NEXRAD image. Work continues to test and improve the newly develop algorithm.

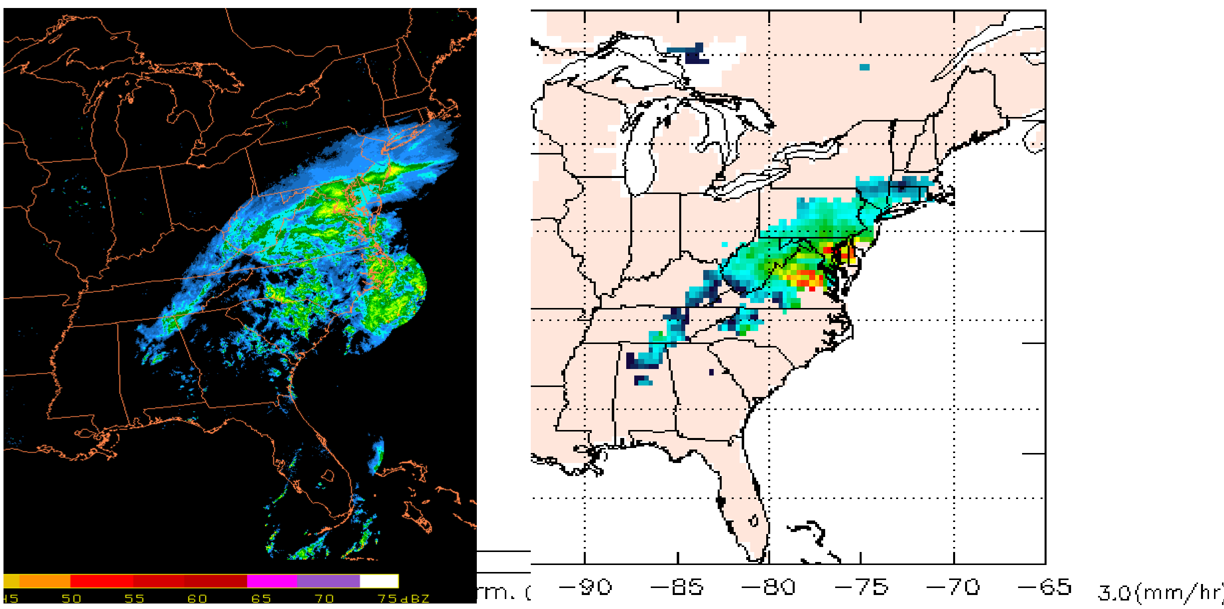


*Figure 1: NEXRAD Reflectivity (left) and new ATMS Snowfall Detection and Snowfall Rate Algorithm on February 13, 2014.*

**PRESENTATIONS**

Meng, H., **C. Kongoli**, N. Wang, J. Dong, R. Ferraro, B. Yan and L. Zhao, 2014, (oral) Snowfall Rate Retrieval using NPP ATMS Passive Microwave Measurements', 13th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment, Pasadena, California, March 24-27, 2014.

**Kongoli, Cezar**, 2013: Snowfall detection using ATMS measurements, *2nd Annual CICS-MD Science Meeting*, College Park, MD (6-7 November), http://cicsmd.umd.edu/assets/1/7/5.6_Kongoli.pdf

Meng, H., B. Yan, R. Ferraro, and **C. Kongoli**, 2013. "Snowfall Rate Retrieval using AMSU/MHS Measurements", 27th Conference on Hydrology, 93rd American Meteorological Society Annual Meeting, Austin, TX, 6-10 January, 2013 (poster).

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

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

| | |
|---|---|
| **Task Leader** | Yuling Liu |
| **Task Code** | EBYL_TSJL_13 |
| **NOAA Sponsor** | Yunyue Yu |
| **NOAA Office** | NESDIS/OSD/SGSP/SEID |
| **Contribution to CICS Themes (%)** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0%. |
| **Main CICS Research Topic** | Future Satellites: Scientific Support for the JPSS Mission |
| **Contribution to NOAA Goals (%)** | Goal 1:20%; Goal 2: 80%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0% |

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

**BACKGROUND**

This report summarizes the ongoing Joint Polar-Orbiting Satellite System (JPSS) project "Satellite Land Surface Temperature (LST) and Albedo". The NPP satellite has been launched on October 27, 2011. The Visible Infrared Imaging Radiometer Suite (VIIRS) provides a majority of the Environmental Data Records (EDR) from the NPP satellite. One of the key EDRs is the VIIRS Land Surface Temperature (LST), which is derived from the VIIRS data collection using a set of dual and split-window regression algorithms. The coefficients of the LST algorithm are surface type dependent, referring the International Geosphere-Biosphere Programme (IGBP) types, separating day and night conditions. Further and continuous testing of the VIIRS LST is needed to evaluate and then to improve the LST product, for ensuring that it meets the mission's requirement.

**ACCOMPLISHMENTS**

We have been conducting the test and evaluation on the VIIRS LST data since January 2012 when the NPP VIIRS LST data stream started, and we found some problems. The LST algorithm software and look-up tables (LUTs) therefore have been updated accordingly. The LST product has reached the provisional status ready for operational evaluations by users.

In detail, the accomplishments include

1) Evaluation of NPP VIIRS LST product with beta maturity. The evaluation is performed through the cross satellite comparison and ground in-situ comparison.
    - The cross comparison is mainly conducted with MODIS AQUA , at various spatial and temporal frame over the Simultaneous Nadir Overpasses (SNO) and near SNO pass. The analysis is done at global scale, regional scale and single granule scale for the whole year and representative months of each season.
    - Ground in-situ evaluation is performed with the data from Surface Radiation Budget Network (SURFRAD), U.S. Climate Reference Network (CRN), as well as ground observations from Africa and China. Related results have been presented in the conference or included in publications. 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.

2) Improvement of land surface temperature (LST) EDR product for the NPP/JPSS mission. Readiness for proposing SNPP LST EDR product maturity status to be provisional version.
   - In evaluating the VIIRS beta LST product, it was found that BT-difference correction is needed for current split-window algorithm; new emissivity dataset (MODIS 10-year average) is applied for this LUT update; the BT-difference correction is performed using MODIS LSTs as reference
   - The updated LUT has been evaluated by comparisons between the new VIIRS LSTs and the SNO MODIS LSTs, as well as comparisons against SURFRAD in-situ LSTs. The overall comparison results meet the L1RD requirements (some are marginal, though). The updated LUT for VIIRS provisional LST release is ready. Further improvement is needed after more evaluations being performed.
3) Maintain the software package and related documentations
   - Support and 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, AOD and some other related documentations update.
4) Validation tool development. Related Tools are developed to support LST evaluation and calibration work.

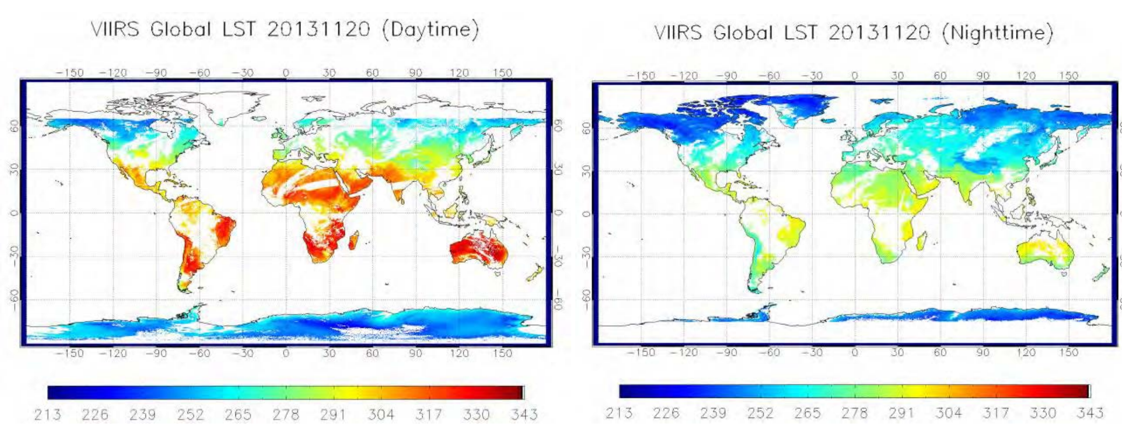


*Figure 1: An example of global provisional VIIRS LST image on Nov. 20, 2013, daytime (left) and nighttime (right)*

All project deliverables (documentation and software) and milestones have been accomplished as planned. Further improvement is needed after more evaluations being performed.

**PLANNED WORK**

- Continue work to monitor and assess the performance of the VIIRS LST EDR product
- Continue work to improve LST product and support tuning for J1 readiness. This work includes the investigation of the algorithm change for VIIRS LST product.
- Supporting the validation tool development

- Update LST software code and ATBD documentation and support the NPP/JPSS Mission Management

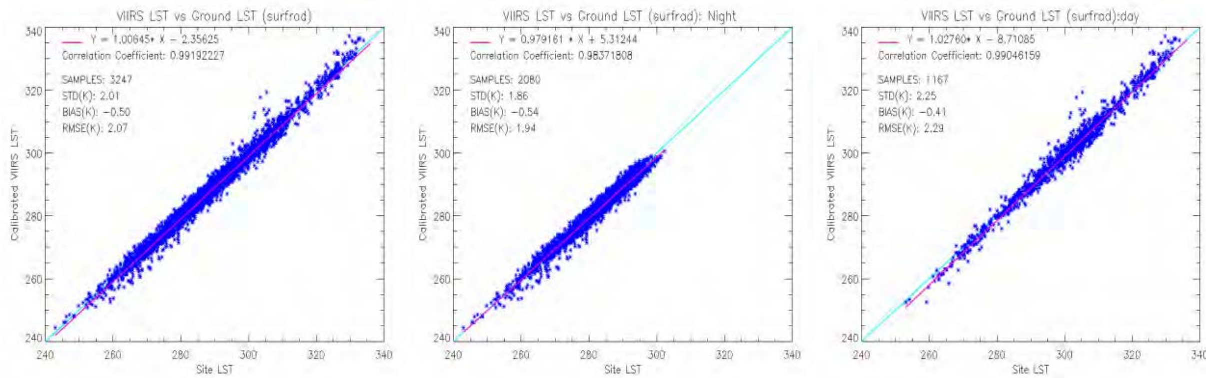


*Figure 2. Ground evaluation results from SURFRAD for whole day(left), nighttime(middle) and daytime (right). Two years of ground data in 2012 and 2013 over six SURFRAD sites are used in the evaluation.*

**PUBLICATIONS**

Yuling Liu, Yunyue Yu, Donglian Sun, Dan Tarpley, Li Fang,Effect of Different MODIS Emissivity Products on Land-Surface Temperature Retrieval From GOES Series,Geoscience and Remote Sensing Letters, IEEE ,Vol. 10(3),May 2013.

Sun, Donglian, Yunyue Yu, Li Fang, Yuling Liu, 2013: Toward an Operational Land Surface Temperature Algorithm for GOES. J. Appl. Meteor. Climatol., 52, 1974–1986. doi: http://dx.doi.org/10.1175/JAMC-D-12-0132.1

Hua Li, Donglian Sun, Yunyue Yu, Hongyan Wang, Yuling Liu, Qinhuo Liu, Yongming Du, Heshun Wang and Biao Cao,"Evaluation of the VIIRS and MODIS LST products in an arid area of Northwest China", Remote Sensing of Environment 142(2014) 111-121.

Yuling Liu, Yunyue Yu, Zhuo Wang, Ivan Ciszar and Pierre Guillevic, “Assessment of Post-launch S-NPP VIIRS Land Surface Temperature Product”, submitted to Geophysical Research-AtmospheresJournal, special issue on Supmi NPP Calibration and Validation Science Results

**PRESENTATIONS**

Yuling Liu, Yunyue Yu, Cezar Kongoli, Zhuo Wang and Peng Yu, "Evaluation of the Suomi NPP VIIRS Land Surface Temperature Product", AMS 94th Annual Meeting on Feb. 2-6, 2014, Atlanta.

Yunyue Yu, Ivan Csiszar, Yuling Liu, Zhuo Wang, Jeffrey Privette, Pierre Guillevic, "JPSS-NPP Land Surface Temperature Product: Beta and Provisional release Status", AMS 94th Annual Meeting on Feb. 2-6, 2014,Atlanta.

Zhuo Wang, Yunyue Yu, Yuling Liu and Peng Yu, "Using the Model Simulation to Improve the Land Surface Temperature Retrieval for JPSS and GOES-R Missions", AMS 94th Annual Meeting on Feb. 2-6,2014, Atlanta.

Yunyue Yu, Ivan Csiszar, Yuling Liu, Zhuo Wang, Jeffrey Privette, Pierre Guillevic, "JPSS-NPP Land Surface Temperature Product: Beta and Provisional release Status", AMS 94th Annual Meeting on Feb. 2-6, 2014,Atlanta.

Poster T-48: Yuling Liu, Yunyue Yu, Zhuo Wang, Dan Tarpley, "Assessment of the Suomi NPP VIIRS Land Surface Temperature Product-Beta to Provisional Maturity", NOAA Satellite Conference, April 8-12, 2013

Poster T-89: Zhuo Wang, Yunyue Yu, Wei Guo, Yuling Liu, Dan Tarpley, Ivan Csiszar, "Radiance-based Validation of VIIRS Land Surface Temperature Product", NOAA Satellite Conference, April 8-12, 2013

Oral presentation: Yunyue Yu, Ivan Csiszar, Yuling Liu, Zhuo Wang, Peng Yu, Jeff Privette, Pierre Guillevic, "JPSS S-NPP land surface temperature product: Beta and Provisional releases", 5th EUMETSAT LSA SAF Workshop, June 17-19, 2013.

Yuling Liu, Yunyue Yu, Zhuo Wang and Peng Yu, "Evaluation of the Suomi NPP VIIRS Land Surface Temperature Product", CICS science meeting, November, 2013

Liu, Yuling, 2013: Satellite Land Surface Temperature Development, CICS-MD Newsletter (June).

**OTHER** (e.g., awards; outreach…

- Yuling Liu, SMCD Certificate of Appreciation for outstanding performance and lasting contributions to the Satellite Instrument Calibration and Product Developments, Awarded date: Jan. 30, 2014
- Yuling Liu, Nominee of STAR Certificate of Appreciation for outstanding performance and lasting contributions to the Satellite Instrument Calibration and Product Developments, Awarded date: May. 29, 2014
- Zhuo Wang, Nominee of STAR Certificate of Appreciation for outstanding performance and lasting contributions to the Satellite Instrument Calibration and Product Developments, Awarded date: May. 29, 2014

**PERFORMANCE METRICS**

| | **FY13** |
|---|---|
| # of new or improved products developed following NOAA guidance | 1 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 0 |
| # of peer reviewed papers | 3 |
| # of non-peered reviewed papers | 1 |
| # of invited presentations | 9 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**PERFORMANCE METRICS EXPLANATION**

This year, all project deliverables (documentation and software) and milestones have been accomplished as planned. The LST product has reached provisional maturity status, ready for operational evaluations from users. We have three journal publications on LST retrieval and validation, one non-peer reviewed paper for CICS newsletter, and nine presentations summarizing the algorithm and evaluation results, and a manuscript on VIIRS LST evaluation has been submitted. Another manuscript is under preparation.

**CUNY-CREST Support for Coastal Site Data Uncertainties and *in situ* Validation**

| | |
|---|---|
| **Task Leader** | Samir Ahmed |
| **Task Code** | SASA_CUNY_13 |
| **NOAA Sponsor** | Heather Kilcoyne |
| **NOAA Office** | NESDIS/JPSSPO |
| **Percent contribution to CICS Themes** | Theme 1: 0%; Theme 2: 100%; Theme 3: 0% |
| **Main CICS Research Topic** | Future Satellites: Scientific Support for the JPSS Mission |
| **Percent contribution to NOAA Goals** | Goal 3: 20%; Goal 4: 30%; Goal5: 50% |

**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 and from the hyperspectral HyperSAS to the CCNY server. 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 IDPS.

**BACKGROUND**

The CREST Long Island Coastal Observatory (LISCO) continues to play an important role of support to the NESDIS VIIRS cal/val team. Data from the AERONET SeaPRISM and the hyperspectral HyperSAS collocated on LISCO have provided inputs to permit evaluation of the quality of VIIRS retrieved OC products for typical coastal waters conditions. As part of that, they provided the basis for a statistical analysis carried out with VIIRS, MODIS and AERONET-OC data. This was extended to the examination of the different processing schemes, both NASA and NOAA's IDPS Because satellite OC EDR products are derived from sensor SDR level data which is continuously adjusted with the calibration gains acquired based on the on-board temporal calibration measurement trends, additional vicarious calibration procedures are also usually required for SDR to OC EDR processing to minimize biases due to residual atmospheric correction or absolute calibration errors, and to maximize spectral consistency. The related vicarious calibration factors are derived from various reference sources (e.g. Marine Optical Buoy (MOBY) data, sea surface reflectance model and climatology of chlorophyll-a concentration). As the consequence, the consistency and validity of these overall calibration processes for the broad range of conditions need to be assessed and evaluated. Moreover, the overall optical complexity of the atmospheric-water system in coastal zones makes observation from space highly challenging, particularly for the atmospheric correction step. Attention was therefore also focused on using LISCO data to examine in detail the respective roles of the vicarious calibration procedures and their impact on the VIIRS's OC data retrievals in order to better interpret the physical or biogeochemical meaning of VIIRS data in coastal areas.

This work is a part of the ongoing NOAA NESDIS led activity "Calibration/Validation of JPSS – VIIRS Sensor, and represents a continuation and enhancement of previous undertakings on generation of quality assured in-situ OC data obtained at the Long Island Sound Coastal Observatory (LISCO) site for JPSS-VIIRS cal/val activities. As noted previously, LISCO is uniquely equipped with collocated multi – spectral AERONET SeaPRISM and hyper – spectral HyperSAS instruments and is thus well equipped to provide these services and assits the VIIRS validation team to check on gains usingcoastal site data.

**ACCOMPLISHMENTS**

- Maintained suite of LISCO instruments and carried out instrument calibrations to ensure delivery of high-quality in-situ data to the JPSS-VIIRS cal/val team.
- All instruments of LISCO have been put back in operation after repairing minor damage sustained during hurricane Sandy and subsequent re-calibration of SeaPRISM at NASA.
- Providing a consistent stream of data from the SeaPRISM instrument on Long Island Sound Coastal Observatory (LISCO) to NASA – AERONET and NRL SSC and from the hyperspectral HyperSAS to the CCNY server.
- The quality assured in-situ OC data stream of LISCO enabled us to evaluate the quality of VIIRS retrieved OC products for typical coastal waters conditions. Through statistical analysis carried out between the VIIRS, MODIS and AERONET-OC data, the impacts of the different processing schemes (particularly for the respective roles of the vicarious calibration procedures) on the VIIRS's OC data retrievals are scrutinized in order to aid the scientific community to better interpret the physical or biogeochemical meaning of VIIRS data in coastal areas. A peer-review journal article was published with this work (Remote Sensing of Environment, 2013).

The *nLw* (λ) match-up spectra of the three NASA VIIRS processing schemes (initial, version 2012.2 & 2013.0), and in-situ SeaPRISM for the LISCO location are presented in Fig. 1 exhibiting a qualitative agreement between the VIIRS and SeaPRISM nLw data.

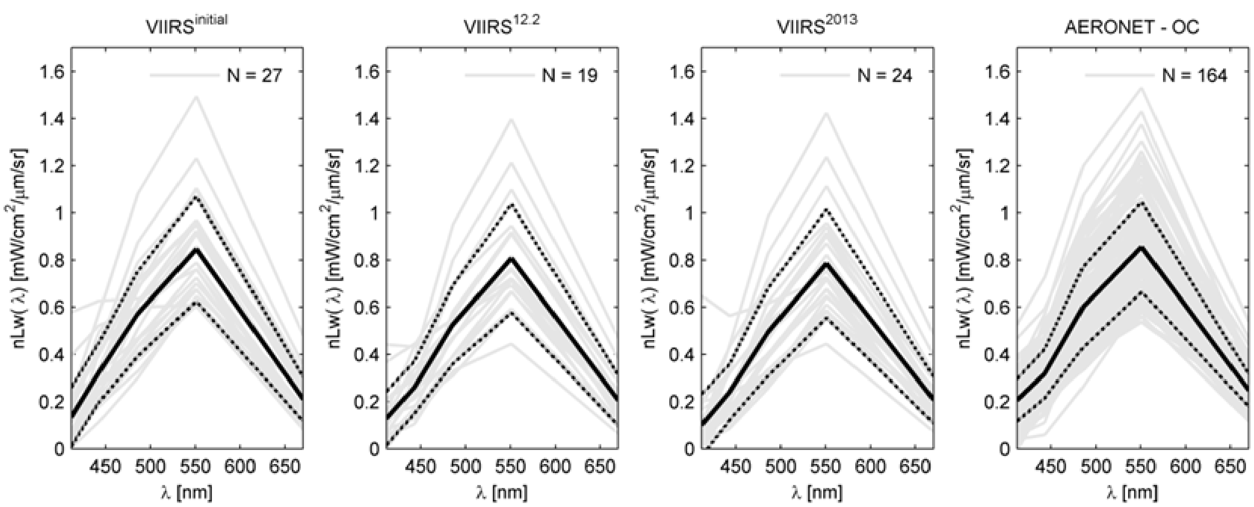


*Figure 1. nLw (λ) match-up spectra of VIIRS$^{initial}$ (1$^{st}$column), VIIRS$^{12.2}$ (2$^{nd}$ column), VIIRS$^{2013}$ (3$^{rd}$ column) and SeaPRISM (4$^{th}$ column) for the LISCO site. N is the total number of spectra. Grey lines represent the individual spectra. Thick black solid lines indicate average and thick dotted lines indicate ± one standard deviation.*

**PLANNED WORK**

- Continue providing stream of data on the LISCO instruments for the calibration/validation of VIIRS sensor and other OC satellites.

- Field measurements in the area of the platform to provide additional matchups for validation VIIRS sensor and other OC satellites.
- Continue work on the improvement of data quality for the satellite – in-situ matchups.
- Assess the impact of atmospheric conditions on the accuracy of retrievals and explore the implementation of approaches to minimize errors and uncertainties in satellite OC retrievals for coastal waters.

**PUBLICATIONS**

S. Hlaing, T. Harmel, A. Gilerson, R. Foster, A. Weidemann, R. Arnone, M. Wang, and S. Ahmed, "Evaluation of the VIIRS ocean color monitoring performance in coastal regions," *Remote Sensing of Environmen*t 139, 398-414 (2013).

S. Ahmed, A. Gilerson, S. Hlaing, A. Weidemann, R. Arnone, M. Wang, “Evaluation of ocean color data processing schemes for VIIRS sensor using in-situ data of coastal AERONET-OC sites,” Proceeding of SPIE 8888, Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions 2013, 88880H (October 16, 2013); doi:10.1117/12.2028821.

S. Ahmed, A. Gilerson, S. Hlaing, I. Ioannou, M. Wang , A. Weidemann, R. Arnone, “Evaluation of VIIRS ocean color data using measurements from the AERONET-OC sites,” Proceeding of SPIE 8724, Ocean Sensing and Monitoring V, 87240L (June 3, 2013); doi:10.1117/12.2017756.

S. Ahmed, A. Gilerson, S. Hlaing, A. Weidemann, R. Arnone, and M. Wang, “Assessments of VIIRS Ocean Color data retrieval performance in coastal regions”, Proceeding of IOCS 2013 meeting, Darmstadt, Germany, 6-8 May 2013.

**PRESENTATIONS**

S. Hlaing, A. Gilerson, A. Weidemann, R. Arnone, M. Wang, and S. Ahmed, “Assessment of VIIRS Ocean Color Data Processing Schemes on the Coastal Sites,” AGU Ocean Science Meeting, Honolulu, Hawaii, February 2014.

S. Ahmed, A. Gilerson, S. Hlaing, A. Weidemann, R. Arnone, M. Wang, “Evaluation of ocean color data processing schemes for VIIRS sensor using in-situ data of coastal AERONET-OC sites,” SPIE Remote Sensing of the Ocean, Sea Ice, Coastal Waters, and Large Water Regions, Dresden, Germany, September 2013.

S. Hlaing, T. Harmel, A. Gilerson, R. Foster, A. Weidemann, R. Arnone, M. Wang, S. Ahmed, “Validation of VIIRS Ocean Color primary products in coastal regions”, CORP Symposium, Madison, Wisconsin, July 2013.

S. Ahmed, A. Gilerson, S. Hlaing, I. Ioannou, M. Wang , A. Weidemann, R. Arnone, “Evaluation of VIIRS ocean color data using measurements from the AERONET-OC sites,” SPIE Ocean Sensing and Monitoring, Baltimore, Maryland, April, 2013.

S. Ahmed, A. Gilerson, S. Hlaing, A. Weidemann, R. Arnone, and M. Wang, “Assessments of VIIRS Ocean Color data retrieval performance in coastal regions”, IOCS 2013 meeting, Darmstadt, Germany, May 2013.

| Performance Metrics | FY13 |
|---|---|
| # of new or improved products developed following NOAA guidance | 0 |

| | |
|---|---|
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops without NOAA guid-ance | 0 |
| # of peer reviewed papers | 1 |
| # of non-peered reviewed papers | 3 |
| # of invited presentations | 0 |
| # of graduate students supported by a CICS task | 4 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 1 |

**PERFORMANCE METRICS EXPLANATION**

The undergraduate student and three of the four graduate students are leveraged.

## CrIMSS Rain Flag

| | |
|---|---|
| **Task Leader** | Wenze Yang |
| **Task Code** | WZRF_CrIMSS_13 |
| **NOAA Sponsor** | Ralph Ferraro |
| **NOAA Office** | NESDIS/STAR/CRPD/SCSB |
| **Percent contribution to CICS Themes** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0% |
| **Main CICS Research Topic** | Future Satellites: Scientific Support for the JPSS Mission |
| **Percent contribution to NOAA Goals** | Goal1: 20%; Goal 2: 80% |

**Highlight:** More extensive validation work has been carried out to confirm the improvement of the new algorithm. The offline rain flag system has been incorporated into the CrIMSS system by introducing fixed and climatological wind speed.

**BACKGROUND**

The NPOESS Preparatory Project (NPP) satellite of NOAA was launched on Oct 28, 2011. On-board sensors on this satellite include the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS), which together would provide the Cross-track Infrared Sounder Microwave Sounder Suite (CrIMSS) Environmental Data Record (EDR), including atmospheric vertical temperature profile, atmospheric vertical moisture profile, etc. The EDR algorithm was originally developed by Northrop Grumman Aerospace Systems (NGAS) for other similar products. The successful operation of the CrIMSS EDR algorithm is a robust verification of the CrIS and ATMS Sensor Data Records (SDRs). Therefore, a task was proposed as a risk reduction for a) the processing of SDRs and EDRs from the CrIS/ATMS, b) the utilization of high spectral resolution infrared data by Numerical Weather Prediction (NWP) centers and c) validation of CrIS/ATMS SDR/EDR algorithms. This project is a subtask to provide algorithm improvements and validation in the area of clouds and precipitation.

The goals of CICS JPSS effort are to i) perform inter-comparisons between the current CrIMSS ATMS cloud water, ice water and precipitation screens with operational derived products, including the MSPPS and MiRS system; ii) document deficiencies of the current NGAS scheme; iii) develop improved clode/ice water and precipitation schemes for use within CrIMSS; iv) document the improvements through inter-comparisons with NGAS scheme; and v) propose an improved rain algorithm to CrIMSS team.

The current NGAS scheme and MSPPS system are based on AMSU-A/B/MHS radiances, so the update of the algorithm is necessary. Additionally, the NGAS scheme used a very preliminary MSPPS algorithm that is several years outdated.

The rain flag information is obtained from ATMS. Comparing to its predecessor AMSU-A/B/MHS, ATMS has some updates regarding to channel frequency and polarization, in addition to spatial resolution. During the first year, some proxy AMSU-A/B/MHS channels were simulated using relative

ATMS channels to compensate these differences, and an offline rain flag system was in shape. During the second year, more extensive validation work has been carried out to confirm the improvement of the new algorithm. The offline rain flag system has been incorporated into the CrIMSS system by introducing fixed and climatological wind speed.

**ACCOMPLISHMENTS**

Our accomplishments during the second year of the project are as follow:

Firstly, more extensive validation work has been carried out to confirm the improvement of the new algorithm. The ground truth data include rain gauge and ground radar data. By doing temporal and spatial statistics, it is shown that the updated algorithm (labeled as the Microwave Surface and Precipitation Processing System, MSPPS) shares comparable properties (correlation, bias, probability of detection (POD), false alarm ratio (FAR), etc) with the Microwave Integrated Retrieval System (MiRS) products, as one example in Figure 1.

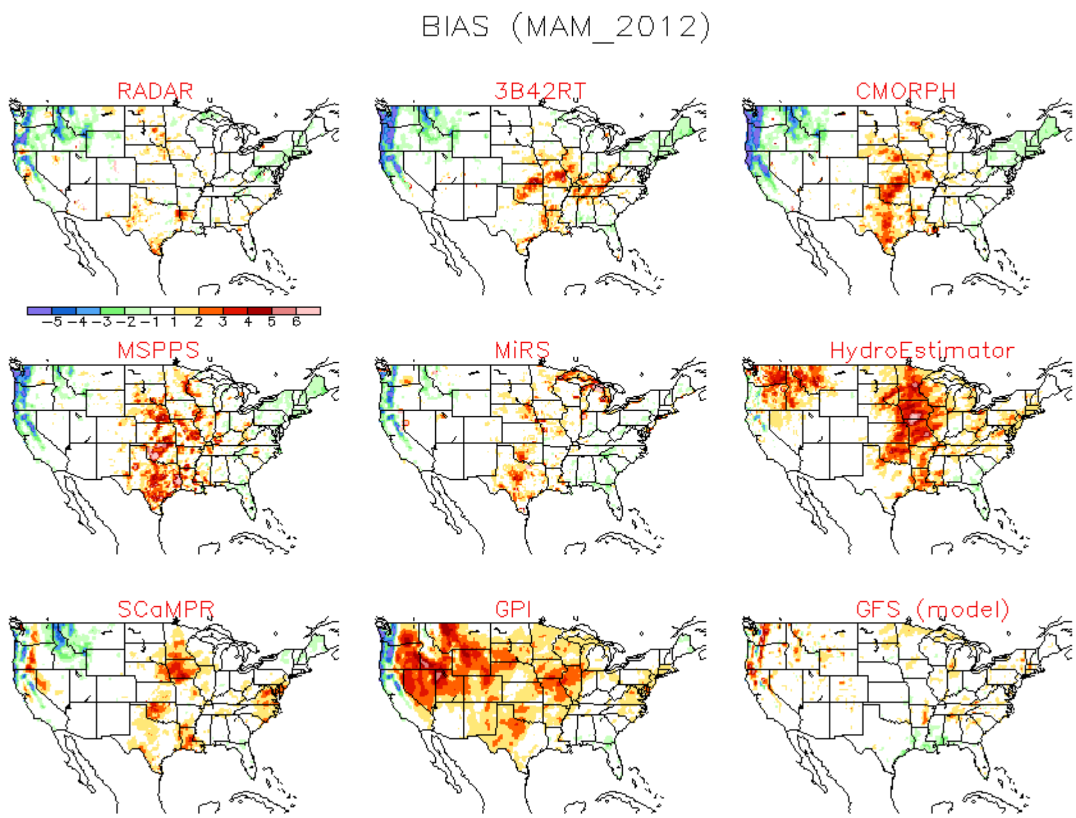


*Figure 1. Bias of rain products, comparing to rain gauge data through US continental of Mar, Apr, and May in 2012.*

Secondly, the offline rain flag system has been incorporated into the CrIMSS system. It is noted that the offline rain flag system, inherited from MSPPS, is written in C language, and the CrIMSS system is written in Fortran language, with the core codes having 1654 lines, relating to the calculation of cloud liquid water, precipitable water, snowfall, surface emissivity, and ultimately rain rate. With careful designation, the interfaces have been seamlessly closed, and the codes have been translated and embedded, now the output of both system is identical, given the same set of inputs.

Thirdly, fixed and climatological wind speeds have been introduced to the CrIMSS system to simplify the calculation while maintaining a satisfactory output. The original MSPPS system needs GFS AVN data sets as input, which increases the complexity of preparing and calculating in the CrIMSS system. With careful analysis, it was recognized that only wind speed information is missing inside the CrIMSS system, other information, such as temperature and humidity profile, surface temperature, can be obtained from within the system, so the interface was redesigned to accept wind speed alone without the input of the huge and realtime GFS AVN data set. Further, we tried to avoid introducing the huge realtime wind speed data set by testing the following four schemes: 1) set low wind speed as 5 m/s globally; 2) set high wind speed as 12.5 m/s globally; 3) interpolate wind speed as a function of latitude; and 4) introduce climatological wind. Our comparison results show that best results are obtained through utilizing scheme four.

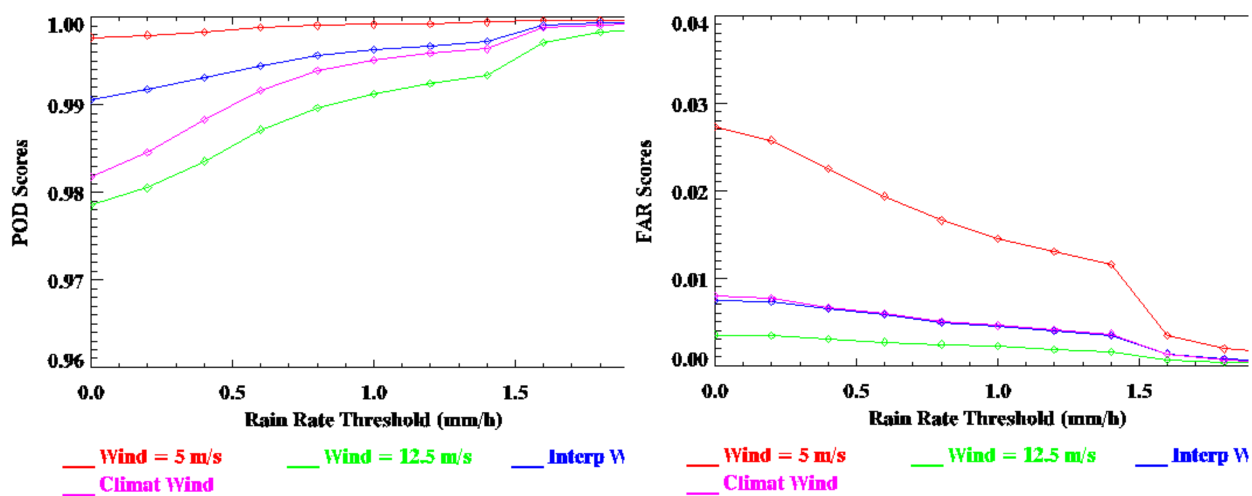


*Figure 2. Compare the statistics of four wind schemes: left panel, probability of detection; right panel: false alarm ratio. Rain data is calculated from MSPPS for May 15, 2012.*

**PLANNED WORK**

Although the improved algorithm developed in the past two year is certainly much better than the original CrIMSS rain flag, Further improvements are planned. In the next phase of the effort, an improved algorithm that formulates the use of the ATMS specific channels in the ice water path and diameter size algorithm (the basis for the rain rate algorithm) would be developed and replace the algorithm that uses the proxy channels.

**PUBLICATIONS**

Divakarla, M., C. Barnet, X. Liu, D. Gu, M. Wilson, S. Kizer, X. Xiong, E. Maddy, R. Ferraro, R. Knuteson, D. Hagan, X.-l. Ma, C. Tan, N. Nalli, A. Reale, A. KMollner, W. Yang, A. Gambacorta, M. Feltz, and F. Iturbide-Sanchez, (2013). The CrIMSS EDR algorithm: Characterization, optimization, and validation, *J. Geophys. Res.* (Accepted).

**PRESENTATIONS**

Yang, W., F. Iturbide-Sanchez, R. Ferraro, M. Divakarla, and A. Reale, "Evaluation and improvement of the NPP CrIMSS Rain Flag" (poster), 94th American Meteorological Society Annual meeting, Atlanta, GA, USA, Feb 2-6, 2014.

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

**Scientific Support for JPSS Instrument Calibration**

| | |
|---|---|
| **Task Leader** | Zhanqing Li |
| **Task Code** | ZLZL_SSJPS_12 |
| **NOAA Sponsor** | Fuzhong Weng |
| **NOAA Office** | NESDIS/STAR/SMCD/SCDAB |
| **Contribution to CICS Themes (%)** | Theme 1: 100% |
| **Main CICS Research Topic** | Future Satellites: Scientific Support for the JPSS Mission |
| **Contribution to NOAA Goals (%)** | Goal 5: 100% |

**Highlight**: CICS Scientist Hu Yang used the Backus-Gilbert (B-G) method as an optimal remapping algorithm, which converts ATMS observations at K, V and W bands from 5.2$^o$ and 2.2$^o$ FOV size to a consistent AMSU-A 3.3$^o$ FOV size. A physical model was developed for ATMS lunar contamination correction, this model has been implemented as operational algorithm of ATMS on-orbit calibration and shows a successful removal of all the lunar contamination on the earth-scene brightness temperature. CICS Scientist Slawomir Blonski has also conducted long-term testing of a new automated procedure for deriving radiometric calibration coefficients for the VIIRS reflective solar bands. The tests not only helped in debugging the revised code, but also enabled improvements of processing coefficients contained in the lookup tables.

## Report by Hu Yang

**BACKGROUND**

Linking ATMS to its heritage instruments AMSU-A/B is highly desirable for climate change study. The oversampling characteristics of ATMS observations make it possible to map the ATMS observations into AMSU-A like observations. In this work, the Backus-Gilbert (B-G) method was used as an optimal remapping algorithm, which converts ATMS observations at K, V and W bands from 5.2$^o$ and 2.2$^o$ FOV size to a consistent AMSU-A 3.3$^o$ FOV size. This method provides not only an optimal average of brightness temperatures within a specified region, but also a quantitative measure of the tradeoff between resolution and noise.

As lunar contamination is observaed in different channel of ATMS, and become a major cause of data gap in TDR if not being properly corrected in calibration. Based on observation data sets, a lunar radiation term is derived as a function of antenna gain, the solid angle of Moon and the brightness temperature of full Moon disk. This algorithm is applied for ATMS on-orbit data processing and shows a successful removal of all the lunar contamination on the earth-scene brightness temperature.

**ACCOMPLISHMENTS**

**1. Optimal ATMS Remapping Algorithm For NWP Application**

The cross-calibrated measurements from Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit-A (AMSU-A) on board different NOAA polar-orbiting satellites have been extensively used for detecting atmospheric temperature trends during the last several decades. AMSU-A observations from NOAA satellites will soon be replaced by the Advanced Technology Microwave Sounder

(ATMS) with the launch of Suomi National Polar-orbiting Partnership (SNPP) satellite. ATMS inherited most of the sounding channels from its predecessor AMSU. It is important to extend AMSU data records with ATMS observations. However, the ATMS field of view (FOV) is different from that of AMSU. In this study, the Backus-Gilbert method was used to optimally remap the ATMS FOVs to AMSU-A like FOVs. Using the simultaneous nadir overpass method, AMSU and ATMS remap observations are then collocated in space and time and the inter-sensor biases are derived for each pair of channels. The brightness temperatures from SNPP ATMS are now well merged into the AMSU data family after remap and cross-calibration.

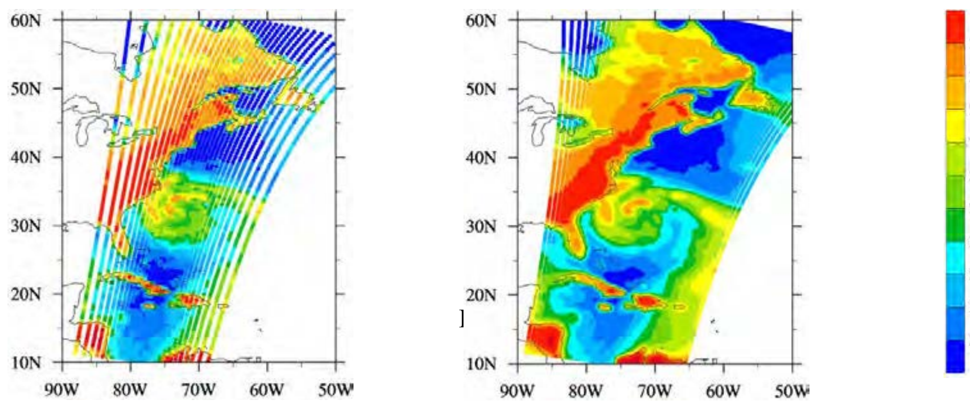


*Figure 1: Comparison of AMSU-A observation and remapped ATMS observation for typhoon "Sandy". The observation is in brightness temperature, color from blue to red indicate scene temperature is from cold to warm. The spatial resolution of ATMS is enhanced from 75 Km to 47Km in nadir after remapping process.*

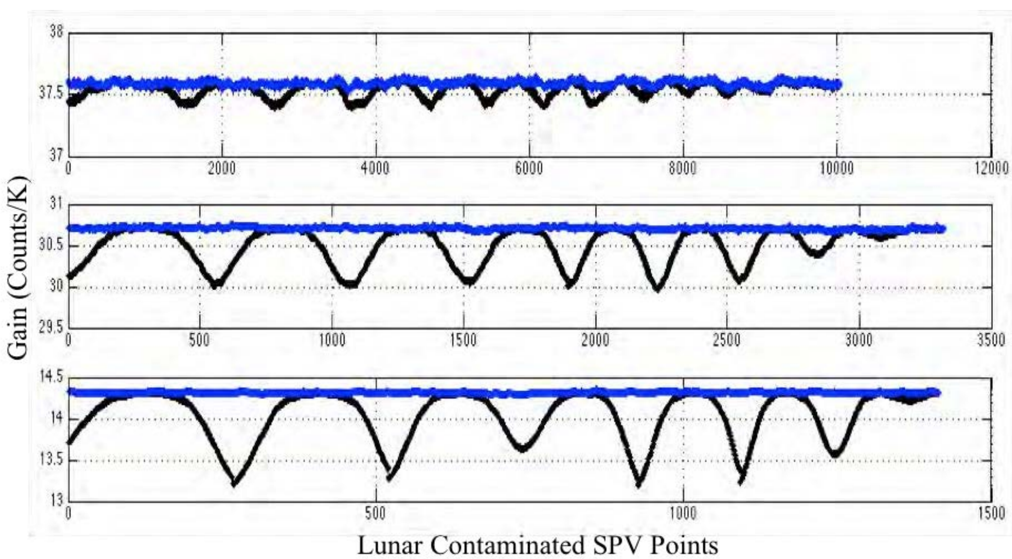


*Figure 2: Comparison of the ATMS calibration gain w/o lunar contamination corrections at channels 1, 8 and 19. Blue lines show the gain after correction and black lines for the gain without the lunar correction.*

**2. On-Orbit Lunar Intrusion Corrections For Advanced Technology Microwave Sounder (ATMS) Instrument**

For ATMS, it is found that the elapse time of LI and the magnitude of the cold count increases are channel dependent. At lower frequency channels having a larger field of view (FOV), the LI events can last as long as 100 minutes and the cold count can increase by 40 counts. At higher frequency channels having a smaller FOV size such as G bands, the lasting time of LI is much shorter but the cold count increase can be as large as 400. It is also found that the increase of cold counts is significant only when the LI happens in ATMS antenna main beam. This study develops a correction model for correction of ATMS observation anormaly arising from LI. The algorithm is applied for ATMS on-orbit data processing and shows a successful removal of all the LI effects on the earth-scene brightness temperature.

**PLANNED WORK**

The planned work includes both continued support for on-orbit calibration and validation of the ATMS instrument on-board the Suomi NPP and develop new science and techniques for the future JPSS-1 and JPSS-2 satellites:

1) Develop a new full radiance based on-orbit calibration algorithm for microwave sounding instruments. The calibration algorithm includes new approaches, such as models for the antenna near-field side lobe correction, lunar intrusion correction, striping noise mitigation, and etc., to improve the calibration accuracy. The error budget in this calibration system is traceable to all the source terms.
2) Develop a generic end-to-end calibration system for processing the microwave sounding data obtained from various satellites operated by NOAA and other space agencies, from level 0 (i.e., RDR) to level 2 (e.g., TDR, SDR, RSDR, and EDR).
3) Apply the above system to process the microwave data from past, present and future satellites in order to produce consistent climate data records for use in weather and climate applications.
4) Update CRTM to accommodate to the future satellite applications. For future satellite algorithm developments, the updated CRTM will has the capability of simulating hot spots, visible channel reflectance for aerosols and clouds,
5) Improve the CRTM framework by updating the coefficient interface and radiative transfer solver for a full polarimetric capability,
6) Develop new emissivity models and data bases for full vector radiative transfer computations

**PUBLICATIONS**

*Peer reviewed*

**Hu Yang** and Xiaolei Zou, "OPTIMAL ATMS REMAPPING ALGORITHM FOR CLIMATE RESEARCH", IEEE Transaction on Geoscience and Remote sensing, 2014, in print

Fuzhong Weng, Xiaolei Zou, Ninghai Sun, **Hu Yang**, Xiang Wang, Lin Lin, Miao Tian, and Kent Anderson, "Calibration of Suomi National Polar-Orbiting Partnership (NPP) Advanced Technology Microwave Sounder (ATMS) ", Journal of Geophysical Research, 2013, Vol.118, No.19, PP. 11,187~11,200

Xiaolei Zou, Fuzhong Weng, and **Hu Yang**, “Connection the Time Series of Microwave Sounding Observations from AMSU to ATMS for Long-Term Monitoring of Climate Change”, 2014, accepted for publication

**Hu Yang** and Fuzhong Weng, “On-Orbit ATMS Lunar Contamination Corrections”, IEEE Transaction on Geoscience and Remote Sensing, 2014, in review

**PRESENTATIONS**

Hu Yang, Fuzhong Weng, “On the evaluation of AMSR2 on-orbit calibration”, GPM XCAL Meeting, 2013, Orlando, FL

Hu Yang, Fuzhong Weng, Ninghai Sun, Lin Lin, Wanchun Cheng, “ATMS Lunar Contamination Correction”, NPP SDR Review Meeting, 2013, NOAA NCWCP, College Park, MD

Hu Yang, Fuzhong Weng, Xiaolei Zou, “Connecting the Time Series of Microwave Sounding Observations from AMSU to ATMS for Long-Term Monitoring of Climate Change”, CICS Science Meeting, 2013, College Park, MD

Hu Yang, Fuzhong Weng, Ninghai Sun, Lin Lin, Wanchun Cheng, “Advanced Radiance Transformation System (ARTS) for Space-borne Microwave Instruments”, AMS 2014, Atlanta, GA

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

**PERFORMANCE METRICS EXPLANATION**

The new or improved product developed following NOAA guidance is the Improved ATMS SDR products (1). The products or techniques transitioned from research to ops following NOAA guidance are ATMS TDR to SDR conversion algorithm and .ATMS lunar contamination correction algorithm (2). The product or technique transitioned from research to ops without NOAA guidance is ATMS B-G Remapping Algorithm (1).

## Report by Slawomir Blonski

### BACKGROUND

The Joint Polar Satellite System (JPSS) is the next generation of the U.S. polar-orbiting satellites that will provide continuity of observations from the existing NOAA Polar-orbiting Operational Environmental Satellites (POES) and the new Suomi National Polar-orbiting Partnership (NPP) mission. The Suomi NPP satellite was launched on October 28, 2011, and the first JPSS spacecraft, scheduled for launch in 2017, will take advantage of technologies developed for the NPP satellite and its scientific instruments. Calibration methods developed for NPP will both improve the current operational data products and apply to the future JPSS measurements. Accurate calibration will ensure continuity of the satellite measurements for operational weather forecasting and climate change studies.

The Visible Infrared Imaging Radiometer Suite (VIIRS) is one of the instruments onboard the current Suomi NPP satellite and the future JPSS-1 and JPSS-2 spacecraft. VIIRS continues and enhances Earth observation capabilities of the AVHRR instruments from the NOAA POES satellites and the MODIS instruments from the NASA Aqua and Terra satellites. It is a 22-band multispectral imaging radiometer with a spectral range from 400 nm to 12 µm that includes both reflective solar bands and thermal emissive bands. VIIRS uses a unique spatial sampling aggregation scheme that reduces changes in the pixel ground footprint size along the Earth surface scan. Several of the spectral channels also use a dual-gain setup that dynamically adjusts to the imaged scene brightness. These novel characteristics necessitate more consideration of image quality issues during on-orbit calibration and validation of the VIIRS instruments.

Shortly after VIIRS acquired first imagery, image quality of the new datasets was evaluated, and it was confirmed that the images display high dynamic range and low noise level, and are free of any spatial and radiometric artifacts from the applied sample aggregation, but it was observed that VIIRS sensor responsivity in the near infrared and adjacent bands decreases with time more quickly than anticipated. Since then, throughout the first two years of this project, radiometric response of the reflective solar bands has been closely monitored using both onboard calibrator solar diffuser measurements and data acquired over pseudo-invariant calibration sites in Sahara and Antarctica as well as during simultaneous nadir observations with MODIS.

### ACCOMPLISHMENTS

Because of the continuing changes in the VIIRS reflective solar band (RSB) responsivity, a code revision that automate updating the RSB radiometric calibration coefficients was prepared for the SDR production software. While the revised code was written by a VIIRS SDR calibration support contractor, we have tested both a prototype version of the code and its operational implementation. Our testing used onboard solar calibration measurements from a two-year time period that started with the release of the SDR data to the public in February 2012 and lasted until present. The long-term testing far exceeded what is currently done during the software engineering tests and allowed to evaluate stability of the automated calibration algorithm. During preparations to the long-term testing, thousands of onboard calibrator intermediate product files had to be converted to a format required by the latest version of the processing software.

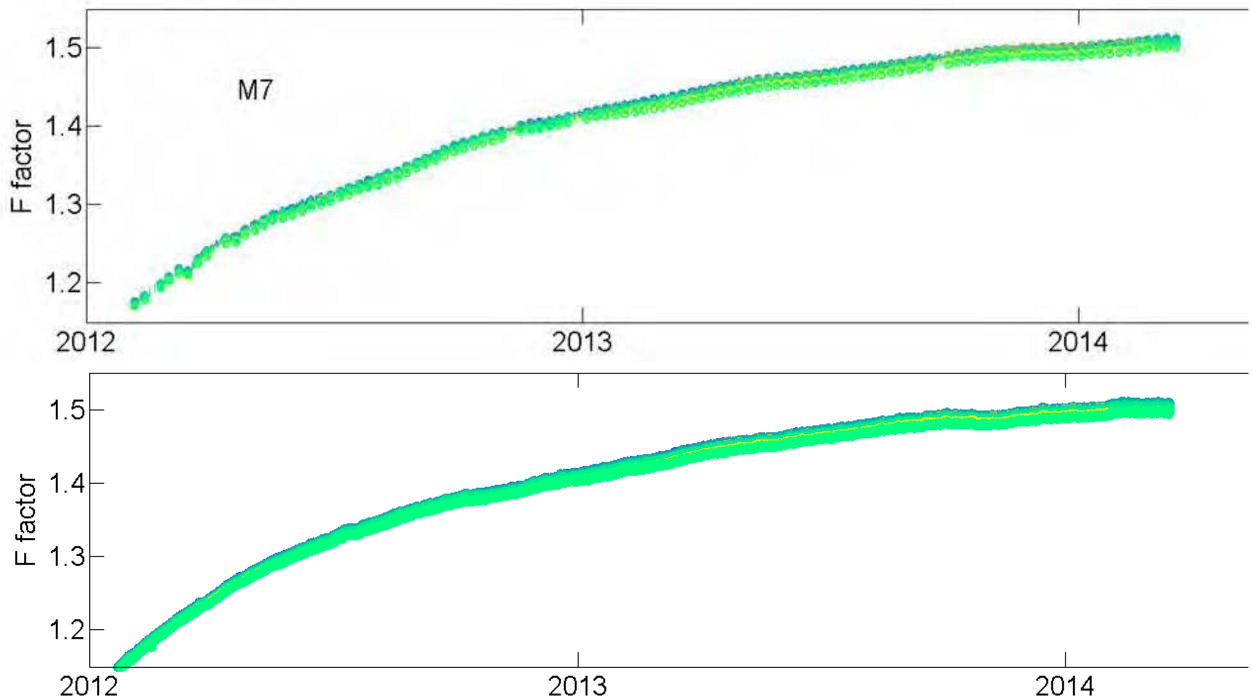


*Figure 1: F factors calculated for the VIIRS band M7 once per orbit by the automated procedure (bottom) and once per week by the current off-line procedure (top). Values for each detector are shown in a different color: high and low gains are marked by the warm (yellow-red) and cool (green-blue) colors, respectively; dots and open circles indicate two sides of the half-angle mirror.*

Onboard solar calibration measurements acquired between January 2012 and March 2014 were processed to derive the calibration coefficients in the automated way (Figure 1). The calculated coefficients, the F factors, are only a scaling part of the calibration coefficients, but they accurately account for the changes in the VIIRS radiometric gains (occurring due to the telescope throughput degradation) as well as for the differences in the detector radiometric response and in the reflectivity of the half-angle mirror sides. While currently the VIIRS F factors are updated only once per week (i.e., approx. every 100 orbits, based on off-line calculations) and predicted ahead for the remainder of the week, the automated procedure generates the updated coefficients much more often: once per orbit. Figures 1 shows that the F factors calculated by the automated procedure agree well with the F factors predicted from the off-line calculations. It is expected that the more frequents updates of the coefficients will reduce uncertainty in the VIIRS radiometric calibration introduced by the predictions.

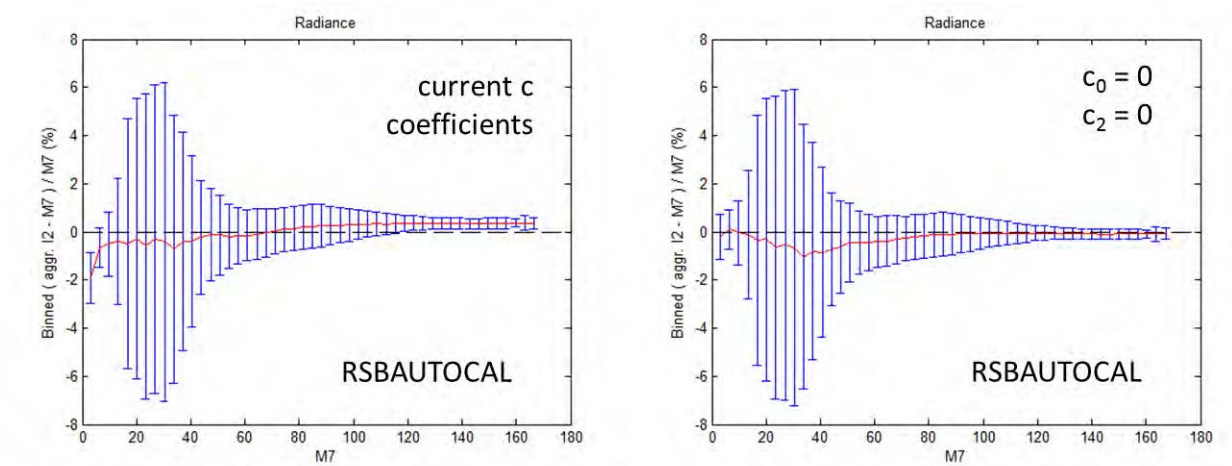


*Figure 2: Top: one of the scenes used in the testing of the VIIRS RSB automated calibration software with different sets of processing coefficients (the c coefficients). Bottom: differences between VIIRS measurements in the imaging band I2 and the moderate-resolution band M7 acquired at 11:07 UTC on September 13, 2013 over the eastern Mediterranean Sea (red line). The VIIRS SDR was produced with the ADL software using the c coefficients from the current operational software (left) and with the $c_0$ and $c_2$ coefficients set to zero (right).*

We have further experimented with the automated radiometric calibration of the VIIRS RSB data to improve consistency between the I2 and M7 bands and to reduce striping in the M7 band. By removing both the free term ($c_0$) and the quadratic term ($c_2$) from the VIIRS RSB radiometric calibration equation, not only is the equation simplified, but also the agreement between measurements in the I2 and M7 bands (which share the same spectral filter) is improved both for low and high radiance values, measured by the dual-gain band M7 with the high and low gain, respectively (Figure 2). At the lowest radiance level, occurring over oceans, the I2/M7 difference is reduced from ~2% to near zero. However, the M7 band striping is only slightly improved by that change, and the response of the edge detectors (#1 and #16) is still lower by approximately 0.5%, which is within sensor requirements, but affects quality of the ocean color products.

We have also used the VIIRS automated calibration code in ADL to conduct a parametric study of the range for the solar diffuser stability monitor (SDSM) elevation angle that should be used to monitor stability of the VIIRS solar diffuser. Because of a glitch in the SDSM design, solar geometry during October and November limits the number of valid SDSM measurements and increases uncertainty of the derived radiometric calibration coefficients. Our study has shown that widening the elevation angle range from $\pm 0.5^o$ to $\pm 0.6^o$ (or even $\pm 0.7^o$) reduces the data gap in the solar diffuser monitoring. The wider angular range eliminates an unexpected decrease in the calibration coefficient values during the October/November time period.

**PLANNED WORK**

The planned work includes both continued support for on-orbit calibration and validation of the VIIRS instrument on-board the Suomi NPP satellite and analysis of pre-launch laboratory testing and calibration of the VIIRS instruments built for the future JPSS-1 and JPSS-2 satellites:

- Provide analysis of the VIIRS SDR processing codes in IDPS and ADL to ensure correct implementation of scientific algorithms and calibration procedures
- Provide validation of updates to the on-orbit look-up tables with processing parameters needed by the JPSS program for the VIIRS SDR algorithms
- Support automation of the VIIRS radiometric calibration by providing validation of the code constants and look-up table updates required for algorithm implementation and deployment
- Continue using simultaneous nadir overpass observations to compare radiometric calibration of VIIRS and MODIS: extend the comparisons to cloud-free ocean scenes whenever possible
- Monitor stability of VIIRS radiometric calibration and geo-location accuracy using multiple CEOS-selected, pseudo-invariant calibration sites in Sahara such as Libya 4, Egypt 1, and Sudan 1
- Analyze JPSS-1 pre-launch test data and derive appropriate sensor constants and look-up tables to maintain VIIRS SDR products within required performance metrics during the post-launch period
- Provide analysis of JPSS-2 pre-launch testing results and support resolution of any anomalies detected during the laboratory measurements

**PUBLICATIONS**

*Peer reviewed*

Cao, C., X. Xiong, S. Blonski, Q. Liu, S. Uprety, X. Shao, Y. Bai, F. Weng, 2013: Suomi NPP VIIRS Sensor Data Record Verification, Validation, and Long-Term Performance Monitoring, *Journal of Geophysical Research: Atmospheres*, **118**, 11,664-11,678, DOI: 10.1002/2013JD020418

Uprety, S., C. Cao, X. Xiong, S. Blonski, A. Wu, X. Shao, 2013: Radiometric Intercomparison between Suomi-NPP VIIRS and Aqua MODIS Reflective Solar Bands Using Simultaneous Nadir Overpass in the Low Latitudes, *Journal of Atmospheric and Oceanic Technology*, **30**, 2720-2736, DOI: 10.1175/JTECH-D-13-00071.1

*Non-peer reviewed*

Blonski, S., and C. Cao, 2013: Monitoring and predicting rate of VIIRS sensitivity degradation from telescope contamination by tungsten oxide, *SPIE Proceedings*, **8739**, 87390D, DOI: 10.1117/12.2016008

Uprety, S., C. Cao, S. Blonski, and X. Shao, 2013: Evaluating radiometric consistency between Suomi NPP VIIRS and NOAA-19 AVHRR using extended simultaneous nadir overpass in the low latitudes, *SPIE Proceedings*, **8866**, 88660L, DOI: 10.1117/12.2023335

**PRESENTATIONS**

Blonski, S., C. Cao, S. Uprety, and X. Shao, 2013: Continuity of VIIRS/MODIS Radiometric Measurements: Simultaneous Nadir Overpass Comparisons for Reflective Solar Bands (poster), *NOAA Satellite Conference*, College Park, Maryland (April 8-12), http://satelliteconferences.noaa.gov/2013/docs/Wednesday Poster Session Final Posters/poster NOAA Sat.Conf.2013 W-70.pdf

Blonski, S., and C. Cao, 2013: Monitoring and predicting rate of VIIRS sensitivity degradation from telescope contamination by tungsten oxide, *SPIE Defense, Security, and Sensing Conference*, Baltimore, Maryland (29 April - 3 May), http://dx.doi.org/10.1117/12.2016008

Blonski, S., C. Cao, S. Uprety, and X. Shao, 2013: Inter-comparison of Terra and Aqua MODIS Reflective Solar Bands Using Suomi NPP VIIRS, *Conference on Characterization and Radiometric Calibration for Remote Sensing (CALCON)*, Logan, Utah (19-22 August), http://digitalcommons.usu.edu/calcon/CALCON2013/All2013Content/35

Cao, C., Q. Liu, S. Blonski, X. Shao, S. Uprety, and F. Weng, 2013: Suomi NPP VIIRS Sensor Data Record (SDR) Calibration and Validation, *4th Asia-Oceania Meteorological Satellite Users Conference*, Melbourne, Australia (9-11 October), http://www.virtuallab.bom.gov.au/index.php/download_file/view/162/220/

Blonski, S., 2013: Intercomparison of Terra and Aqua MODIS Reflective Solar Bands Using Suomi NPP VIIRS, *2nd Annual CICS-MD Science Meeting*, College Park, Maryland (6-7 November), http://cicsmd.umd.edu/assets/1/7/2.3_Blonski.pdf

Blonski, S., 2013: VIIRS RSB Validation: AutoCal and Inter-comparison Update, *Suomi NPP SDR Science and Products Review*, College Park, Maryland (18-20 December), http://www.star.nesdis.noaa.gov/star/documents/meetings/SNPPSDR2013/dayTwo/Blonski_VIIRS.pdf

**PERFORMANCE METRICS**

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

## 1.5 Climate Research, Data Assimilation, and Modeling

**OSU-CIOSS Support to GOES Improvement and Product Application Program, GOES SST Assimilation for Nowcasts and Forecasts of Coastal Ocean Conditions)**

| | |
|---|---|
| **Task Leader** | Alexander Kurapov |
| **Task Code** | AKAK_GIMPAP_13 |
| **NOAA Sponsor** | Mark DeMaria |
| **NOAA Office** | NOAA/NESDIS/STAR, GIMPAP |
| **Contribution to CICS Themes (%)** | Theme 1: 40%; Theme 2: 40%; Theme 3: 20% |
| **Main CICS Research Topic** | Climate Research, Data Assimilation and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 1: 0%; Goal 2: 40%; Goal 3: 40%; Goal 4: 10%; Goal 5: 10% |

**Highlight**: We have implemented assimilation of GOES SST, in combination with other data, to improve accuracy of real-time forecasts of ocean temperature, currents, and other oceanic variables along the Oregon coast.

**BACKGROUND**

During the report period (April 2013-March 2014), we continued to assimilate hourly GOES SST in combination with the alongtrack altimetry and surface currents from a network of coast-based high-frequency (HF) radars into the coastal ocean forecast system off Oregon. The assimilation component is based on the 4-dimensional variational (4DVAR) algorithm, implemented in a series of 3-day time windows (Fig. 1). 3 day forecasts of sea surface temperature (SST) and surface currents have been made available to the NOAA Office of Response and Restoration (for oil and marine debris tracking) and to local fishery communities (in collaboration with the Northwest Association of Networked Ocean Observing Systems - NANOOS, which is a component of the NOAA IOOS project).

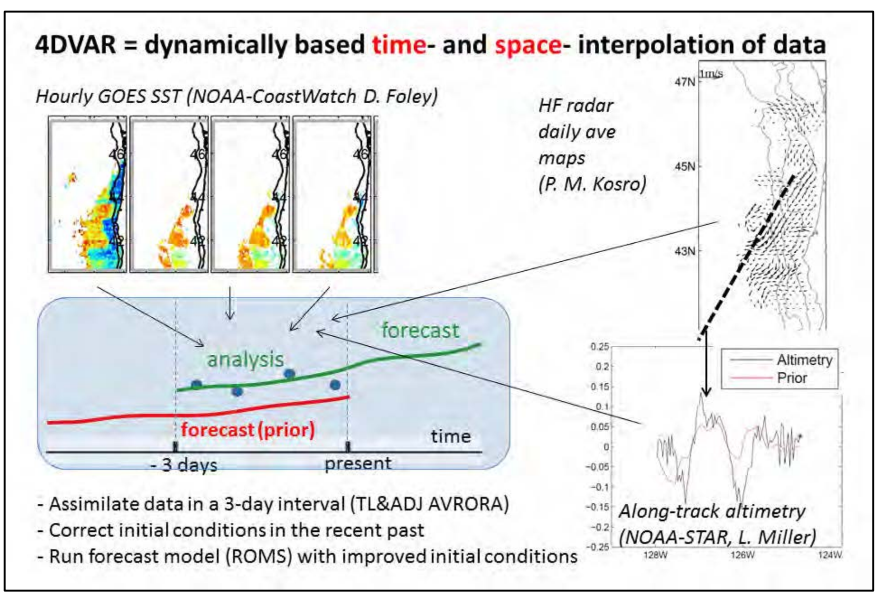


*Figure 1: The Oregon coastal ocean data assimilation system provides time and space interpolation of diverse, noisy, and sparse data sets and yields an improved ocean estimate (analysis) in a given assimilation window [as shown in the figure, over the 3 days in the past] and a forecast. Red line: a prior model solution (earlier forecast); blue dots: observations; green line: the nonlinear analysis-forecast solution started from the improved initial conditions at time t= -3 days.*

New efforts during the report period were focused on the model improvements, which included: (a) the new domain, extended to the Washington coast, (b) better (2-km) horizontal resolution, (c) model representation of the Columbia River plume, (d) tests of the new model error covariance, based on an ensemble of model forecasts, to better represent time- and space- variability influenced by the river plume.

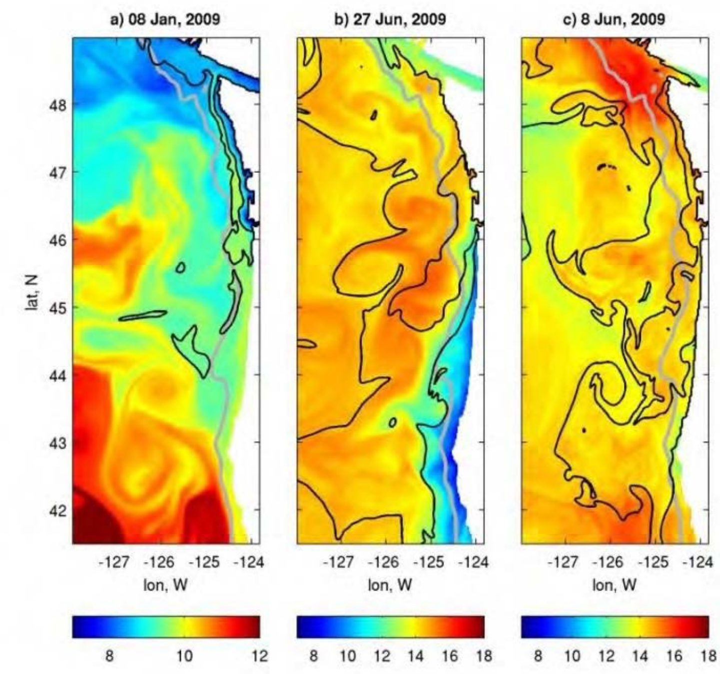


*Figure 2: Model estimates of SST (color) and SSS (black contours, 30 and 32.5 psu) in the new model domain (OR+WA), during several events: (a) winter downwelling, 8 Jan 2009, (b) strong summer upwelling, 27 Jun 2009, (c) relaxation from upwelling to downwelling favorable conditions, 8 June 2009. The direction of the plume is changed with seasons. The plume impacts SST in both seasons.*

**ACCOMPLISHMENTS**

The new model version has been developed, and is being tested in hindcast experiments. Model tests without assimilation have been run (Figure 2). Cases with and without the Columbia River plume have been compared, to understand the influence of the river plume on the SST pattern (winter – cooler waters along the WA coast, summer – warmer waters south of the river mouth and offshore, colder waters inshore of the river plume edge).

Initial assimilation tests in the new domain, with the Columbia River, have been run and the impact of the assimilated data on the surface and subsurface oceanic fields is being analyzed.

The PhD student involved in this project (Ivo Pasmans) has developed an effective algorithm for implementation of the ensemble-based initial condition covariance, which includes spatial localization (to inhibit spurious long-tail correlations). Tests are underway to demonstrate that such a covariance (which accounts for time-varying background ocean conditions) helps to utilize the data better than the static covariance, currently used in the real-time application.

**PLANNED WORK**

- Continue with the real-time implementation of the Oregon forecast model
- Complete hindcast data assimilation tests of the new OR-WA model (which would include the Columbia River)
- Compare performance of the new model version with the old (static) and new (dynamic, ensemble-based) initial condition error covariance
- Enable transition of the new model as the real-time model, replacing the current version of the Oregon coastal ocean forecast system
- Enable transition of the tools and assimilation algorithms to the NOAA West Coast Ocean Forecast System (at the planning stage - NOAA NOS / NESDIS / JCSDA)

**PUBLICATIONS**

Kurapov, A. L., P. Yu, R. K. Shearman, and J. S. Allen, 2014: Sea surface temperature variability in the upwelling region off Oregon influenced by the Columbia River plume, J. Geophys. Res., in revision.

Osborne J. J., A. L. Kurapov, G. D. Egbert, and P. M. Kosro, 2014: Energetic diurnal tides along the Oregon coast, J. Phys. Oceanogr., in press.

**DELIVERABLES**

- The new algorithm for model error covariance localization
- Components of the new OR-WA coastal ocean forecast system
- Every-day updates of 3-day forecasts of oceanic conditions off Oregon, utilizing NOAA data (GOES SST, altimetry)

**PRESENTATIONS**

Kurapov, A., P. Yu, I. Pasmans, R. K. Shearman, J. S. Allen, and G. D. Egbert, SST variability in the upwelling region off Oregon influenced by the Columbia River plume, Ocean Sci Meeting, Honolulu, HI, Feb. 2014.

Kurapov, A., Improvements in the Oregon coastal ocean forecast system: data assimilation in the presence of the Columbia River plume, GODAE COSS-TT Workshop, Rincon, Puerto Rico, Jan 2014

Kurapov, A.: Assimilation of satellite SSH in coastal ocean circulation models, NASA SWOT Science Definition Team Meeting, Washington, DC, Jan 2014.

Kurapov A.: Coastal ocean circulation modeling: Oregon and neighborhoods, Modeling in Support of Coastal Hypoxia, Acidification and Nutrient Management in the California Current Ecosystem, South California Coastal Water Research Project Authority, Costa Mesa, CA, Dec 2013 [INVITED]

Kurapov, A., P. Yu, R. K. Shearman, P. T. Strub, J. S. Allen: SST variability in the upwelling region off Oregon influenced by the Columbia River plume, The 2013 Gordon Research Conference on Coastal Ocean Circulation, U. Maine, Jun 2013.

**OTHER**

Forecasts are provided to a group of OSU students as part of their research project (the CEOAS MSc program in Marine Resource Management, C. Duncan)

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

This year, we developed a new, improved coastal model, which will serve as a prototype to the NOAA West Coast Ocean Forecast System (1). The paper on the influence of the Columbia River plume on SST in summer has been submitted and is currently in revision (1). The paper discussing details of high-frequency motions along the Oregon coast (J. Osborne is the lead author) has been accepted for publication (1). The PI has been invited to present at the workshop sponsored by SCCWRPA (1); a total of 5 presentations reflecting this research have been made. The PI had advised 2 students (one of them, J. Osborne, defended his thesis this year). PhD student Ivo Pasmans has been partially supported by this project and contributed to the improvements in data assimilation. The summer NSF REU intern Mr. Kevin Tennyson has been advised in 2013.

**Support for Diagnostic, Monitoring and Forecast Activities at CPC**

| | |
|---|---|
| **Task Leader** | Augustin Vintzileos |
| **Task Code** | AVAV_CPC_13 |
| **NOAA Sponsor** | Mike Halpert and Jon Gottschalck |
| **NOAA Office** | NOAA/NWS/NCEP/CPC |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 0%; Theme 3: 100%. |
| **Main CICS Research Topic** | Climate Research, Data Assimilation and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0% |

**Highlight**: We developed and transitioned to operations several products as part of a new tool being used in realtime by forecasters of the Global Tropics Hazards and Benefits Outlook (GTH). We continued research on the physics of the MJO and the importance of air – sea coupling. We are evaluating links between climate and health and the capacity of models to predict hazardous atmospheric conditions at sub-seasonal lead times.

**BACKGROUND**

This report summarizes work of the ongoing NOAA project entitled “CICS Support for Diagnostic, Monitoring and Forecast Activities at Climate Prediction Center”. This work is evolving along three components:

- Creating an automatic multi-model, bias corrected first-guess forecast for the Global Tropics Hazards and Benefits Outlook (GTH) forecaster. The GTH is a CPC operational outlook product that provides weekly Week 1 and Week 2 predictions of hazardous or beneficial conditions in the global tropics and assess tropical to mid-latitude influences.
- Investigating the physics of subseasonal variability with focus on air-sea interactions. This component includes the comparison of model forecasts with observations in order to quantify model strengths and weaknesses.
- Exploring the possibility of subseasonal forecasts of hazardous atmospheric conditions e.g., heat waves, over the CONUS.

**ACCOMPLISHMENTS**

A suite of CFS based model products has been designed, tested and transitioned to CPC operations which includes bias corrected anomaly and categorical forecasts for Week-1 to Week-4 of OLR, precipitation, total column water content, sea level pressure, temperature at 2 meters, wind shear and winds at 200 hPa and 850 hPa. Additional products have been developed and are being evaluated at this time. These include tropical cyclogenesis potential guidance as well as depictions of signal to noise assessment products for forecast awareness. An example of a categorical forecast of precipitation for Weeks 1-4 is shown in Figure 1.

We continued investigating the physics of subseasonal variability for model evaluation purposes. We evaluated observed atmospheric and oceanic conditions during the DYNAMO campaign and detected periods during which the SST signal is uncoupled, weakly coupled and strongly coupled with atmospheric subseasonal variability. We compared the uncoupled GFS and coupled CFS forecasts of the

MJO and we found that during the uncoupled periods both models have the same skill while during the strongly coupled period, the CFS outperforms the GFS (Figure 2). Process studies comparing mechanisms for subseasonal variability in the observations and the GFS suggest a fast decoupling between dynamics and thermodynamics in the GFS with a hypothesis that this may be caused by a very wet upper troposphere in the GFS.

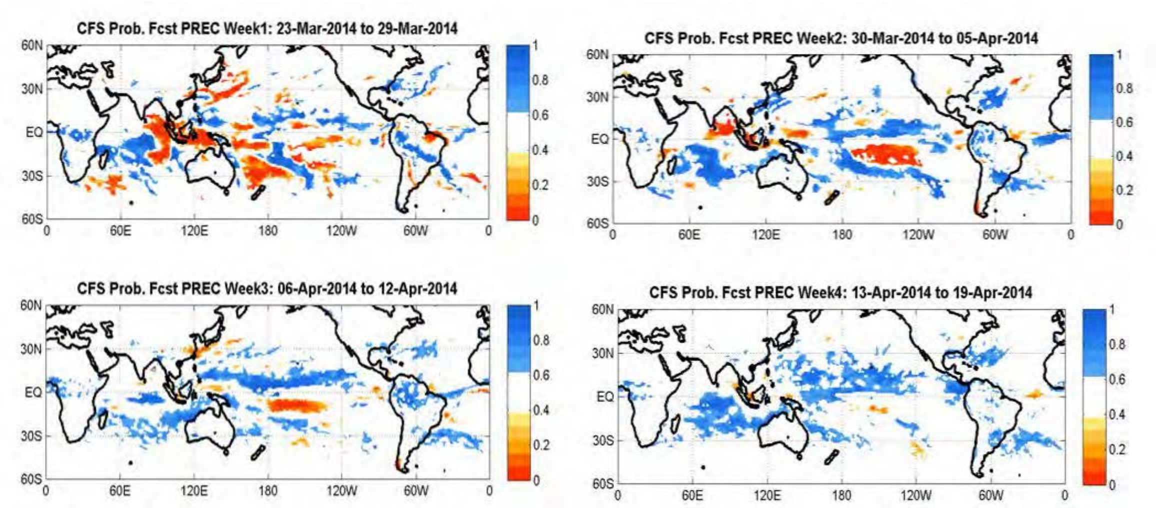


*Figure 1: Forecast of precipitation for forecast Week-1 to Week-4. Blue colors show areas where ensemble mean precipitation exceeds 60% of the model climatological distribution for the given forecast lead. Red colors indicate areas of precipitation below the 40% of the climatological distribution.*

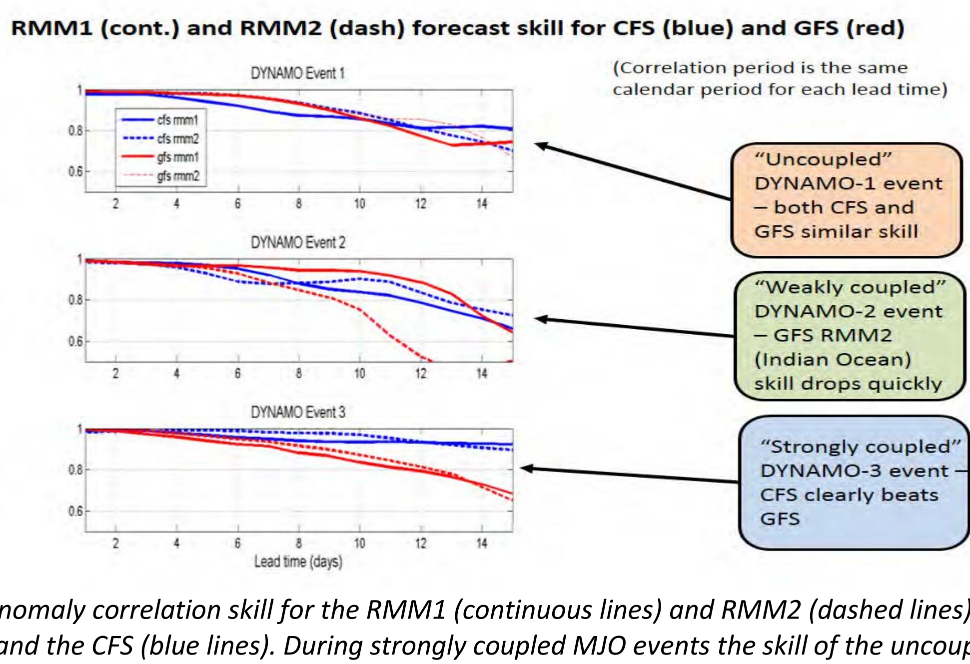


*Figure 2: Anomaly correlation skill for the RMM1 (continuous lines) and RMM2 (dashed lines) for the GFS (red lines) and the CFS (blue lines). During strongly coupled MJO events the skill of the uncoupled GFS drops faster than of the coupled CFS.*

Finally, the investigation of predictability of hazardous climate conditions for human health was initiated. Initial analysis of mortality data suggests a significant impact of climate on health especially for the more sensitive age group of 75+. For example, Figure 3 shows an astonishing correlation between the low-pass filtered (retaining the decadal signal) mortality in Oklahoma City and global surface temperature. In the remaining months we will predictability of heat waves at a forecast lead time of two weeks.

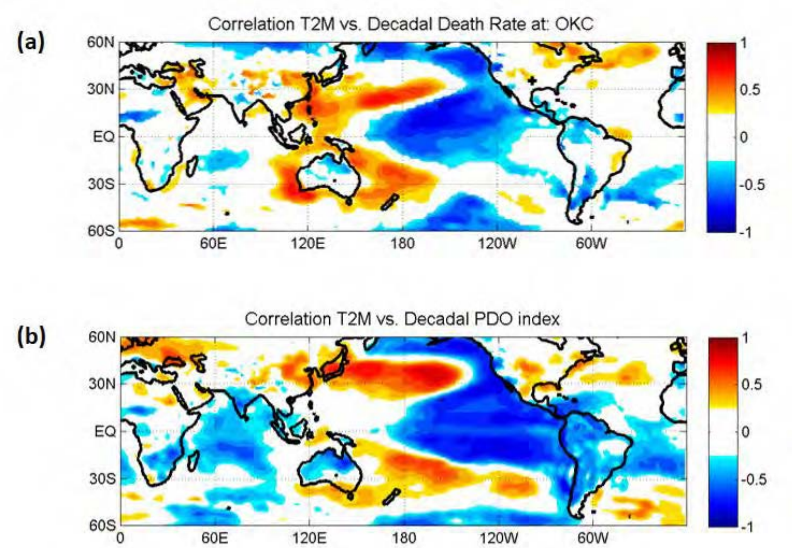


*Figure 3: (a) correlation between decadal mortality rate fluctuations at Oklahoma City and analyzed temperature at 2 meters; (b) correlation between filtered (minus) PDO index and analyzed temperature at 2 meters.*

**PLANNED WORK**

- To continue investigation of predictability of heat waves at subseasonal time scales and transition of findings to operations if appropriate
- To continue developing tools for the GTH targeting a multi-model, bias corrected objectively combined first-guess prediction to be used by the GTH forecasters
- To validate novel satellite products and use them for continuing the investigation of the physics of subseasonal variability

**PUBLICATIONS**

Gottschalck, J., P. E. Roundy, C. J. Schreck, A. Vintzileos, and C. Zhang, 2013: Large-Scale Atmospheric and Oceanic Conditions During the 2011-2012 DYNAMO Field Campaign. *Mon. Wea. Rev.*, doi:10.1175/MWR-D-13-00022.1.

Chattopadhyay, R., A. Vintzileos, and C. Zhang, 2013: A Description of the Madden-Julian Oscillation Based on a Self-Organizing Map. *Journal of Climate*, **26**, 1716–1732, doi:10.1175/JCLI-D-12-00123.1.

Flatau, M., Chen, S., Shinoda, T., Jensen, T., Baranowski, D., Vintzileos, A., and Nasuno, T., Evaluating MJO precipitation in limited area models. (in review) *Monthly Weather Review*.

Vintzileos, A., J. Gottschalck: On the fast decoupling between dynamics and thermodynamics at sub-seasonal time scales in the GFS (in preparation)

**DELIVERABLES**

- Automated operational categorical forecasts from Week-1 to Week-4 for several variables
- Experimental tool for estimating the potential for tropical cyclogenesis from Week-1 to Week-4
- A first estimate of predictability of heat waves at Week-2
- Identification of model processes responsible for the decrease in forecast skill of the MJO

**PRESENTATIONS**

Vintzileos, A., and J. Gottschalck, J., 2013: Global model forecast support for DYNAMO at NCEP, AMS Annual Meeting, 6-10 January 2013, Austin, Texas.

Gottschalck, J., and A. Vintzileos, Q. Zhang and MJO Task Force members, 2013: The current status of MJO prediction in an operational forecast context, AMS Annual Meeting, 6-10 January 2013, Austin, Texas.

Vintzileos, A. and J. Gottschalck, 2013: Coupled versus uncoupled forecasts of the MJO during DYNAMO, DYNAMO Field Data and Science Workshop, 4-8 March 2013, Hapuna Beach Resort, Hawaii.

Vintzileos, A. and J. Gottschalck, 2013: Challenges in forecasting the MJO, Workshop on the Nature of the MJO, 10-11 June 2013, George-Mason University, Fairfax, Virginia.

Gottschalck, J., A. Vintzileos and MJO Task Force members, 2013: MJO forecast skill for a suite of operational dynamical model forecasts and its application at the Climate Prediction Center, Workshop on the Nature of the MJO, 10-11 June 2013, George-Mason University, Fairfax, Virginia.

Vintzileos, A., 2013: The DYNAMO campaign, US-CLIVAR Summit **(invited)**, Annapolis, Maryland.

Vintzileos, A., 2013: Forecasting at the interface between weather and climate: Sources of predictability for lead times from Week 2 to Week 4 and challenges in effectively mining them, COLA-GMU seminar series **(invited)**, Fairfax, Virginia.

Vintzileos, A. and J. Gottschalck, 2013: Forecasting at the interface between weather and climate: beyond the RMM-index, 38th Climate Diagnostics and Prediction Workshop, College Park, Maryland.

Vintzileos, A. and J. Gottschalck, 2013: Forecasting at the interface between weather and climate: beyond the RMM-index,, American Geophysical Union annual Meeting, Sam Francisco, California.

Vintzileos, A. and J. Gottschalck, 2014: Challenges in Forecasting the MJO, 1st Subseasonal-to-Seasonal Conference, College Park, Maryland.

Vintzileos, A., Scott Sheridan and Mike Halpert, 2014: Investigating links between mortality and climate, 12th Annual Climate Prediction Applications Science Workshop, George Mason University, Fairfax, Virginia.

**PERFORMANCE METRICS**

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

## Support for the 6th WMO International Symposium on Data Assimilation

| | |
|---|---|
| **Task Leader** | Ernesto Hugo Berbery/Kayo Ide |
| **Task Code** | EBDS_WMO_13 |
| **NOAA Sponsor** | Mike Halpert/Daryl Kleist |
| **NOAA Office** | NCEP/CPC & EMC |
| **Contribution to CICS Themes (%)** | Theme 1: 40%; Theme 2: 40%; Theme 3: 20%. |
| **Main CICS Research Topic** | Climate Research, Data Assimilation, and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 1: 25%; Goal 2: 25%; Goal 3: 25%; Goal 4: 05%; Goal 5: 20% |

**Highlight**: In support of organization and hosting of the prestigious WMO Conference, we have successfully provided the Local Organizing Committee with the necessary access to UMD Conference and Visitor Services that NOAA does not have.

### BACKGROUND

National Oceanic and Atmospheric Administration (NOAA) planned to host the 6th World Meteorological Organization (WMO) International Symposium on Data Assimilation (DA) at National Center for Weather and Climate Prediction, College Park, MD, for October 7-11, 2013. However, with the government shutdown that occurred at the time, CICS-MD took a leading role in the organization, moving the meeting's venue to the University Campus and ensuring a successful meeting. Aiming to improve the quality of environmental prediction by advancing theory, modeling, observing systems, and computing capacity, DA leads to not only better understanding of the earth sciences but also significant benefits from applications of DA.

### ACCOMPLISHMENTS

The task of CICS-MD was two-fold:

- Provide travel support to selected young scientists;
- Assist NOAA to plan and manage this International Symposium.

### PUBLICATIONS

The Official Symposium website (http://das6.umd.edu) contains

- All abstracts;
- Most presentations in both slides and video recording.

### DELIVERABLES

- Assisted NOAA to plan the 6th WMO International Symposium on DA and gave access to the UMD Conference and Visitor Services.
- Provided travel support to selected young scientists to the Symposium.

**PRESENTATIONS**

Over 300 international participants from 20 countries attended the Symposium and made:

- 74 oral presentations
- 227 poster presentations

**Others** (Awards, Outreach)

- The Official Symposium website (http://das6.umd.edu) is accessible online for anyone interested.
- A special collection of articles in the American Meteorological Society journals highlighting the work presented at the symposium is being put together, and will include a brief, online only summary article, for dissemination of the Symposium outcome.
- Four early career scientists were given travel support.
- We stepped in to manage the Symposium when it coincided with the US federal government shutdown.
- The Local Organizing Committee was recognized for the highly successful event.

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

The project aimed to help NOAA organize and host the International Symposium and thus used unusual metrics.

**Student Support for CPC: Interpretation of Real-Time Weather and Climate Data for Spherical Displays**

| | |
|---|---|
| **Task Leader** | E. Hugo Berbery |
| **Task Code** | EBEB_CPC_13 |
| **NOAA Sponsor** | Mike Halpert |
| **NOAA Office** | NWS/CPC |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 0%; Theme 3: 100%; |
| **Main CICS Research Topic**: | Climate Research, Data Assimilation and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 1: 50%; Goal 2: 25%; Goal 3: 25%; Goal 4: 0%; Goal 5: 0% |

**Highlight**: This year, graduate student Katherine Lukens, under the advisement of Dr. E. Hugo Berbery, focused on ascertaining the characteristics and behaviors of seasonal storm over North America for her PhD thesis on "The interconnectivity of extreme precipitation events, storm tracks, and modes of variability via the applications of large-scale global climate dynamics."

**BACKGROUND**

This report summarizes the research conducted from April 2013 to March 2014 by Katherine E. Lukens, GRA II with the working title of "The interconnectivity of extreme precipitation events, storm tracks, and modes of variability via the applications of large-scale global climate dynamics."

Katherine focused mainly on her coursework required for the doctoral program in the Department of Atmospheric and Oceanic Science at the University of Maryland until May 2013; these courses included Introduction to Earth System Science, Atmospheric Dynamics I & II, Atmospheric and Oceanic Climate, and Chemistry and Physics of the Atmosphere I & II. From April to May 2013 she studied and prepared for the first part of her graduate program's Candidacy Qualifying Examination, which she passed at a PhD level at the end of May 2013.

She utilized her meteorology background as a solid foundation and thus plunged into research. She read the literature to inform herself of the results, methods, and background needed to explore storm tracks, extreme precipitation events (droughts and wet periods), and lower frequency modes of variability. The content of two particular papers stood out among the rest.

Becker et al. (2011) revealed circumstances in which the Madden-Julian Oscillation (MJO) modifies precipitation patterns over the United States, peaking Katherine's inquisitive nature due to her undergraduate work involving the link between the MJO, Rossby wave propagation, and the Pacific North American pattern (PNA).

Berbery and Vera (1996) provided a basis upon which to formally begin her research encompassing precipitation and climate dynamics at CICS-MD and the University of Maryland.

**ACCOMPLISHMENTS**

Under the advisement of Dr. E. Hugo Berbery, Katherine currently focuses on ascertaining the characteristics and behaviors of seasonal storm tracks in the Northern Hemisphere, specifically over North America. She poses the question: "How are extreme precipitation events connected to the strength and spatial patterns of storm tracks?" She primarily programs using the NCAR Command Language (NCL) and has continued to expand her knowledge of this language and sharpen her programming skills by reproducing the results of Berbery and Vera (1996), but for both the Northern and Southern Hemispheres. The paper by Berbery and Vera contains one-point correlations of upper tropospheric storm tracks at specific grid points with the entire Southern Hemisphere, producing wave trains that are further studied. Katherine has improved her computational skillset by studying one-point correlation and Hovemuller diagram procedures and practices explained in this paper.

With these newfound tools, Katherine has calculated and examined correlations between the Northern Hemisphere winter storm tracks and surface measurements of precipitation during the same DJF season from 1979 to 2010 via the techniques used in Berbery and Vera; however, upon discovering little to no signal between the two variables, she searched in the literature for other storm track diagnostic techniques already developed, encountering one which employs 850hPa winds. Following the aforementioned technique, she computed and plotted storm tracks at this pressure level as well as correlations between said storm tracks and surface precipitation. Storm tracks here are represented by the spatial pattern and intensity of the standard deviation of the meridional component of the anomalous wind (v). A point of high standard deviation implies a location of a strong storm track. Choosing points near North America, Katherine correlated the strong 850hPa storm tracks at these points with global precipitation, producing wave patterns of similar structure to those found in Berbery and Vera.

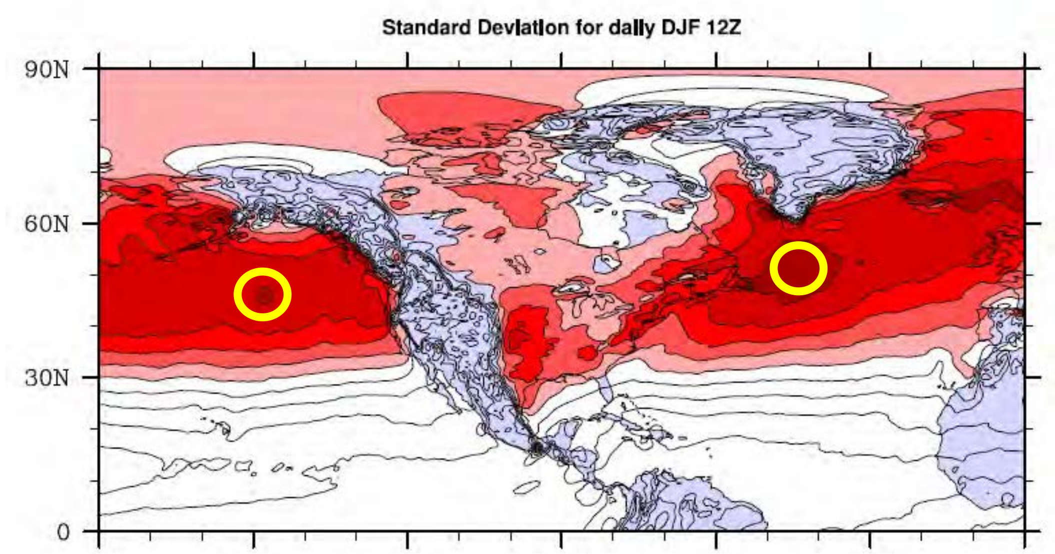


*Figure 1: Standard deviation of the anomalous meridional wind at 850hPa. Low deviations (0-7) have been cleared of color for clarity. Deviations darken in red as they increase. Yellow circles identify 2 points of high standard deviation used in Fig. 2.*

Figure 2 exhibits correlations with a more well-defined signal than those using storm tracks analyzed at the 200hPa level, with Figure 1 displaying the 850hPa storm track patterns at 2 locations of strong storm tracks around North America, with circles indicating the specific grid points analyzed in the correlation plots.

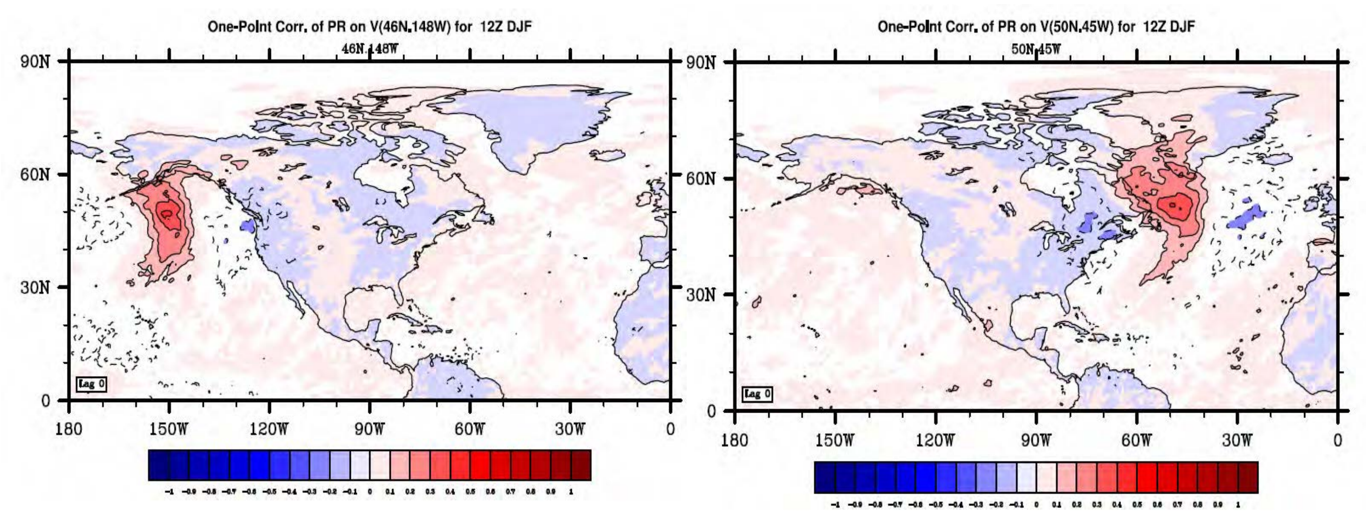


*Figure 2: One-point correlations of the anomalous meridional component of wind at 850hPa at 46N,148W (left, Fig. 1 left yellow circle) and 50N,45W (right, Fig. 1 right yellow circle) with surface precipitation on the entire field of view for 12Z daily values in the DJF season (Northern Hemisphere winter). Each panel displays Lag 0 for each correlation. High (low) correlations are in red (blue). The correlations range from -1.0 to 1.0.*

The standard deviation of the meridional wind (Figure 1) spatially resembles Figure 5 in Woollings et al; considering that the Figure 5 from Woollings et al. only spans the DJF season from 85/86 to 99/00, Katherine views this observation as promising for the continued and future exploration of a new storm track diagnostic method employed by Hoskins and Hodges (2002) and Woollings et al. (2009). This method is very involved computationally, but in general it examines the full, non-anomalous vorticity field at 850hPa. Cyclones are characterized as vorticity maxima and are tracked. A track density is calculated and plotted to visually describe the general position and intensity of storm tracks at this level. She expects to employ this vorticity and track density technique in the diagnoses and analyses of storm tracks during her research endeavors.

The data used in all of the abovementioned calculations, and upcoming calculations, comes from the Climate Forecast System Reanalysis (CFSR) product from the National Center for Atmospheric Research (NCAR). For more information, visit: [https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr](https://climatedataguide.ucar.edu/climate-data/climate-forecast-system-reanalysis-cfsr)

**PLANNED WORK**

- Continue to learn and apply new storm track diagnostic methods and analyses to CFSR data.
- Use lower tropospheric CFSR wind data to create a storm track index from January 1979-December 2010
  - Use this index to help determine how regional extreme precipitation events are modified by storm tracks.
- Investigate impacts of lower frequency modes of variability on storm tracks and thus extreme precipitation events, graduating from regional- to global-scale analyses.

**PUBLICATIONS**

N/A

**DELIVERABLES**

N/A

**PRESENTATIONS**

N/A

**OTHER** *(awards, outreach, etc.)*

- Completed and passed the written Comprehensive Examination (Part 1 of 2 of the Candidacy Qualifying Examination) at a PhD Level in the Department of Atmospheric and Oceanic Science - *University of Maryland, May 2013*
- Participated in the CICS summer internship, served as an extra resource for the interns, and held a graduate school informational session for the interns – *CICS-MD, summer of 2013*
- Panel participant on higher education for high school students visiting CICS – *ESSIC, summer of 2013*
- Vice President of MetoGrads (the graduate student organization for the Department of Atmospheric and Oceanic Science) - *University of Maryland, April 2013 to present*

**REFERENCES**

Becker, E. J., E. H. Berbery, and R. W. Higgins, 2011: Modulation of cold-season U.S. daily precipitation by the Madden-Julian Oscillation. *J. Climate*, **24,** 5157-5166.

Berbery, E. H., and C. S. Vera, 1996: Characteristics of the Southern Hemisphere winter storm track with filtered and unfiltered data. *J. Atmos. Sci.*, **53,** 468-481.

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

Woollings T., et al., 2009: Storm track sensitivity to sea surface temperature resolution in a regional atmosphere model. *Clim. Dyn.* **35,** 341-353.

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

Graduate Student Katherine Lukens was supported for FY13 under this CICS Task.

**Use of LETKF Sensitivity to Improve QC of Data from JPSS Polar Orbiting Instruments and to Detect the Origin of the NCEP "5-Day Forecast Skill Dropouts"**

| | |
|---|---|
| **Task Leader** | Eugenia Kalnay |
| **Task Code** | EKEK_LETK_13 |
| **NOAA Sponsor** | Dr. Mitch Goldberg |
| **NOAA Office** | NESDIS/ JPSSPO |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 100%; Theme 3: 0%. |
| **Main CICS Research Topic** | Climate Research, Data Assimilation and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 1: 50%; Goal 2: 50%; Goal 4: 0%; Goal 5: 0% |

**Highlight**: We have implemented a new ensemble-based formulation of forecast sensitivity to observation (EFSO) to a lower-resolution version of the operational hybrid GSI. We have found that the EFSO results are insensitive to the choice verification and evaluation lead-time.

**BACKGROUND**

This report summarizes the year-1 work of the ongoing NOAA project entitled "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'". We have implemented a new Ensemble-based formulation of Forecast Sensitivity to Observations (EFSO, Kalnay et al., 2012) to a lower-resolution version of the operational hybrid GSI on JCSDA's S4 cluster computer system. For efficiency sake, however, in our system we replaced the operational Serial EnSRF with the LETKF developed by Yoichiro Ota (Ota et al., 2013). We tried various configurations of EFSO computation with different combinations of the "truth" (with which the forecast is verified) and the evaluation lead-time to investigate how sensitive the EFSO results are to those combinations. The importance of this is that it allows implementing "Proactive Quality Control" (Ota et al. 2013) of observations after only 6 hrs, thus making it feasible for operational applications. Below are the accomplishments during the first year of the project, by Daisuke Hotta, followed by future plans for next year.

**ACCOMPLISHMENTS**

We conducted a one-month cycling experiment for the period from January 7th 2012 to February 10th 2012, and computed EFSO-estimated impacts of each observation to the forecast using different combinations of verifying truths and evaluation lead-times. The most significant finding of our investigation is that EFSO results are rather insensitive to the choice of verifying truth or that of forecast lead-time. As an example, we show, in Figure 1, the case of EFSO computation for the initial of 18UTC February 6th 2012 with the triangular target area near the North Pole. Here EFSO results are computed for the evaluation lead-times of 6, 12 and 24 hours. Observational impacts are summed up separately for each type of observation. For all of the three forecast lead-times, EFSO results dictate that MODIS-wind observations are likely to have most significantly increased the forecast errors. Figure 1 shows results of the EFSO results verified against GSI analysis. The EFSO results verified against LETKF analysis (not shown) are also consistent.

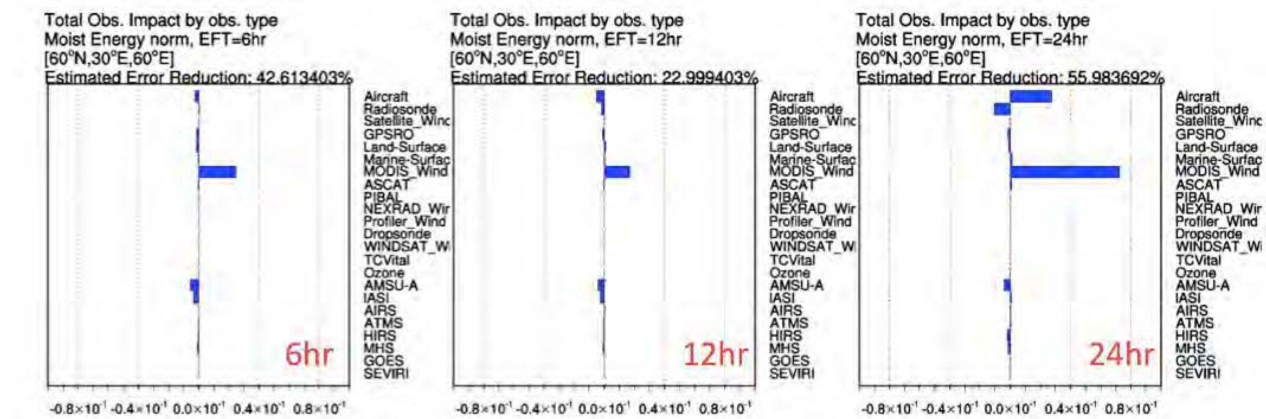


*Figure 1: Estimated forecast error reduction contributed from each observation types for lead-times of (left) 6 hours, (middle) 12 hours and (right) 24 hours for 18 UTC 6 February 2012 initial. The forecast errors are measured with the moist total energy norm (unit: $J\,kg^{-1}$) for the area of [60°N–90°N, 30°E–60°E].*

The fact that "flawed" observations can be detected only after 6 hours from the analysis shows clear potential of improving the analysis and forecast by identifying them and taking them out from the data assimilation. Moreover, by putting them "into a bucket" with additional metadata, this method would provide valuable information with which algorithm developers can identify the problem with the observation and improve the algorithm.

All project deliverables (documentation and software) and milestones have been accomplished as planned. Currently, the data-denial experiments, in which the analysis and forecast are repeated rejecting the detected flawed observations, are underway.

**PLANNED WORK**

- Conduct data-denial experiments to ascertain if rejection of detected "flawed" observation actually improves the forecast.
- Repeat the algorithm using the system with operational resolution.
- Transition algorithm to operations.

**PUBLICATIONS**

*Non-Peer Reviewed*

Hotta, Daisuke, 2014: Proactive Quality Control, *CICS-MD Website*, http://cicsmd.umd.edu/proactive-quality-control .

**DELIVERABLES**

- Automated algorithm for "regional forecast dropout" detection; and
- Automated algorithm for "flawed" observation detection using EFSO.

**PRESENTATIONS**

Kalnay, Eugenia, 2013: Ensemble Forecast Sensitivity to Observations (EFSO) and Proactive Quality Control, *WMO 6th Symposium on Data Assimilation*, College Park, MD (7-11 October), http://das6.cscamm.umd.edu/program/Daily/slides/18.3-Kalnay_Eugenia.pdf

Hotta, Daisuke, 2013: Ensemble Forecast Sensitivity to Observations (EFSO) and Proactive Quality Control, *2nd Annual CICS-MD Science Meeting*, College Park, MD (6-7 November), http://cicsmd.umd.edu/assets/1/7/4.3_Hotta.pdf

Hotta, Daisuke, 2013: Ensemble Forecast Sensitivity to Observations and its Application to Proactive Quality Control, *5th Annual PSU-UMD Data Assimilation Workshop*, University Park, PA (18 December), http://www.weatherchaos.umd.edu/group_log/data/workshop/psu/psu_umd_y13/131218_psu_umd_hotta.pdf

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

This year, we implemented EFSO algorithm to the quasi-operational hybrid GSI system. One non-peered reviewed paper was published on CICS-MD's website (1). The student (Daisuke Hotta) is now preparing his dissertation to be finished this August, from which will be submitted several journal papers. Three oral presentations about our achievements have been made (3). He will be returning to the Japanese Meteorological Agency and we plan to continue collaborating on this project. His work will be also continued by another graduate student.

**Comparison of 4DVAR and LETKF in Assimilating JPSS-Derived Sea-Surface Temperature in the Chesapeake Bay Operational Forecasting System**

| | |
|---|---|
| **Task Leader** | Hugo Berbery/Bin Zhang |
| **Task Code** | PACB_JPSS_13 |
| **NOAA Sponsor** | Christopher W. Brown |
| **NOAA Office** | NESDIS/STAR |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 0%; Theme 3: 100%. |
| **Main CICS Research Topic** | Climate Research, Data Assimilation and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 3: 50%; Goal 4: 50%; |

**Highlight**: We have configured and adapted 4D-Var data assimilation to the Chesapeake Bay Operational Forecasting System. Assimilation of daily composite AVHRR SST into CBOFS successfully lowers the model bias.

**BACKGROUND**

This report is a summary of the last year work of the ongoing NOAA project "Comparison of 4DVAR and LETKF in Assimilating JPSS-derived Sea-Surface Temperature in the Chesapeake Bay Operational Forecasting System".

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 sea-surface temperatures (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 proposed to evaluate the skill of two data assimilation techniques, Four-Dimensional Variational analysis (4D-Var) and Local Ensemble Transform Kalman Filter (LETKF), in assimilating JPSS-derived SST into the CBOFS. The implementation of the data assimilation technique deemed most effective for CBOFS will be transferred to CSDL for operational use. In addition, the skill associated with using SSTs from Visible/Infrared Imager Radiometer Suite (VIIRS) versus Advanced Very High Resolution Radiometer (AVHRR) in CBOFS forecasts will be estimated and compared to quantify the improvements of the VIIRS sensor over heritage AVHRR measurements.

**ACCOMPLISHMENTS**

### 1. Comparison of CBOFS with Observations

We compared the CBOFS surface temperature and salinity with the Chesapeake Bay Interpretive Buoy System (CBIBS) measurements and AVHRR SST (Figures 1–3). Generally speaking, the CBOFS has a bias towards warmer and more saline results. We will use data assimilation of available observational data to correct this model bias.

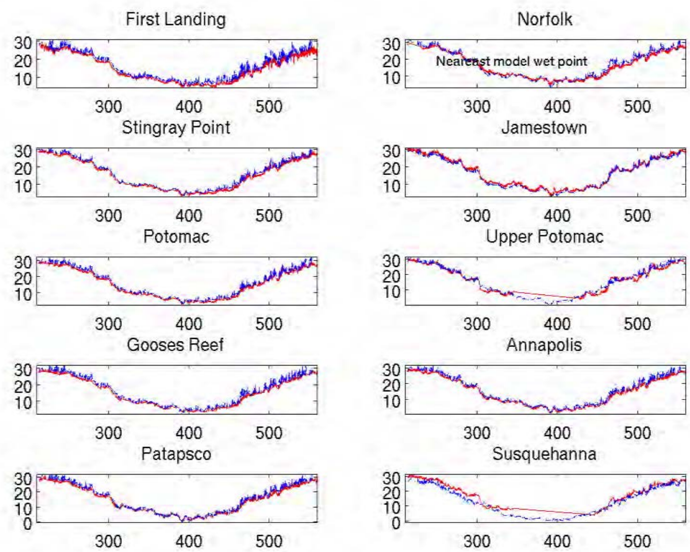


*Figure 1: Comparison of model surface temperature and salinity with observations: Surface temperature compares with CBIBS stations.*

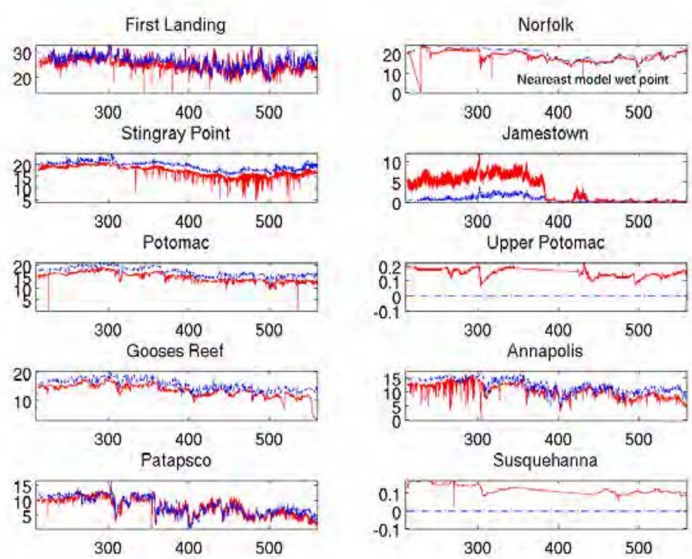


*Figure 2: Comparison of model surface temperature and salinity with observations: Surface salinity compares with CBIBS stations.*

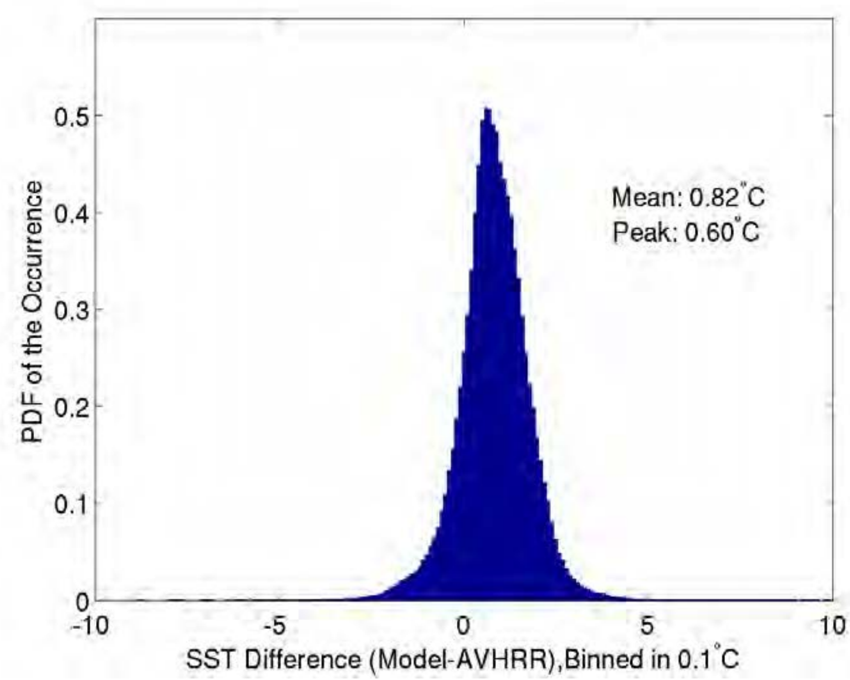


*Figure 3: Comparison of model surface temperature and salinity with observations: Histogram of the difference between daily mean surface temperature and daily composite AVHRR SST.*

## 2. The 4D-Var Implementation with CBOFS

We have updated the CBOFS with latest Regional Ocean Modeling System (ROMS). The current CBOFS uses an early version of ROMS and lacks the state-of-art 4D-Var design of the latest ROMS. To use the embedded 4D-Var technology in ROMS, the offline version of CBOFS has been updated to latest ROMS version, 3.6, and is validated using the same forcing and open boundary conditions as in the operational mode. ROMS has been developed with several kinds of 4D-Var techniques. Here we only consider the adjustment of model initial conditions, Incremental Strong constraint of 4D-Var (IS4DVAR), with assumption of model errors being zero.

We calculated background normalization coefficient matrix and historical standard deviation, which are needed in calculation of the background error covariance matrix. Normalization coefficient matrix calculation requires the estimation of the decorrelation scale. From AVHRR daily composite SST for the NOAA coastal watch program, using a simple spatial autocorrelation algorithm, a horizontal decorrelation scale of 17 km is estimated. A vertical decorrelation scale of 3 m is used which is estimated from a general minimum mixed layer depth near the lower Chesapeake Bay. A one year rerun of CBOFS from 08/2012 to 07/2013 is carried out and the results are used to calculate the background standard deviation by removing the major tidal signals and annual cycles in the physical variables. The length scales are used in ROMS to calculate the normalization coefficient matrix, together with the standard deviation, being used to implicitly from the background covariance matrix in IS4D-VAR.

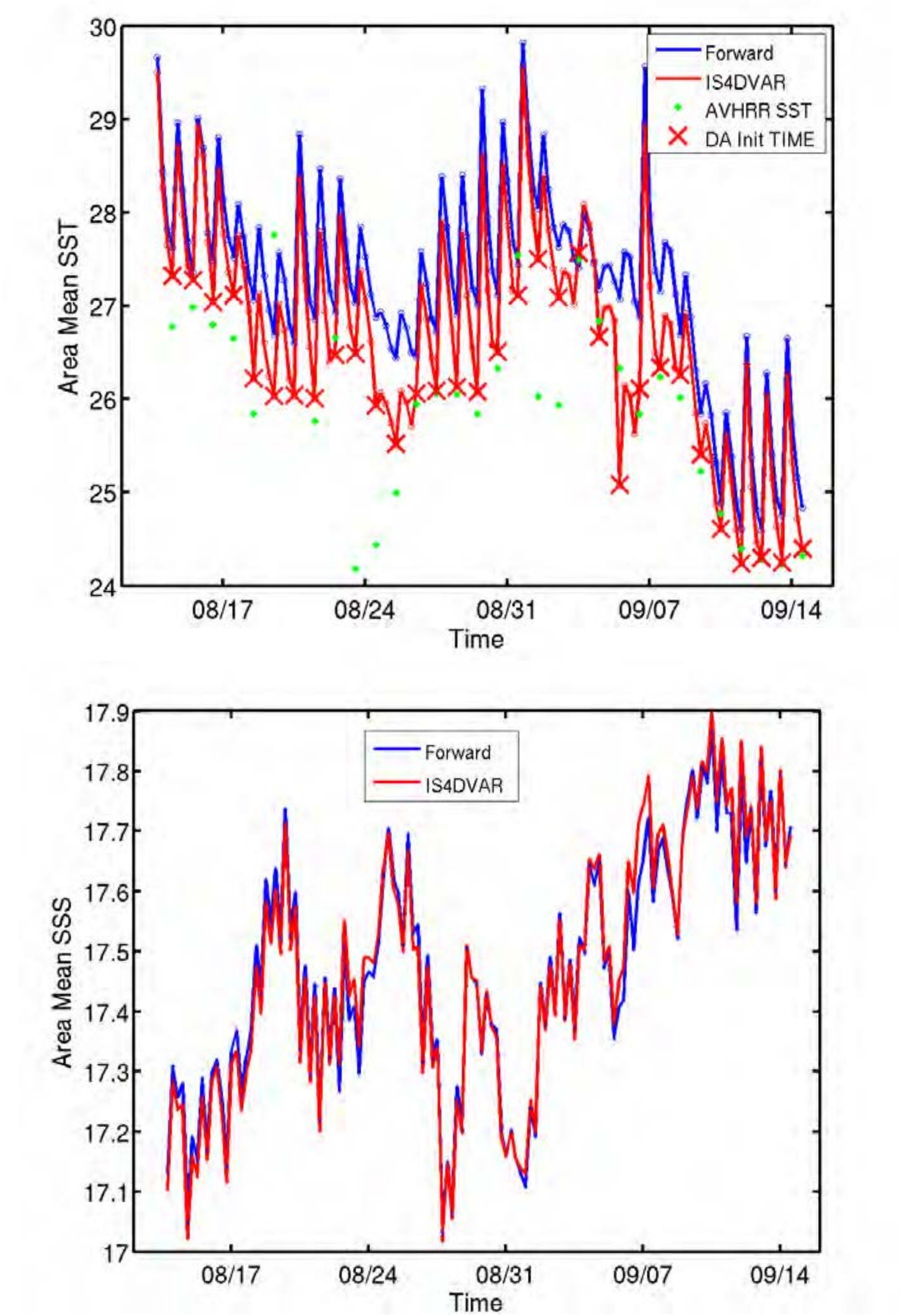


*Figure 4: Time series of SST and SSS every 6 hours with data assimilation. The assimilation of AVHRR SST lowers the model surface SST significantly and changes little on SSS. The high differences between AVHRR SST and model SST are caused by fewer SST estimates due to cloud contamination.*

### 3. Assimilation of AVHRR SST

To estimate the efficiency of the IS4DVAR with CBOFS, we tested this setup using the AVHRR daily composite SST products for the Chesapeake Bay. After a preliminary quality control, the 1km-gridded coastal watch SST are assimilated in a six-hourly window to adjust the initial conditions of the CBOFS forward run in a one-month sequential run from 08/14/2012 to 09/15/2012. With the AVHRR SST assimilated, the model bias in 30 days period is reduced by 0.5°C reference to the mean AVHRR data after 24 hours. The results also indicate that the SST assimilation has large impact on the salinity near the Chesapeake Bay mouth rather than other areas.

### 4. Test Assimilation with CTD profiles

To test how data assimilation results are sensitive to the Conductivity Temperature Depth (CTD) vertical profiles, in addition to AVHRR SST, we assimilated CTD temperature and salinity data from Chesapeake Bay Program and CBIBS in one assimilation window. The results show that CTD data are very helpful in correcting the model stratifications. Even with a few CTD stations in a six-hour window, the model salinity bias over next assimilation is reduced from 1.09 to -0.38 at observational stations and reduced by 0.13 over whole model domain. The temperature keeps as close as that with only SST assimilation.

### 5. Computational time cost evaluation

IS4DVAR costs usually tens to hundred times of forward run-time. One of important task in this proposal is to evaluate the computational cost in operational mode. In the AVHRR SST assimilation, the computational cost is around 80 times of forward run; with CTD data, the cost is around 360 times. If we assimilate SST with an appropriate parameter (inner/outer loop choice) and suitable assimilation window, the IS4DVAR is likely viable in an operationally mode with current CBOFS setup.

*Table I: IS4DVAR computational cost statistics based on 96 Intel Xeon 2.6GHz CPUs. The normalization coefficients calculation is carried on one time only.*

| Forward Run (6 hour window) | IS4DVAR with SST only (6 hours window with 10 Inner loops) | IS4DVAR with all data (6 hour window with 30 inner loops) | Normalization Coefficient with (3200 radomized Steps) | |
|---|---|---|---|---|
| | | | 3D variable | 2D Variable |
| 3 minutes | 4 hours | 18 hours | 72 hours | 12 hours |

### 6. Discussion

The assimilation of AVHRR SST is successful in reducing model SST bias. But it does not capture the corrections to the tidal cycle in the SST field so a high temporal and spatial resolution SST product, such as Suomi-National Polar-Orbiting Partnership (S-NPP) VIIRS SST will be used later. In the IS4DVAR background error covariance setup, we did not consider the dependencies among different variables, but the model dynamics can play a role in adjusting all variables consistently.

Due to the high computational cost of 4DVAR, the LETKF scheme will be evaluated since LETKF usually costs much less than 4DVAR and its time cost depends on the choice of ensembles.

The errors from open and surface boundary may also contribute to the model bias. In that case, the adjustment of surface and open boundary forcing may be needed in a reasonable time cost.

**PLANNED WORK**

1. We will assimilate S-NPP VIIRS SST into CBOFS using IS4DVAR and compare with AVHRR SST.
2. We will implement LETKF with CBOFS, assimilate VIIRS and AVHRR separately and compare results with those of IS4DAVR.
3. Both data assimilation setup will deliver to NOAA NOS.

**PRESENTATIONS**

4DVAR and LETKF Development for NOAA's Chesapeake Bay Operational Forecasting System, Matt Hofmann, Bin Zhang, Lyon W. J. Lanerolle and Christopher W. Brown, *AGU Ocean Science Meeting*, Honolulu, Hawaii, 2014.

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

**Graduate Student Support: ENSO Representation in CMIP5 Models**

| | |
|---|---|
| **Task Leader** | Phil Arkin |
| **Task Code** | BASE |
| **NOAA Sponsor** | Ingrid Guch |
| **NOAA Office** | NESDIS/STAR |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 0%; Theme 3: 100%. |
| **Main CICS Research Topic** | Climate Research, Data Assimilation and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 05% |

**Highlight**: We found that most CMIP5 models exhibit phenomena that resemble ENSO in their spatial and spectral signatures, with impressive consistency across ensemble members. There might also be an amplification of ENSO-related precipitation in the last century.

**BACKGROUND**

This task began in spring 2013 with the goal of investigating CMIP5 (Coupled Model Intercomparison Project Phase 5) models' simulation of ENSO (El Niño/Southern Oscillation) and the related precipitation. ENSO is the most significant interannual climate phenomenon, and is associated with large-scale changes in sea surface temperature (SST), surface pressure and atmospheric circulation. As a result, ENSO is the single most important determinant of variability in global precipitation fields on seasonal to interannual time scales. It is important to understand and predict ENSO and ENSO-related precipitation due to its connection with many environmental and societal problems. However, since ENSO is associated with complex atmosphere-ocean coupling, it is still difficult for models to accurately represent its behavior, as well as the related precipitation. CMIP5, as a project involving models across the world, provides us a great opportunity to inter-compare current models and to further understand ENSO. Below are our specific objectives:

1. Examine the ability of CMIP5 models to simulate ENSO and ENSO-related precipitation variability during the past century;
2. Compare future ENSO-like patterns to the past in the models; and
3. Use CMIP5 models' outputs to further understand ENSO and characterize model errors.

**ACCOMPLISHMENTS**

For the past year, we mainly focused on our first objective. We chose 11 CMIP5 models (historical runs) with ensemble members no less than 5 and with a 1901-2005 timespan. We used Empirical Orthogonal Functions (EOF), ENSO composites, simple correlation and power spectrum analysis to describe the mean-state and variance of ENSO-like phenomena (1901- 2005) in each CMIP5 model, from both precipitation and SST perspectives, and compared them to observational datasets (20th Century Reanalysis and Reconstructed Precipitation developed by Dr. Tom Smith for precipitation; HadISST and ERSST for SST). Here are the major results we have found:

1. Both EOF and composites results indicate that CMIP5 models and observations exhibit coherent large-scale variability in precipitation in the tropical Pacific region (see Fig.1). Most

CMIP5 models exhibit phenomena that resemble ENSO in their spatial and spectral signatures, with impressive consistency across ensemble members. The detailed spatial patterns, however, differ quite substantially from the observed ENSO precipitation anomalies;
2. Some models have better correlation with the observations than the other, which indicates there might be a good model cluster;
3. There is some evidence of change in ENSO circulation during the past century. The 2nd half of 20th century ENSO composite minus the 1st half (with background trend removed) result of the Reconstruction Precipitation suggests an amplification of ENSO in the last century, which might be a result of stronger La Niñas in the 2nd half.

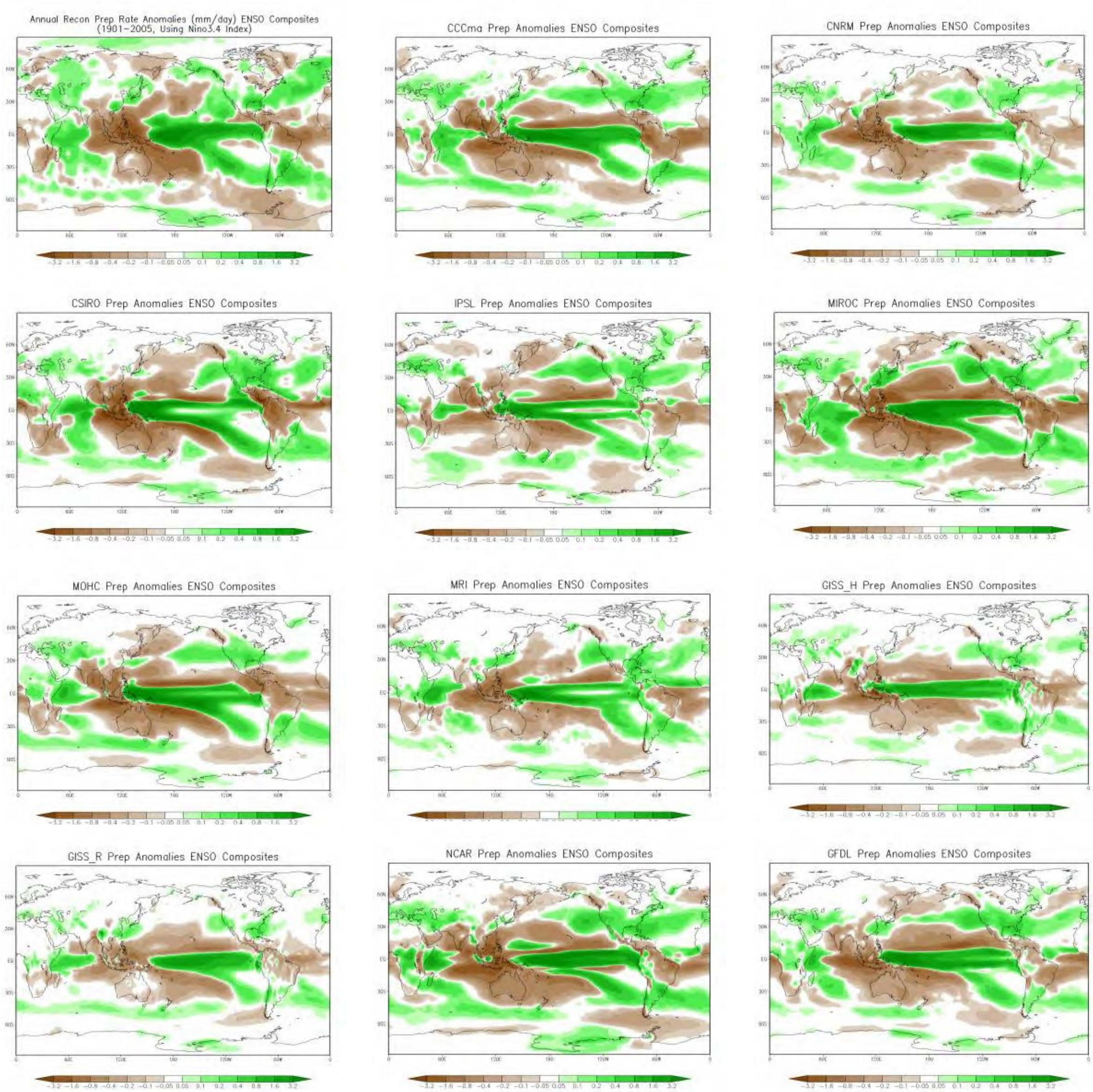


*Figure 1: Reconstruction of Precipitation and the 11 CMIP5 Models' Precipitation ENSO composite mean results*

**PLANNED WORK**

- Continue to describe the main characteristics of ENSO mean-state and variance in CMIP5 models;
- Investigate why each model's ENSO-related precipitation behaves in its own way;
- Describe future ENSO-like patterns in each CMIP5 model

**PUBLICATIONS**

Ni Dai and Phil Arkin, ENSO-related Precipitation Representation in CMIP5 Models (draft paper)

**DELIVERABLES**

Re-gridded CMIP5 monthly precipitation and sea surface temperature (2.5° by 2.5° historical runs)

**PRESENTATIONS**

Ni Dai and Phil Arkin, 2014: ENSO-related Precipitation Representation in CMIP5 Models, abstract submitted to 7th International Scientific Conference on the Global Energy and Water Cycle, 14-17 July, 2014, Hague, Netherlands

Ni Dai and Phil Arkin, 2013: ENSO Representation in CMIP5 Models: A Precipitation Perspective, 46th annual Fall Meeting of American Geophysical Union (9-13 December)

Ni Dai and Phil Arkin, 2013: ENSO Representation in CMIP5 Models' Precipitation (poster), 2nd Annual CICS-MD Science Meeting, College Park, Maryland (6-7 November)

Ni Dai and Phil Arkin, 2013: ENSO Representation in CMIP5 Models (poster), NOAA NOAA's 38th Climate Diagnostics and Prediction Workshop, College Park, Maryland (21-24 October)

**OTHER** (awards)

Jacob K. Goldhaber Travel Grant for 46th AGU Meeting (Received on 5 Dec, 2013)

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

| # of undergraduate students mentored during the year | 0 |
|---|---|

**Support for Community Radiative Transfer Model Development at the JCSDA**

| | |
|---|---|
| **Task Leader** | Quanhua (Mark) Liu |
| **Task Code** | QLQL_JCSDA_11 |
| **NOAA Sponsor** | Sid Boukabara |
| **NOAA Office** | JCSDA |
| **Percent contribution to CICS Themes** | Theme 1: 50%; Theme 3: 50%. |
| **Main CICS Research Topic** | Climate Research, Data Assimilation and Modeling |
| **Percent contribution to NOAA Goals** | Goal 5: 100% |

**Highlight**: CICS scientists are supporting Community Radiative Transfer Model development at the Joint Center for Satellite Data Assimilation. CRTM is a core component of the satellite radiance assimilation system in supporting of daily weather forecasting and satellite product generations.

**BACKGROUND**

Joint Center for Satellite Data Assimilation (JCSDA) has been improving and accelerating the uses of research and operational satellite data in numerical weather and climate prediction models. JCSDA provides a focal point for the development of common models and infrastructure among NASA, NOAA and the Department of Defense (DoD). The latest Community Radiative Transfer Model (CRTM) release is version 2.1.1 and is applicable for passive microwave, infrared and visible sensors. It supports all NOAA satellite instruments, NASA MODIS, and many foreign meteorological satellites. The CRTM includes dual transmittance models, Optical Depth in Absorber Space (ODAS) and Optical Pressure in Absorber Space (ODPS), sensor specific transmittance models: fast transmittance model for Stratospheric Sounding Unit (SSU) to take account for $CO_2$ cell pressure variation, fast transmittance model for Special Sensor Microwave Imager/Sounder (SSMIS) Upper Atmospheric Sounding (UAS) Channels including Zeeman-splitting. It also includes Non-local Thermodynamic Equilibrium (NLTE) Radiative Transfer, Comprehensive Surface Emissivity/Reflectivity Models, Aerosol, Cloud, and Molecular Scattering Models, Pre-computed look-up tables for extinction, scattering coefficients and phase functions, Dual Radiative Transfer Solver, Adding Double-Adding method, Adding Matrix Operator method, and (Successive-Order-of-Interaction) SOI method.

The CRTM is composed of four important modules for gaseous transmittance, surface emission and reflection, cloud and aerosol absorption and scatterings, and a solver for a radiative transfer. The gaseous transmittance describes atmospheric gaseous absorption, so that one can utilize remote sensing information in data assimilation/retrieval system about atmospheric temperature, moisture, and trace gases such as $CO_2$, $O_3$, $N_2O$, CO, and $CH_4$. The aerosol module is fundamental to acquire aerosol type and concentration for studying air quality. The cloud module contains optical properties of six cloud types, providing radiative forcing information for weather forecasting and climate studies. The CRTM surface module is complex to include surface static- and atlas-based emissivity/reflectivity for various surface types. Two radiative solvers have been implemented into the CRTM. The advanced doubling-adding (ADA) method is chosen as a baseline. Recently, the SOI radiative transfer model developed at the University of Wisconsin has also been implemented in the CRTM.

In the past year, the supported works of the CRTM included:

(1) Optimizing the CRTM;
(2) Investigating the issues in the CRTM water vapor Jacobians;
(3) Investigating the un-apodized radiance simulation capability;
(5) Upgrading the sea emissivity model;
(6) Simulating fast overcast radiance;
(7) Identifying the root cause of the large Jacobian values at the first few layers in NCEP regional model,
(8) Helping in the radiative transfer-related efforts coordination by co-leading the CRTM Working Group, participating in the NESDIS GAADA team, interacting with JCSDA partner and externally-funded scientists; and
(9) Helping with publications and presentations.

CRTM has been become a key component in U.S. data assimilation for weather forecasting at the National Center for Environmental Prediction (NCEP). CRTM is operationally used in the NOAA Microwave Integrated Retrieval System (MiRS) for satellite remote sensing products. The CRTM has been supporting satellite programs, GOES-R and Suomi NPP/JPSS.

**ACCOMPLISHMENTS**

The CICS scientist provides scientific supports and coordination to the CRTM development and maintenance. The CRTM version 2.1.4 will be publically released very soon. The release includes the new functionalities for fast overcast radiance calculations and various options for ocean surface reflection. We have found and corrected a segmentation fault and incorrect sensor characteristics in using Korean COMS-1. We have worked and delivered surface solar reflectance data to the Global Forecasting System (GFS).

Many accomplishments have been documented in the published papers. For example, Liu and Boukabara (2014) documented the application of CRTM for Advanced Technology Microwave Sounder (ATMS) data validation:

We analyzed the bias between ATMS measurements and the CRTM simulations using the ECMWF analysis. The bias is mainly caused by the uncertainties in the model inputs, the error in cloud identification, and uncertainties in the surface emissivity model. In order to avoid the complexity of microwave land surface emissivity, analyses were carried out over oceans. Clouds are a big issue in the comparison because there are large uncertainties in cloud variables. Traditionally, clouds are screened out by using cloud liquid water path, estimated from microwave window channels at two low frequencies (Weng and Grody, 1994). The horizontal resolution of the ATMS window channels 1 and 2 is very poor and quite different from the spatial resolution for other channels. The various spatial resolutions among the ATMS channels are challenging to the cloud screen method. In the paper, we use the uniformity to exclude cloudy pixels. ATMS channel 3 at 50.3 GHz, with fields of view averaged to $3 \times 3$, is used for the uniformity test. A threshold of 0.7K is used. The uniformity test result at channel 3 is used for all other channels. As shown in Figure 1, the large tail (red line) due to clouds on the right side is reduced (green line). Over oceans, clouds contribute more radiation to the

ATMS measurements than oceans. There are still tails on the right side in green curves in which the uniformity test at channel 3 is applied. When we further limit data within 50% in the histogram of channel 3, we may find (see black line) that more cloudy pixels are excluded. The uniformity test left 30% of total data points for use. The second condition (50% histogram) further reduces the data by 10%.

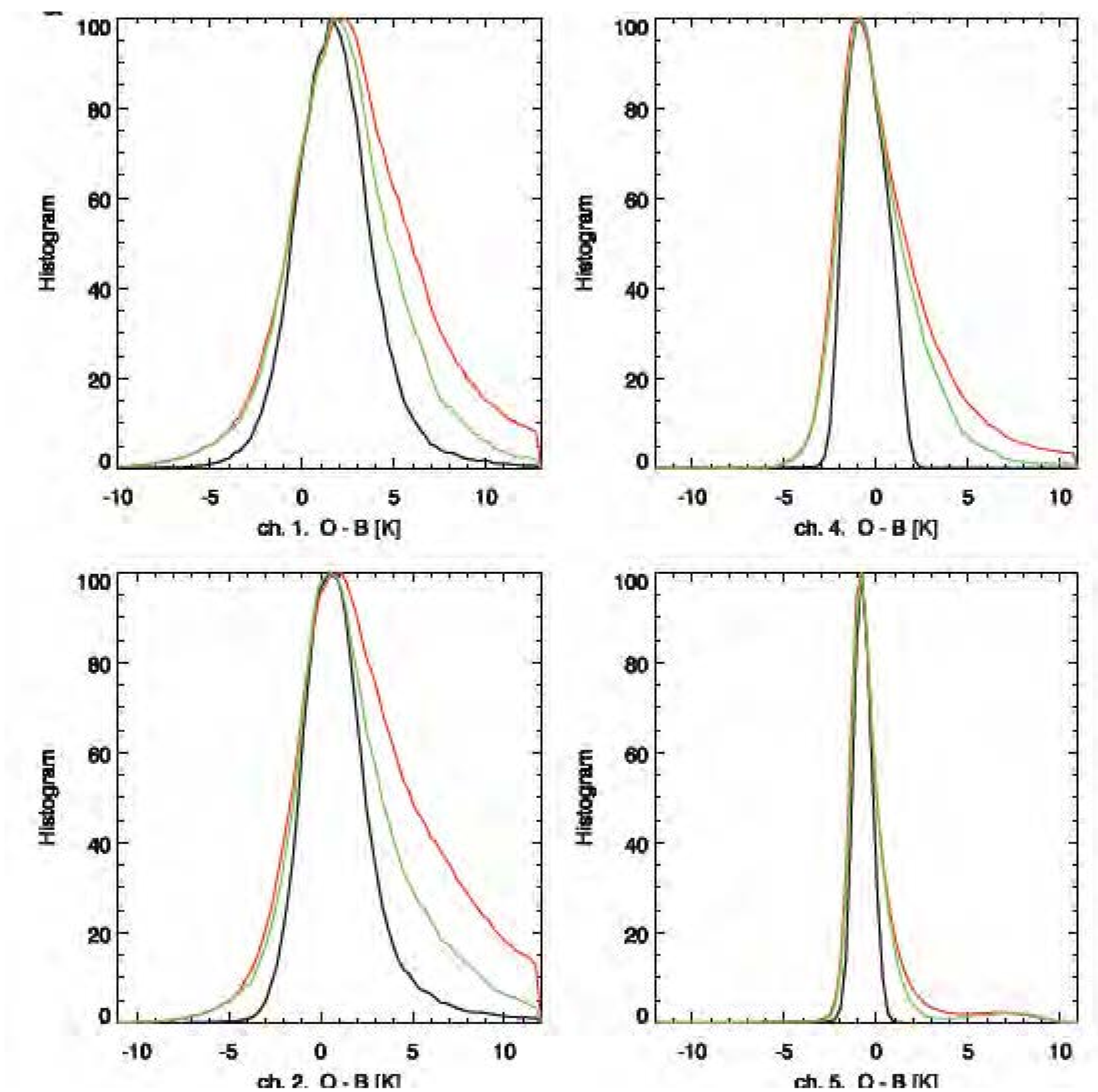


*Figure 1. Histograms of the ATMS observations minus the CRTM simulations over oceans. The red line uses all data. The green line is for the data which passed the uniformity test of channel 3. The black line is for the data which passed the uniformity test and within central 50% of the histogram of channel 3.*

**PLANNED WORK**

- **Large enhancement of the CRTM calculation efficiency**: It was turned out that the Prototype CRTM (pCRTM) used in the MiRS is faster than the current CRTM for using two streams, and latter uses a rigorous solution for all streams and the former uses a specific solution for two streams. The CRTM efficiency prevented the delivery of the MiRS with the latest CRTM version. We have known a solution and need to implement a new solver.

- **CRTM option to obtain hydrometeor Jacobians when initial atmosphere contains no cloud**: In radiance assimilation and retrieval algorithms of satellite products, the first guess may be for clear-sky conditions even observations are for clouds. The current CRTM doesn't provide Jacobian values of hydrometeors for the cases which caused either incorrect calculations or rejection of using satellite observations. We need to develop the capability.
- **Exploration of the possibility to extend CRTM capabilities to simulate active sensors**: More and more products from active sensors are assimilated into the GSI and provided useful information. To directly assimilate the reflectance of the active sensors can enhance the values of the measurements, for example reduce the ambiguity in wind direction for OSCAT data.
- **Removal of large top atmosphere layer Jacobians when using NCEP forecast model vertical coordinates:** For both regional and global NCEP vertical coordinates erroneous large top atmosphere layer temperature Jacobians have been reported by Gridpoint Statistical Interpolation (GSI) developers. The large top atmosphere layer Jacobians are particularly noticeable for regional NCEP vertical coordinates, but the problem is also apparent in CRTM k-matrix output when global NCEP vertical coordinates are provided. A simplistic mapping of CRTM build test atmospheres to NCEP vertical coordinates indicates that the reported problem is reproducible. The CRTM team identified the cause and will work with customers to solve the issue.
- **Addition of $SO_2$ as a trace gas**: Sulfur dioxide ($SO_2$) is a short-lived gas which can act as pollutant near the surface, with detrimental health and acidifying effects. With a mean life time of just a couple of days in the troposphere, emitted $SO_2$ is quickly converted to sulfate aerosol ($SO_4$) through oxidation by OH or by reaction with $H_2O_2$ within clouds. The resulting $SO_4$ exerts a direct radiative effect on the atmosphere and it can also have an indirect radiative effect by inducing changes in cloud and precipitation microphysics.
- **Extension of the Aerosol Optical Module**: Currently, the program Create_SpcCoeff_from_SRF takes SRF format netCDF files as input and creates SpcCoeff files. The program needs to be updated to take oSRF format netCDF files as input instead of the SRF format netCDF files.
- **Development of a unified surface emissivity/reflectance interface:** Current CRTM uses the assumption of Lambertian, specular, and bidirectional reflection distribution function (BRDF) for a given surface type and a given sensor. The assumption is not robust and even inaccurate in some applications. The new development is going to include the most advanced surface emissivity/reflectance data and methodologies.

**PUBLICATIONS**

**Liu**, Q., and S. Xiao, 2014: Effects of Spectral Resolution and Signal-to-Noise Ratio of Hyperspectral Sensors on Retrieving Atmospheric Parameters, *Opt. Lett.*, **39**, 60–63.

**Liu**, Q., 2014: Electric Car with Solar and Wind Energy May Change Environment and Economy – A tool for utilizing the renewable energy resource, *Earth's Future*, http://doi.org/10.1002/2013EF000206.

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

**Liu**, Q., and S. Boukabara, 2014: Community Radiation Transfer Model (CRTM) Applications in Supporting the Suomi National Polar-Orbiting Partnership (SNPP) Mission validation and Verification, *Remote Sen. Environ*., **140**, 744–754.

**Liu**, Q., C. Cao, and F. Weng, 2013: Striping in the Suomi NPP VIIRS Thermal Bands through Anisotropic Surface Reflection, *J. Atmos. Oceanic. Technol*., **30**, 2478–2487, http://dx.doi.org/10.1175/JTECH-D-13-00054.1

**Liu**, Q., C. Li, and Y. Xue, 2013: Sensor-based clear and cloud radiance calculations in the community radiative transfer model, *Appl. Opt.*, **52**, 4981–4990.

**Liu**, Q., C. Cao, and F. Weng, 2013: Assessment of Suomi National Polar-Orbiting Partnership VIIRS Emissive Band Calibration and Inter-Sensor Comparisons, *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, http://dx.doi.org/10.1109/JSTARS.2013.2263197 .

**Liu**, Q., and F. Weng, 2013: Using advanced matrix operator (AMOM) in community radiative transfer, *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.*, http://dx.doi.org/10.1109/JSTARS.2013.2247026 .

Boukabara, S.-A.,, K. Garrett, C. Grassotti, F. Iturbide-Sanchez, W. Chen, Z. Jiang, S. A. Clough, X. Zhan,P. Liang, Q. **Liu**, T . Islam, V. Zubko, and A. Mims, 2013:,A physical approach for asimultaneousretrieval of sounding,surface, hydrometeor, and cryospheric parameters from SNPP/ATMS, *J. Geophys. Res. Atmos*., **118**, 12,600–12,619, http://dx.doi.org/10.1002/2013JD020448 .

**PRESENTATIONS**

Liu, Q., P. van Delst, D. Groff, A. Collard, F. Weng, S. Boukabara, and J. Derber, Community Radiative Transfer Model (CRTM) for aerosol radiance assimilation, San Francisco, California, AGU 2013.

Liu, Q., P. van Delst, M. Chen, Y. Chen, D. Groff, Y. Han, A. Collard, F. Weng, S. Boukabara, and J. Derber, Progress in Community Radiative Transfer Model for radiance assimilation, Atlanta, Georgia, AMS 2014.

Cao, C., Q. Liu, S. Blonski, X. Shao, and S. Uprety, Suomi NPP VIIRS Calibration/Validation Progress Update, Atlanta, Georgia, AMS 2014.

**PERFORMANCE METRICS**

| | FY13 |
|---|---|
| # of new or improved products developed following NOAA guidance | 1 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 2 |
| # of new or improved products developed without NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 0 |
| # of peer reviewed papers | 9 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 3 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**PERFORMANCE METRICS EXPLANATION**

The improvements to the new version of the CRTM are listed above (1). Research was moved to operations with the new functionalities for fast overcast radiance calculations and various options for ocean surface reflection (2). Nine peer-reviewed journal articles on the project were published this fiscal year (9) and three conference presentations were given (3), all listed above.

**Participation in Climate Research Activities at the Air Resources Laboratory NOAA & Particulate Matter Forecasting and Analysis Systems**

| | |
|---|---|
| **Task Leader** | Russ Dickerson |
| **Task Code** | RDRD_PCAQ_13 & RDRD_PMFA_13 |
| **NOAA Sponsor** | Richard Artz & Laury Miller |
| **NOAA Office** | OAR/ARL & NESDIS/STAR |
| **Percent contribution to CICS Themes** | Theme 1: 0%; Theme 2: 50%; Theme 3: 50% |
| **Main CICS Research Topic** | Climate Research, Data Assimilation and Modeling<br>Surface Observing Networks |
| **Percent contribution to NOAA Goals** | Goal 1: 25%, Goal 2 50%; Goal 3: 25% |

**Highlight**: In 2013, the six CICS research scientists working with NOAA's ARL are made air quality measurements and forecasts to complement ongoing atmospheric chemistry studies at UMD: http://www.arl.noaa.gov/.

## Report of Li Pan

**BACKGROUND**

Dr. Pan continues to provide scientific and technical support for the National Air Quality Forecasting Capability (NAQFC) under the CICS ARL (RDRD_PCAQ_13) grant and staffed the new Particulate Matter Forecasting and Analysis Systems (RDRD_PMFA_13) project. This includes support for operational ozone and experimental $PM_{2.5}$ forecasting for the continental US. CMAQ model simulations were conducted in support of the DISCOVER-AQ Houston field program and the NOAA SENEX 2013 field measurement campaign. Dr. Pan is contributing to the launch of a chemical data reanalysis project aiming to provide reliable initial and boundary conditions for air quality related studies.

**ACCOMPLISHMENTS**

- NAQFC
  - In May 2013, NOAA National Center for Environmental Prediction (NCEP) decided to retire IBM Central Computer System (CCS) and move all the operational systems to Weather & Climate Operational Supercomputing System (WCOSS). The system porting was successfully completed and the verification testing was finished before the transition deadline.
  - Fire is one of important emissions sources in CONUS. NOAA Hazard Mapping System (HMS) detects fires using satellite imagines and ground observation. The current emissions process used in NAQFC was updated by including real-time fire emissions into CMAQ forecasting.
  - Emissions from wind blowing dust are also included into current NAQFC system and PM emissions were adjusted by snow covering data.

- Field Campaigns
  - Contributed to two field campaigns, which are Deriving Information on Surface Condition from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) in Houston and NOAA Southeast Nexus (SENEX) 2013, by providing CMAQ forecasts.
- Particulate matter forecasting and analysis system
  - CMAQ version 4.7.1 was operationalized and was invoked to perform particulate matter (PM) forecasting in an on-demand basis during two intensive measurement campaigns: (a) Discover-aq, conducted over the San Joaquin Valley (SJV) between January 13 to February 10, 2013, and (b) SOAS, Southern Oxidant and Aerosol Study, over Centreville, Alabama and its vicinity, between June 13 and July 10, 2013. Both campaigns focused on PM. During winter in SJV there are frequent episodes of haze and fog. During the summer in Alabama, large atmospheric loadings of organic aerosols are frequently observed. For both of these studies CMAQ, a chemical transport model (CTM), was driven by NCEP's North American Mesoscale meteorological model (NAM) to better understand PM loadings.
  - Model simulations are required by the air quality research community to address air pollution health problems cited in State Implementation Plans (SIP). The accuracy of model simulations is dependent, in part, on model inputs such as model initial and boundary conditions. Based on a WRF-CMAQ coupling system, a chemical data reanalysis project was conducted, and included two sets of observational data: (a) the US EPA Air Quality System (AQS) PM data set, and (b) a MODerate resolution Imaging Spectro-radiometer (MODIS) satellite-based aerosol optical depth data set. These data sets are ingested into the model simulation by data assimilation methods. The disparity of the nature of these two data sets posed challenges: the former is composed of hundreds of point measurements over CONUS, and the latter is a column integrated quantity with a geographical spread involving thousands of pixels.
  - Substantial progress has been achieved to address and overcome this data disparity issue through the adoption of an optimal interpolation data assimilation algorithm. It is a state-of-the-science scheme derived from an Ensemble Kalman Filter (EnKF) approach. This approach can complement the 3 Dimensional variational (3DVar) methodolgy if one can safely assume that both the observation and model errors are normally distributed. The code was designed so that the National Centers for Environmental Prediction grid point statistical interpolation (GSI), an official data assimilation protocol at NCEP, can be easily merged into the constructs of the code. It achieved high computational efficiency as demonstrated through the generation of a one month chemical reanalysis data set for July, 2011. The reanalysis chemical fields were used as best estimates for "ground-truth" states of the atmosphere and were used as the basis to extract dynamic boundary conditions for a proxy SIP modeling simulation for the Baltimore and Washington region. Drs. Yongtao Hu and Talat Odman of the Georgia Institute of Technology (GaTech) assisted with the SIP modeling project. In addition to the AQS data set, the GaTech – CICS-MD partnership used AErosol RObotic NETwork (AERONET), and Interagency Monitoring of Protected Visual Environments (IMPROVE) data to verify the reanalysis fields used to generate SIP modeling results.

**PLANNED WORK**

- $PM_{2.5}$ forecasting;
- Reducing ozone forecasting bias;
- DISCOVER-AQ participation in Denver, 2014;
- Demonstration of chemical data reanalysis

**PUBLICATIONS**

Li Pan, D. Tong, P. Lee, H. C. Kim, T. Chai and C. Ding, "Diagnostic evaluation of NOx upgrades on air quality forecast", *Air Pollution Modeling and its Application XXIII*, Douw. G. Steyn and Rohit Mathur (eds.), Springer International Publishing, Switzerland, 2014.

Li Pan, Daniel Tong, Pius Lee, Hyuncheol Kim and Tianfeng Chai, "Assessment of NOx and O3 forecasting performances in the U.S. National Air Quality Forecasting Capability before and after the 2012 major emissions updates" submitted to *Atmospheric Environment*, March 2014.

**PRESENTATIONS**

Li Pan, Pius Lee, Daniel Tong, Fantine Ngan, Hyuncheol Kim, and Tianfeng Chai, "NMMB- CMAQ 4km forecasting system in Houston: model simulation and evaluation", 93rd AMS Annual Meeting, January 2013, Austin, TX.

Li Pan, Daniel Tong, Pius Lee. Hyuncheol Kim and Tianfeng Chai "The analysis of NOx predictions in CMAQ (Community Multiscale Air Quality) Model: emission updating, simulation improvement and remaining problem", NASA Air Quality Applied Sciences Team (AQAST) 5th Biannual Meeting, June 2013, College Park, MD.

Li Pan, Daniel Tong, Pius Lee, Hyuncheol Kim and Tianfeng Chai "Diagnostic evaluation of NOx upgrades on air quality forecast", ITM (International Technical Meeting on Air Pollution Modeling and its Application) 2013, Aug 2013, Miami, FL.

Li Pan, Pius Lee, Hyuncheol Kim, Daniel Tong, Rick Saylor and Tainfeng Chai, "Preliminary analyses of flight measurements and CMAQ simulation during Southeast Nexus (SENEX) field experiment", 12th Annual CMAQ Conference, Oct 2013, Chapel Hill, NC.

Pius Lee, Tianfeng Chai, Hyuncheol Kim, Daniel Tong and Li Pan, Ted Russell, Yongtao Hu and Talat Odman, "Support of AQ community by providing long term reanalysis Chemical fields through data assimilation – prototype & testing" AQAST 5th Semi-annual, June 4-6, 2013.

Pius Lee, Greg Carmichael, Tianfeng Chai, Rick Saylor, Li Pan, Hyuncheol Kim, Daniel Tong, Ariel Stein, and Yongtao Hu "A Regional Chemical Reanalysis Prototype", 12th CMAS: Oct_28_to_30_2013, Chapel Hill, NC.

Pius Lee, Daniel Tong, Hyuncheol Kim, Li Pan, "Partnership in Air Quality Forecasting --- Local agency forecasters, managers and NOAA", MARAMA, Charlottesville, VA, July 24 2013.

Rick Artz and Pius Lee, Daniel Tong, Tianfeng Chai, Hyuncheol Kim, Li Pan, and Fantine Ngan, "Research on Air Quality Forecasting and Source Attribution", Air Resources Lab and CICS, UMD for MDE Quarterly Jan 18th 2013.

Pius Lee, Li Pan, Hyuncheol Kim, Daniel Tong "Intensive campaigns supported by air quality forecasting capability to identify chemical and atmospheric regimes susceptible to standard violations" ITM: Aug_26_to_30_2013, Miami, FL.

Daniel Tong, Li Pan, Tianfeng Chai, Hyuncheol Kim, Pius Lee, Rick Saylor, "Assimilating satellite products in emission modeling to support air quality and climate modeling", ITM: Aug_26_to_30_2013, Miami, FL.

Pius Lee, Hyuncheol Kim, Li Pan, Daniel Tong, Tianfeng Chai, "Maintenance*, Performance Evaluation and Development of the National Air Quality Forecasting Capability (NAQFC)", ARL/NOAA for NAQFC Focus Group Meeting Sep 26th 2013, Washington D.C.

Pius Lee, Jeff McQueen, Ivanka Stajner, Daniel Tong, Jianping Huang, Hyuncheol Kim, Li Pan, Barry Baker, Sarah Lu ,Jerry Gorline, Daiwen Kang, Sikchya Upadhaya3 "Improvement on PM forecasting – Anthropogenic fugitive dust (primary PM emission) – modulated by snow/ice cover", National AQ : Feb_10_to_12_2014, Durham, NC.

Daniel Tong, Hang Lei, Li Pan, Pius Lee and Menghua Wang "Global estimate of marine isoprene emission based on Soumi-NPP VIIRS ocean color data", the Air-Sea exchange session at the 2014 AGU Ocean Science Meeting, Feb 24-28, 2014, Honolulu, HI.

## Report of Paul Kelley

**BACKGROUND**

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

**ACCOMPLISHMENTS**

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

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

Mr. Kelley performs weekly maintenance and repair at the Beltsville, MD site to keep it operating according to AMNET protocols. Two trips in 2013 were made to the Grand Bay, MS site to repair instruments and perform calibrations.

In February 2013, a complete mercury speciation system was installed on the hangar roof of the Sub-millimeter Array at the summit of Mauna Kea, HI. Additionally continuous monitors for $SO_2$ and $O_3$ were also installed on Mauna Kea, as well as a CO monitor and an elemental mercury detector at the Mauna Loa Observatory across the valley. These additional instruments are part of a short-term intensive designed to understand unusually high FPM measurements that have been found episodically at Mauna Loa over the past two and a half years. During these periods of high FPM we detect lower than normal elemental mercury.

Because this anomalous partitioning shows a strong diurnal cycle, the problem may be related to large changes in water mixing ratio that occur as free tropospheric air washes down-slope at night. A heated bubbler system has been tested at Beltsville to introduce a small flow of moist air to the mercury speciation system inlet to prevent periods of water mixing ratio less than a few gm/m$^3$.

**(2) $NO_x$ measurements during DISCOVER-AQ in Galveston**

A three-channel NOx system was prepared and installed in Galveston, TX for the NASA DISCOVER-AQ intensive held in Sept.- Oct., 2013. In addition $SO_2$ and $O_3$ measurements were also made at the Galveston site, as well as $NO_2$ measurements at a ground site in Manvel Croix, TX.

**PLANNED WORK**

- Continue support for long-term Hg monitoring at the three AMNET sites.
- Install humidity system to the inlet of Mauna Loa mercury speciation system.

**PUBLICATIONS**

Ren, X., D. van Duin, M. Cazorla, S. Chen, J. Mao, L. Zhang, W. H. Brune, J. H. Flynn, N. Grossberg, B. L. Lefer, B. Rappenglück, K. W. Wong, C. Tsai, J. Stutz, J. E. Dibb, B. T. Jobson, W. T. Luke, and P. Kelley, Atmospheric oxidation chemistry and ozone production: Results from SHARP 2009 in Houston, Texas, *J. Geophys. Res. -Atmos.*, 118, 5770–5780, doi:10.1002/jgrd.50342, 2013.

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

Brooks, S., X. Ren, W. T. Luke, P. Kelley, M. Cohen, R. Artz, A. Hynes, W. Landing, and B. Martos, Airborne vertical profiling of mercury speciation in Tennessee, USA, *Atmosphere*, submitted, 2014.

## Report of Fong Ngan

**BACKGROUND**

The NOAA dispersion model, Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) has been coupled to the Advanced Research WRF (WRF-ARW). This coupled version of HYSPLIT takes advantage of the higher temporal output frequency of meteorological variables that provides more detail descriptions of atmospheric conditions for the dispersion calculation between the normal output interval of meteorological models.

The meteorological input is one of the important factors to determine the accuracy of HYSPLIT results since it controls the transport and dispersion of pollutants, as well as the processes of wet and dry deposition. The data should properly represent the continuous fields of winds, temperature, precipitation and mixing property of planetary boundary layer in space and time dimension.

**ACCOMPLISHMENTS**

**1. Development of WRF-HYSPLIT inline coupling**

The coupled HYSPLIT is currently available in the latest release of WRF-ARW version 3.5.1 which includes more updated physics schemes than WRF-ARW version 3.2 used initially in the coupling implementation. Instead of constructing its own vertical structure, HYSPLIT has been modified to use the same WRF-ARW vertical coordinate which is the terrain-following hydrostatic pressure coordinate. This is an essential step to bring the linkage of WRF and HYSPLIT to tight coupling level for more frequent communication of two models. The eta coordinate implemented in HYSPLIT was fully evaluated with simulations for six releases during the Cross-Appalachian Tracer Experiment (CAPTEX). The results were comparable to runs using original vertical coordinate in the standard version of HYSPLIT.

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

To better describe the mesoscale feature in the meteorological modeling for the plume dispersion calculations, finer resolution meteorological simulations were conducted using the WRF-ARW with data assimilation by bringing observations to the simulation through objective analysis and nudging strategy. The model evaluations were performed with surface and upper level observations to characterize model results that lead to further understanding of the possible uncertainty in the dispersion calculation due to the inaccuracy of meteorological input. The assimilated WRF-ARW data are available for tracer experiments including CAPTEX and Nevada nuclear test in 1950s, as well as the measurement campaigns at Grand Bay for the atmospheric fate and transport of mercury in summer 2010 and spring 2011. These applications of the WRF-ARW results for HYSPLIT modeling are included in the manuscripts submitted to journal publications.

**PLANNED WORK**

- Advance the WRF-HYSPLIT the coupling by parallelizing the HYSPLIT model to be consistent with the WRF-ARW domain decomposition that more frequent communication between the two models will be made possible.
- Generate meteorological inputs in fine spatial resolution for other tracer experiments such as the Atmospheric Studies in Complex Terrain (ASCOT) and mercury episodes in recent years at Grand Bay stations.

**PUBLICATIONS**

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**PRESENTATIONS**

**Ngan, F.,** A. Stein and R. Draxler, 2013: Inline coupling of WRF-HYSPLIT: Development and results for CAPTEX-83. Traversing New Terrain in Meteorological Modeling, Air Quality and Dispersion. UC Davis, CA.

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## Report of Hyun Cheol Kim

**BACKGROUND**

The development of an IDL-based geospatial data processing framework for meteorology and air quality modeling project investigates basic computational algorithms to handle Geographic Information System (GIS) data and satellite data essential in regional meteorological and chemical modeling. It develops a set of generalized libraries within a geospatial data processing framework aiming to process geospatial data more efficiently and accurately. The tool can process GIS data both in vector format (e.g., ESRI shape files) and raster format (e.g., GEOTIFF and IMG) for any given domain. Processing speeds are improved through selective usages of polygon-clipping routines and other algorithms optimized for specific applications. The raster tool is developed utilizing a histogram reverse-indexing method that enables easy access of grouped pixels. It generates statistics of pixel values within each grid cell with improved speed and enhanced control of memory usage. Geospatial data processing tools to determine spatial allocation that use polygon clipping algorithms require huge computational resources to calculate fractional weighting between GIS polygons of the physical space (and/or polylines) and gridded cells of the modeling space. To overcome the speed and computational accuracy issues, an efficient polygon/polyline clipping algorithm is crucial. One key element for faster spatial allocation is to optimize computational iterations in both polygon clipping and map projection calculations.

The project had the following specific objectives: (A) To develop an optimized geospatial data processing tool that can transform raster data format and vector data format to any target domain within the data coverage with vastly shortened processing time and enhanced accuracy. (B) To collect and to process sample GIS and satellite data so that they are readily deployable for modeling studies. Applications include a spatial regridding method for emissions and satellite data. (C) To perform engineering tests to demonstrate the tool's capability in improving routine data processing for meteorological and air quality models. An example test case has been included in the user-guide and users' installation sample testing package delivered in conjunction with this report.

**ACCOMPLISHMENTS**

In the Comparing GOME-2, OMI and CMAQ $NO_2$ columns using conservative reconstruction method study, we present that traditional spatial regridding methods applied to space-based observations tend to cause serious bias for retrieved data when subject to varying footprint pixel resolution in fine-scale comparisons between different satellite platforms, or even within single instrument. In order to resolve this issue, we designed a new spatial regridding method which performs (a) lossless fractional weighting using accurate polygon clipping algorithms, and (b) spatial reconstruction (or downscaling) based on fine-scale information using moving spatial weighting kernels. We first applied the method to a case for $NO_2$ columns from the Global Ozone Monitoring Experiment-2 (GOME-2), the Ozone Monitoring Instrument (OMI) and the Community Multiscale Air Quality (CMAQ) model NO2 columns (4-km resolution)in 2008 southern California. The new method successfully produces fine scale satellite-derived $NO_2$ columns, showing excellent agreement with CMAQ $NO_2$ columns ($R=0.96$ for GOME-2 and $R=0.93$ for OMI in August 2008) and with surface $NO_2$ concentrations from U.S. Environmental Protection Agency (EPA) Air Quality System (AQS) monitoring sites ($R=0.91$ for GOME-2 and $R=0.80$ for OMI in August 2008). Nonetheless, traditional methods show significant negative biases in highly urbanized regions or near active traffic activities. We further investigated bias dependency in raw data pixel resolution over urban cities in the Contiguous United States. While satellite measurement at nadir provides best resolution data (e.g. $13\times24=312km^2$ for OMI), its actual coverage is extremely small; using 50% of available pixels (pixel size < 450 $km^2$) results in only ~11% coverage. When bigger pixels are allowed, satellite's coverage increases (e.g. data coverage at 75% (<721 $km^2$) and 100% (<1732 $km^2$) are 24% and 60%, respectively) but it tends to underestimate column density over urban cities with traditional regridding method. The new spatial regridding method successfully removes pixel-dependent biases over urban cities and maximizes data coverage.

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### *Journals*

Chai, T., **H. Kim**, P. Lee, D. Tong, L. Pan, Y. Tang, J. Huang, J. McQueen, M. Tsidulko, and I. Stajner, 2013, Evaluation of the United States National Air Quality Forecast Capability real-time forecasts in 2010 using Air Quality System ozone and $NO_2$ measurements, *Geosci. Model Dev*., 6, 1831-1850, doi:10.5194/gmd-6-1831-2013, 2013.

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**Kim, H. C**., H. Choi, F. Ngan, and P. Lee, Surface ozone variability in synoptic pattern perspectives, *Air Pollution Modeling and its Application XXIII*, D. Steyn and R. Mathur (eds.), Springer Proceedings in Complexity, DOI 10.1007/978-3-319-04379-1__91, in press

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## Report of Tianfeng Chai

### BACKGROUND

The National Oceanic and Atmospheric Administration, through the National Weather Service (NWS) with support from the Office of Atmospheric Research (OAR), is one of the WMO designated Regional Specialized Meteorological Centers (RSMC) for transport model products. NOAA backtracking support to the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) started on October 1, 2012 for the implementation of the CTBTO-WMO (World Meteorological Organization) Backtracking Response System required by the CTBTO Verification regime. Such backtracking capability to the RSMC-Washington is planned to be added and tested operationally in 2014.

### ACCOMPLISHMENTS

A web-based interface for the CTBTO backtracking Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) run has been developed. It is designed to allow users, e.g., NWS Central Operations (NCO) personnel in future operations, to check inputs before the model run. After the backtracking HYSPLIT run, model results will be plotted and displayed through the web interface before they are uploaded to CTBTO. The system has been continuously updated since its initial version in April 2013. Updates include quality control steps, improved user interface, and a few bug fixes. It has been used to process the CTBTO requests ever since April 2013. Computer codes and scripts have been provided to NWS to prepare the future operation test.

A source attribution analysis system is being developed to determine the most likely source strength, location, and/or time, based on monitor data. Fukushima incident is used a test case and the temporal profile of the release strength is adjusted according to the HYSPLIT model results and measurements from CTBTO and other organizations.

An intensive effort was made to meet the stringent demand of providing PM forecast for two intensive field measurement campaigns with co-ordination of multiple measurement platforms: satellites, aircraft, ground-based lidars and air impact-samplers. The forecast provided required information concerning pollution plume locations and vertical stability stratification profiles to enable field managers to plan flight transacts and spirals to traverse layers of sharp gradients of PM loading. Post analyses for an older campaign performed in 2011 entailed analysis of a large amount of data collected by the aforementioned measurement platforms. The Optimal Interpolation methodology (OI), a special truncated case of the Ensample Kalman Filter (EnKF) approach, was implemented for this retrospective chemical reanalysis study.

**PLANNED WORK**

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

**PUBLICATIONS**

"Evaluation of the United States National Air Quality Forecast Capability experimental real-time predictions in 2010 using Air Quality System ozone and NO2 measurements," by **Chai, T**., H. Kim, P. Pius, D. Tong, L. Pan, Y. Tang, J. Huang, J. McQueen, M. Tsidulko, and I. Stajner, Geosci. Model Dev., 6, 1831-1850, doi:10.5194/gmd-6-1831-2013, previous discussion paper, in Geosci. Model Dev. Discuss., 6, 2609-2654, doi:10.5194/gmdd-6-2609-2013, 2013.

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"Sensitivity Study on Generating Atmospheric Chemistry Reanalysis Field for the Contiguous Unites States Using Community Multi scale Air Quality (CMAQ) Modeling System," by **Chai, T**., P. Lee, H. Kim, L. Pan, and D. Tong, Sixth WMO Symposium on Data, College Park, MD, Oct. 7-11, 2013.

## Report of Xinrong Ren

**BACKGROUND**

Aerosol optical depth (AOD) observed from satellites can provide a view broad in space and time, but the accuracy of retrievals for varying surface properties, and varying aerosol optical properties, as well as the relationship between remotely sensed AOD and surface concentration of $PM_{2.5}$ remain as major unanswered questions in atmospheric science. Mercury is a serious environmental toxin. In the troposphere gaseous elemental mercury (GEM) is observed ubiquitously. The distributions of gaseous oxidized mercury (GOM) and particulate bound mercury (PBM) are not well documented. It is highly desirable to conduct measurements of a variety of trace gases along with atmospheric mercury to facilitate source identification. There are few studies on measurements of atmospheric mercury from aircraft.

**ACCOMPLISHMENTS**

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

*(1) Aircraft Observations in Support of GOES-R/VIIRS Calibration and Validation*

Dr. Xinrong Ren conducted aircraft observations of aerosol properties and trace air pollutants in summer 2013 over the Eastern Shore to validate GOES EAST Aerosol/Smoke Product (GASP) and the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS). The objective of this study is to link the satellite-observed aerosol optical depth (AOD) to the surface particulate matter (PM). Initial analysis shows that the integrated aerosol extinction (AOD) within the aerosol layer observed by the aircraft is highly correlated with the $PM_{2.5}$ concentration observed at the surface. In collaboration with a group at the NOAA/NESDIS/STAR, these aircraft observations are being compared to the concurrent satellite observations.

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

Dr. Xinrong Ren provided support of weekly maintenance for a long-term atmospheric mercury monitoring site in Beltsville, Maryland operated by NOAA Air Resources Laboratory (ARL) according to EPA Atmospheric Mercury Network (AMNET) protocols. He also provided support for the operation of other two AMNet sites located Mississippi and Hawaii, respectively.

*(3) Data analysis of airborne mercury profiling study conducted in Tullahoma, TN*

Atmospheric transport and in-situ oxidation are important in influencing mercury concentrations at the surface and wet and dry deposition rates. Contributions of both natural and anthropogenic processes can significantly impact burdens of mercury in local, regional, and global scales. To address these key issues in atmospheric mercury research, airborne measurements of mercury speciation and ancillary parameters were collected over a region near Tullahoma, Tennessee, USA from August 2012 to June 2013. Here, for the first time, we present vertical profiles of Hg speciation from aircraft for an annual cycle over the same location. These airborne measurements included gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM) and particulate bound mercury (PBM) as well as ozone ($O_3$), sulfur dioxide ($SO_2$), condensation nuclei (CN), and meteorological parameters. The flights were conducted typically one week out of each month to characterize seasonal variations in mercury concentrations. Data obtained from 0 to 6 km altitudes show that GEM exhibited a relatively constant vertical profile for all seasons with an average concentration of 1.38±0.17 ng $m^{-3}$. A slight trend of GEM depletion occurs at 4-6 km, suggesting oxidation of GEM in the mid-troposphere. Significant seasonal variation of GOM was observed, with highest GOM concentrations up to 100 pg $m^{-3}$ in the summer flights and lowest (0-20 pg $m^{-3}$) in the winter flights. Vertical profiles of GOM show the maximum levels at altitudes between 2 and 4 km. Limited PBM measurements exhibit similar levels of GOM and PBM at all altitudes. GOM and PBM enhancements at altitude were seasonally correlated to modelled hydroxyl radical (OH) concentration, suggesting OH might mediate GEM oxidation. High

PBM levels (up to ~200 pg $m^{-3}$) were usually associated with cold front passages. These data were analyzed using HYSPLIT back trajectory and source-receptor relationships were investigated for mercury species in this continental environment.

A manuscript summarizing the results from this aircraft study has been submitted to an Atmospheric Mercury special issue in *Atmosphere*.

*(4) Data analysis for the Grand Bay mercury intensive in summer 2010 and spring 2011*

During two intensive studies in summer 2010 and spring 2011, measurements of mercury species including gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and particulate-bound mercury (PBM), trace chemical species including $O_3$, $SO_2$, CO, NO, $NO_Y$ and black carbon, and meteorological parameters were made at an Atmospheric Mercury Network (AMNet) site at the Grand Bay National Estuarine Research Reserve (NERR) in Moss Point, Mississippi. Surface measurements indicate that the mean mercury concentrations were 1.42±0.12 ng $m^{-3}$ for GEM, 5.4±10.2 pg $m^{-3}$ for GOM, and 3.1±1.9 pg $m^{-3}$ for PBM during the summer 2010 intensive and 1.53±0.11 ng $m^{-3}$ for GEM, 5.3±10.2 pg $m^{-3}$ for GOM, and 5.7±6.2 pg $m^{-3}$ for PBM during the spring 2011 intensive. Elevated daytime GOM levels (>20 pg $m^{-3}$) were observed on a few days in each study and were usually associated with either elevated $O_3$ (>50 ppbv), BrO, and solar radiation or elevated $SO_2$ (>a few ppbv) but lower $O_3$ (~20–40 ppbv). This behavior suggests two potential sources of GOM: photochemical oxidation of GEM and direct emissions of GOM from nearby local sources. Lack of correlation between GOM and Beryllium-7 ($^7Be$) suggests little influence on surface GOM from downward mixing of GOM from the upper troposphere. These data were analyzed using the HYSPLIT back trajectory model and principal component analysis in order to develop source-receptor relationships for mercury species in this coastal environment. Trajectory frequency analysis shows that high GOM events were generally associated with high frequencies of the trajectories passing through the areas with high mercury emissions, while low GOM levels were largely associated the trajectories passing through relatively clean areas. Principal component analysis also reveals two main factors: direct emission and photochemical processes that were clustered with high GOM and PBM. This study indicates that the receptor site, which is located in a coastal environment of the Gulf of Mexico, experienced impacts from mercury sources that are both local and regional in nature.

A manuscript summarizing the results from these two intensives has been submitted to an Atmospheric Mercury special issue in *Atmosphere*.

**PLANNED WORK**

- To conduct further airborne observations in support of GOES-R/VIIRS calibration and validation;
- To continue the monitoring of mercury compounds (GEM, GOM, and PBM) at the three EPA Atmospheric Mercury Network (AMNet) sites operated by NOAA ARL;
- To conduct data analysis for the atmospheric mercury observations at three AMNet sites in the past 6-7 years.

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**PRESENTATIONS**

Ren, X., P. Kelley, and W. Luke, Ozone production during DISCOVER-AQ 2013: Results from a photochemical box model, NASA DISCOVER-AQ Science Meeting, Hampton, VA, February 24-28, 2014.

Luke, W., X. Ren, and P. Kelley, NOAA/Air Resources Laboratory Surface Observations at Galveston and Manvel-Croix: Summary and Comparison with Aircraft Data, NASA DISCOVER-AQ Science Meeting, Hampton, VA, February 24-28, 2014.

Ren, X., P. Kelley, and W. Luke, Measurements of Trace Gases at the Manvel Croix and Galveston Sites during DISCOVER-AQ, the 6th NASA AQAST meeting at Rice University, Houston, TX, January 15-17, 2014.

Ren, X., J. Mao, L. Zhang, D. Miller, W. Brune, and the DC3 science team, HOx Photochemistry during DC3, AGU 2012 Fall Meeting, San Francisco, CA, December 9-13, 2013.

Brune, W. H., Mao, J., Ren, X., Zhang, L., and Miller, D, Hydroxyl (OH) and hydroperoxyl ($HO_2$) in and out of clouds during the Deep Convective Clouds and Chemistry (DC3) experiment, AGU 2012 Fall Meeting, San Francisco, CA, December 9-13, 2013.

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**PERFORMANCE METRICS**

| Performance Metrics | FY13 |
|---|---|
| # of new or improved products developed following NOAA guidance | 2 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 1 |
| # of new or improved products developed without NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 0 |
| # of peer reviewed papers | 17 |
| # of non-peered reviewed papers | 4 |
| # of invited presentations | 34 |
| # of graduate students supported by a CICS task | 1 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**PERFORMANCE METRICS EXPLANATION**

For the two “new or improved products,” the team ported the operational and experimental NAQFC model implementations onto the new NCEP computer on short notice. The products are generated with 127 computational units (PE), and (b) NAQFC has been optimized to run about 2.5 times faster on the new NCEP computer. For the one product/technique transitions from research to operations, the team tested parallelization efficiency and robustness of the code and scripting used in the NAQFC operational system. An allocation of 127 PEs was found to be efficient in speed and modest concerning source requirements.

## 1.6 Climate Data & Information Records/Scientific Data Stewardship

**Support for the National Oceanographic Data Center**

**Task Leader** Hugo Berbery
**Task Code** EBEB_NODC_12 & PAPANCREP11
**NOAA Sponsor** Terry Tielking
**NOAA Office** NESDIS/NODC
**Contribution to CICS Themes (%)** Theme 1: 10%; Theme 2: 57%; Theme 3: 33%.
**CICS Specific Research Topics** Future Satellite Programs, Surface Observing Networks, Calibration & Validation, Climate Data and Information Records and Scientific Data Stewardship, Climate Research, Data Assimilation and Modeling, and Earth System Monitoring from Satellites.
**Contribution to NOAA Goals (%)** Goal 1: 46%; Goal 2: 5%; Goal 3: 19%; Goal 4: 7%; Goal 5: 23%

**Highlights** In 2013 CICS played a significant role in the development of improved satellite data products, working with the ocean science community to provide global and regional ocean data, and by validating new space-based ocean observing technologies. CICS enhanced NOAA's ability to understand, predict and communicate climate variability by data distribution and education through web based satellite data, detailed descriptions of these data, and the continued enhancement of the World Ocean Database.

**BACKGROUND**

Archival of oceanographic data at NODC for long-term preservation; Coral Reef Temperature Anomaly Database (CoRTAD) Version 5 Development; Processing and Merging of hydrographic data into the World Ocean Database (WOD); Quality Control and Application of Global Salinity Anomaly Fields derived from WOD; The release of the World Ocean Atlas 2013 products as well as the World Ocean Database 2013; and National Oceanographic Data Center Satellite Support; Integrated Ocean Observing System (IOOS) Regional Association (RA) Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS), IOOS Regional Association (RA) Southeast Coastal Ocean Observing Regional Association (SECOORA), IOOS Regional Association (RA) Great Lakes Observing System (GLOS); NOAA Rolling Deck to Repository (R2R) from the NOAA Office of Marine and Aviation Operations (OMAO); Stewardship of thermosalinograph data; Quality control of Greenland Iceland and Norwegian Seas and Northwest Atlantic Ocean climatology; Development of the data distribution, archive and quality monitoring systems for Jason-2/3 products; Development of the Gridded level-3 products from SMOS and Aquarius satellites; Development of the archive appraisals and technical solutions designed to improve archive, disseminate and access to NOAA's Ocean Color products; Ocean acidification data management project development; NODC online submission system (Send2NODC) development; Transfer of data from the Carbon Dioxide Information Analysis Center (CDIAC) to NODC; Transfer of data from the Biological and Chemical Oceanography Data Management Office(BCO-DMO); Global carbonate saturation states (Omega) data processing; The eXpendable BathyThermograph (XBT) profiles forms an important component of historical subsurface temperature measurements contributing 56% of ocean temperature profiles between

1967 and 2001; Extended Pathfinder V5.2 SST through 2012.

Mathew Biddle (NOAA Collaborators: Dr. Krisa Arzayus, Steven Rutz, Dr. Deirdre Byrne); Gregg Foti (NOAA Collaborators: Dr. Kenneth Casey, Dr. Deirdre Byrne); Liquing Jiang (NOAA Collaborators: Dr. Krisa Arzayus, Dr. Rost Parsons); Nisha Kurian (NOAA Collaborators : Tim Boyer, Sydney Levitus); Alexey Mishonov (NOAA Collaborators: Dr. Krisa Arzayus, Tim Boyer); James Reagan (NOAA Collaborators: Dr. Krisa Arzayus, Tim Boyer); Yongsheng Zhang (NOAA Collaborators: Dr. Deirdre Byrne, Dr. Eric Bayler)

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

The satellite team is responsible for the archiving and delivery of ocean data products that are derived from sensors operating in space. These include sea surface temperature, ocean altimetry, ocean vector winds and other products derived from these measurements. The satellite team adds value by providing metadata, making the data discoverable, performing quality assurance and providing scientific and technical support to users of these data (http://www.nodc.noaa.gov/SatelliteData/).

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

The World Ocean Database (WOD) is one of the most requested products from the NODC (http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html). It is a vast hydrographic database that includes over 13 million profiles dating back to the late 18$^{th}$ century. In order for the WOD to keep growing, and to keep being used by the public for a multitude of different ocean studies, data from the NODC archive must be continually processed and merged into the WOD. This requires that the data be converted into a common format, checked for uniqueness and quality, and merged into the WOD.

The WOD is also used in calculating gridded climatologies of the ocean. The World Ocean Atlas as well as a multitude of regional climatologies (http://www.nodc.noaa.gov/OC5/indprod.html) have been created from the WOD. The climatologies require extensive amounts of quality control to ensure an accurate product. More recently, since the introduction of Argo floats, monthly gridded products have also been able to be produced. One current research project has been to look at gridded monthly salinity anomalies derived from WOD and compare and contrast it with the Aquarius Sea Surface Salinity data.

The regional climatologies are created based on the public's need and additionally constrained by the regional hydrographic data distribution. Because regional climatologies are only calculated in regions of high data distribution, vertical resolutions of 102 standard levels and horizontal resolutions up to 1/10$^{th}$ degree are attainable. The World Ocean Atlas 2013 also increased, at least for some variables and time periods, its vertical resolution to 102 standard levels and horizontal resolution to a quarter-degree. The movement to higher vertical and horizontal resolutions in both regional and global climatologies is important for resolving small scale structures (i.e. fronts) and usage in ocean and climate models, among others.

The ongoing satellite data products are all automatically ingested and placed in the NODC public data area. Here they are made available to the public with an array of online tools including ftp, http, OPeNDAP, THREDDS and our geoportal.

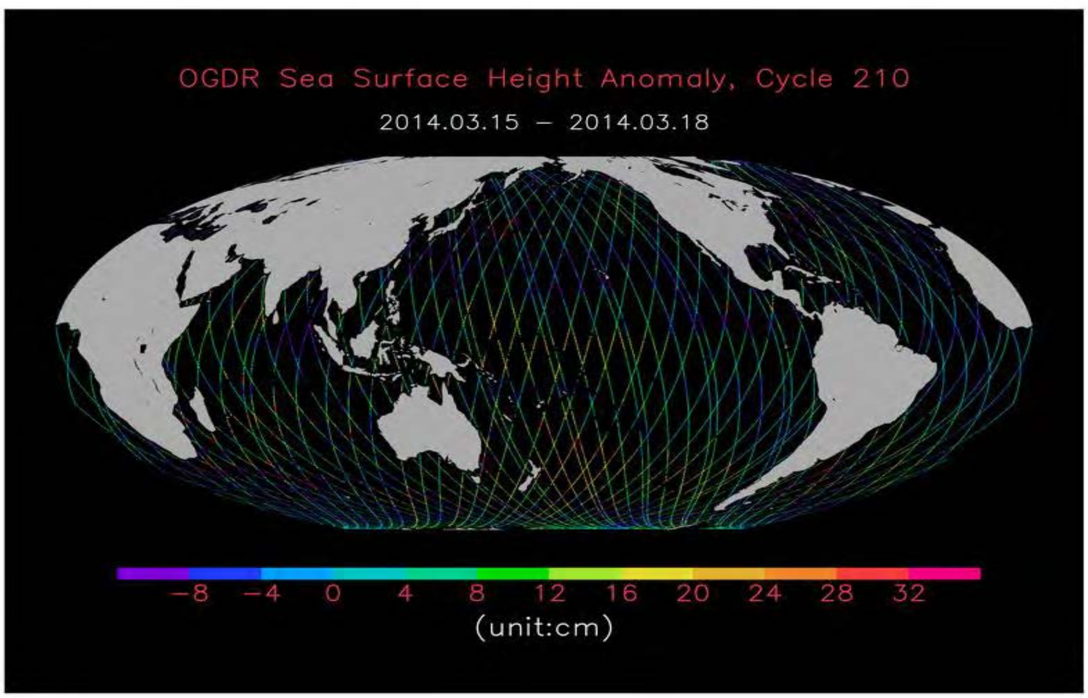



*Figure 1. Real-time sea surface height anomaly from NODC-produced level-3 0.25x0.25 binned data of Jason-2 operational Geophysical Data Record (OGDR). Data is published at: [http://data.nodc.noaa.gov/jason2/QA_assurance/](http://data.nodc.noaa.gov/jason2/QA_assurance/)*

NODC is currently in the process of automating several in-situ datasets as well. CICS staff is currently negotiating with the Integrated Observing Systems (IOOS) Regional Associations MARACOOS, SECOORA, and GLOS to automate the full archive of in-situ data. Once the agreement is defined, CICS staff will work with NODC IT staff to implement the automation and archive while providing public access to the in-situ data. These three RA's will be used as test beds and use cases for the remaining 9 observing systems.

One of the roles of the National Oceanographic Data Center is to fully steward environmental data, which consist of converting and applying quality control tests as applicable. Currently at the NODC, there is a significant ammount of thermosalinograph (TSG) data that comes in through various pathways and in various file formats. Currently CICS staff is working with NODC to steward the TSG data and provide various quality control flags along with community influenced data file formats and temporal scales.

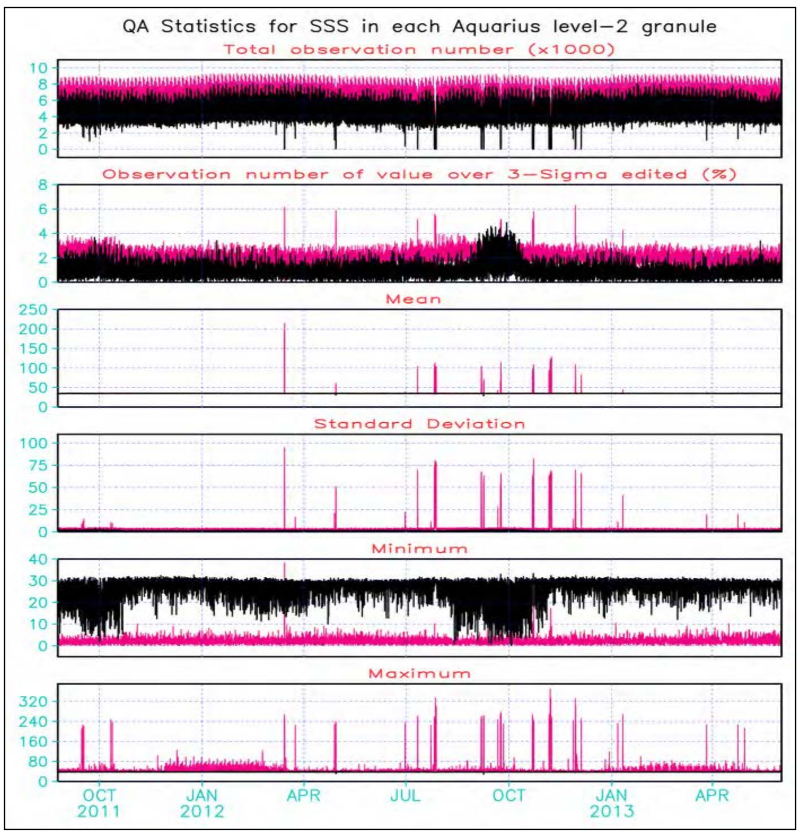



*Figure 2: Data quality statistics of sea surface salinity from each Aquarius level-2 data (V2.0) file during 2011-13. Black lines denote the results after the contaminated records are filtered by using radiometer and scatterometer quality flags while the red ones present those from original data without any quality flag filtering.*

In its role as the US archive for oceanographic data, NODC provides near real-time and delayed-mode product distribution, rigorous archive services, and long-term data stewardship for the Jason-2/Ocean Surface Topography Mission (OSTM) and future Jason-3 products. An important component of NODC's data stewardship for Jason-2/3 products is to develop a data quality monitoring system known as the Rich Inventory which provides an important tool to monitor and track the data assurance statistics and metadata attributes in each granule, and to provide those results to the public. This system improves the integrity of the Jason-2/3 archive, thereby enhancing the usefulness and deepening the understanding of the data for climate and other long-term applications. In FY 2013, this work at NODC is focused on establishment of quality monitoring on operational Geophysical Data Record (OGDR), improvement of processing software and development new tools (for instance, QA monitoring table) for data monitoring.

Cooperation with STAR/NESDIS, NODC works to produce gridded level-3 data from SMOS and Aquarius satellites leve-2 granules by applying data quality flags and simple interpolation method (e.g., box average). The outputs cover various time scales from swath to 3-day, 7-day and monthly mean. NODC also work to establish and operationally implement of data quality monitoring on the level-2 sea surface salinity (SSS) products from SMOS and Aquarius satellites. The QA statistics (observation number, mean, standard deviation, minimum, maximum, and number over 3-sigma edited) have been calculated in each level-2 granule and saved into NetCDF format. The visualization of the QA statistics and the data will be published through a web interface. The data process and visualization generation are made to be updated in automation in a time-length consistent with the data latency.

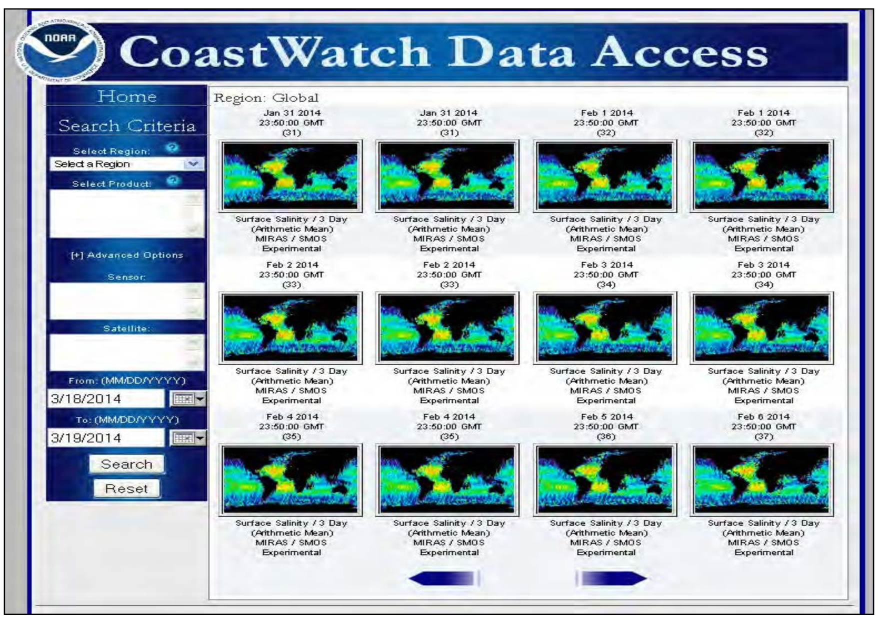



*Figure 3. Snapshot of interface on CoastWatch web site for serving NODC-generated SMOS level-3 3-day mean sea surface salinity product. http://coastwatch.noaa.gov/cwn/search/interface.html*

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

The eXpendable BathyThermograph (XBT) profiles forms an important component of historical subsurface temperature measurements. The XBT instrument measure depth using fall rate equation which calculates depth from the time elapsed since the XBT probe entered water. The inter-comparison of the XBT and high-quality hydrographic data suggests that depth-temperature measurements from XBTs to be systematically biased. There has been a number of suggested XBT bias correction algorithms published in the literature. Easy access and use of these correction schemes is important for calculation and comparison of ocean heat content integrals.

**ACCOMPLISHMENTS**

The Coral Reef Temperature Anomaly Database (CoRTAD) version 5 alpha is being developed. The NODC provided tools for discovery, outreach, data usage and comprehension of these data. Improvements over previous versions of CoRTAD include:

- CoRTAD 5 no longer divides the earth into 128 tiles. The new version has separate files for each global parameter.
- CoRTAD 5 has a richer set of statistical analysis.
- Pathfinder, the only Climate Data Record (CDR) for SST was extended from 1981 through 2011.

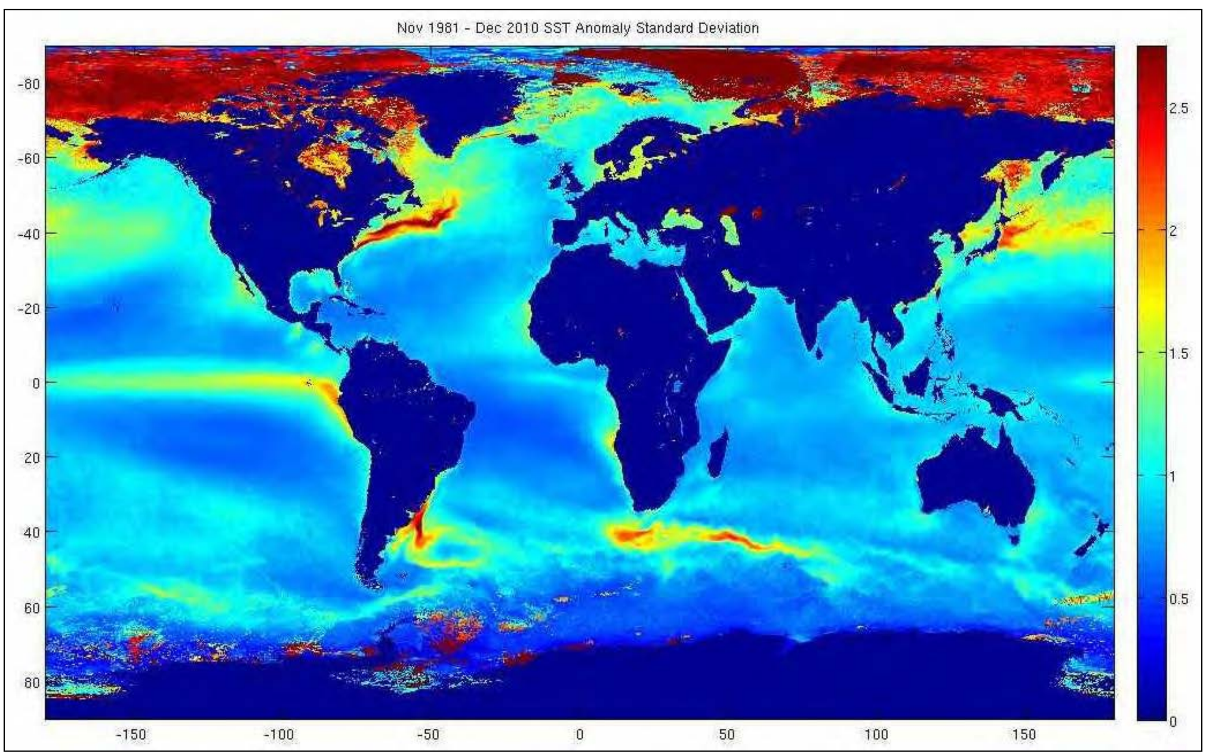



*Figure 4: CoRTAD SST Anomaly Standard Deviation from November 1981 through December 2010.*

The Satellite team has been working with various agencies to evaluate new data products including geostationary and polar satellite SST, Ocean wind and Coastal Ocean Dynamics Applications Radar (CODAR) coastal current with the purpose of reaching agreements to distribute and archive these data.

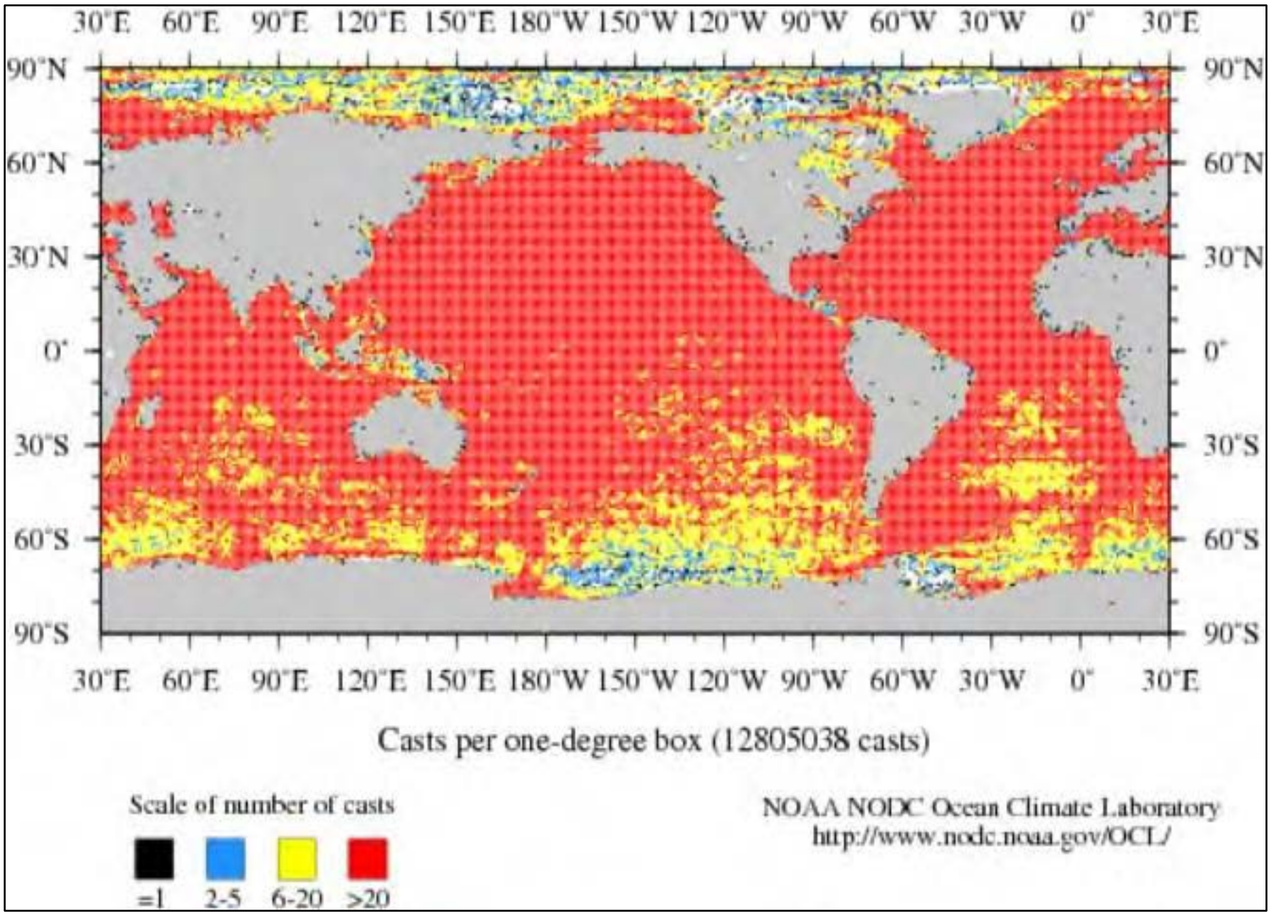



*Figure 5: WOD13 Data Distribution Plot. WOD13 contains 12,805,038 casts from bottle, CTD, XBT, MBT, profiling floats, drifting buoys, moored buoys, autonomous pinniped BT, undulating oceanographic recorders, and gliders.*

The World Ocean Database 2013 was released on September 30, 2013. The World Ocean Database 2013 contains roughly 12.8 million quality-controlled in situ ocean profiles all in a common format. The World Ocean Database 2013 has its own publication, in addition to two internal reports detailing how to access, read, and use WOD13 (including using ODV). Constant data updates to WOD are needed to maintain and enhance the database. CICS staff currently conducts quarterly updates of bottle and CTD data from the CLIVAR & Carbon Hydrographic Data Office (CCHDO) and the International Council for the Exploration of the Sea (ICES). We also perform annual updates of CTD data from the Northeast Fisheries Science Center (NEFSC). Furthermore, any other miscellaneous dataset that comes in and is assigned to us will be processed for inclusion into WOD.

The World Ocean Atlas 2013 (WOA13) was fully released as of February 21, 2014. The World Ocean Atlas 2013 consists of four different atlases: Temperature, Salinity, Oxygen, and Nutrients. The temperature and salinity atlas contains one-degree and quarter-degree decadal and decadal average climatologies on 102 standard levels from 0-5500 m for annual and seasonal time periods. Monthly time periods are available on 57 standard levels from 0-1500 m. The six decades are: 1955-1964, 1965-1974, 1975-1984, 1985-1994, 1995-2004, and 2005-2012. Monthly climatologies on a quarter-degree resolution are not available for the first five decades due to lack of data. The oxygen and nutrient atlases are available at one-degree resolution on 102 standard levels from 0-5500 m for the annual climatology, and on 37 standard levels from 0-500 m for the seasonal and monthly climatologies. The nutrients and oxygen climatologies, due to a lack of historical data, are not available by decade.

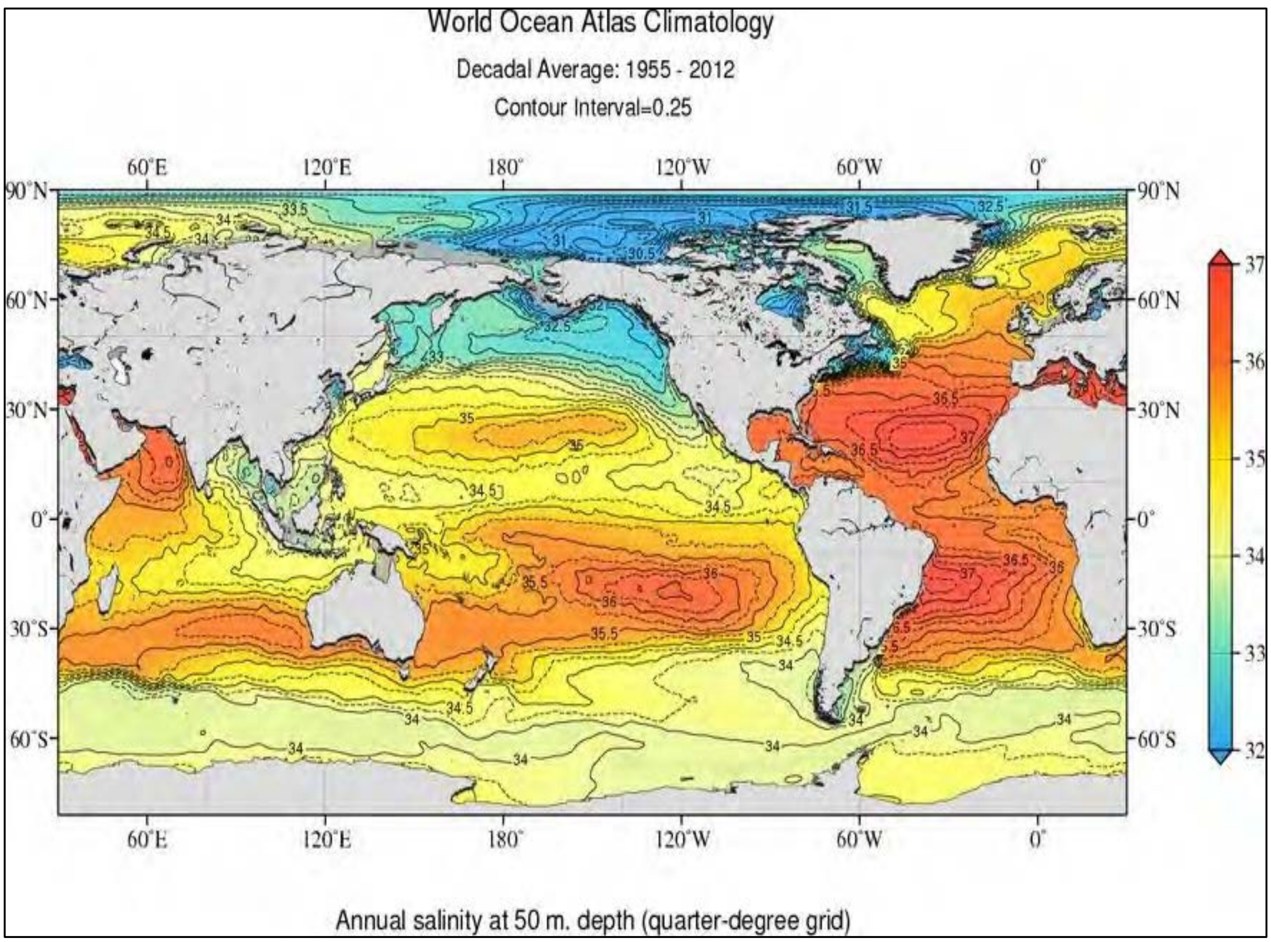



*Figure 6: World Ocean Atlas 2013 climatology for the annual 50 m salinity at the surface. http://www.nodc.noaa.gov/cgi-bin/OC5/woa13f/woa13f.pl?parameter=s*

There was a large amount of quality control that went into these atlases, with most of the time dedicated to removing “bullseyes” in the gridded fields. The “bullseyes” are seen as concentric circles emanating from a specific location. CICS staff assisted a great deal on the quality control and documentation of both the temperature and salinity atlases. Each of the four atlases has its own publication.

In addition to quality control on WOA13, quality control on the 2012 and 2013 monthly and seasonal salinity anomalies were completed. The monthly salinity anomalies were a vital data set used in our recently submitted manuscript to JGR-Oceans where we compared and contrasted WOD analyzed sea surface salinity to Aquarius sea surface salinity. We found that Aquarius exhibits a negative bias in the tropics which transitions to a positive bias in high latitudes. We also find that utilizing non-Argo data is essential to validating Aquarius in areas with little Argo coverage, and that using different algorithms and rain corrections causes strong differences in the validation of Aquarius. Overall, Aquarius compared very well with in situ sea surface salinity fields under multiple comparison examinations; however, both products have their own strengths and weaknesses and a synthesis of the two is recommended to study global scale SSS variability.

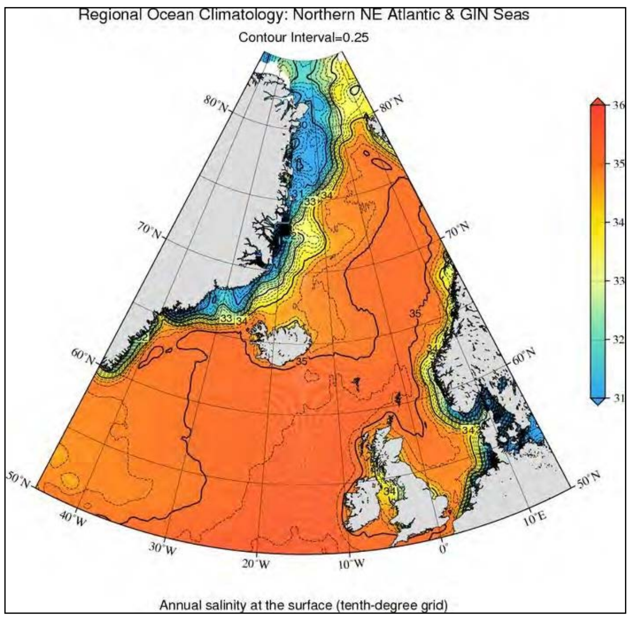



*Figure 7: Regional climatology using the high-resolution grids in the GIN Seas, found at http://www.nodc.noaa.gov/OC5/regional_climate/gin-seas-climate/. CICS staff reviewed these images and added flags to the World Ocean Database to mark "bullseyes", or anomalous data not representative of the climatology.*

In conjunction with the WOA13 objective analysis, an objective analysis of the Greenland Iceland and Norwegian (GIN) Seas was conducted. This followed the same procedures as described above including the increased depth levels and increased grid resolution. "Bullseyes" were marked and the climatology was published online at http://www.nodc.noaa.gov/OC5/regional_climate/gin-seas-climate/. An interview with CICS staff and ESSIC on November 13, 2013 can be found here http://essic.umd.edu/joom2/index.php/current-news/featured-essic/1527-biddle-participates-in-nodc-gins-campaign.

CICS staff worked directly with NOAA Office of Marine and Aviation Operations (OMAO) and NODC IT staff to automate the archival of Shipboard Computer System (SCS) underway data collected by the NOAA fleet. Through this automation 28 archival packages, consisting of data from 8 NOAA vessels, have been generated since its inception in September, 2013. The OMAO SCS data is part of the NOAA R2R program and this automation will provide a starting point for the rest of the NOAA fleet's archival of oceanographic data. The archival packages can be found at the following NODC search page http://data.nodc.noaa.gov/geoportal/rest/find/document?searchText=%22NOAA%20R2R%22&start=1&max=250&contentOption=intersecting&f=searchPage.

CICS staff worked directly with NODC staff to develop a comprehensive understanding of the NODC archival holdings for thermosalinograph data. Along with understanding the NODC archival holdings, CICS staff have began to compile stakeholder input on what the resulting product should look like.

CICS staff created a metadata content template that can be applied to all types of OA data for the Project. This really clears out one of the major hurdles that prevented us from getting data from the PIs. From now on, we can tell the OA PIs that we are ready to take their data. With help from NODC's ISO experts, I created the first version of OA metadata ISO 19115-2 xml template and developed an ATOVA Authentic skin and a submission form in the format of spreadsheet, for the collection of OA metadata from the PIs. I also developed a script that can generate an ISO metadata record collected with the above spreadsheet metadata file automatically.

CICS staff designed an OA data search Portal. This Portal, once completed, will allow users to search for OA data based on: Geographic coverage, Observation dates, Variables/Parameters, Observation types, biological subject, etc, in a user friendly interface. The Portal will interact with the rich OA metadata template we developed to make sure OA data can be search in the best possible way. Another advantage is that it will enable users to do their search by clicking several checkbox, and a button, instead of asking them to write their own search phrases/sentences, which requires knowledge on search engines that are not known to everyone.

CICS staff also designed a mooring data viewer. The product, once completed, will allow users to download buoy data by clicking their buoy icons on a map. It also allows users to check out more information about the buoys in the landing page. I created a working prototype of this product.

NODC is working to create an online data submission system (Send2NODC), which will make it easier for data providers to submit their data; and automate a lot of the archiving procedures to reduce the time needed to get data archived. This is an online data submission tool that could revolutionize the way metadata and data are sent to NODC, and potentially increase the amount of one-off data submissions to NODC. The purposes of the tool are: 1) to allow data providers to apply more of their scientific knowledge of their data into data submission process (they would be able to access NODC controlled vocabularies from the interface); 2) to make data submission more user friendly through tab based navigation, browse and click style data uploading, etc, and 3) to lay out the foundation for subsequent automations procedures within NODC.

As the project lead, CICS staff has been drafting requirements, organizing weekly meetings to discuss implementation details, getting inputs from external users as well as the NODC personnel, etc. We successfully released the Alpha-2 version in July 2013, and demonstrated to the public during the Ocean Sciences meeting in February 2014. The public beta version is scheduled to be released in the comings months. Below are some pictures of the submission tool. Below are two screen shots of the Send2NODC interface.

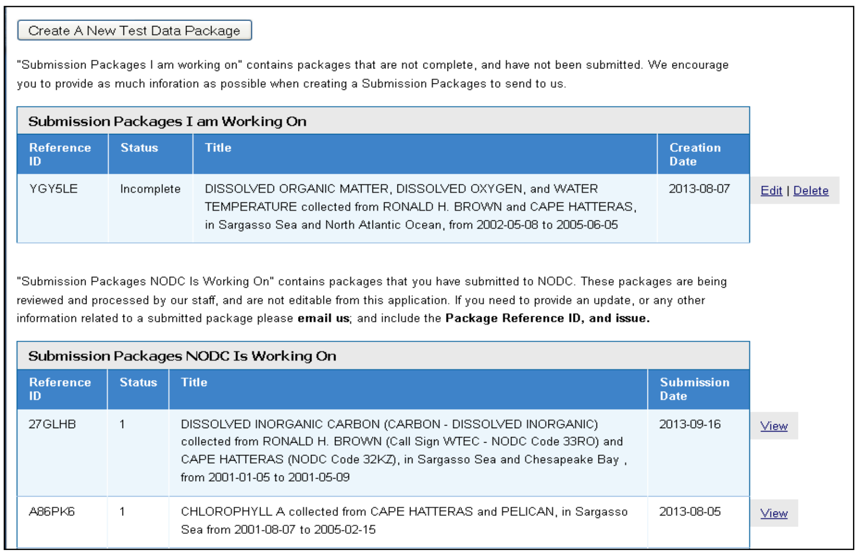



*Figure 8: Main page of Send2NODC – My submission packages.*

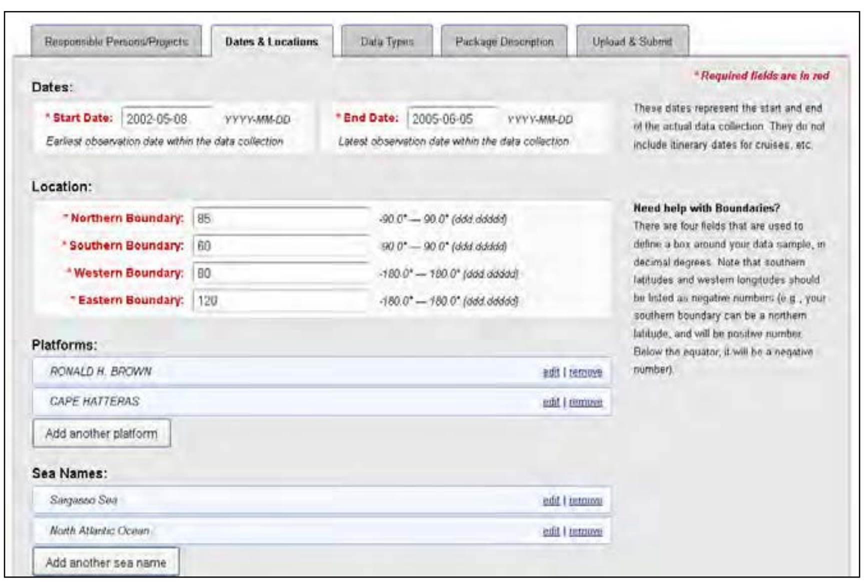



*Figure 9: Send2NODC interface to input metadata.*

The transfer of data from the Carbon Dioxide Information Analysis Center (CDIAC) began. Over 700 accessions to NODC (including data from voluntary observing ships, time-series, and global coastal program) have been created. A similar effort to transfer data from the Biological and Chemical Oceanography Data Management Office (BCO-DMO) with over 120 accessions generated. The goals of these two projects have never been solely about the quantities of accessions that are published.

CICS staff also compiled a global database of ocean carbon data by importing data from the CARINA (CARbon dioxide IN the Atlantic Ocean) data, the PACIFICA (PACIFic ocean Interior CArbon), and the World Ocean Database. Then, calculated aragonite carbonate saturation states (Omega) out of them, and analyzed the decadal changes in the Equatorial and Northern Pacific Ocean. Below are several example plots from this study.

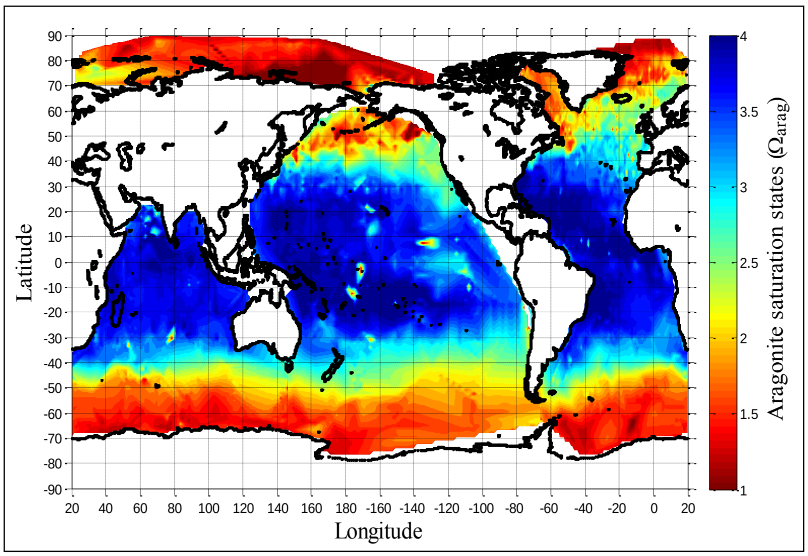



*Figure 10. Surface distribution of Omega in the global oceans.*

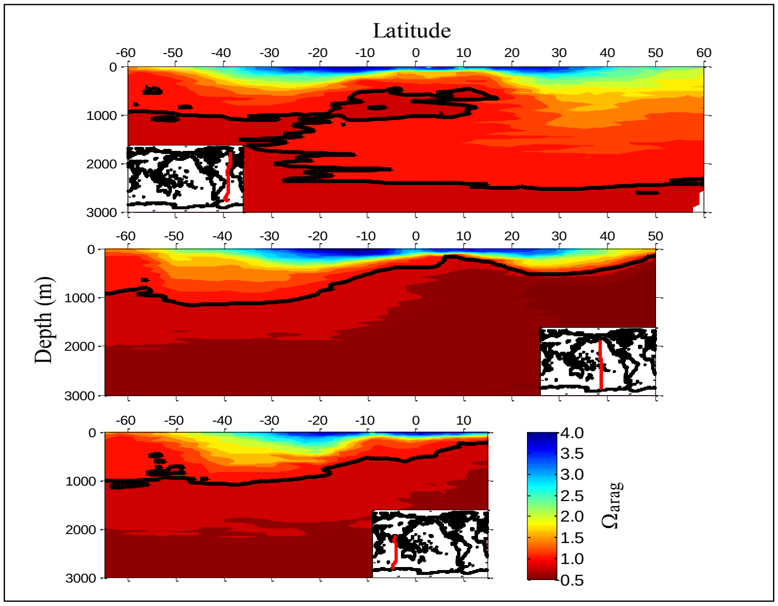



*Figure 11. Vertical distributions of Omega in the three Ocean basins.*

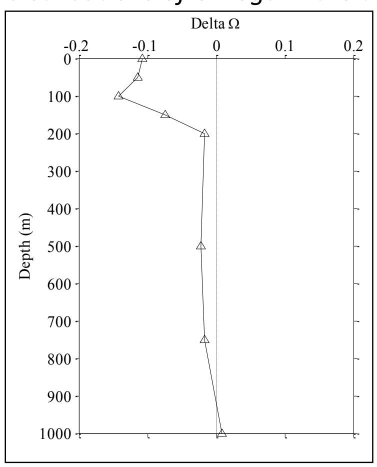



*Figure 12. Decadal changes of Omega in the Equatorial and Northern Pacific from 1989-1995 to 2005-2010.*

The NODC website provides updated bias information of XBT and Mechanical BathyThermograph (MBT) for oceanographic community and they are made available at http://www.nodc.noaa.gov/OC5/XBT_BIAS/xbt_bias.html and http://www.nodc.noaa.gov/OC5/mbt-bias/ . These web pages contain a list of peer-reviewed publications on XBT and MBT corrections and are updated as new papers with estimates of corrections are published. It provides an explanation of the corrections detailed, the equations used and the tables used in each study.

Also, a web page http://www.nodc.noaa.gov/OC5/XBT_BIAS/xbt_bibliography.html provides the list of all known research papers that discuss problems with XBTs which lead to measurement uncertainty. It also has cruise reports, notes and technical reports with reference to comparison tests with other instruments, usually Conductivity-Temperature-Depth (CTD) probes. Many of these reports show side-by-side XBT/CTD drops, showing XBT errors against a CTD reference. This webpage is also updated regularly to include new results.

The NODC website also hosts a WODselect selection tool for the World Ocean Database. The WODselect allows the users to download the XBT and MBT data with any of the ten published bias correction applied, as well as without any correction or with only Hanawa et al. (1995) correction applied.

The project of updating the XBT and MBT bias web pages and the XBT/CTD comparison studies has been completed. Also, the WODselect- the tool for the oceanographic community to download XBT data with different depth and temperature corrections applied- is also completed and ready to use.

In the Bay of Bengal using the passenger ships plying between the Indian mainland and the Andaman Nicobar islands an XBT data collection program is ongoing since 1990. This data set has been used to examine the long term variability of the temperature structure in the Bay of Bengal. The results from this study are under preparation as a scientific article.

**DELIVERABLES**

- World Ocean Atlas 2013 and associated documentation
- World Ocean Database 2013 and associated documentation
- Developed processing and visualizing tools resulted in establishment of quality monitoring on Jason-2 operational Geophysical Data Record (OGDR); Developed new tools (for instance, QA monitoring table, operational reprocessing file check) for an improved data monitoring; Implemented required acceptance tests on NODC/CLASS archive system from developing NOAA Jason ground system (NJGS), a future NOAA satellite ground system for supporting the simultaneous operation of the Jason-2 and Jason-3 Ocean Surface Topography Missions.
- Developed NODC-binned level-3 7-day and monthly mean sea surface salinity data from Level-2 Aquarius V2.0 and CAPv2.0 products. The data are published on NOAA CoatWatch website (http://coastwatch.noaa.gov/);
- Finalized the Rich Inventory (QA statistics data) for AVHRR Pathfinder V5.2 SST products and published via NODC data servers (http://data.nodc.noaa.gov/pathfinder/Version5.2/RI_Statistics/) and Live Access Server (http://data.nodc.noaa.gov/las/getUI.do)
- Development of archive appraisals and technical solutions designed to archive NOAA ocean color satellite products (MODIS/Aqua chlorophyll frontal products, Global *Emiliania huxleyi* bloom maps, NOAA NPP VIIR ocean color reprocess).
- Generated highly comprehensive ISO 19115 metadata for MODIS/Aqua chlorophyll frontal products.
- Implemented routine data archive and access services for real-time Jason-2 products.

**PLANNED WORK**

- Continue working with partners to provide global and regional products and climatologies identified as high priority by users, particularly users within NOAA.
- Begin the integration of Quality Monitoring for ocean surface salinity. This endeavor will use data from new salinity sensing satellites as well as in-situ ocean surface salinity products.
- Maintain leading role in world's SST community by operating the Group for High Resolution SST (GHRSST) *Long Term Stewardship and Reanalysis Facility* (*LTSRF*). The NODC LTSRF archives over 30GB of SST data each day. These data are created in the US, Europe, Australia and Japan.
- Continued developing the next version of Pathfinder 5.3 as a SST Climate Data Record (CDR)
- Continue operational efforts by conducting scientific records (archive) appraisals for ocean satellite products and accessioning those products assessed as suitable for long-term archive. Products currently undergoing assessment include:
    - Geostationary Operational Environmental Satellites (GOES) SST
    - Polar Operational Environmental Satellites (GOES) SST with AVHRR Clear-Sky Processor over Oceans (ACSPO) processing
    - Merged GOES with Polar orbiting satellite SST products
    - Ocean wind products derived from *synthetic aperture radar (SAR*) instruments.
    - Near shore ocean current products derived from land based High frequency (*HF*) *radar*

- Continue to discover, assess, acquire and archive the wide array of new ocean data as they become available.
- Improve NODC's profile/participation in satellite mission stewardship and satellite data exploitation. Achieve an increased role in defining archive requirements for mission data and routine inclusion of NODC in budget for stewardship of large ocean datasets to be created or acquired by NOAA.
- Continue to archive hydrographic data in the NODC archive.
- Continue to process data for the WOD. This includes CCHDO, ICES, and NEFSC data, as well as other data sets received by NODC.
- Continue to QC monthly and seasonal salinity anomaly fields derived from the WOD.
- Develop climatological fields of mixed layer depths, as well as other related variables, as a first step in monitoring seasonal/interannual changes in mixed layer depth
- Continue to analyze sea surface salinity variability through satellite and in situ data
- Fully automate the archival of IOOS SECOORA data.
- Fully automate the archival of IOOS GLOS data.
- Maintain and improve the automated archival of NOAA OMAO data.

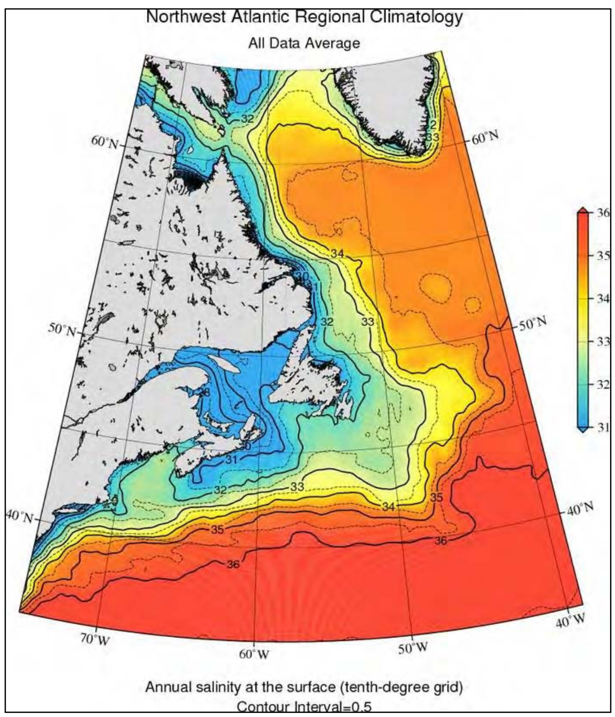



*Figure 63. Current regional climatology focused on the Northwest Atlantic. NODC regional Climatology team members and CICS staff are reviewing and marking appropriate flags for the region. Currently, this region is still under review by NODC regional Climatology team members and CICS staff and will be marked for appropriate "bullseyes".*

- Expand the NOAA OMAO SCS data submissions to include P.I. specific data holdings (e.g. CTD).

- Continue to perform quality control for the regional climatologies (specifically the Northwest Atlantic), including various sub-regions of the arctic. Identify other regions for climatology.
- Enhance NODC's stewardship of thermosalinograph data through the development of QC procedures and possibly a database or enhanced data access services.
- Develop NODC NJGS testbed: migration of current services, web pages, file systems, QM scripting and metadata templates into NJGS. Participate end-to-end tests for all services of which NODC has been developed for NJGS;
- Continuously develop tools to improve satellite data quality monitoring, access, search and discovery;
- Develop, test, and implement appropriate flag-filtering and production codes for both SMOS and Aquarius (V2 and CAPv2) SSS data, make them consistent with and supportive of STAR's 4SQM system;
- Complete data archive and distribution of NODC-generated level-3 binned SMOS and Aquarius (v2 and CAPv2) at NODC via http, ftp, OPeNDAP, and THREDDS;
- Implement SSS level-2 data monitoring at NODC: set up data quality monitoring home page to publish QA statistical time series of SMOS and Aquarius level-2 granules;
- Continuously develop technical solutions designed to archive NOAA ocean color satellite products;
- Develop NOAA-NASA integrated altimeter data portal;
- Develop experimental application of the satellite observed altimetry, SST and SSS data in climate monitoring at NODC.
- Continue building the infrastructure for Ocean Acidification Data Stewardship (OADS) project, including making some of the designs into reality:
    - Creation of an OA Data Search Portal
    - Creation of a Mooring Data Viewer
    - Modify the Send2NODC for collection of OA data.
    - Improvement of the current OADS website, to make it appealing and easy to use.
- Continue archiving Ocean Acidification Program (OAP) funded data, and start documenting them with our current rich metadata template.
- Continue effort in automating the transfer of more Carbon Dioxide Information Analysis Center (CDIAC) data.
    - Work to generate rich metadata records for all the CDIAC data sets, with the new metadata template we created.
- Continue effort to automate transfer of data from the Biological and Chemical Oceanography Data Management Office (BCO-DMO);
- Use the XBT data with different corrections applied and the XBT data without corrections applied to understand how it affects the representation of the seasonal and inter seasonal cycle of ocean sub surface temperature.
- Complete, vet and release Coral Reef Temperature Anomaly Database (CoRTAD) version 5.0.

**PUBLICATIONS**

Boyer, T.P., J.I. Antonov, J.R. Reagan, C. Schmid, R. Locarnini (in review) [Subsurface salinity], Global

Oceans [in State of the Climate in 2013]. Bull. Amer. Meteor. Soc.

Boyer, T.P., J.I. Antonov, O.K. Baranova, C. Coleman, H.E. Garcia, A. Grodsky, D.R. Johnson, R.A. Locarnini, A.V. Mishonov, T.D. O'Brien, C.R. Paver, J.R. Reagan, D. Seidov, I.V. Smolyar, M.M. Zweng, 2013, World Ocean Database 2013. Sydney Levitus, Ed.; Alexey Mishonov, Technical Ed.; NOAA Atlas NESDIS 72, 209 pp.

Boyer, T., S. Levitus, J. Antonov, J. Reagan, C. Schmid, and R. Locarnini (2013), Global oceans: Subsurface salinity. In State of the Climate in 2012, J. Blunden and D.S. Arndt (eds.). Bulletin of the American Meteorological Society, 94(8), S60-S62.

Casey, K. S., E. R. Selig, and G.Foti (2012): The Coral Reef Temperature Anomaly Database (CoRTAD) Version 4 - Global, 4 km Sea Surface Temperature and Related Thermal Stress Metrics for 1981-10-31 to 2010-12-31 (NODC Accession 0087989). National Oceanographic Data Center, NOAA. Dataset. doi:10.7289/V59G5JR3

Garcia, H. E., R. A. Locarnini, T. P. Boyer, J. I. Antonov, O.K. Baranova, M.M. Zweng, J.R. Reagan, D.R. Johnson, 2014. World Ocean Atlas 2013, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation. S. Levitus, Ed., A. Mishonov Technical Ed.; NOAA Atlas NESDIS 75, 27 pp.

Garcia, H. E., R. A. Locarnini, T. P. Boyer, J. I. Antonov, O.K. Baranova, M.M. Zweng, J.R. Reagan, D.R. Johnson, 2014. World Ocean Atlas 2013, Volume 4: Dissolved Inorganic Nutrients (phosphate, nitrate, silicate). S. Levitus, Ed., A. Mishonov Technical Ed.; NOAA Atlas NESDIS 76, 25 pp.

Jiang, L.-Q., W.-J. Cai, Y. Wang, J. E. Bauer. 2013. Influence of terrestrial inputs on continental shelf carbon dioxide. Biogeosciences, 10: 839-849, doi:10.5194/bg-10-839-2013.

Jiang, L.-Q., P. A. Raymond. 2014. River de-acidification in the United States over the past 100 years, to be submitted soon.

Levitus, S., J. I. Antonov, O. K. Baranova, T. P. Boyer, C. Coleman, H. E. Garcia, A. I. Grodsky, D. R. Johnson, R. A. Locarnini, A. V. Mishonov, J. R. Reagan, C. Sazama, D. Seidov, I. Smolyar, E. S. Yarosh, and M. M. Zweng (2013), The World Ocean Database In, Special Issue of the Proceedings of the 1st WDS Conference in Kyoto, 3 - 6 September 2011, Kyoto University, Kyoto, Japan, Data Science Journal , v.3, 229-234.

Locarnini, R. A., A. V. Mishonov, J. I. Antonov, T. P. Boyer, H. E. Garcia, O. K. Baranova, M. M. Zweng, C. R. Paver, J. R. Reagan, D. R. Johnson, M. Hamilton, and D. Seidov, 2013. World Ocean Atlas 2013, Volume 1: Temperature. S. Levitus, Ed., A. Mishonov Technical Ed.; NOAA Atlas NESDIS 73, 40 pp.

Nisha, K., M. Lengaigne, V. V. Gopalakrishna, J.Vialard, S. Pous, A-C. Peter, F. Durand, S.Naik, 2013: Processes of India's offshore summer intraseasonal sea surface temperature variability, Ocean Dyn. 63 (4), 329 – 346. doi: 10.1007/s10236-013-0604-6

Reagan, J., T. Boyer, J. Antonov, M. Zweng (in review), Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity. J. Geophys. Res. Oceans.

Seidov, D., J.Antonov, K. Arzayus, O. Baranova, M. Biddle, T. Boyer, D. Johnson, A. Mishonov, C. Paver, M.Zweng, 2013(?). Oceanography North of 60°N from World Ocean Database, *Progress in Oceanology* (Accepted man. PROOCE-D-13-00019R1)

Zweng, M.M, J.R. Reagan, J.I. Antonov, R.A. Locarnini, A.V. Mishonov, T.P. Boyer, H.E. Garcia, O.K.

Baranova, D.R. Johnson, D.Seidov, M.M. Biddle, 2013. World Ocean Atlas 2013, Volume 2: Salinity. S. Levitus, Ed., A. Mishonov Technical Ed.; NOAA Atlas NESDIS 74, 39 pp.

**PRESENTATIONS**

Biddle, M., S. Rutz. A NOAA Rolling Deck to Repository project: Automate the archiving of OMAO's SCS data. NOAA DAA meet and greet with NODC. Silver Spring, MD. 5 December, 2013

Deirdre Byrne and Yongsheng Zhang, 2013: NOAA archive and access services for jason-2/3 products. *Ocean Surface Topography Science Team (OSTST) Meeting*, October 7-11, 2013 Boulder, CO, USA.

Reagan, J., T. Boyer, J. Antonov. Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity. CICS-MD Science Meeting. University of Maryland, College Park, MD. 6-7 November 2013.

Reagan, J., T. Boyer, J. Antonov. Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity. 8th Aquarius/SAC-D Science Meeting. Buenos Aires, Argentina. 12-14 November 2013.

Reagan, J., T. Boyer, J. Antonov, M. Zweng. Comparison analysis between Aquarius sea surface salinity and World Ocean Database in situ analyzed sea surface salinity. 2014 Ocean Sciences Meeting. Honolulu, HI. 23-28 February 2014.

| Performance Metrics | FY13 |
|---|---|
| # of new or improved products developed following NOAA guidance | 13 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 1 |
| # of peer reviewed papers | 6 |
| # of non-peered reviewed papers | 8 |
| # 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 |

## Operational Generation of the HIRS Outgoing Longwave Radiation Climate Data Record

| | |
|---|---|
| **Task Leader** | Hai-Tien Lee |
| **Task Code** | HLHL_HIRS_13 |
| **NOAA Sponsor** | Jeff Privette |
| **NOAA Office** | NESDIS/NCDC/RSAD |
| **Percent contribution to CICS Themes** | Theme 1: 10%; Theme 2: 90% |
| **Main CICS Research Topic** | Climate Data & Information Records/Scientific Data Stewardship |
| **Percent contribution to NOAA Goals** | Goal 1: 100% |

**Highlight**: NOAA/NCDC CDR Program has acquired the Initial Operational Capability (IOC) for HIRS OLR CDR Product and is moving toward Full Operational Capability (FOC), while CICS continues to take charge of maintaining science integrity and developing QA/QC system. We also started the development of the 1°x1° Daily HIRS OLR CDR product in response to the continued requests for an OLR CDR product with higher temporal and spatial resolution. http://www.ncdc.noaa.gov/cdr/operationalcdrs.html

**BACKGROUND**

The primary goals of this project are to prototype an operational production system for the outgoing longwave radiation climate data record while continue the improvements and validation efforts for the existing product and algorithms. An end-to-end system has been proposed to produce OLR CDR product using HIRS level-1b data input. The derivation of climate data record involves several careful procedures with OLR retrieval performed for each HIRS pixel, including: applying inter-satellite calibration to maintain continuity; use of diurnal models to minimize orbital drift effects in temporal integral; and consistent radiance calibration. We are also developing OLR algorithms for the operational sounders following the HIRS, including the IASI and CrIS, such that the OLR CDR time series can be extended into the foreseeable future (~2040) without data gaps.

**ACCOMPLISHMENTS**

*1. HIRS 1° Daily OLR CDR Development*

We developed a framework to generate accurate daily mean OLR by incorporating Imager observation from geostationary satellites. Imager OLR models were developed and applied to the Gridsat CDR data set to provide geostationary-based OLR data. The daily mean OLR is generated with the grid-based 7-day moving boxcar that provides accurate, robust and smooth blending process. Fig. 1 shows an example comparison of the daily OLR fields between HIRS and the CERES SYN1deg-3H products. The preliminary assessments showed that the daily mean OLR also has significantly improved the time series stability, benefited mainly from the revised OLR estimation models and reduction of orbital drift effects. The new HIRS daily OLR CDR product is shown to be better than the ESRL interpolated AVHRR OLR by eliminating the artifacts including the orbital drifts effects, the wavenumber 14 spectral signals and the spurious longitude shift after March 2008. (**Acknowledgment: Carl Schreck** (CICS-NC) for providing spectral analysis and evaluation for HIRS daily OLR product.)

*2. HIRS OLR CDR Quality Assurance*

As part of the continued validation campaign, the HIRS OLR CDR was compared to the latest CERES Energy Balanced And Filled (EBAF) v2.6 product, a Level4 product that considered to reach the highest scientific integrity (see Figure 1). The results showed very good agreement between HIRS OLR and CERES EBAF products in both absolute radiometric measurement scales as well in the OLR temporal and spatial variations.

*3. Transition from Research to Operation*

The HIRS OLR CDR production system has reached Initial Operational Capability (IOC) phase since September 2011. We continue to assist NCDC CDR Program to achieve Full Operational Capability (FOC) while providing maintenance on the production system.

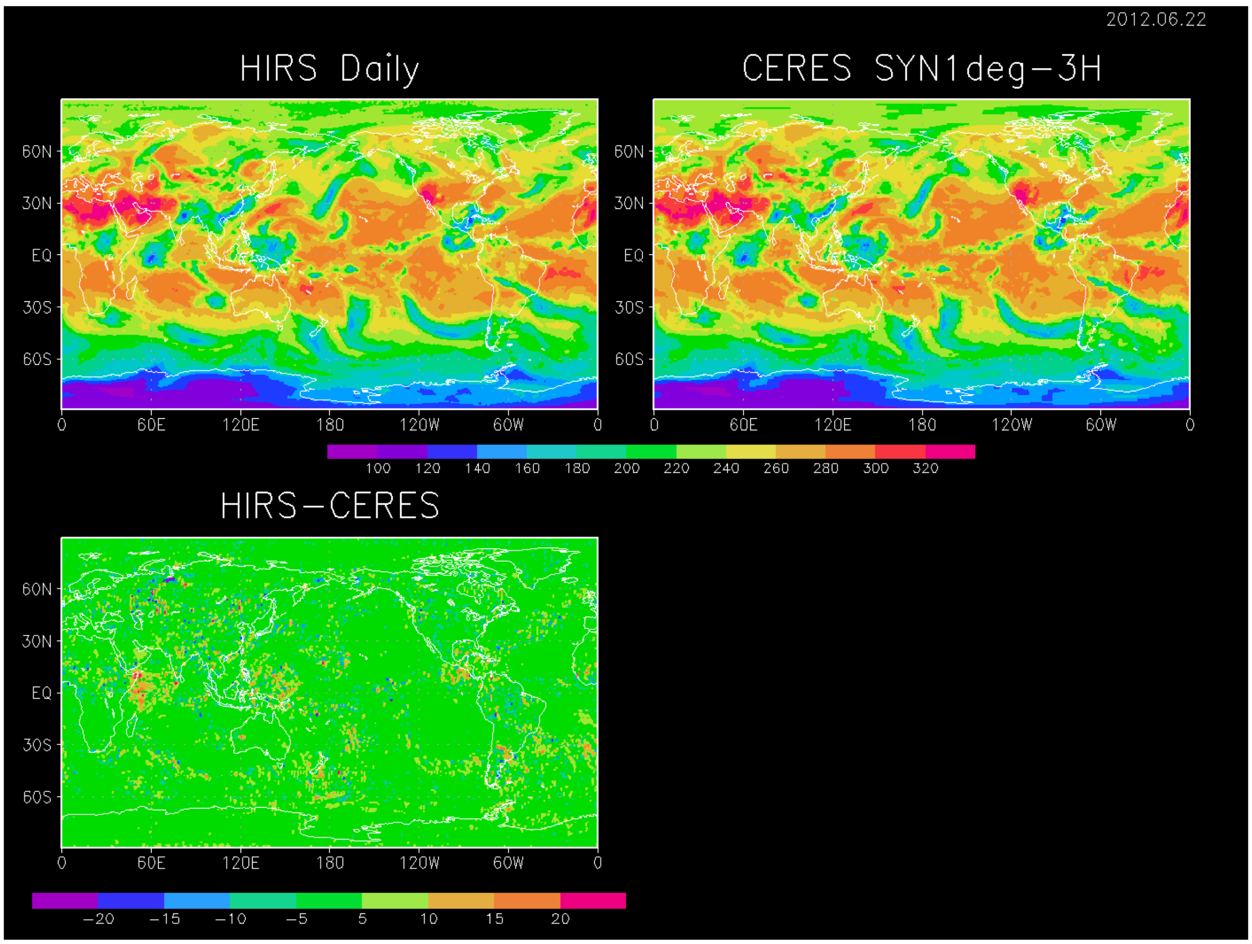



*Figure 1. Comparison of 1°x1° daily OLR fields between HIRS and CERES SYN1deg-3H products for June 22, 2012, as an example. The OLR differences are within ±5 Wm$^{-2}$ for nearly the entire map. The overall rms OLR differences, HIRS minus CERES, are at about 5 Wm$^{-2}$ with a relative bias of about -1 Wm$^{-2}$ that both are within the uncertainties of the CERES products.*

**PLANNED WORK**

Tasks (April 1 2014 – March 30 2015):

- Develop of the 1°x1° Daily HIRS OLR CDR production system and documentations (continued)
- Set up a near-real time delivery system for 1°x1° Daily HIRS OLR CDR
- Verification of HIRS OLR CDR Operational Production at NCDC
- Running parallel HIRS OLR CDR production system at CICS
- Maintenance of NCDC HIRS OLR CDR Operational Production System for v02r02-1 package
- Implement new OLR models for Monthly OLR CDR production.
- Prepare journal articles and conference presentations

**PUBLICATIONS**

Lee, H.-T. and R. G. Ellingson, 2013: HIRS OLR Climate Data Record - Production and Validation Updates. *Proceedings of the 2012 International Radiation Symposium (IRS'2012). AIP Conf. Proc., **1531**, 420 (2013); doi: 10.1063/1.4804796*

Randhir Singh, C M Kishtawal, Danish Hussain, P K Pal and A S Kiran Kumar, and Hai-Tien Lee, 2013: A New Technique for Prediction of Indian Summer Monsoon Rainfall using Satellite Observed Outgoing Longwave Radiation. JGR (submitted 2013JD021342)

**PRESENTATIONS**

Lee, H.-T., 2013: Assessment of HIRS OLR CDR intersatellite calibration errors. The CERES II Science Team Meeting, May 7-9, 2013, Hampton, VA

Lee, H.-T., 2013: Monthly and Daily Outgoing Longwave Radiation CDR. CDRP Team Meeting, Jul 29-Aug 1, 2013, Ashville, NC

Lee, H.-T., and R. G. Ellingson, 2013: Improvement of HIRS OLR CDR inter-satellite calibration using IASI observations. 2013 joint EUMETSAT/AMS Meteorological Conference, 16-20 September 2013, Vienna, Austria

Lee, H.-T., 2013: Improvement of HIRS OLR CDR Using IASI Observations. 2nd Annual CICS-MD Science Meeting - From Satellite Observations to Climate Prediction. Nov 6-7, 2013 College Park, MD

**DELIVERABLES**

- HIRS Monthly OLR CDR product in NetCDF format, January 1979 to March 2014.
- HIRS Monthly OLR CDR Production System v2.2-1 software and document package.

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

**The Development of AMSU Climate Data Records (CDR's) for Hydrological Applications**

| | |
|---|---|
| **Task Leader** | Wenze Yang & Isaac Moradi |
| **Task Code** | WZRF_AMSU_13 |
| **NOAA Sponsor** | Ralph Ferraro & Huan Meng |
| **NOAA Office** | NESDIS/STAR/CRPD/SCSB |
| **Percent contribution to CICS Themes** | Theme 1: 100%; Theme 2: 0%; Theme 3: 0% |
| **Main CICS Research Topic** | Climate Data & Information Records/Scientific Data Stewardship |
| **Percent contribution to NOAA Goals** | Goal 1: 50%; Goal 2: 50% |

**Highlight:** The inter-satellite calibration for AMSU-A window channels and for AMSU-B/MHS water vapor channels is nearly completed.

**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 fourth year of the project, we conducted major inter-satellite calibration for AMSU-A windlow channels, and for AMSU-B/MHS water vapor channels.

***A. Inter-satellite Calibration of AMSU-A Window Channels***

As the warm target contamination problem is a major problem in inter-satellite calibration, and not easy to solve using other approaches, during the report period, we focused on introducing Dr. Cheng-Zhi Zou's sequential adjusting process to solve it and other problems.

The sequential adjusting process has been developed and applied in sounding channels of AMSU-A

FCDR, the basic procedure include following steps:

1. Generate intermediate SNO data set, which include 142 variables for each SNO events
2. Calculate SNO coefficients (α, β, a0, a1)
3. Set $\delta R_{N15} = 0$, and $\mu_{N15}$, calculate $\delta R_k$, $\mu_k$, k = 1 to 5
4. Generate level-1c radiances for all six satellites using recalibration coefficients
5. Compute tropical ocean mean time series of ΔTb for available overlaps between pairs
6. Change the value of $\mu_{N15}$ and repeat steps 3, 4, and 5
7. Stop when summation of root mean square of ΔTb is minimum

The basic equations are as following, and the derivation of them are referred to Zou et al., 2006, 2009, 2010 and 2011.

$$I. \quad Z_j = \beta Z_k + \alpha + \zeta$$

$$II. \begin{cases} \sum_{i=1}^{N} \Delta R_{L,i} = a_0 + a_1 \sum_{i=1}^{N} Z_{k,i} \\ \sum_{i=1}^{N} Z_{k,i} \Delta R_{L,i} = a_0 \sum_{i=1}^{N} Z_{k,i} + a_1 \sum_{i=1}^{N} Z_{k,i}^2 \end{cases}$$

$$III. \begin{cases} a_0 = \Delta \delta R + \alpha \mu_j \\ a_1 = -\mu_k + \beta \mu_j \end{cases}$$

$In\ which$ :

$$R = R_L - \delta R + \mu Z$$

$$R_L = R_c + S(C_e - C_c)$$

$$S = \frac{R_w - R_c}{C_w - C_c}$$

$$Z = S^2 (C_e - C_c)(C_e - C_c)$$

The iterative adjusting of $\mu_{N15}$ can be illustrated in Figure 1. By setting $\mu_{N15}$ from -25 to 25 (sr m2 cm$^{-1}$)(mW)$^{-1}$, $\delta R_k$ and $\mu_k$ can be calculated, as mentioned in step 3 above. Then a set of level 1c radiance over the tropical ocean is generated, and compared with that of NOAA-15. Each satellite pair would reach minimum STD of delta Tb, but the minimum Average STD of delta Tb is selected.

After the iterative process, the optimal $\mu$ and $\delta R$ are listed in Table 1, it is noted that inter-calibrated $\mu$ is quite different from the prelaunch calculated $\mu$.

The optimal $\mu$ and $\delta R$ is applied to calculate the inter-calibrated brightness temperature for all satellites/years, then the tropical ocean brightness temperature time series from nadir observations are extracted, the comparison before and after the correction are as Figure 2 and 3.

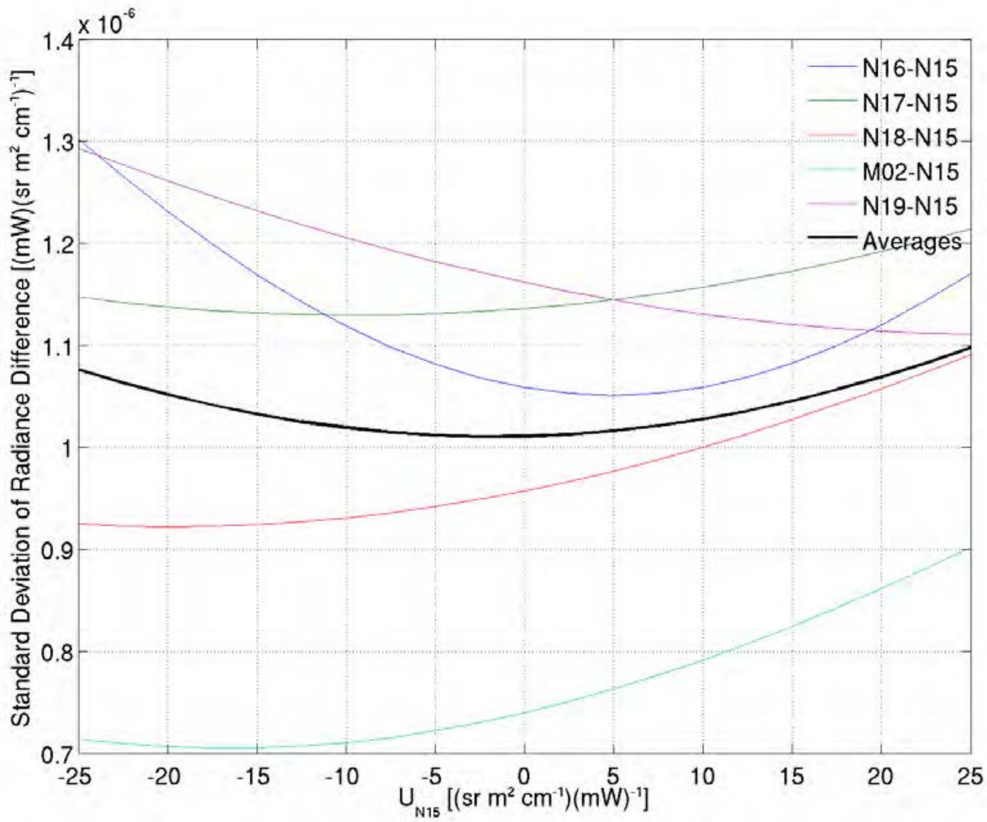



*Figure 1. Iterative search for $\mu_{N15}$ of 23.8 GHz channel.*

*Table 1. Optimal $\mu$ and $\delta R$.*

| | | N15 | N16 | N17 | N18 | M02 | N19 |
|---|---|---|---|---|---|---|---|
| $\mu$ | Ch1 | -2.90860 | -7.75889 | -10.30357 | 0.54319 | -3.12837 | 0.09178 |
| | Ch2 | 1.05310 | -2.15364 | -3.06236 | 3.79401 | -4.42838 | -0.79372 |
| | Ch3 | -1.98488 | -2.46439 | -1.69333 | -1.77138 | -3.13583 | -1.12520 |
| | Ch15 | -3.98007 | -6.70802 | -6.35800 | -5.85813 | -6.16404 | -5.65483 |
| $\delta R$ | Ch1 | 0.000E+00 | -4.505E-07 | -7.846E-07 | 1.389E-06 | -6.149E-07 | -4.975E-07 |
| | Ch2 | 0.000E+00 | 1.064E-07 | 6.151E-08 | 2.861E-07 | -1.104E-07 | 3.753E-07 |
| | Ch3 | 0.000E+00 | -1.311E-06 | -2.104E-06 | 9.705E-06 | -5.078E-06 | -4.291E-06 |
| | Ch15 | 0.000E+00 | 1.191E-05 | -1.983E-06 | -4.071E-05 | -1.029E-04 | -5.833E-05 |

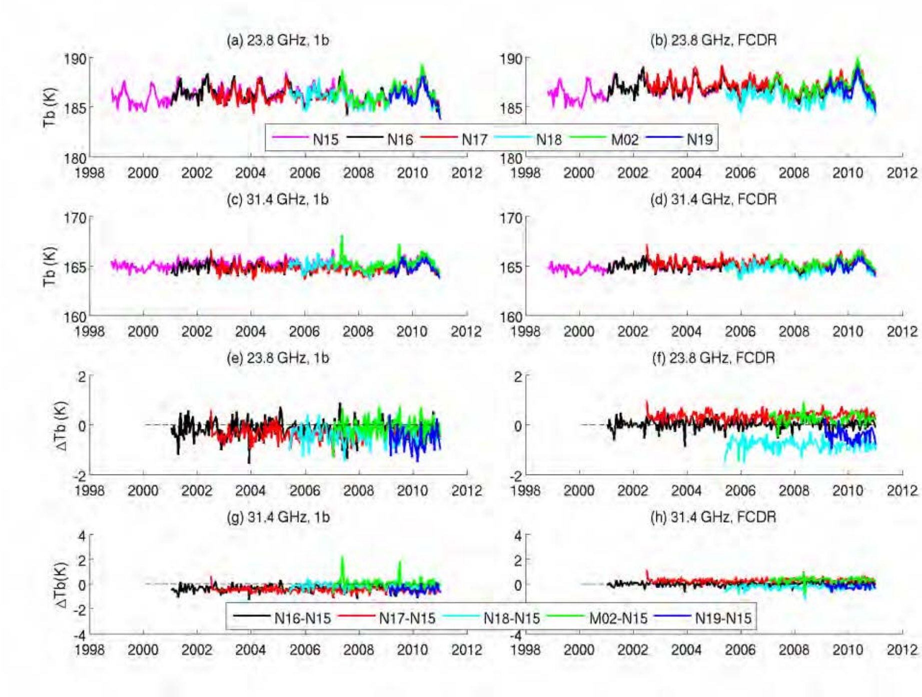



*Figure 2. Tropical ocean mean Tb and ΔTb for 23.8 and 30.4 GHz channels. Left panels display the values before correction, while right panels are after correction.*

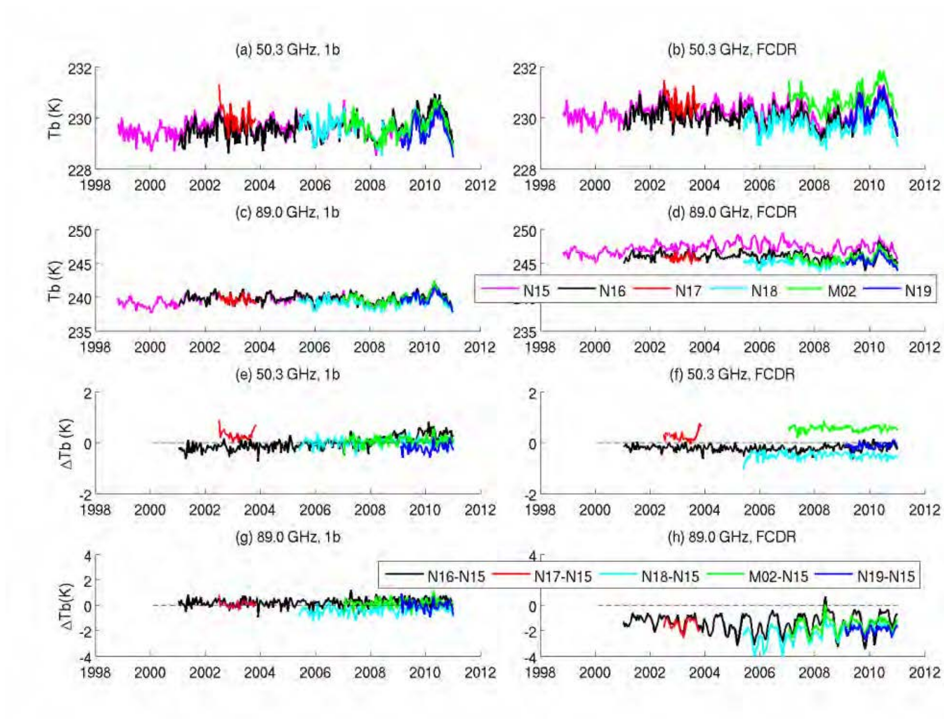



*Figure 3. Similar to Figure 2, but for 50.3 and 89.0 GHz channels.*

After inter-calibration, the impact of warm target contamination has been minimized. Table 2 shows the comparison of the STD of ∆Tb calculated from Figure 2(e)-(h) and Figure 3(e)-(h), with the exception of 89.0 GHz, the improvement of other channels are approximately 50%. With special concern, 50.3 GHz of NOAA-16 displays up trend before correction, which is due to the bias drift, and the trend has been deliberately removed after correction; 89.0 GHz of NOAA-15 seems to suffer from frequency shift, which still need further investigation.

*Table 2. Tropical Ocean STD of ∆Tb*

| | Before | | | | After | | | |
|---|---|---|---|---|---|---|---|---|
| Channel | 23.8 | 31.4 | 50.3 | 89 | 23.8 | 31.4 | 50.3 | 89 |
| N16-N15 | 0.374 | 0.263 | 0.267 | 0.315 | 0.217 | 0.193 | 0.125 | 0.716 |
| N17-N15 | 0.285 | 0.217 | 0.191 | 0.225 | 0.19 | 0.191 | 0.171 | 0.411 |
| N18-N15 | 0.386 | 0.259 | 0.168 | 0.337 | 0.238 | 0.196 | 0.129 | 0.647 |
| M02-N15 | 0.37 | 0.384 | 0.167 | 0.328 | 0.215 | 0.207 | 0.107 | 0.518 |
| N19-N15 | 0.424 | 0.276 | 0.174 | 0.374 | 0.262 | 0.186 | 0.115 | 0.296 |

***B. Inter-Satellite Calibration of AMSU-B/MHS Water Vapor Channels***

The intercalibration of AMSU-B and MHS water vapor channels was conducted using a two point generic method that uses area averaged tropical brightness temperatures (latitude band from -25° to +25°) as the warm point and the polar averaged (latitude < -75°) brightness temperatures as the cold point. Then the daily averaged values were used for inter-comparison. A linear relation was developed between the brightness temperatures from the reference satellite as the independent variable and the target satellite as the dependent variable. The relations are defined for each year separately to account for the sensor drift.

Figure 4 shows the daily averaged polar and tropical brightness temperatures from NOAA15 AMSU-B Chan 1 versus corresponding observations from NOAA17 AMSU-B Chan 1 and Figure 5 shows the same scatterplots for MetOp-A MHS Chan 1 versus NOAA-18 MHS Chan 1. The lower range indicates the observations from the polar region and the upper range shows the tropical data. The calibration coefficients were calculated as TB_TARGET = a x TB_REFERENCE + B.

The effect of clouds on the inter-calibration coefficients was investigated using filtering the clouds using brightness temperature difference. The idea is that because of the laps rate in atmospheric temperature, the lower channels have larger brightness temperature than the higher channels. Therefore, in clear-sky conditions the Tbs of lower channels are warmer than the Tbs of higher channels. In the case of clouds, the relation is changed which can be used as a filter to remove cloud contaminated pixels. Figure 6 shows the distribution of the brightness temperatures for different MHS channels in the presence of a relatively deep cloud. The cloud filters defined using brightness temperature differences are shown in Figure 7.

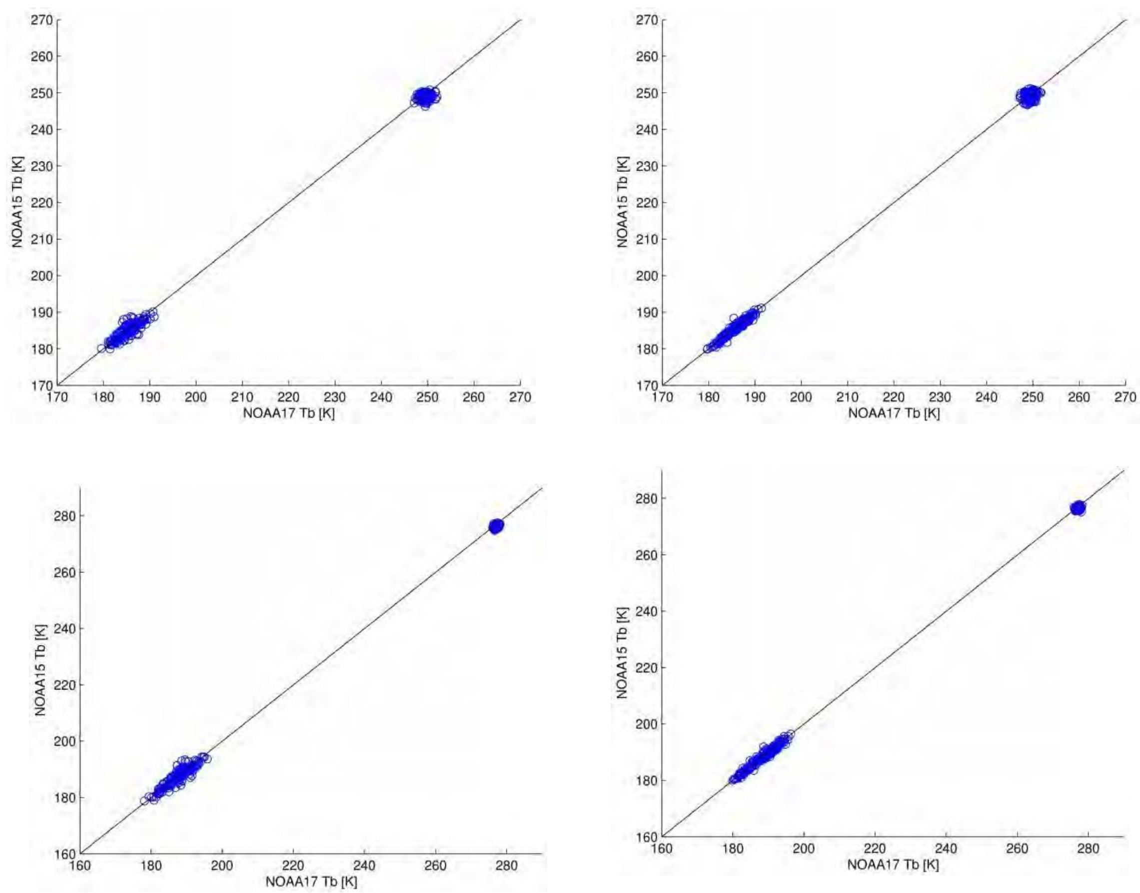



*Figure 4: Observations from NOAA-15 AMSU-B Chan 1 versus observations from NOAA-17 AMSU-B Chan 1 (top) and Channel 2 (bottom), left 2007, right 2009.*

Because of the dry atmosphere in the polar region it is very difficult to apply the brightness temperature difference technique to the observations from the polar region. The effect of surface emissivity becomes important in the polar region and it obscures the cloud effects. Besides, MW observations are only sensitive to deep-convective clouds which are not present in the polar region. Therefore, it was decided that it is not necessary to apply the cloud detection techniques to the polar observations. However in the tropical region the brightness temperatures from the window channels can be affected by the deep-convective clouds. We tested two different filters: channel 3 – channel 4 and channel 5 minus channel 2 as the cloud filters. The statistics (percentage of the observations affected by the clouds) are shown in Figure 8. The statistics show that the Chan3-Chan4 is only able to detect a small percentage of the clouds as those channels peak very high in tropical region and are also very similar because of high relative humidity. It was already expected that water vapor channels are not very sensitive to clouds since those channels normally peak high and are only affected by over-shooting clouds. Therefore, based on the analysis of the impact of clouds on different channels, it was decided to apply the Chan5 – Chan2 filter to the observations from the window channels and then inter-calibrate the target and reference satellites' observations.

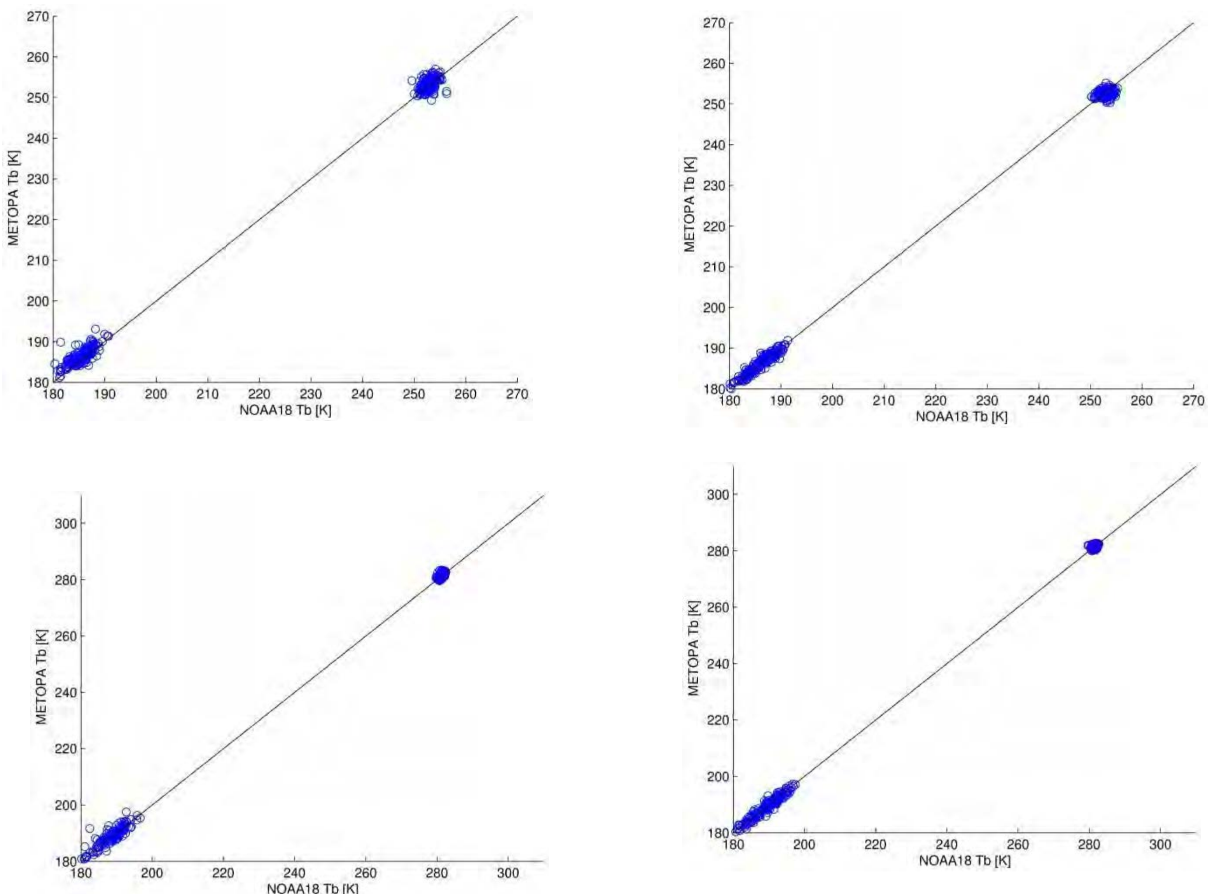



*Figure 5: Observations from MetOp-A MHS Chan 1 versus observations from NOAA-18 MHS Chan 1 (top) and Channel 2 (bottom), left 2007, right 2009.*

**PLANNED WORK**

The planned work is scheduled as following:

For AMSU-A window channels, we plan to 1) go over 50.3 GHz of NOAA16 from SNO, ocean data to coefficients and products; 2) quantify frequency shift of 89 GHz, NOAA15; 3) finish TCDR code, so as to do the validation, inter-satellite comparison, and see the improvements; 4) improve the quality assessment; and 5) finish a paper on Inter satellite calibration.

We will finish documentation in the proposed period, which will include Algorithm Theoretical Basis Document (ATBD), Operational Algorithm Description (OAD), source code, research papers, etc. With the progress of the project, more research papers will be prepared, and these publications will contribute to the future documentations.

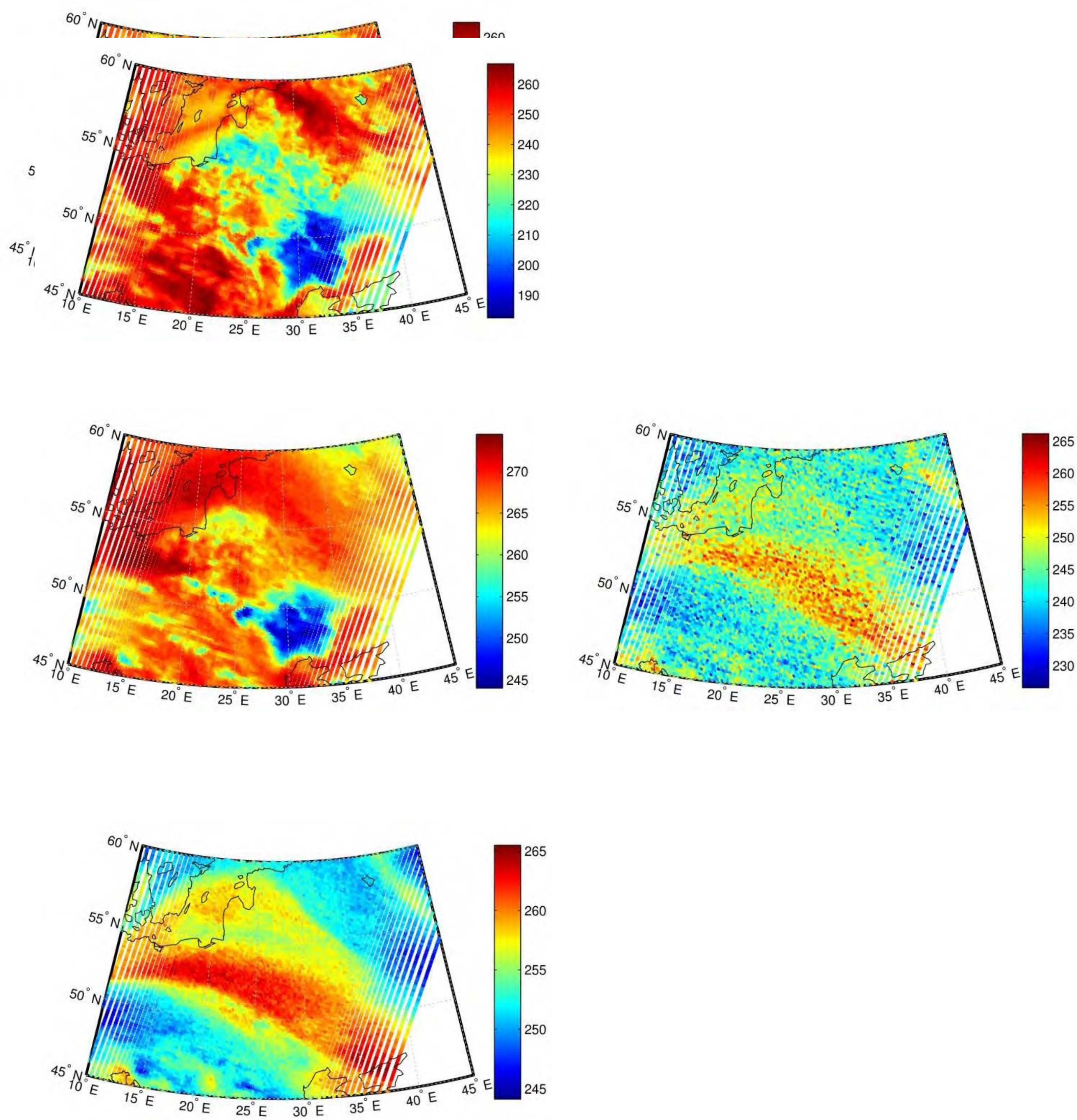



*Figure 6: Brightness temperatures from different MHS Channels, Channels 1 to 5, from left to right then top to bottom. The plots indicate the upper-level channels are less sensitive to clouds than the lower channels.*

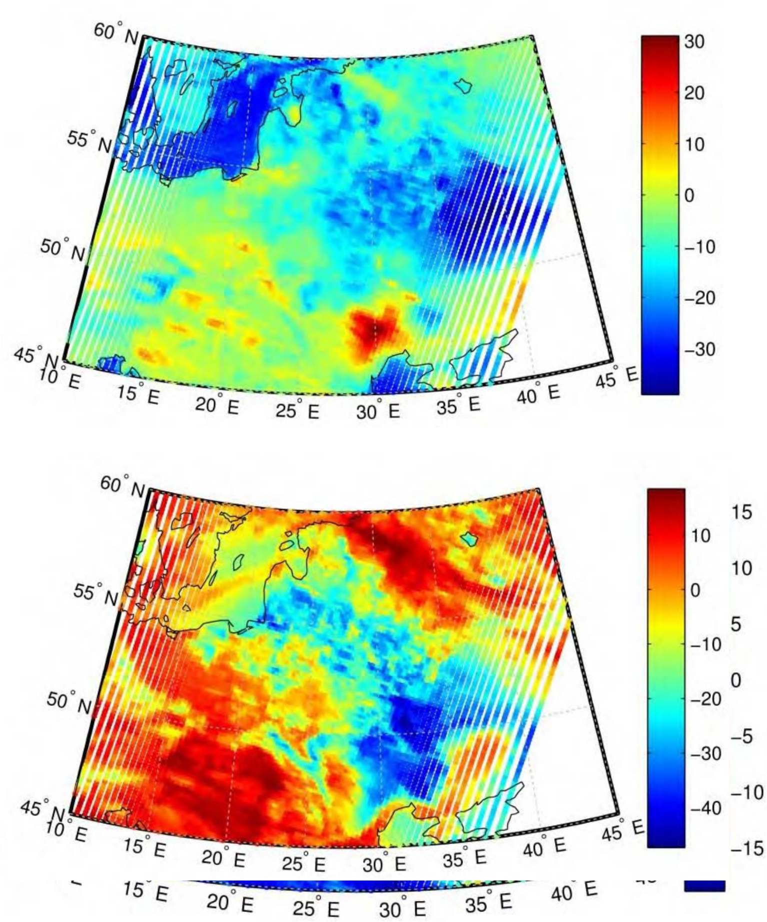
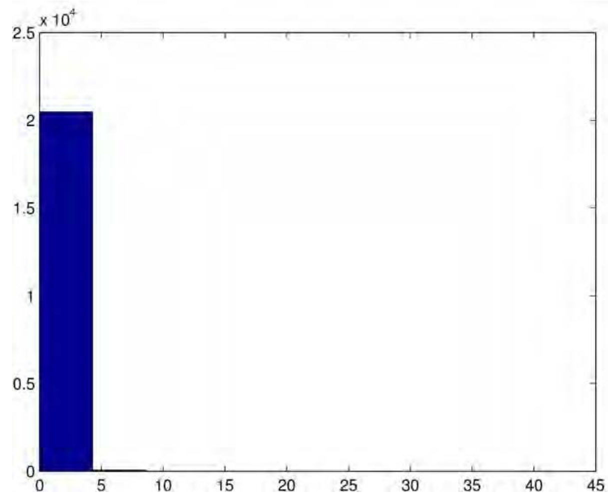
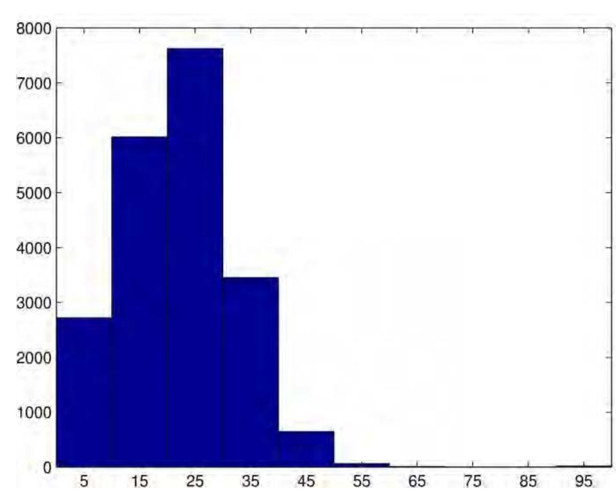
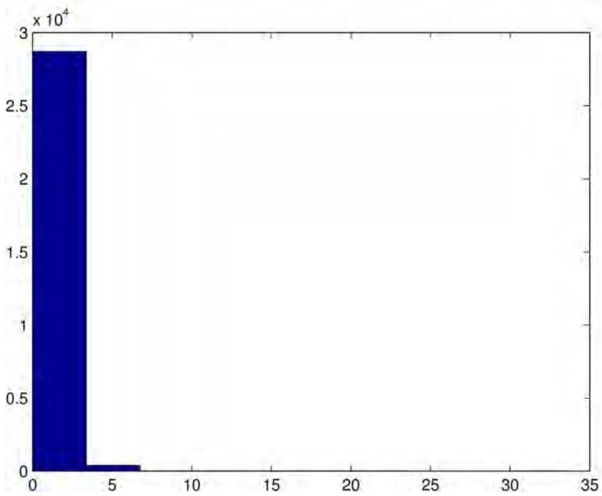



*Figure 7: Cloud Filters defined using brightness temperature differences. (top) Chan 1 minus Chan 2, (middle) Chan 2 – Chan 5 and (bottom) Chan 3 – Chan 5.*





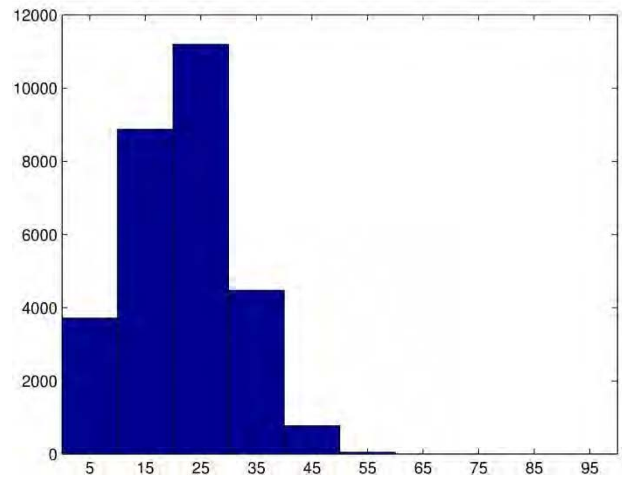




*Figure 8: the percentage of clouds based on different cloud filters over the tropical region.*

**PRESENTATIONS**

Yang, W., H. Meng, and R. Ferraro, Inter-Calibration of AMSU-A Window Channels, NOAA Satellite Confernence, College Park, Maryland, Apr 8-12, 2013.

Ferraro, R., H. Meng, W. Yang, I. Moradi, The Development of AMSU FCDR's and TCDR's for Hydrological Applications, CDR PI meeting, Asheville, NC, Jul 30 - Aug 1, 2013.

Ferraro, R., H. Meng, W. Yang, and I. Moradi, AMSU/MHS Climate Data Records for Hydrological Products, 2013 EUMETSAT Meteorological Satellite Conference & 19th AMS Satellite Meteorology, Oceanography, and Climatology Conference, Vienna, Austria, Sep 16-20, 2013.

Yang, W., H. Meng, R. Ferraro, Inter-Calibration of AMSU-A Window Channels, EUMETSAT/AMS Conference, Vienna, Austria, Sep 16-20, 2013.

Yang, W., H. Meng, and R. Ferraro, Inter-Calibration of AMSU-A Window Channels, Second CICS-MD Science Meeting, College Park, Maryland, Nov 6-7, 2013.

Yang, W., H. Meng, and R. Ferraro, Application of Dr. Zou's Approach on Inter-Calibration of AMSU-A Window Channels, GSICS Microwave Sub-Group Web Meeting, Dec 3, 2013.

Yang, W., H. Meng, and R. Ferraro, An Improved Microwave Satellite Data Set for Hydrological and Meteorological Applications, AMS annual meeting, Atlanta, GA, Feb 2-6, 2014.

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

| | |
|---|---|
| # of products or techniques transitioned from research to ops without NOAA guidance | 0 |
| # of peer reviewed papers | 0 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 7 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

## 1.7 Land and Hydrology

**A GOES Thermal-Based Drought Early Warning Index for NIDIS and Dual Assimilation of Microwave and Thermal Infrared Satellite Observations of Soil Moisture into NLDAS for Improved Drought Monitoring.**

| | |
|---|---|
| **Task Leader** | Dr. Christopher Hain |
| **Task Code** | CHCH_MAPP_13 |
| **NOAA Sponsor** | Dr. Xiwu Zhan |
| **NOAA Office** | NESDIS/STAR |
| **Contribution to CICS Themes (%)** | Theme 1: 33%; Theme 2: 33%; Theme 3: 3%. |
| **Main CICS Research Topic** | Land and Hydrology |
| **Contribution to NOAA Goals (%)** | Goal 1: 70%; Goal 2: 30% |

**Highlight**: CICS scientist are developing a land data assimilation system using the NASA Land Information System (LIS) which assimilates soil moisture retrievals from a thermal infrared methodology (e.g., ALEXI) and from passive microwave sensors (e.g., AMSR-E; Windsat; AMSR2) to improve drought monitoring over the continental United States.

**BACKGROUND**

Evapotranspiration deficits in comparison with potential ET (PET) rates provide proxy information regarding soil moisture availability. In regions of dense vegetation, ET probes moisture conditions in the plant root zone, down to meter depths. Our group has spearheaded use of anomalies in the remotely sensed ET/PET fraction ($f_{PET}$) generated with ALEXI as a drought monitoring tool that samples variability in water use, and demonstrating complementary value in combination with standard drought indices that reflect water supply. Additionally, our research group has demonstrated that diagnostic information about SM and evapotranspiration (ET) from microwave (MW) and thermal infrared (TIR) remote sensing can significantly reduce soil moisture (SM) drifts in LSMs such as Noah. The two retrievals have been shown to be quite complementary: TIR provides relatively high spatial resolution (down to 100 m) and low temporal resolution (due to cloud cover) retrievals over a wide range of vegetation cover, while MW provides relatively low spatial (25 to 60 km) and high temporal resolution (can retrieve through cloud cover), but only over areas with low vegetation cover. Furthermore, MW retrievals are sensitive to SM only in the first few centimeters of the soil profile, while in vegetated areas TIR provides information about SM conditions integrated over the full root-zone, reflected in the observed canopy temperature. The added value of TIR over MW alone is most significant in areas of moderate to dense vegetation cover where MW retrievals have very little sensitivity to SM at any depth. This synergy between the two different retrieval techniques should provide a unique opportunity for the development of a dual assimilation system with the potential to improve drought assessments from the NLDAS suite of land surface models.

**ACCOMPLISHMENTS**

Soil moisture (SM) products from multiple sources are inter-compared with each other to assess their relationships and are validated against in-situ observations from the North American Soil Moisture Database (NASMD) to evaluate their relative performance. Three types of SM products are compared herein including Noah offline simulations as representative of SM predictions from land surface models, ECV and SMOPS products as representative of satellite based microwave (MW) SM products and ALEXI SM proxy as representative of satellite based thermal infrared (TIR) SM products. Time series anomaly correlations from each of the SM datasets are computed and then validated against ground based SM measurements over more than 400 sites from 21 different SM networks in the NASMD. The comparison and validation period expends from 2007 to 2010, a common period when all four datasets have archives. Anomaly correlations are calculated over the pixels when all products have valid observations. In addition, time series anomaly correlations are tested for statistical significance at a confidence interval of 99%.

Figure 1 present the anomaly correlations between each of the four SM products (Noah, SMOPS, ECV, and ALEXI), where black shading indicates pixels which did not exhibited a statistically significant anomaly correlation. In general, satellite based SM products agree well with the Noah LSM predictions, especially over the central and eastern United States. The relationship between ALEXI and SMOPS products is expected to be relative lower since these two datasets are derived from two different satellite channels which are quite complimentary. Similarly, all products performed well in the central and eastern United States, while the correlations tend to be relatively lower in the western area. Average correlations from all ground sites are computed for each product. Noah predictions present the highest mean time series anomaly correlation of 0.50 relative to the ground validation dataset from 423 sites, with ECV and ALEXI each exhibited a mean time series correlation of 0.33. It is not unexpected that Noah shows the highest value when forced with a high quality gauge-based precipitation dataset, as exists over the CONUS.

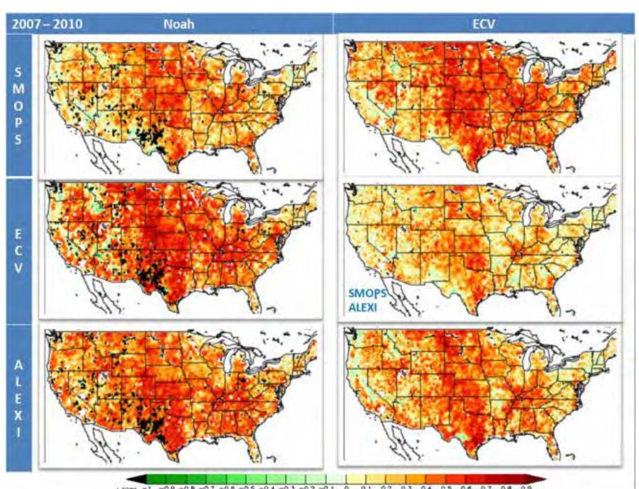



*Figure 1. Time series anomaly correlation coefficients between each of the four SM products (Noah, ECV, SMOPS and ALEXI) over the period of 2007 – 2010.*

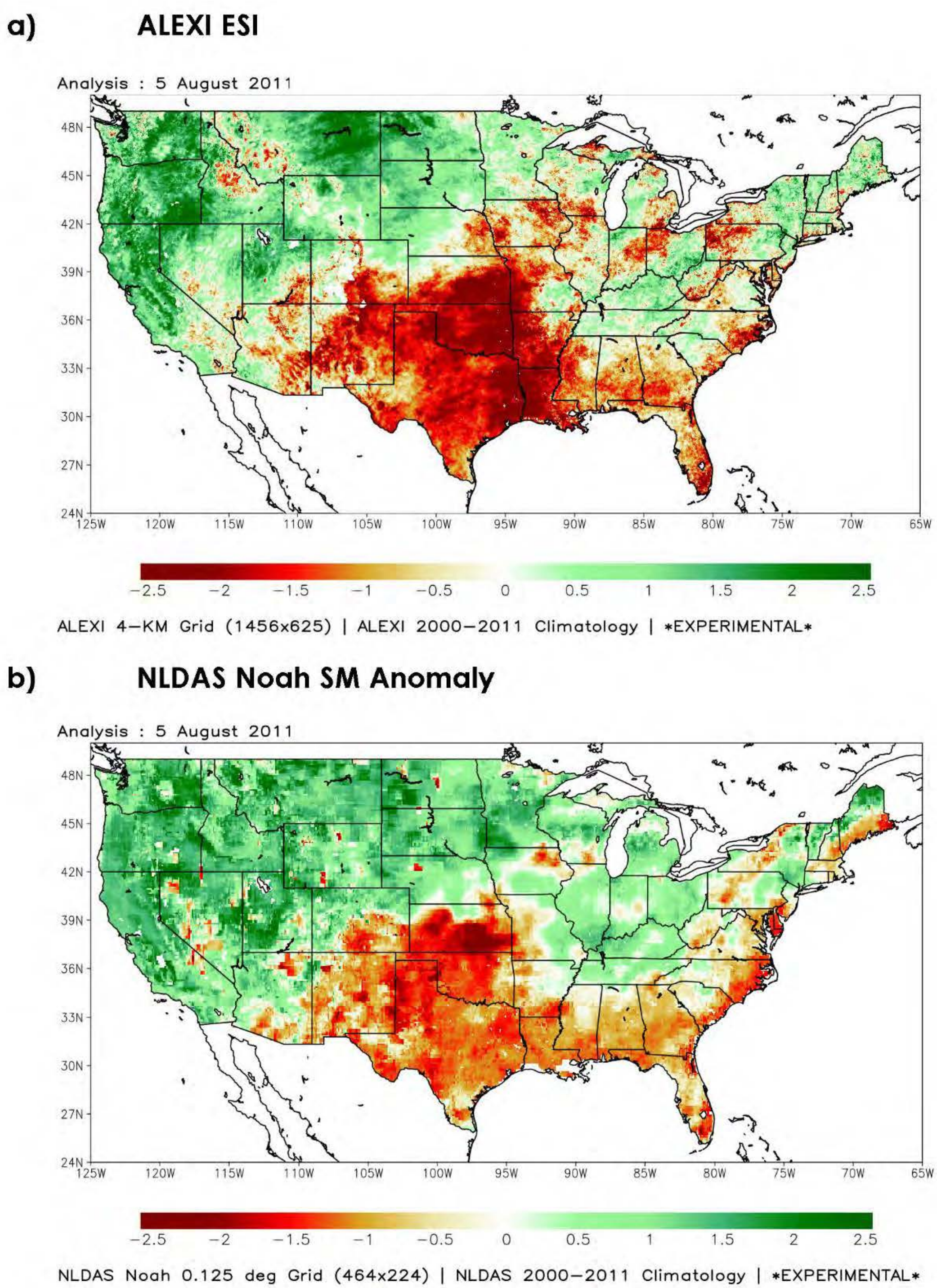
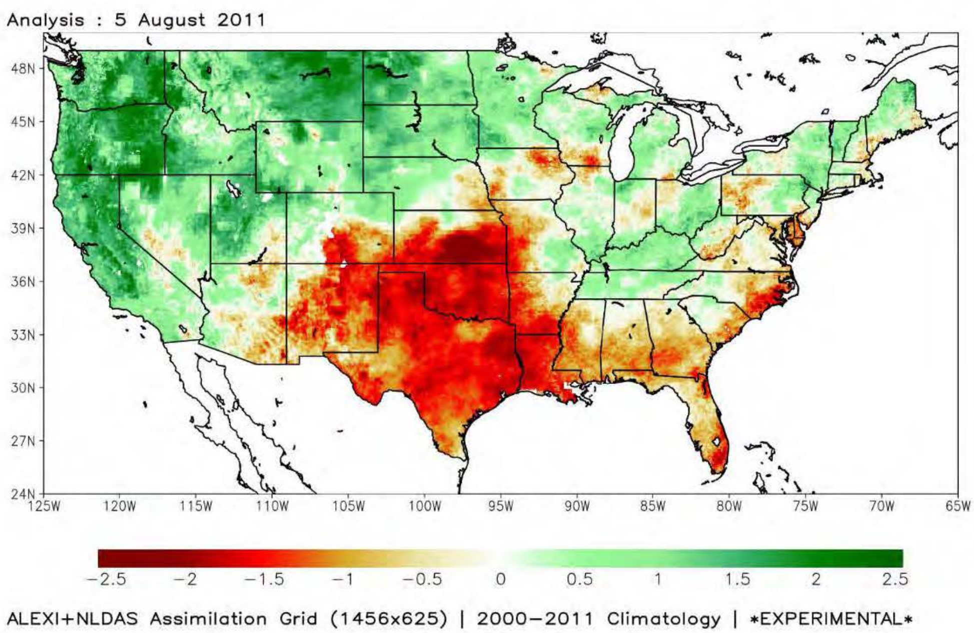
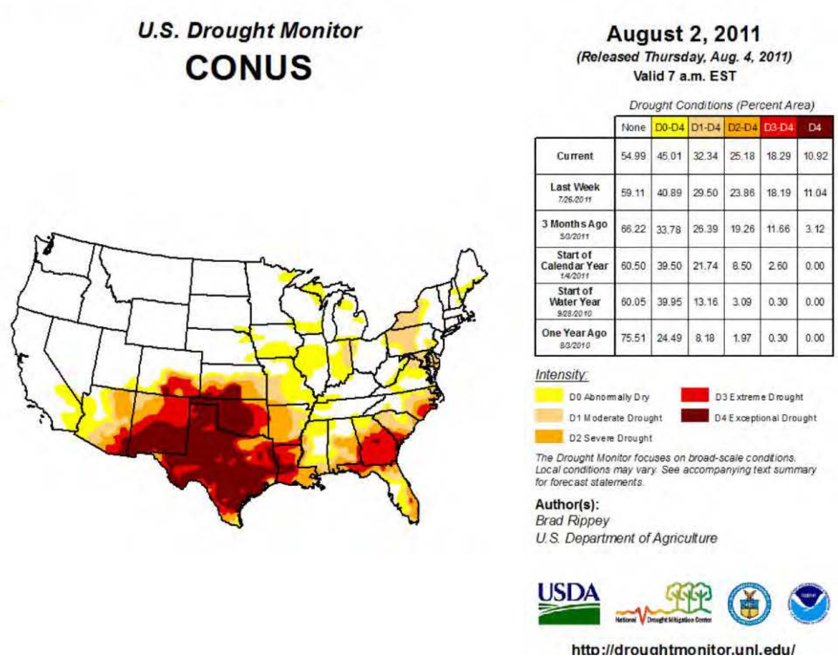



*Figure 2. Drought products valid on 5 August 2011 for a) ALEXI Evaporative Stress Index, b) open-loop simulation of Noah.*

c) **Merged ALEXI+NLDAS Noah**




d) **USDM**




| | None | D0-D4 | D1-D4 | D2-D4 | D3-D4 | D4 |
|---|---|---|---|---|---|---|
| Current | 54.99 | 45.01 | 32.34 | 25.18 | 18.29 | 10.92 |
| Last Week 7/26/2011 | 59.11 | 40.89 | 29.50 | 23.86 | 18.19 | 11.04 |
| 3 Months Ago 5/3/2011 | 66.22 | 33.78 | 26.39 | 19.26 | 11.66 | 3.12 |
| Start of Calendar Year 1/4/2011 | 60.50 | 39.50 | 21.74 | 8.50 | 2.60 | 0.00 |
| Start of Water Year 9/28/2010 | 60.05 | 39.95 | 13.16 | 3.09 | 0.30 | 0.00 |
| One Year Ago 8/3/2010 | 75.51 | 24.49 | 8.18 | 1.97 | 0.30 | 0.00 |

*Figure 2 (cont.): Drought products valid on 5 August 2011 for c) merged ALEXI and NLDAS and d) U. S. Drought Monitor Drought Classifications.*

Ongoing work is actively assessing the impact of ALEXI and MW SM retrievals in a data assimilation framework towards improving SM-based estimates of drought from the Noah LSM. In general, the addition of ALEXI SM retrievals has shown improvements in the representation of drought as compared to an open-loop simulation of Noah. The assimilation of ALEXI SM information into Noah has also shown the ability to highlight regions of rapid development of "flash drought" conditions, for example during the significant drought of 2012, ALEXI showed significant degradation of soil moisture conditions well before the introduction of drought classifications in the USDM. Figure 2 shows an example of using ALEXI SM information to improve the open-loop simulation of Noah during August 2011. Both ALEXI and OLP Noah showed a large area of significant drought across the south central US, although ALEXI anomalies were much stronger, especially over eastern TX and was more in agreement with the USDM which showed D3/D4 drought. Another significant difference was ALEXI showing scattered drought conditions across the southern Great Lakes states where OLP Noah showed no drought. Fig. 2c shows the merged product where ALEXI is used to update the OLP Noah simulation. In general, the merged product matches the current USDM map more closely than either one in isolation. Another significant impact of ALEXI information is to improve the spatial resolution of the Noah analyses which are forced with relatively coarse meteorological forcing.

**PLANNED WORK**

Ongoing and future work will focus on:

- Quantitative assessment of data assimilation SM results with in-situ soil moisture observations, NLDAS products and CFSRR forecasts.
- Comparison of data assimilation SM anomalies with the United States Drought Monitors and anomalies in all available standard drought metrics.
- Real-time product delivery of ALEXI SM assimilation drought maps to NIDIS-USDP, CPC and NDMC.

**PUBLICATIONS**

Otkin, J. A., M. C. Anderson, **C. R. Hain**, I. E. Mladenova, J. B. Basara and M. Svoboda, 2013: Examining rapid onset drought development using the thermal infrared based evaporative stress index, *Journal of Hydrometeorology*. Aug2013, Vol. 14 Issue 4, 1057-1074.

Mishra V, Cruise JF, Mecikalski JR, **Hain CR**, Anderson MC. A Remote-Sensing Driven Tool for Estimating Crop Stress and Yields. *Remote Sensing*. 2013; 5(7):3331-3356.

Anderson, M. C., **C. R. Hain**, J. Otkin, X. Zhan, K. Mo, M. Svoboda, B. Wardlow and A. Pimstein, 2013: An intercomparison of drought indicators based on thermal remote sensing and NLDAS-2 simulations with U.S. Drought Monitor classification, *Journal of Hydrometeorology*, Vol. 14 Issue 4, 1035-1056.

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

**Hain, C. R**., M. C. Anderson, W. T. Crow, and M. T. Yilmaz, 2013: Diagnosing Neglected Soil Moisture Source/Sink Processes via a Thermal Infrared-based Two-Source Energy Balance Model, *Submitted to J. of Hydromet*.

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

Temimi, M, **C. R. Hain**, X. Zhan, R. Rabin, M. C. Anderson, C. Notarnicola, J. Stepinski, and A. Bonhomme, 2013: On the synergistic use of microwave and infrared satellite observations to monitor soil moisture and flooing, In Press, *In Remote Sensing of Land Surface Turbulent Fluxes and Soil Surface Moisture Content: State of the Art*, Taylor & Francis.

Anderson, M. C., W. P. Kustas, **C. R. Hain**, C. Cammalleri, F. Gao, M. T. Yilmaz, I. E. Mladenova, J. Otkin, M. Schull and R. Rouberg, 2013: Mapping surface fluxes and moisture conditions from field to global scales using ALEXI/DisALEXI, In Press, *In Remote Sensing of Land Surface Turbulent Fluxes and Soil Surface Moisture Content: State of the Art*, Taylor & Francis.

McCabe, M., W. P. Kustas, M. C. Anderson, C. Kongoil, A. Ershadi and **C. R. Hain**, 2013: Global scale estimation of land surface heat fluxes from space: current status, opportunities and future direction, In Press, *In Remote Sensing of Land Surface Turbulent Fluxes and Soil Surface Moisture Content: State of the Art*, Taylor & Francis.

**PRESENTATIONS**

**Hain, C. R**., M. C. Anderson, and M. T. Yilmaz, 2013. “Mapping Water Use and Drought with Thermal Remote Sensing”, The African Monsoon Multidisciplinary Analysis Land Surface Model Intercomparison Project – Phase 2 International Workshop in Toulouse, France, 15-17 April 2013 [INVITED].

**Hain, C. R**., M. C. Anderson, X. Zhan and M. T. Yilmaz. “Monitoring evapotranspiration and water resources with thermal infrared geostationary sensors: An intercomparison with model-based ET predictions and tower observations”, 93nd Annual Meeting of the American Meteorological Society in Austin, TX 6-10 January 2013 [INVITED].

Anderson, M. C., **C. Hain**, J.A. Otkin and X. Zhan. “Evaluation of a Remotely Sensed Evaporative Stress Index for Monitoring Patterns of Anomalous Water Use”, 93nd Annual Meeting of the American Meteorological Society in Austin, TX 6-10 January 2013.

Otkin, J. A., M. C. Anderson, **C. R. Hain**, I. E. Mladenova, J. B. Basara and M. D. Svoboda. "Examining flash drought development using the Evaporative Stress Inex (ESI)", 93rd Annual Meeting of the American Meterological Society in Austin, TX 6-10 January, 2013.

Semmens, K. A., M. C. Anderson, I. E. Mladenova, **C. R. Hain**, J. A. Otkin and N. Guindin. "Assessing the remote sensing derived Evaporative Stress Index with ground observations of crop condition to advance drought early warning", 2013 AGU Fall Meeting in San Francisco, CA, 9-13 December 2013.

Semmens, K., M. Anderson, I. Mladenova, **C. Hain**, J. Otkin, and N. Guindin, "Assessing the remote sensing derived Evaporative Stress Index with ground observations of crop condition to advance drought early warning", 94th Annual Meeting of the American Meteorological Society in Atlanta, GA, 2-6 February, 2014.

Otkin, J., M. Anderson, **C. Hain**, M. Svoboda, "Examining the relationship between drought development and rapid changes in the thermal-based Evaporative Stress Index", 94th Annual Meeting of the American Meteorological Society in Atlanta, GA, 2-6 February, 2014.

**Fang. L**, **C. Hain**, X. Zhan and J. Yin, "Impact of Near-real-time Satellite Observations on Flux and Soil Moisture Simulations of Noah LSM in NLDAS",94th Annual Meeting of the American Meteorological Society in Atlanta, GA, 2-6 February, 2014.

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 1 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 1 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 0 |
| # of peer reviewed papers | 9 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 2 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**PERFORMANCE METRICS EXPLANATION**

We developed and tested a dual data assimilation framework to assimilate thermal infrared and passive microwave retrievals into the Noah LSM to improve drought monitoring tools. All soil moisture products were extensively validated against all available in-situ observations from the North American Soil Moisture Database. It was found that thermal infrared and passive micro-wave retrieval techniques exhibit similar levels of skill averaged over all sites but each provides unique complementary capabilities. Research from this project lead to seven accepted peer review papers from our research team and direct collaborators, with an additional two papers currently in review. Our research team also gave two invited presentations and five additional presentations at various scientific conferences this year. Findings from this work will potentially be transitioned into the currently under development GET-D ET and Drought Product System at NOAA.

**Hydroclimatological Support for the Climate Prediction Center**

| | |
|---|---|
| **Task Leader** | Li-Chuan Chen |
| **Task Code** | LCLC_HACP_13 |
| **NOAA Sponsor** | Kingtse Mo |
| **NOAA Office** | NWS/NCEP/CPC |
| **Contribution to CICS Themes (%)** | Theme 2: 25%; Theme 3: 75% |
| **Main CICS Research Topic** | Land and Hydrology |
| **Contribution to NOAA Goals (%)** | Goal 1: 50%; Goal 2: 50% |

**Highlight**: CICS researcher evaluated the predictive skill of meteorological drought based on the North American Multi-Model Ensemble (NMME) forecasts and showed higher skill than that based on single-model forecasts.

**BACKGROUND**

This work is to support NOAA/NCEP Climate Prediction Center's (CPC's) efforts on drought monitoring and prediction. Tasks include (1) monitoring the production of operational data such as North American Regional Reanalysis (NARR) and North American Land Data Assimilation System (NLDAS) to support U.S. Drought Monitor and Outlook, (2) working on research to advance the science and technology necessary for drought prediction, and (3) developing algorithms and techniques for building a drought early warning system. Three indices: standardized precipitation index (SPI), soil moisture percentile (SMP), and standardized runoff index (SRI) are used in the development of a real-time objective drought prediction system at CPC. SPI, which measures precipitation deficits, is used to identify meteorological drought. SMP, computed based on probability distributions, is used to classify agricultural drought. SRI, similar to SPI and measuring runoff deficits, represents hydrological drought.

**ACCOMPLISHMENTS**

In the last two years, the CFSv2-based SPI Outlooks I developed in 2011 were expanded to using dynamical precipitation forecasts from the North American Multi-Model Ensemble (NMME). NMME is a multi-model seasonal forecast system consisting of six model forecasts from U.S. and Canada modeling centers, including the CFSv2, CM2.1, GEOS-5, CCSM3.0, CanCM3, and CanCM4 models. 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 Midwest Flash Drought in August and September and the on-going California drought since December 2013. A website to deliver the real-time NMME SPI Outlooks to the public was developed and started in operation in March 2013. In July, 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.

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. Before predicting SPI, monthly-mean precipitation(P) forecasts from each model were bias corrected and spatially downscaled to regional grids of 0.5-degree resolution over the contiguous United States based on the probability distribution functions derived from the hindcasts. The corrected P forecasts were then appended to the CPC Unified Precipitation Analysis to form a P time series for computing 1-month, 3-month, 6-month, and 12-month SPIs (SPI1, SPI3, SPI6, and SPI12, respectively). The ensemble SPI forecasts are the equally weighted mean of the six model forecasts. Two performance measures, the anomaly correlation coefficient (ACC) and root-mean-square errors (RMSE) against the observations 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 (Figure 1).

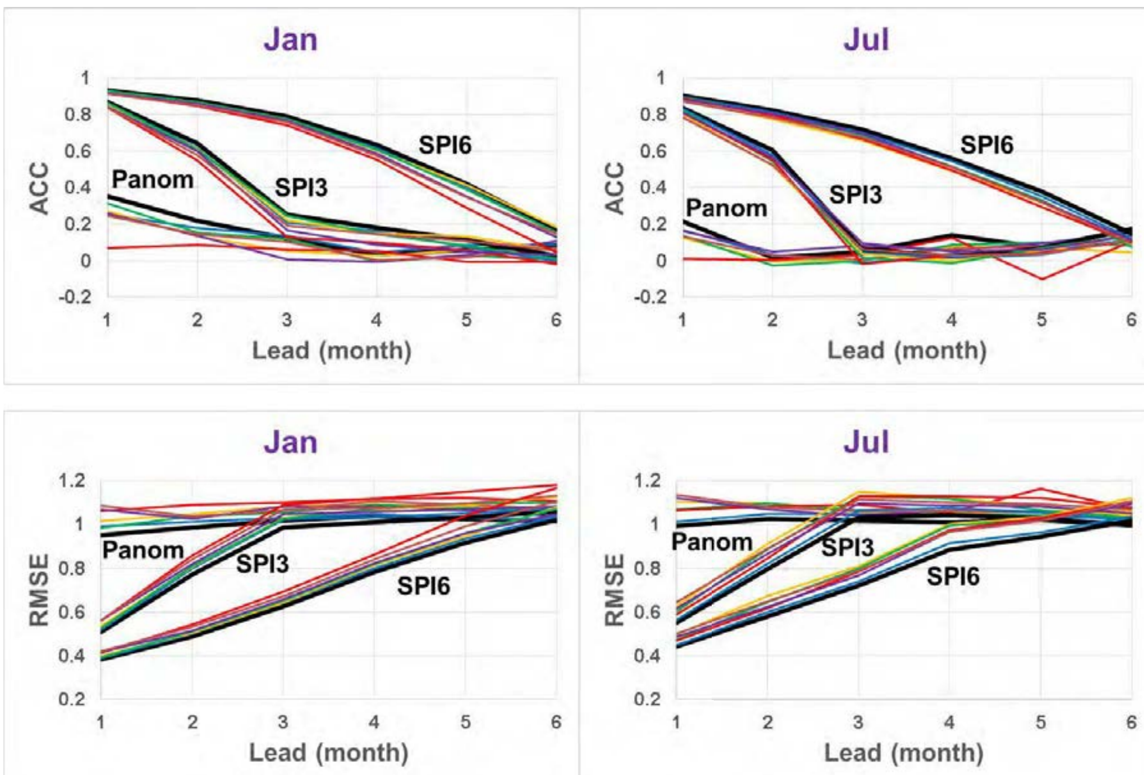



*Figure 1 Relation of SPI forecast skill to lead time for January and July.*

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 (Figure 2), 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

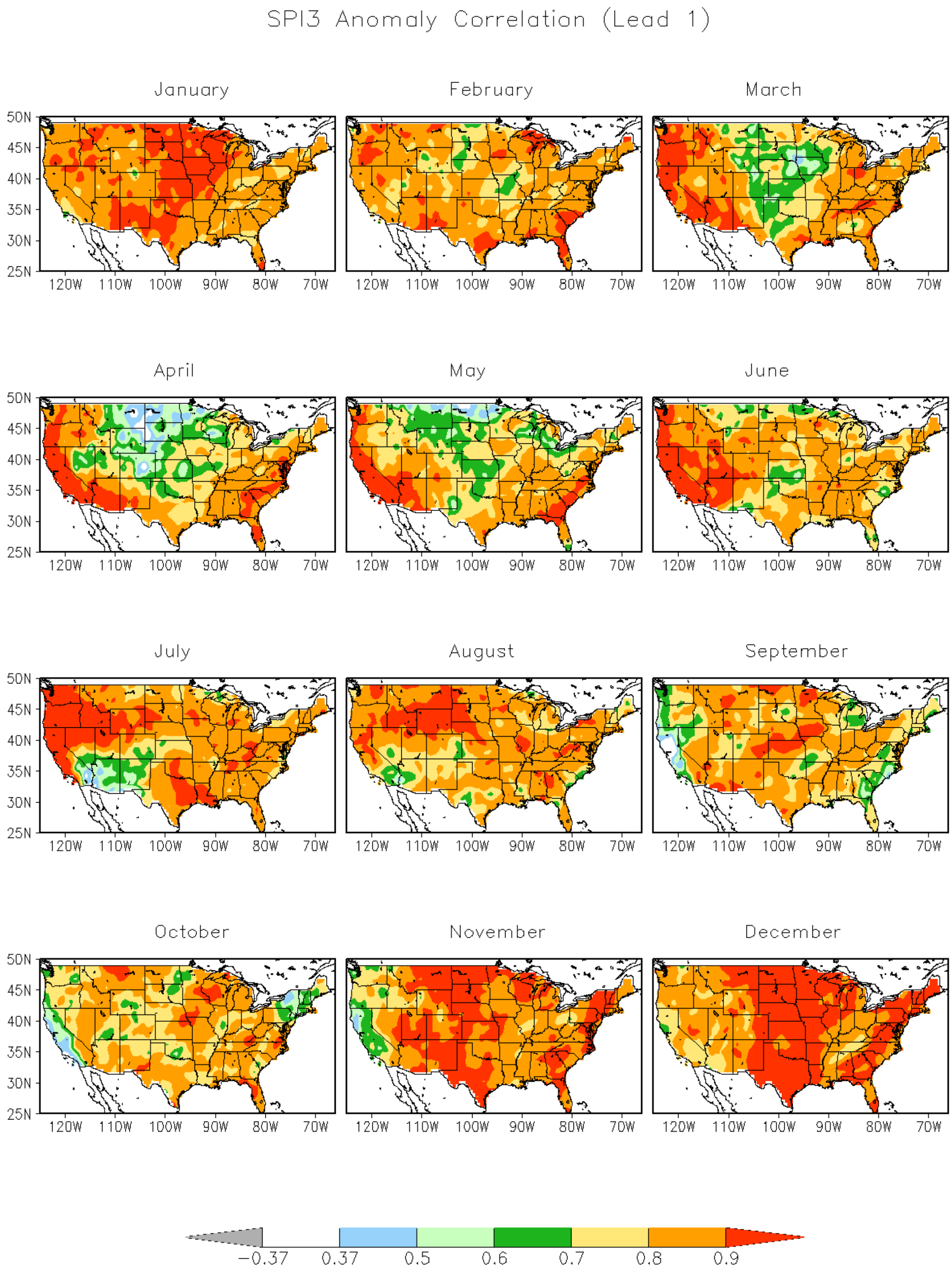



*Figure 2: ACC maps of Month-1 SPI3 forecasts for all 12 months.*

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 are 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 real-time NMME SPI prediction system, I developed an experimental hydroclimate forecast system using CFSv2 forecasts at CPC. My collaborators and I have conducted an assessment of the soil moisture and runoff forecasts from CFSv2 using its retrospective forecasts from 1982 to 2009 to evaluate their usefulness for drought prediction. We investigated whether seasonal soil moisture forecasts derived from a land surface model forced by seasonal climate model (CFSv2) forecasts (i.e., hydroclimate forecasts) are more skillful than the baseline forecasts derived from the same land surface model but with forcing taken from resampled climatological precipitation, surface temperature, and low-level winds. We found that soil moisture predictive skill based on seasonal climate forecasts is not higher than the baseline forecasts for most forecast leads and over the western U.S. For one-month leads, the CFSv2-based forecasts are skillful when and where the precipitation forecasts from the climate model has skill. We further analyzed the runoff forecasts from the same hydroclimate forecast system and found similar results to the soil moisture forecasts that CFSv2 contributes to the runoff forecasts when and where precipitation forecasts are skillful. However, preliminary results have shown that regional SRI forecasts from a hydroclimate forecast system have higher skill than the baseline forecasts during the transition seasons (e.g., April and October) and where dynamical forcing is active, and demonstrated their potential usefulness for predicting hydrological drought. The results of these studies are published in Geophysical Research Letters in December 2012 and presented in several conferences and meetings, including the 2012 AGU Fall Meeting and 2013 Chapman Conference. Another manuscript focused on SRI predictability has been prepared and will be submitted for journal publication.

**PLANNED WORK**

- Continue the development of NMME SPI forecast system to incorporate new models and high-frequency data available in Phase-II NMME project.
- Develop a real-time forecast verification system for the operational NMME SPI prediction products.
- Conduct research to explore the potential of developing a probabilistic seasonal drought prediction system using NMME forecasts.
- Develop a real-time SMP and SRI forecast system and products.

**PUBLICATIONS**

Chen, L.-C., K. C. Mo, Q. Zhang, and J. Huang (2013), Meteorological Drought Prediction Using a Multi-Model Ensemble Approach, 38th NOAA Climate Diagnostics and Prediction Workshop Special Issue, Climate Prediction S&T Digest, 48-50.

**PRESENTATIONS**

Chen, L.-C., K. C. Mo, Q. Zhang, and J. Huang (2013), Meteorological Drought Prediction Using a Multi-Model Ensemble Approach, Abstract H44C-05 presented at 2013 Fall Meeting, American Geophysical Union, San Francisco, CA, 9-13 Dec.

Chen, L.-C., K. C. Mo, Q. Zhang, and J. Huang (2013), Meteorological Drought Prediction Using a Multi-Model Ensemble Approach, 2nd Annual CICS-MD Science Meeting, College Park, MD, 6-7 Nov.

Chen, L.-C., and S. Shukla (2013), Seasonal Runoff Forecasts Based on the Climate Forecast System Version 2, AGU Chapman Conference on Seasonal to Interannual Hydroclimate Forecasts and Water Management, Portland, OR, 28-31 July.

**DELIVERABLES**

- Software system for real-time NMME SPI forecasts
- Operational NMME SPI Outlooks website at http://www.cpc.ncep.noaa.gov/products/Drought/Monitoring/spi_outlooks_3.shtml
- Operational data and products for drought monitoring and forecasts, available at CPC Drought Information website: http://www.cpc.ncep.noaa.gov/products/Drought

**PERFORMANCE METRICS**

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

## CUNY-CREST River and Lake Ice Mapping Using NPP/JPSS VIIRS Sensor to Support NOAA NWS

| | |
|---|---|
| **Task Leader** | Naira Chaouch |
| **Task Code** | NCNC_JPSS_13 |
| **NOAA Sponsor** | Mitch Goldberg |
| **NOAA Office** | NOAA/NESDIS/STAR |
| **Contribution to CICS Themes (%)** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0%. |
| **Main CICS Research Topic** | Land and Hydrology |
| **Contribution to NOAA Goals (%)** | Goal 1: 50%; Goal 2: 50%; Goal 3:0%; Goal 4:0%; Goal 5: % |

**Highlight**: We have developed a river ice product over major rivers in Alaska and North Central US. This product is running operationally in NOAA NWS and displayed in their Advanced Weather Interactive Processing System.

**BACKGROUND**

This research proposes the development of a new data product that provide information on inland ice precisely in lakes and major rivers which constitute principal components of hydrological processes in northern watersheds namely and key indicator of climate change. It is an expansion of a previous work, which has been supported by NWS Eastern Region Hydrologic Services Division, for the mapping of ice in the Susquehanna River which is one of the major ice-flood prone rivers in the U.S. A first application was already developed using MODIS data and a preliminary version of an operational web tool, CREST River Ice Observation System (CRIOS) (http://water.ccny.cuny.edu/crios) was implemented with a particular focus on the Susquehanna River. The advent of new satellites like VIIRS will expand the capabilities of the developed systems. The availability of images from VIIRS will complement information derived from MODIS and reduce through image compositing the impact of could obstruction augmenting therefore the chances to obtain larger cloud free scenes during the day.

The generation of this additional data product will greatly maximize the benefit of the mission which fulfills the goal of its risk reduction program. Second, the developed ice maps can be ingested into land surface and river routing models to assess the improvement in their performances. River and lake ice product will be tested into river routing models like HEC-RAS which is in use in Northeast River Forecast Center. It is expected that including ice in the modeling of river hydraulics will significantly improve the accuracy of these models and their capabilities to reproduce the river stage and to forecast the river discharge.

**ACCOMPLISHMENTS**

The first goal of this research is to expand the existing operational river ice tool (CRIOS) through the integration of VIIRS data. In addition, it intends to expand geographically CRIOS to include additional rivers in Alaska and North Central US along with the already covered rivers in the northeast like the Susquehanna and the Mohawk Rivers. In Collaboration with Alaska River Forecast Center and North

Central River Forecast Centers, different sections over Yukon, Kuskokwim and Mississippi rivers known as major ice prone areas were identified.

We implemented the decision tree based approach for the development of an automated approach for ice detection using VIIRS data. For this propose, we processed winter 2013 VIIRS swath data, import VIIRS data, project them, mask river area and identify cloudy pixels. The decision tree based technique for ice identification consists of clustering the pixels within the study area using the frequency distribution of the near infrared reflectance values. Daily classified images using the decision tree based technique and the corresponding RGB color compositing images were generated using VIIRS images which were acquired from April 2013 to June 2013.

The accuracy of VIIRS-based ice mapping results was assessed using aerial photography and Landsat images. Figure 1-a shows the comparison between VIIRS ice product and the aerial photography taken over Galena area. These photos are obtained from Alaska River Forecast Center. It shows a good agreement between both data sources. While aerial photos are local, VIIRS ice maps are also compared to MODIS RGB color compositing product, figure 1-b. This image shows the spatial variation pattern of the ice along the river over Galena area. Ice map product agrees with the ice cover distribution observed in MODIS image. Ice maps were also compared to a cloud free Landsat 7 ETM+ image at 30 m spatial resolution, figure 1-c. A good agreement between Landsat image and the ice product on May 27$^{th}$ 2013 is also obtained.

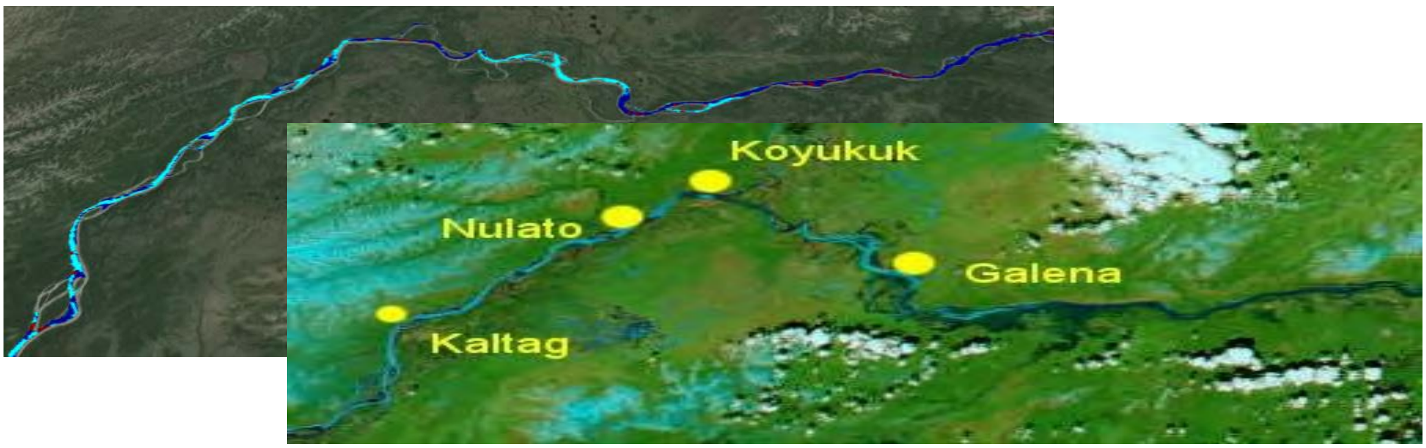
**PLANNED WORK**

- Run the ice detection methodology to additional rivers in Alaska and north central US operationally
- Validation of River Ice product during 2014 ice breakup and ice onset periods
- Ice detection in lakes
- Generation of running composite ice maps.

**DELIVERABLES**

- Automated algorithm for ice detection along northern Rivers; and
- Daily River ice maps over selected rivers.

(a)




(b)

(c)

*Figure 1: Comparison between VIIRS river ice map (Google view) and (a) Aerial photography, (b) MODIS RGB color composite (top) and (c) Landsat ETM+ images (bottom) over Galena area (Yukon River, Alaska) on 05/27/2013*

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

We generated daily river ice maps product over Yukon, Kuskokwim and Mississippi Rivers (1). The ice detection technique is now running operationally over Alaska and North Central US and displayed in NOAA National Weather Service's Advanced Weather Interactive Processing System (1).

## Improvements to the AMSR-E Rain Over Land Algorithm

| | |
|---|---|
| **Task Leader** | Nai-Yu Wang |
| **Task Code** | NWNW_AMSRE_13 |
| **NOAA Sponsor** | Ralph Ferraro |
| **NOAA Office** | NESDIS/STAR/CoRP/SCSB |
| **Contribution to CICS Themes (%)** | Theme 1: 100%; Theme 2: 0%; Theme 3: 0%. |
| **Main CICS Research Topic** | Land and Hydrology |
| **Contribution to NOAA Goals (%)** | Goal 1: 25%; Goal 2: 75%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0% |

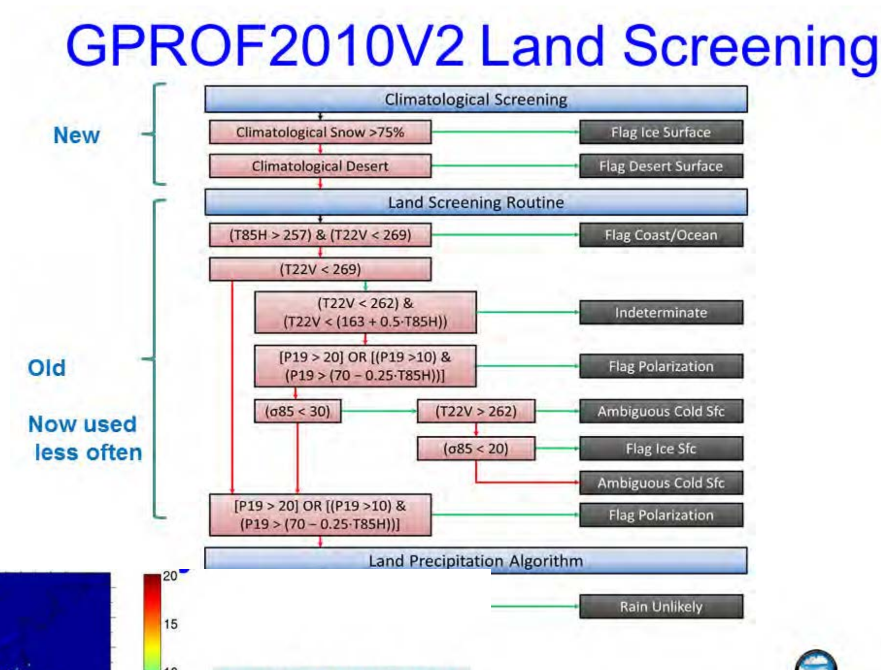
**Highlight**: A final version of GPROF2010V2 over land was completed, tested and delivered to the NASA/MSFC processing center for AMSR-E. The entire record of AMSR-E is being reprocessed at MSFC using this vastly improved algorithm (including improvements over ocean developed by CIRA/Colorado State Univ.).

**BACKGROUND**

This report summarizes the year-3 work of the ongoing NOAA project entitled “Improvements to the AMSR-E Rain over Land Algorithm”. This project focuses on the continued development and improvement of the Advanced Microwave Scanning Radiometer on board the Aqua satellite (AMSR-E) L2 and L3 facility precipitation retrieval algorithm. This project focuses on the land portion of the algorithm, which is incorporated within the Goddard Profiling Algorithm (GPROF; Kummerow et al. 2001).

Previous work leveraged off of an improved TRMM Microwave Imager (TMI) GPROF2010 algorithm which greatly improved a warm season bias in rain rates and brings the TMI product (TRMM 2A12) in closer agreement with the PR product (2A25) (Gopolan et al. 2010).

*Figure 1: Flow chart of the AMSR-E GPROF2010V2 algorithm. Use of the climatological snow and desert information minimizes the use of the older, decision tree "screens" which can be problematic in the rain over land retrievals.*



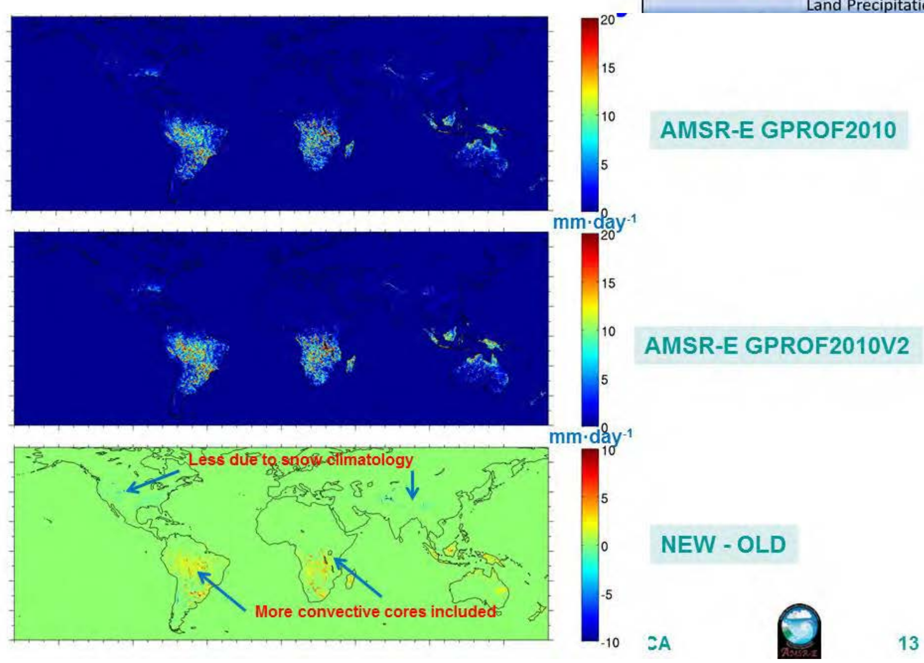




*Figure 2: Comparison of the previous version of GPROF2010 (top), the newest version (middle) and their difference (bottom) for January 2010. Note the areas of improvement between the new and old algorithm.*

**ACCOMPLISHMENTS**

The AMSR-E version of GPROF2010 was enhanced with a climatological snow and desert mask, which greatly improved some of the surface "screening" procedures which have been problematic for several years. The new version, denoted GPROF2010 V2, provides improved global precipitation estimates. Figure 1 summarizes the flow of the new algorithm whereas Figure 2 provides some of the global comparisons of the new versus old algorithm.

**PLANNED WORK**

- Ensure that the reprocessed data sets at NASA/MSFC are of scientific quality
- Determine if any further incremental improvements can be made to the algorithm, including a monthly varying arid land mask
- Investigate the continuity of the time series with the GCOM AMSR-2 sensor

**REFERENCES**

Gopolan, K., N.Y. Wang, C. Liu and R. Ferraro, 2010: Version 7 of the TRMM 2A12 Land Precipitation Algorithm. *J. Atmos. Oceanic Tech..,* **27,** 1343-1354.

Kummerow, C., Y. Hong, W. S. Olson, S. Yang, R. F. Adler, J. McCollum, R. Ferraro, G. Petty, D.-B. Shin and T. T. Wilheit, 2001: The evolution of the Goddard Profiling Algorithm (GPROF) for rainfall estimation from passive microwave sensors. *J. Appl. Meteor.*, **40**, 1801-1820.

**DELIVERABLES**

- GPROF2010V2 software and related documentation

**PRESENTATIONS**

Ferraro, R., P. Meyers, N.Y. Wang, C. Kummero and D. Randel, 2013: Updates to the AMSR-E GPROF Rain Algorithm and Applications to AMSR-2 . *2013 AMSR-E Science Team Meeting, Oxnard, CA (4-5 September).*

Meyers, P., N.Y. Wang, R. Ferraro, C. Kummerow, D. Randel, W. Berg, S. Rudlosky, Z. Jelenak and P. Chang, 2013: Validation of NOAA's AMSR-E Precipitation Product. *AGU Fall Meeting, San Francisco, CA (December 10-14).*

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

This year, we developed an improved version of GPROF2010 (denoted GPROF2010V2) to the NASA/MSFC AMSR-E processing facility. Presentations were given at the AGU fall meeting and at the AMSR-E science team meeting (this one, the NOAA funder gave the presentation).

## 1.8 *Earth System Monitoring from Satellites*

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

| | |
|---|---|
| **Task Leader** | Christopher Hain |
| **Task Code** | CHCH_GETD_13 |
| **NOAA Sponsor** | Xiwu Zhan |
| **NOAA Office** | NESDIS/STAR/SMCD/EMB |
| **Contribution to CICS Themes (%)** | Theme 1: 50%; Theme 2: 50%; Theme 3: 0%. |
| **Main CICS Research Topic** | Earth System Monitoring from Satellites |
| **Contribution to NOAA Goals (%)** | Goal 1: 70%; Goal 2: 30% |

**Highlight**: We are developing an operational evapotranspiration and drought monitoring system using GOES land surface temperature product, meteorological data and other ancillary satellite remote sensing data.

**BACKGROUND**

This report summarizes the year-1 work of the ongoing NOAA project to develop an operational evapotranspiration and drought monitoring system at the NOAA Office of Satellite and Product Operations (OSPO) in 2015. Our group has developed a surface energy balance model specifically adapted for geostationary satellite data to calculate the evapotranspiration (ET) and the potential ET (PET). Primary remote sensing inputs to the Atmosphere-Land Exchange Inverse (ALEXI) model are time-changes in land-surface temperature (LST), hourly downwelling short and long-wave radiation, and leaf area index. We have spearheaded use of anomalies in the remotely sensed ET/PET fraction (fPET) generated with ALEXI as a drought monitoring tool that samples variability in water

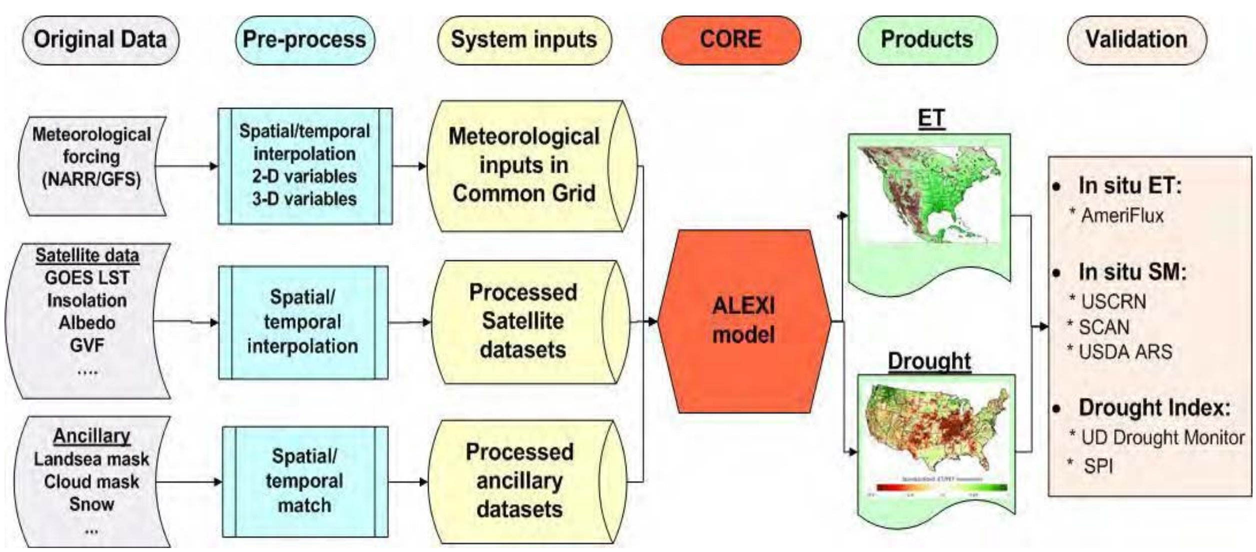



*Figure 1. GOES Evapotranspiration and Drought Product (GET-D) system design.*

use, and demonstrating complementary value in combination with standard drought indices that reflect water supply. ALEXI provides a framework for interpreting LST and vegetation index remote sensing drought signals within the context of a physically based energy balance model.

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

**ACCOMPLISHMENTS**

We have started the product development following the Development Project Plan (DPP) of GET-D project. The software system was under development in the first year of the project. Figure 2 presents an example of the algorithm generating the meteorological data into common grids that will be used later for the ALEXI model simulation.

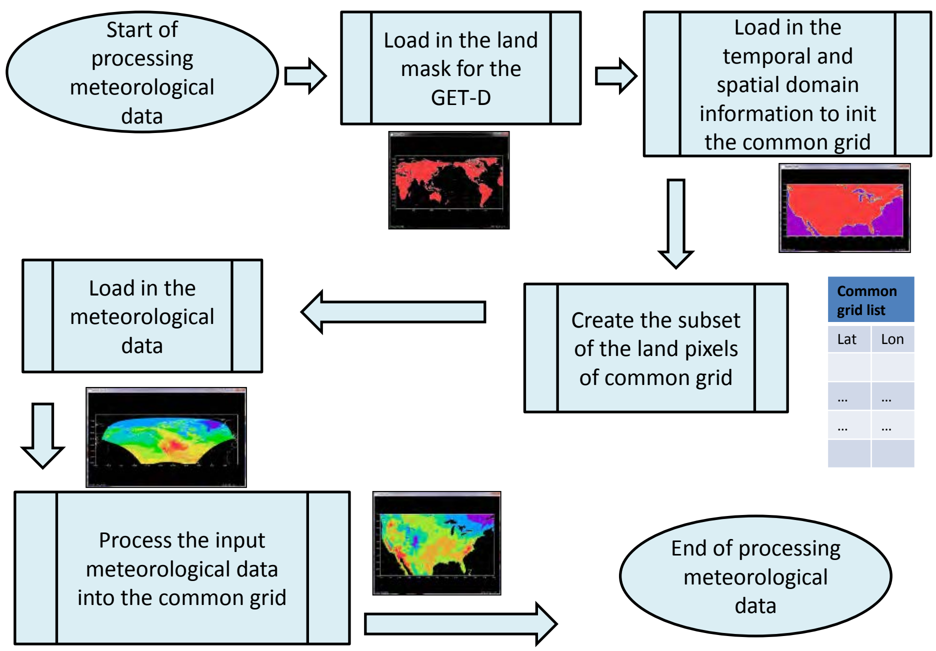



*Figure 2: The part of GET-D system of processing the meteorological data inputs to common grids for ALEXI model simulation.*

The new algorithm enables faster scaling of the meteorological input data into different sub regions and in different resolutions. The project deliverables (documentation and software) and milestones have been accomplished as planned. Currently, the rest of the software system is under development.

**PLANNED WORK**

- Continue work to develop the rest of the system as planned in the DPP.
- Continue work to refine the data flows in the algorithm and to improve its performance.
- Transition algorithm to operations

**PUBLICATIONS**

None

**DELIVERABLES**

- Algorithm and software for processing different meteorological data sets into the common grids for ALEXI model simulation;
- Documentation for algorithm and software system.

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

This year, we began development of transitioning the ALEXI ET and Drought Product System (GET-D) into operations at NOAA OSPO. A faculty research assistant was hired to begin transitioning the ALEXI source code to meet all necessary formats and conventions for NOAA operations. The product system will be successfully delivered to NOAA in Year 2.

## Atmospheric Rivers: Detection and Climatology

| | |
|---|---|
| **Task Leader** | E. Hugo Berbery/ Wenze Yang |
| **Task Code** | EBWY_ARDC_13 |
| **NOAA Sponsor** | Ralph Ferraro |
| **NOAA Office** | NESDIS/STAR/CRPD/SCSB |
| **Percent contribution to CICS Themes** | Theme 1: 100%; Theme 2: 0%; Theme 3: 0% |
| **Main CICS Research Topic** | Earth System Monitoring from Satellites |
| **Percent contribution to NOAA Goal** | Goal 1: 0%; Goal 2: 100% |

**Highlight:** An approach to extract atmospheric river has been developed, and verified using topography, wind and extreme precipitation. A journal paper is in preparation.

**BACKGROUND**

Filamentary structure is a common feature of water vapor transport in the atmosphere, especially in the troposphere; hence the term "atmospheric river (AR)" is used to describe the river-like structure, and to stress for the large amount of water vapor carried in the filaments. They are thousands of kilometers long and, on average, only 400 km wide; 75% of the water vapor transport occurs below 2.25-km altitude. At any time, there are at least 3 to 5 atmospheric rivers worldwide.

Atmospheric rivers have a central role in the global water cycle. ARs "are long, narrow zones within extratropical cyclones that contain large quantities of water vapor and strong winds are responsible for > 90% of all atmospheric water vapor transport in midlatitudes."

They are also identified as the major cause of extreme precipitation hitting west coastal areas of the world, including North America, Europe, and North Africa. When the flowing atmospheric rivers meet the mountains on the west coasts, there could be heavy rainfall and successive flooding. Other causes of extreme precipitation are hurricanes and tropical storms, and their impacts are comparable.

Although atmospheric rivers are vital important in atmospheric/hydrological research, most previous identification work was done manually, and it is just in an early stage to develop the technique for automatic identification of ARs. Wick et al., 2013 developed an Atmospheric River Detection Tool (ARDT) to address this problem, yet currently it performs only satisfactory in one region (northeastern Pacific Ocean), and still need quite some improvements, including dealing with gaps between satellite swath, and global coverage. This project aims to develop an atmospheric river detection methodology, and make prototype climatology using water vapor products, e.g., AMSU-A total precipitable water (TPW) of thematic climate data record (TCDR).

**ACCOMPLISHMENTS**

Our accomplishments of the project are as follow:

Firstly, the extraction of TPW AR signature has been obtained, which is a critical procedure to capture the dendritic structure of AR's. Our very preliminary result, shown in Figure 1, demonstrates that our methodology can extract the AR signature remarkably well from a global total precipitable water field. Note the TPW shown in Figure 1 is from re-analysis output, which contains no satellite swath gap. Our methodology can also extract the AR signature well from global satellite observed TPW field with swath gap, though not shown here.

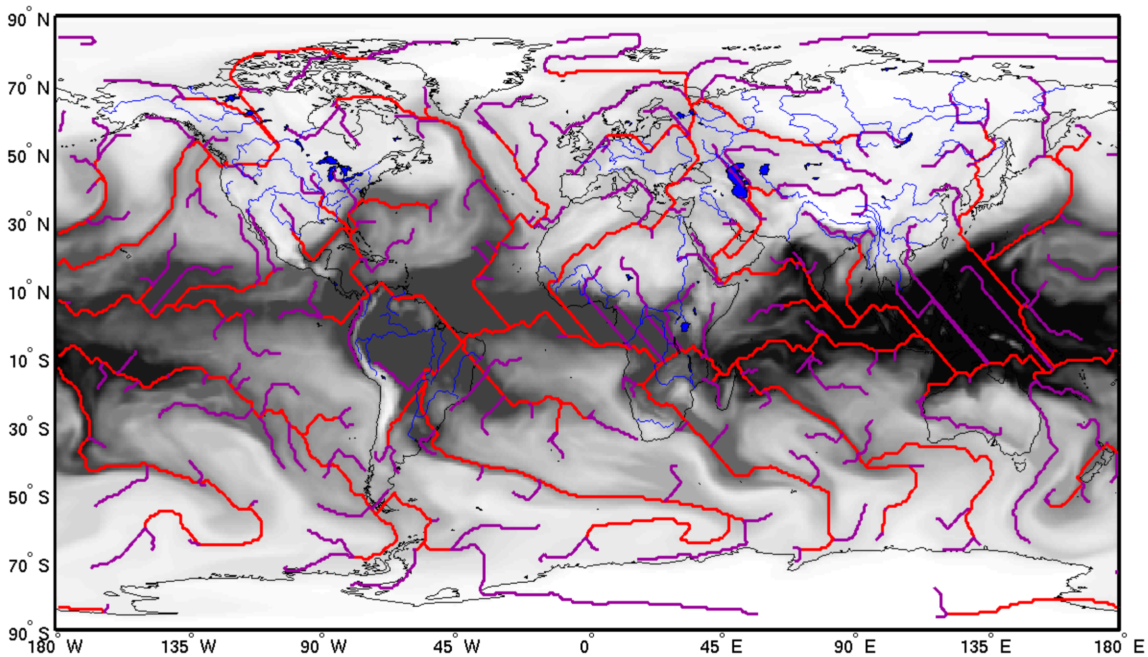



*Figure 1. Atmospheric rivers of the whole globe on 18 UTC, Nov 30, 2008, extracted from ERA-Interim. ARs with Strahler order 4 are shown in purple, with Strahler order 5 and up are shown in red. IWV fields are shown in grey scale, with darker grey indicating higher IWV. Surface rivers are shown in blue.*

Secondly, the extracted AR has been verified with topography, wind, and extreme precipitation. During May 1 and 2, 2010, a historical rainfall occurred across western and central Tennessee and Kentucky, with Nashville, Tennessee received 344.7 mm in this single event. This heavy rainfall led to a devastating flood with the probability of one in one thousand years, which in turn incurred 11 fatalities and nearly $2 billion in damages (Moore et al., 2012). By checking the water vapor distribution around that period, one can find an AR trough with a width of 400 km, originating from eastern tropical Pacific, extending northward through the Gulf of Mexico, and intruding the center of USA. At peak raining time indicated by CMORPH time series, the IWV value at the ridge of the AR is above 6 cm, comparable to the IWV values in ITCZ, as shown in Figure 2.

Thirdly, a journal paper describing the method, the verification and weather related impacts is in preparation.

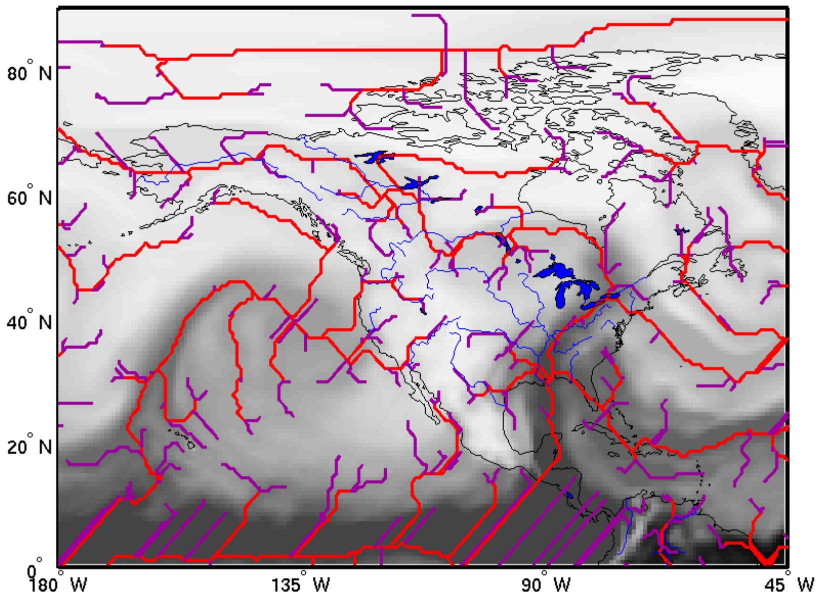



*Figure 2: Atmospheric rivers of North America on 18 UTC, May 1, 2010, extracted from ERA-Interim, to illustrate the AR impact on Tennessee 2010 extreme precipitation.*

**PLANNED WORK**

In the next phase of the project, we will build an AR climatology using over ten years of TPW product, with following questions in mind: Over what period do we look for the rivers, several hourly, daily, or monthly? What are the parameters of the river – length, orientation, etc.

**PUBLICATIONS**

Yang, W., R. Ferraro, P. Arkin, and G. Wick, "A prototype automated technique to identify atmospheric rivers and to characterize global water vapor transportation," Geophys. Res. Lett., 2014 (in preparation).

*Non-Peer Reviewed*

Yang, Wenze, 2013: Atmospheric Rivers, *CICS-MD Website*, http://cicsmd.umd.edu/atmospheric-rivers/?pg=3 .

**PRESENTATIONS**

Yang, W., H. Meng, and R. Ferraro, An Improved Microwave Satellite Data Set for Hydrological and Meteorological Applications, AMS annual meeting, Atlanta, GA, Feb 2-6, 2014.

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

**Eddies in Sea Level at High Latitude**

| | |
|---|---|
| **Task Leader** | James Carton |
| **Task Code** | JCJC_PDOC_13 |
| **NOAA Sponsor** | Laury Miller |
| **NOAA Office** | NESDIS/STAR |
| **Percent contribution to CICS Themes** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0% |
| **Main CICS Research Topic** | Earth System Monitoring from Satellites |
| **Percent contribution to NOAA Goal** | Goal 1: 0%; Goal 2: 0%; Goal 3: 100%; Goal 4: 0%; Goal 5: 0% |

**Highlight:** This proposal explores the potential of a combined set of satellite altimeters (JASON2, ENVISAT, and CRY-OSAT2) to understand the variable circulation in this key region of the ocean and its contribution to the changing Arctic Ocean..

**BACKGROUND**

The main oceanic connection between the Arctic Ocean and the rest of the World Ocean occurs in the region of the Nordic Seas, east of Greenland and at the northern edge of the North Atlantic. In the past decade there have been remarkable changes in the Arctic Ocean including a dramatic warming of surface temperatures and shrinkage of sea ice coverage as well as salinification of water in the Nordic Seas. This proposal will explore the potential of a combined set of satellite altimeters (JASON2, ENVISAT, and CRYOSAT2) to understand the variable circulation in this key region of the ocean and its contribution to the changing Arctic Ocean.

**ACCOMPLISHMENTS**

In preparation to conduct an analysis of satellite altimetry we have begun looking at the historical tide gauge records and sea level from a set of seven ocean reanalyses. Figure 1 shows a comparison of the gauges and reanalyses for a half-century base period. The results show generally good agreement for the half-century period with ensemble average correlations in excess of 0.55 and RMS differences of 2.2 cm. These results support the conclusion that much of the interannual to multi-decadal variability that appears in the tide gauge records is meteorologically driven and that ocean products can be used to isolate this variability from the signal associated with the underlying global sea level rise.

**PLANNED WORK**

- Compare the three satellite altimeter sea level estimates at all crossover points. The goal of this com-parison is to help quantify the accuracy characteristics of CRYOSAT-2.
- Combine sea level from the three altimeters and use the combined estimates to provide seasonal and geo-graphic description of the eddy field in the subpolar gyre and Nordic Seas.

In support of this work we will be bringing in a postdoc in the next six months who can help us accelerate this effort.

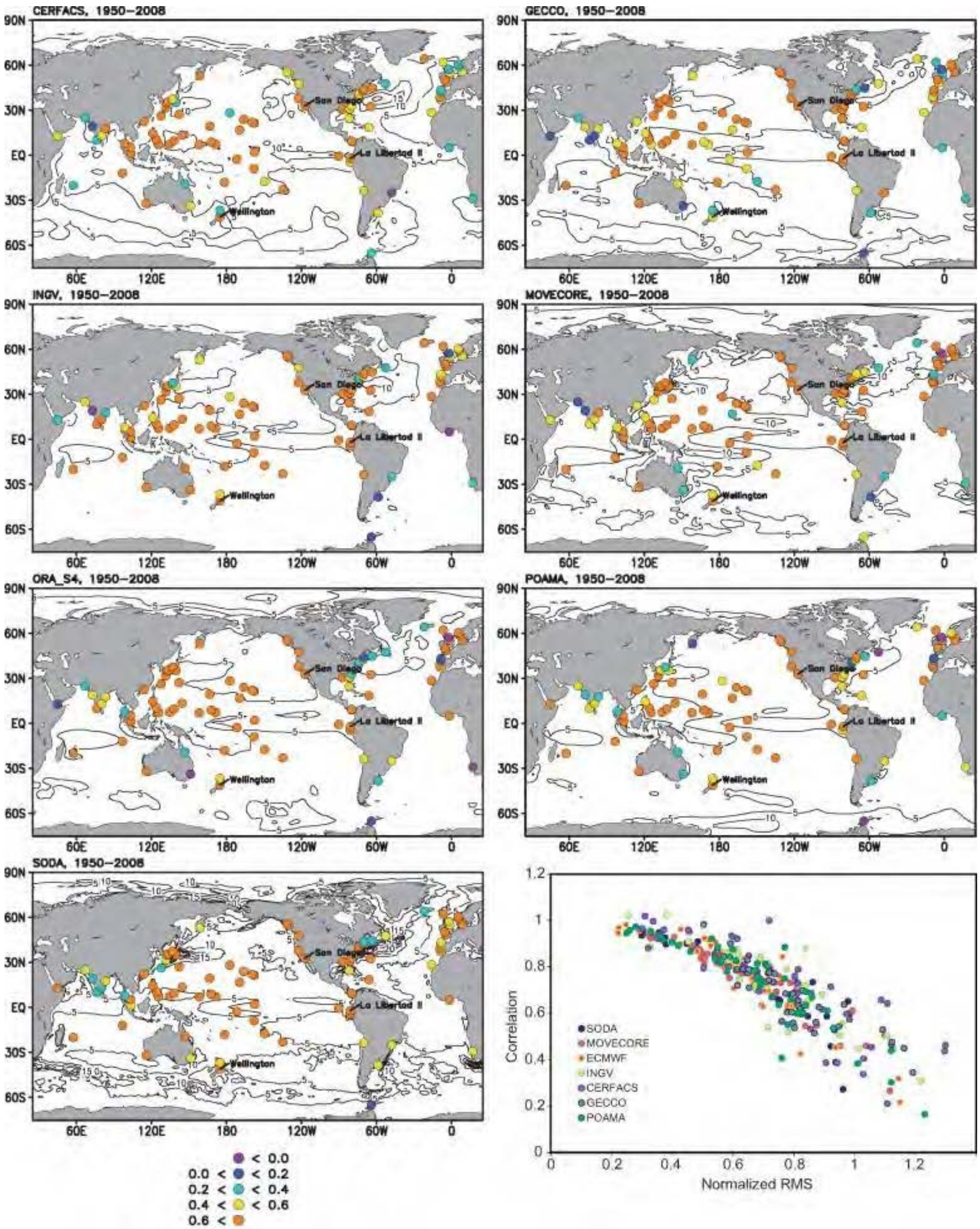



*Figure 1: Correlations between tide gauge and reanalysis sea level at 87 stations (location indicated by circle position, magnitude by color) for a 50-yr period. Scatter diagram of correlation versus normalized RMS difference for all stations and products (lower right).*

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

**Investigations over Arctic Sea Ice using Satellite and Aircraft Altimetry**

| | |
|---|---|
| **Task Leader** | Sinéad L. Farrell |
| **Task Code** | SFSF_IOAS_13 |
| **NOAA Sponsor** | Dr. Laury Miller |
| **NOAA Office** | NESDIS/STAR/SOCD/OPB Laboratory for Satellite Altimetry |
| **Contribution to CICS Themes** | Theme 1: 30%; Theme 2: 60%; Theme 3: 10%. |
| **Main CICS Research Topic** | Earth System Monitoring from Satellites; Calibration and Validation |
| **Contribution to NOAA Goals** | Goal 1: 50%; Goal 2: 50% |

**Highlights**: We have assessed changes in Arctic sea ice thickness over the last five years (2009-13) and find the thickness of ice in the high, central Arctic has stabilized, after a precipitous decline in 2007-08. We have developed an algorithm to derive snow depth and uncertainty with respect to ice type, for application to airborne radar altimeter data. We are establishing new collaborations with members of the numerical modeling community to provide sea ice observations to help improve parameterizations of sea ice physical processes. See 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. Recent satellite altimetry observations from ICESat and CryoSat-2 indicate a decline in the thickness of the ice pack over the last decade, by 36 % in the autumn and by 9 % in the winter (2003 to 2012). 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. Satellite altimeters on ICESat and Envisat provided measurements of Arctic sea ice from 2002 – 20012, while CryoSat-2's radar altimeter satellite has been operating since 2010. The joint CNES/ISRO SARAL mission carrying the AltiKa altimeter was launched in 2013, and acquires measurements of the ice pack to 81.5 $^{o}$N, along a similar orbit to Envisat. The Operation IceBridge mission, which commenced operations in March 2009, is on-going, and includes yearly (every March/April) airborne campaigns over critical regions of the Arctic ice pack, extending the monitoring afforded by satellites. NASA plans the launch of ICESat-2 in 2017, supporting continuity of the Arctic sea ice time series through at least 2020. Together these altimeter data provide almost two decades of Arctic sea ice measurements.

**ACCOMPLISHMENTS**

The goal of this investigation is to assess how well Arctic sea ice elevation and ice thickness can be mapped using satellite altimeters including those onboard NASA's ICESat and the European Space Agency's CryoSat-2. The results contribute to a longer-term goal of assimilating satellite estimates of sea ice thickness into Arctic Ocean sea ice forecasts and predictive models. Monitoring ice thickness and volume change is technically challenging due to the small sea ice freeboard signal, and the complex distribution and density structure of sea ice and its snow cover. A number of airborne observing systems are used to validate the satellite altimetry data, in particular NASA's Operation IceBridge.

During the Arctic Spring 2011 and 2014 IceBridge campaigns, internationally coordinated surveys of the Arctic ice pack were conducted. A multi-scale, nested approach to mapping the snow depth and ice thickness distributions was undertaken. Measurements of snow and ice thickness were collected *in situ* at a number of field sites, across a range of ice types, for the calibration and validation of measurements from remote sensing instruments on board both aircraft (IceBridge, NRL DISTANCE) and satellite (CryoSat-2) platforms. The ongoing analyses of these spatially coincident data sets has enabled us to derive a set of uncertainty estimates associated with snow depth and sea ice thickness measurements, as a function of ice type. Figure 1 illustrates the comparison of airborne snow depth estimates with snow depths measured *in situ* over a range of sea ice types at the Navy's ICEX field site in 2011 (Newman et al., *in prep*). Figure 2 illustrates the interannual variability in Arctic sea ice thickness over the last five years (2009-2013) as measured by the IceBridge Mission (Richter-Menge and Farrell, 2013).

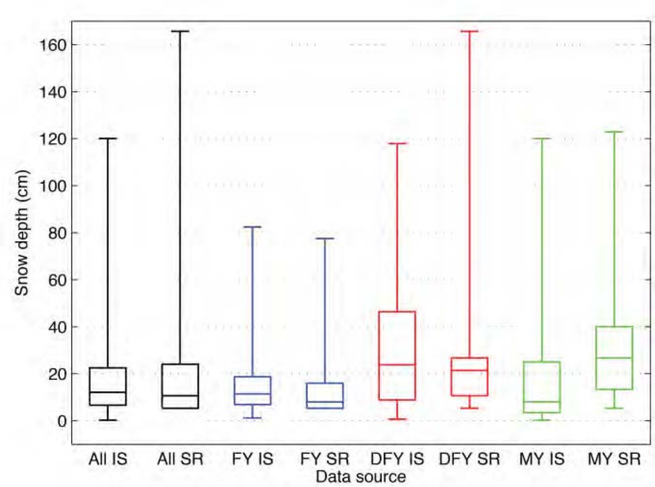



*Figure 1: Box and whisker plot comparing in situ (IS) and airborne snow-radar-derived (SR) snow depths across all ice types at the ICEX survey area (All), undeformed first-year ice (FY), deformed first-year ice (DFY), and multi-year ice (MY). Considering the statistics across all ice types, there is excellent agreement between the IS and SR snow depth measurements. The mean and median IS snow depths are 0.18 and 0.12 m, respectively, while the mean and median SR snow depths are 0.18 ± 0.05 m and 0.11 m ± 0.05 m, respectively.*

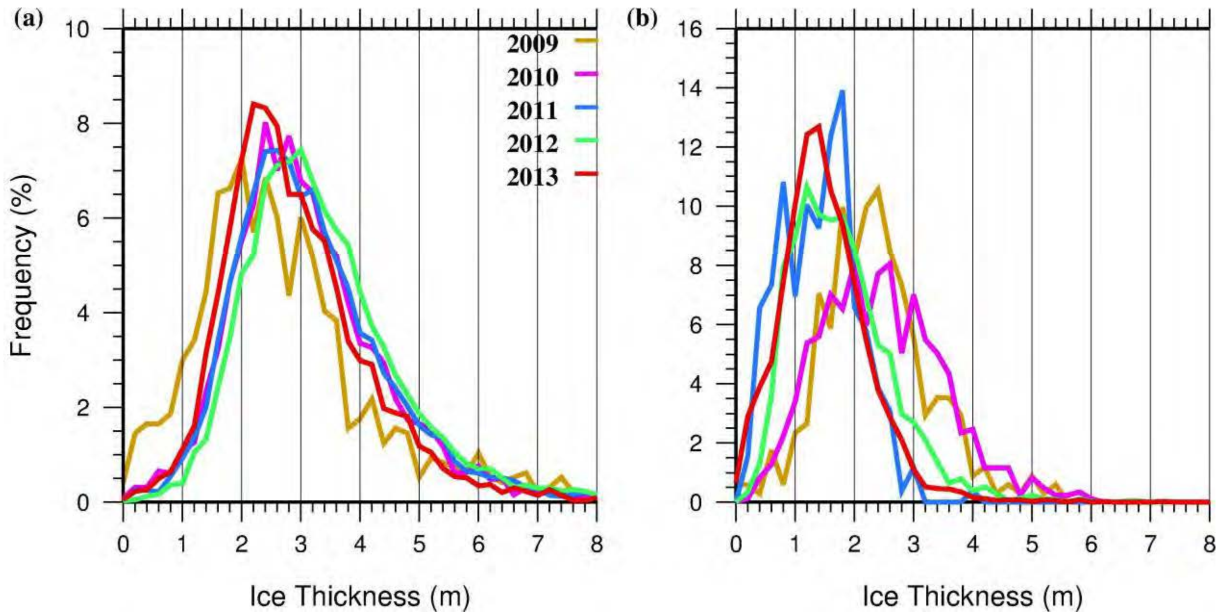



*Figure 2: The latest sea ice observations from NASA's Operation IceBridge Mission in March/April over the western Arctic were assessed to investigate changes in Arctic sea ice thickness over the last five years (2009-13). Sea ice thickness change in two Arctic regimes was compared. Sea ice in the central Arctic has remained largely consistent through March 2013. Mean and modal thickness in the central Arctic is 3.2 m and 2.4 m, respectively (Fig. 2a), and this region remains dominated by multi-year sea ice (≥ 90%). Sea ice in the southern Beaufort Sea and western Chukchi Sea is a complex mix of ~ 75% first-year ice and 25% multiyear ice. Mean thickness in this region may have decreased from ~ 2.5 m to as low as 1.6 m over the 5-year period (Fig. 2b).*

Our results were presented at numerous local, national and international meetings and included three invited presentations at the American Geophysical Union Fall Meeting 2013. Our results were published in seven peer-reviewed articles during the reporting year.

**PLANNED WORK**

- Participation in NASA Operation IceBridge Antarctic 2014 and Arctic 2015 airborne campaigns.
- Finalize results on Arctic snow depth and associated uncertainty for rough/ridged sea ice surfaces.
- Continued assessment of CryoSat-2 data over Polar Oceans and development of algorithms to exploit Level 1b waveforms to improve understanding of the impact sea ice ridges and leads on the retrieved CryoSat-2 elevations and quantify the associated penetration error.
- Continue collaborations with the NOAA Laboratory for Satellite Altimetry, NASA GSFC, the Naval Research Laboratory (NRL), CREEL, 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.
- Examine the observed changes in the sea ice pack in the context of atmospheric forcing and sea ice drift and dynamics.

**PUBLICATIONS**

Webster, M. A., I. G. Rigor, S. V. Nghiem, N. T. Kurtz, S. L. Farrell, D. K. Perovich, and M. Sturm (2014), Interdecadal Changes in Snow Depth on Arctic Sea Ice, *J. Geophys. Res.*, under review.

Tsamados, M., D. Feltham, D. Schroeder, D. Flocco, S. Farrell, N. Kurtz, S. Laxon, and S. Bacon (2014), Impact of atmospheric and oceanic form drag on simulations of Arctic sea ice, *J. Phys. Oceanog*, JPO-D-13-0215, doi: 10.1175/JPO-D-13-0215.1.

Richter-Menge, J., and S. L. Farrell (2013), Arctic Sea Ice Conditions in Spring 2009 - 2013 Prior to Melt, *Geophys. Res. Lett.,* 40, 5888-5893, doi: 10.1002/2013GL058011.

Kurtz, N., S. L. Farrell, M. Studinger, N. Galin, J. Harbeck, R. Lindsay, V. Onana, B. Panzer, and J. Sonntag (2013), Sea ice thickness, freeboard, and snow depth products from Operation IceBridge airborne data, *The Cryosphere*, 7, 1035-1056, doi:10.5194/tc-7-1035-2013.

Connor, L. C., S. L. Farrell, D. C. McAdoo, W. B. Krabill, and S. Manizade (2013), Validating ICESat over thick sea ice in the northern Canada Basin, *IEEE Transactions on Geoscience & Remote Sensing*, 51(4), 2188-2200, doi:10.1109/TGRS.2012.2211603.

Laxon, S.W., Giles, K. A., Ridout, A. L., Wingham, D. J., Willatt, R., Cullen, R., Kwok, R., Schweiger, A., Zhang, J., Haas, C., Hendricks, S., Krishfield, R., Kurtz, N., Farrell, S. L., Davidson, M. (2013), CryoSat Estimates of Arctic Sea Ice Volume, *Geophys. Res. Lett.*, 40(4), 732-737, doi:10.1002/grl.50193.

McAdoo, D. C., S. L Farrell, S. W. Laxon, A. L. Ridout, H. J Zwally and D. Yi (2013), Gravity of the Arctic Ocean from satellite data with validations using airborne gravimetry: oceanographic implications, *J. Geophys. Res.*, 118, 917–930, doi:10.1002/jgrc.20080.

**PRESENTATIONS** (April 1, 2013 - March 31, 2014)

Farrell, S. L., J. Richter-Menge, N. Kurtz, T. Newman, J. Ruth, D. McAdoo, J. Zwally (2014), A Decadal Record of Arctic Sea Ice Thickness Change, from ICESat IceBridge and ICESat-2, Abstract, International Glaciological Society Symposium on Sea Ice in a Changing Environment 2014, Hobart, Australia, 10-14 March 2014.

Farrell, S. L., J. Richter-Menge, N. T. Kurtz, D. C. McAdoo, T. Newman, H. J. Zwally and J. Ruth (2013), A Decade of Arctic Sea Ice Thickness Change from Airborne and Satellite Altimetry *(Invited)*, Abstract C11C-05, presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec. 2013.

Kurtz, N. T., N. Galin, M. Studinger, S. L. Farrell, J. P. Harbeck, T. Markus, V. Onana, J. Richter-Menge and D. Yi (2013), Linking IceBridge, ICESat, and CryoSat-2 for improved seasonal to decadal-scale estimates of sea ice thickness and volume *(Invited)*, Abstract C54A-01, presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec. 2013.

Webster, M., I. G. Rigor, S. V. Nghiem, N. T. Kurtz and S. L. Farrell (2013), Spring Snow Depth on Arctic Sea Ice using the IceBridge Snow Depth Product *(Invited),* Abstract C54A-02, presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec. 2013.

Tilling, R., A. Ridout, D. J. Wingham, A. Shepherd, C. Haas, S. L. Farrell, A. J. Schweiger, J. Zhang, K. Giles and S. Laxon (2013), Trends in Arctic Sea Ice Volume 2010-2013 from CryoSat-2, Abstract C54A-04, presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec. 2013.

Farrell, S. L., J. Richter-Menge, N. T. Kurtz (2013), Arctic sea ice thickness conditions from airborne and satellite altimetry (*Invited*), Cooperative Institute for Climate and Satellites-MD (CICS-MD), Earth System Science Interdisciplinary Center (ESSIC), University of Maryland, College Park, 6-7 Nov. 2013.

Farrell, S. L., J. Richter-Menge, N. T. Kurtz (2013), An update on Arctic sea ice thickness conditions from airborne and satellite altimetry, Forum for Arctic Ocean Modeling and Observational Synthesis (FAMOS) Workshop #2, Woods Hole Oceanographic Institution, Woods Hole, MA, 22 – 25 Oct. 2013.

Ruth, J. M., S. L. Farrell, K. M. Brunt (2013), Assessment of Arctic sea ice freeboard from photon-counting laser altimetry: Pre- launch activities for NASA's ICESat-2 Mission, Forum for Arctic Ocean Modeling and Observational Synthesis (FAMOS) Workshop #2, Woods Hole Oceanographic Institution, Woods Hole, MA, 22 – 25 Oct. 2013.

Farrell, S. L., D. C. McAdoo, A. L. Ridout, S. Thomas, D. Wingham and H. J. Zwally (2013), Sea Ice Thickness and Dynamic Topography of the Arctic Ocean from Satellite Altimetry (*invited*), European Space Agency Living Planet Symposium, Edinburgh, U. K., 9 – 13 Sept. 2013.

Farrell, S. L., N. T. Kurtz, J. Richter-Menge, D. C. McAdoo, H. J. Zwally, D. Yi and J. Ruth (2013), Monitoring Arctic Sea Ice Thickness Change with ICESat, IceBridge and ICESat-2, European Space Agency Living Planet Symposium, Edinburgh, U. K., 9 – 13 Sept. 2013.

Newman, T., S. Farrell, J. Richter-Menge, N. Kurtz, L. Connor, B. Elder, J. Gardner, J. Brozena, R. Hagen, D. Ball and R. Liang (2013), Assessment of Airborne Estimates of Snow Depth and Sea Ice Thickness over Arctic Sea Ice, European Space Agency Living Planet Symposium, Edinburgh, U. K., 9 – 13 Sept. 2013.

McAdoo, D., S. Farrell, A. Ridout, K. Giles, and H. Zwally (2013), Gravity and Topography of the Polar Oceans from Satellite Altimetry: Geoscience results from ERS-1 to CryoSat (*invited*), European Space Agency Living Planet Symposium, Edinburgh, U. K., 9 – 13 Sept. 2013.

Farrell, S. L. (2013), Measuring and Monitoring Arctic Sea Ice Thickness (*Invited*), Environmental Modeling Center (EMC), National Centers For Environmental Prediction (NCEP), National Weather Service (NWS), 25 June 2013.

Farrell, S.L. and T. Newman (2013), AOSC 401: Global Environment, Aspects of the Cryosphere: Sea Ice and Snow (*Invited*), Guest Lecture for Prof. Zhanqing Li, Dept. of Atmospheric and Oceanic Science, University of Maryland, College Park, MD, April 18 2013.

**OTHER** (PERTINENT ACTIVITES)

- Dr. Alek Petty joined the research team in January 2014 as a CICS post-doctoral research associate.
- Drs. Farrell, Newman, Petty and McAdoo are members of the NOAA/NESDIS/STAR Sea Ice Team.
- Dr. Farrell serves as a member of the NASA Operation IceBridge Science Team (2009-2016), the NASA ICESat-2 Science Definition Team (2012-2015) and is the liaison to the Naval Research Lab. – Stennis, MS, who have been selected as "Early Adopters" on the ICESat-2 mission.
- Dr. Farrell is a formal international collaborator on the European Space Agency's (ESA) "Cryosat Sea Ice Product Validation using CryoVex and IceBridge campaign data" (CryoVal-SI) Project (2013-2015). Drs. Farrell and McAdoo are science investigators on the ESA CryoSat-2 Mission.

- Dr. Newman conducted field work in Barrow, AK, in collaboration with the Naval Research Laboratory - DC and USACE CRREL.
- Dr. Farrell participated in the CSPAN "StudentCam" competition with Eastern Middle School, Silver Spring, MD. Their documentary on climate change was awarded 2nd prize in the middle school division (http://www.viddler.com/v/87dea4f4).
- Dr. Farrell participated in the Higher Achievement (http://www.higherachievement.org) project at University of Maryland. Program enables school children from schools in Washington, D.C. to visit faculty, and learn about scientific research, being undertaken at the University of Maryland.
- Dr. Farrell co-organized and co-hosted the "New and Emerging Research in Cryospheric Studies" meeting held at the Earth System Science Interdisciplinary Center (ESSIC), University of Maryland, College Park on 18 January 2013.

| **Performance Metrics** | **FY13** |
|---|---|
| # of new or improved products developed following NOAA guidance | 2 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 0 |
| # of peer reviewed papers | 6 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 8 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 1 |

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

| | |
|---|---|
| **Task Leader** | Sujay Kaushal |
| **Task Code** | SKSK_WQRA_13 |
| **NOAA Sponsor** | Paul DiGiacomo |
| **NOAA Office** | NESDIS/STAR/SOCD |
| **Percent contribution to CICS Themes** | Theme 1: 100%; Theme 2: 0%; Theme 3: 0%. |
| **Main CICS Research Topic** | Earth System Monitoring from Satellites |
| **Percent contribution to NOAA Goals** | Goal 1: 20%; Goal 2: 80% |

**Highlight**: Typology of sediment distribution across an estuary turbidity maximum is proposed based on analysis of a high-resolution time series from 1997 to 2013. We find that there are four continuous and one intermittent types of sediment distribution in the studied estuary. This analysis can serve as a diagnostic tool for many environmental research and applications. To start the follow-up endeavors, we find a consistent pattern with respect to timings of the continuous types within one week to one month after a discharge event. Over a decadal time scale, we find a regime shift in the typology after a high-discharge event in the year 2004, which implies that a high discharge event may have long-lasting effects upon the sediment distribution in estuaries.

**BACKGROUND**

Sediment, organic carbon and their sources in coastal regions are a significant concern owing to large and growing populations, increasing levels of urbanization and excessive growth of algae. Increased sediment loads from watershed are influencing coastal water quality and habitat of benthic biota. Carbon dynamic in coastal watershed plays a critical role in regional carbon budgets, sources of greenhouse gases to the atmosphere, and influencing coastal oceanic acidification. However, coastal zones are complex, dynamic environments, and identification of carbon source from different land use vs. in situ production with tradition approaches are challenging.

Satellite remote sensing is an invaluable tool for improving the understanding and management of coastal regions. The objectives of this project include the application of satellite remote sensing data for improving our understanding of transfer of sediment and organic carbon from rivers to the coasts and coastal marine ecosystem dynamics and productivity, focusing on sediment and coastal water organic carbon dynamic quality. Specifically, we work to improve, innovate and apply SeaWiFS and MODIS-Aqua OCR data products/algorithms in monitoring water quality of the Chesapeake Bay, examining the dynamics of total suspended sediment (TSM), POC, chlorophyll-a and primary production, and colored DOM (CDOM) and relating coastal water quality with climate and land-use changes.

**ACCOMPLISHMENTS**

**TSM of Chesapeake Bay**

We conducted a typology analysis of surface sediment distribution in the upper third of the Chesapeake Bay. This is the first time sediment distributions across an estuary turbidity maximum zone are classified. The analysis is accomplished through three main steps. First, the concentration of

TSM, hereafter written as [TSM], were derived from optical reflectance data acquired by multiple satellite sensors. Then, we sub-sampled the multi-sensor [TSM] data along an axial transect from the Susquehanna River mouth to 100 km downstream. Data measured by all sensors on the same day were merged into one daily profile of [TSM] along the transect. These processes allow us to construct a high-resolution time series of [TSM] profiles from 1997 to 2013. In the last step, we analyzed the [TSM] time series along with ancillary data including the Susquehanna River flow and wind velocity.

A typology of sediment distribution across the upper Chesapeake Bay is drawn based on spatial features such as turbidity maximum, and the temporal continuity of those features. We identified four continuous types (Fig. 1a) and one intermittent type (Fig. 1b) of sediment distribution in this region. The continuous types appear to be affected mainly by river flow and the intermittent type is associated with wind events as well as river discharge. New insights about short- and long-term riverine impacts upon the bay are gained from our typology analysis. For example, we found a consistent pattern with respect to the timings of the four continuous types within one week to one month after a discharge event. Over a decadal time scale, we find a regime shift in the typology after a high-discharge event in the year 2004, which implies that a high discharge event may have long-lasting effects upon the sediment distribution in estuaries.

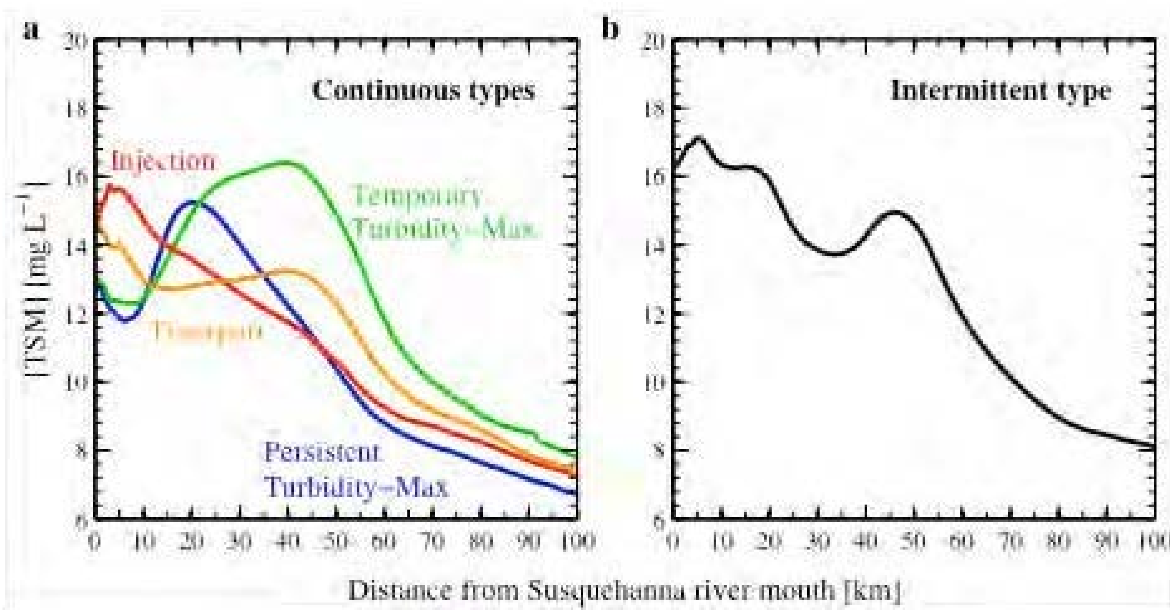



*Figure 1: Typology of sediment distribution in the upper Chesapeake Bay: (a) Four continuous types and (b) one intermittent type. Each curve represents the mean of all cases that fall into the same category.*

The results of this work were presented at the 2014 Ocean Sciences meeting in Honolulu, Hawaii.

**PLANNED WORK**

- Finish a paper about the typology analysis of sediment distribution in the upper Chesapeake Bay.
- Apply a novel absorption-partitioning algorithm developed specifically for the Chesapeake Bay to satellite-derived total absorption coefficient of seawater for this region.
- Study the transformation of river plumes in the Chesapeake Bay using results from the new algorithm.

**PRESENTATIONS**

Zheng, G., P. M. DiGiacomo, S. S. Kaushal, M. A. Yuen-Murphy, S. Duan, Typology of the estuary turbidity maximum in the Chesapeake Bay, Ocean Sciences Meeting, Oral presentation, Honolulu, HI, February 2014.

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

## Using Satellite Data to Improve Operational Atmospheric Constituents Forecasting Capabilities

| | |
|---|---|
| **Task Leader** | Xiaoyang Zhang (South Dakota State University) |
| **Task Code** | SKXZ_USDI_12 |
| **NOAA Sponsor** | Shobha Kondragunta |
| **NOAA Office** | NESDIS/STAR/SMCD/SCDAB |
| **Main CICS Research Topic** | Earth System Monitoring from Satellites |
| **Percent contribution to CICS Themes** | Theme 1: 20%; Theme 2: 40%; Theme 3: 40%. |
| **Percent contribution to NOAA Goals** | Goal 1: 60%; Goal 2: 40% |

**Highlight**: We developed operational computer codes to produce a new global biomass burning emissions product. This product is called GBBEP-Geo-Leo, which blends polar orbiting and geostationary satellite data. The computer codes have been transferred to NOAA/NESDIS/OSPO. This operational product is expected to serve as a significant input to aerosol module (GFS-GOCART) in the next-generation operational weather forecasting system, National Environmental Modeling System (NEMS), for predicting global aerosols.

**BACKGROUND**

This report summarizes complements of a continuous task that is to produce an operational global biomass burning product (GBBEP-Geo-Leo). The NOAA/NWS National Center for Environmental Prediction (NCEP) is developing a capability to predict aerosols in the next-generation operational weather forecasting system, National Environmental Modeling System (NEMS). This project is to continue the development of infrastructure required in preparation for operational assimilation of satellite aerosol products (Aerosol Optical Depth, fire emissions) into the NCEP Gridpoint Statistical Analysis (GSI) data assimilation system.

In support of NCEP's model development and subsequent operational deployment, NOAA/NESDIS/STAR and NASA have developed the following datasets that have planned to be transitioned to operation for NCEP's model applications:

- Aerosol Optical Depth (AOD) from Aqua and Terra MODIS
- Quick Fire Emissions Data (QFED version 2) from Aqua and Terra MODIS
- Global Biomass Burning Emissions Product (GBBEP-Geo) from a network of geostationary satellites (GOES-East, GOES-West, Meteosat-9, and MTSAT)

Among these datasets, MODIS AOD products are operational at NESDIS/OSPO and are readily available. In order to provide global biomass burning emissions product with complete global and diurnal coverage, the proposed activity is to combine emissions from MODIS and the multiple geostationary satellites. MODIS based QFED dataset offers complete global coverage but observes fires only four times a day (two times for Aqua and two times for Terra, no full diurnal coverage) whereas a geostationary satellite observes fires every ~30 minutes. The use of multiple geostationary satellites provides good coverage between 60S and 60N but high latitude fires (boreal forests in Canada or Siberia) are not captured. As a result, the combination of QFED and GBBEP-Geo datasets could improve the temporal and spatial coverage of global biomass emissions.

During the previous period, we generated C and Perl based computer codes to produce MODIS fire emissions that are based on the NASA's QFED algorithms for the purpose of NOAA's operational processing. On the other hand, GBBEP-Geo has been routinely produced in our local machine. To make GFS-GOCART-derived AODs that are modeled with GBBEP-Geo-Leo fire emissions as a key input comparable to MODIS observed AOD, both GBBEP-Geo and QFED are adjusted using a set of scaling factors. A set of scaling factors have been added to the computer codes for producing the blended biomass burning emissions product. The algorithms and products are being developed in such a way that when new satellites are launched, transition to new datasets is transparent to NCEP. For example, NPP VIIRS AOD and fire emissions are expected to replace MODIS products that are currently available. Therefore, the task during the past year was to develop operational computer codes and to transfer and ingest in NESDIS OSPO operational system.

**ACCOMPLISHMENTS**

- A package of documents was prepared for the critical design review of the GBBEP-Geo-Leo product.
- Quality control and monitoring plan were designed and conducted in our operational computer codes. Particularly, the modified code is able to produce a spatially-distributed $PM_{2.5}$ image in each run for visually monitoring spatial pattern of emissions. Moreover, an automatically alerting file was designed by comparing current emissions with previous values to detect spurious values that might occur if input data was missed.
- Burned area component was added to the operational codes. During the critical design review, we were requested to provide burned area for the fire detections from geostationary satellites. To meet this requirement, we used diurnal pattern of fire size to estimate burned area for each fire pixels. Accordingly, a patch of computer code was developed and tested.
- GBBEP-Geo-Leo was tested and evaluated in our local machine. This activity assured the stability in producing global emission products.
- Operational computer codes were finalized and transferred to OSPO. The computer codes are able to produce both scaled biomass burning emissions that blend MODIS and geostationary satellite data with NefCdf4 format, and un-scaled global biomass burning emissions that are derived only from geostationary satellites of GOES, Meteosat SEVIRI, and MTSAT. Moreover, we closely worked with scientists in OSPO to ingest the computer codes into OSPO operational system by checking input data and code modification (Figure 1).
- Documents were prepared for operation in OSPO. The completed documents include external user's manual, internal user's manual, and system maintenance manual. The Algorithm Theoretical Basis Document (ATBD) is under preparation.
- Elevation of operational product was started. The computer codes have been ingested in the OSPO operational system. We have started to compare outputs from OSPO with our local machine.
- Long-term biomass burning emissions derived from GOES-E data were investigated. Particularly, we used this data to analyzing fire seasonality and climate impacts across Contiguous United States during past 17 years (Figure 2).

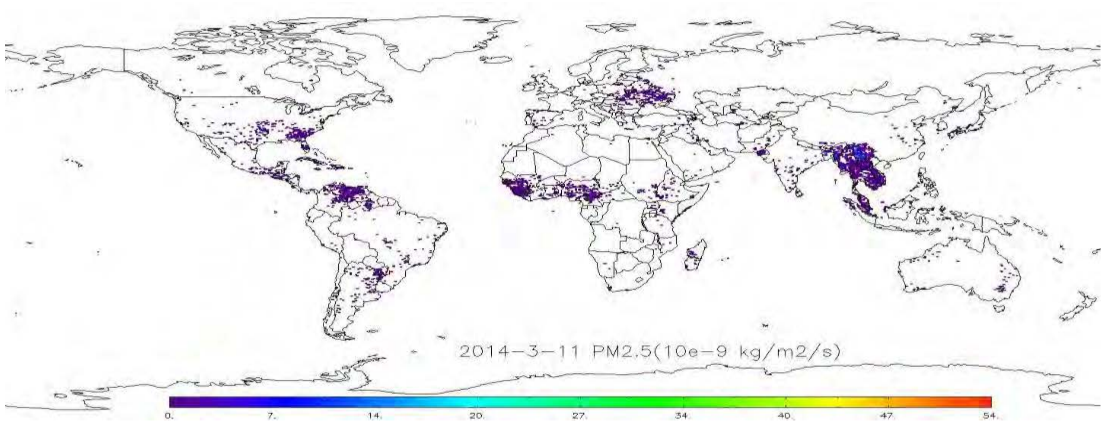



*Figure 1. Global daily biomass burning emissions estimated from polar-orbiting satellites and geostationary satellites (GBBEP-Geo-Leo). The product is at the testing phase at OSPO.*

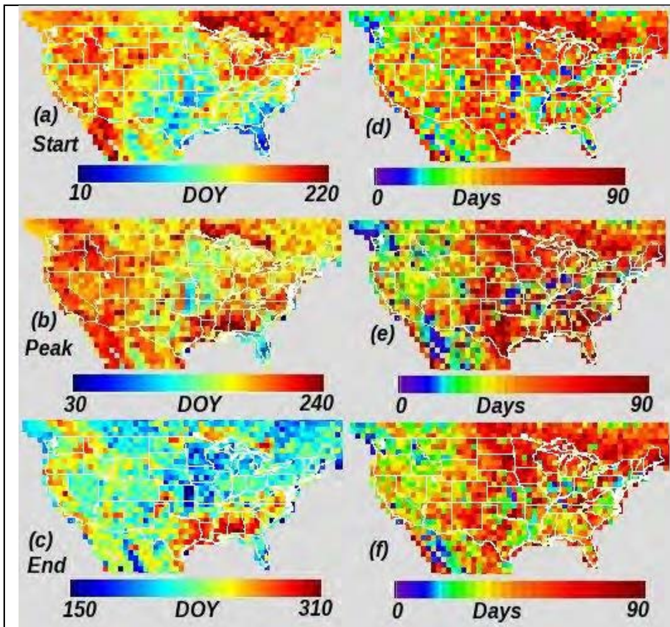



*Figure 2. Fire seasonality derived from geostationary operational environmental satellites (GOES) series across the contiguous United States from 1995 to 2011. Average fire seasonality metrics are (a) start of fire season, (b) peak of fire season, (c) end of fire season. Corresponding interannual variations represented by standard deviation (STD) are (d) STD in the start of fire season, (e) STD in the peak of fire season, (f) STD in the end of fire season.*

- Biomass burning emissions data were prepared for user communities. We generated global blended daily biomass burning emission (January 2012-Januray 2013) for NOAA NCEP NWP for air quality forecasting, burned area and biomass burning emissions in spring 2013 in George for the George Institute of Technology, and biomass burning emissions data in Africa for Department of Earth & Atmospheric Sciences, University of Nebraska – Lincoln.

**PLANNED WORK**

- Complete documents for operation in OSPO
- Evaluate and assess the estimates of biomass burning emissions in OSPO

**PUBLICATIONS**

Zhang, X., Kondragunta, S., Roy, D.. Interannual Variation in Biomass Burning and Fire Seasonality Derived from Geostationary satellite data across the Contiguous United States from 1995–2011. Journal of Geophysical Research-Biogeoscience, (a revised version was submitted).

**DELIVERABLES**

- Operational codes for global biomass burning emissions from polar orbiting and geostationary satellites
- Evaluation of product output

**PRESENTATIONS**

Zhang, X., Kondragunta, S., Da Silva, A., Lu, S., Kim, H., 2013, Development of Operational Global Biomass Burning Emissions Product Using Fire Radioactive Energy Derived from MODIS and Geostationary Satellites, *International Smoke Symposium*, 21-24 October 2013, Adelphi, MD, USA.

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

**Monitoring Land Surface Vegetation Phenology from VIIRS**

| | |
|---|---|
| **Task Leader** | Xiaoyang Zhang (South Dakota State University) |
| **Task Code** | XZXZ_VIIRS_13 |
| **NOAA Sponsor** | Yunyue Yu |
| **NOAA Office** | NESDIS/STAR/SMCD/EMB |
| **Percent contribution to CICS 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 algorithm and operational computer codes to produce vegetation phenology from VIIRS data. An annual time series of VIIRS data (NDVI, EVI, and snow cover) in 2013 was investigated. Methods for smoothing annual time series of EVI were developed and tested. Algorithm for the detection of phenological metrics was further modified.

**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 will also 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. Therefore, we are to develop algorithms in monitoring global vegetation phenology for the NPP/JPSS mission with the support from *JPSS Proving Ground and Risk Reduction Program*. This project is to develop and validate land surface vegetation phenology from VIIRS. Specifically, we will develop and implement a land surface vegetation phenology climate data record from NPP VIIRS globally and will model temporal trajectories of the vegetation growth for near real-time monitoring vegetation phenology in Contiguous United States (CONUS).

**ACCOMPLISHMENTS**

- Annual time series of VIIRS data were collected and investigated for phenology detections**.** We completed to investigate an annual time series of TOA NDVI, TOC EVI, snow flag, LST flag, and quality flag for algorithm development and test. The collected global time series is at a spatial resolution of 4km and covers the period from DOY 262, 2012 to DOY 365, 2013. For the processing of annual time series, we divided the globe into four sub-regions. Each sub-region consists of 5000 columns and 1808 rows. The activity of investigating the time series of VIIRS EDR data (VI, LST, snow and cloud cover) will be continued for 500 m datasets.

- Algorithm and computer codes for reconstructing annual time series of VIIRS EVI were developed, modified, and tested**.** We completed to refine and test the computer codes for reconstructing EVI temporal trajectories. Unlike MODIS data, the VIIRS Top of Canopy (TOC) EVI product contains unrealistically high values (Figures 1 and 2). The EVI outliers are likely associated with snow cover and other abiotic factors, which contradicts our conventional understanding (e.g., maximum value composites) that abiotic factors generally lower vegetation index values. It is challenging to distinguish good observations from both high and low outliers. After examined various datasets, we removed these spuriously high outliers using the relative difference between VIIRS EVI with VIIRS NDVI. Moreover, missing observations because of cloud cover were replaced using simulated values from the logistic model. This algorithm could produce spatially and temporally continuous EVI value across the globe (Figure 2).

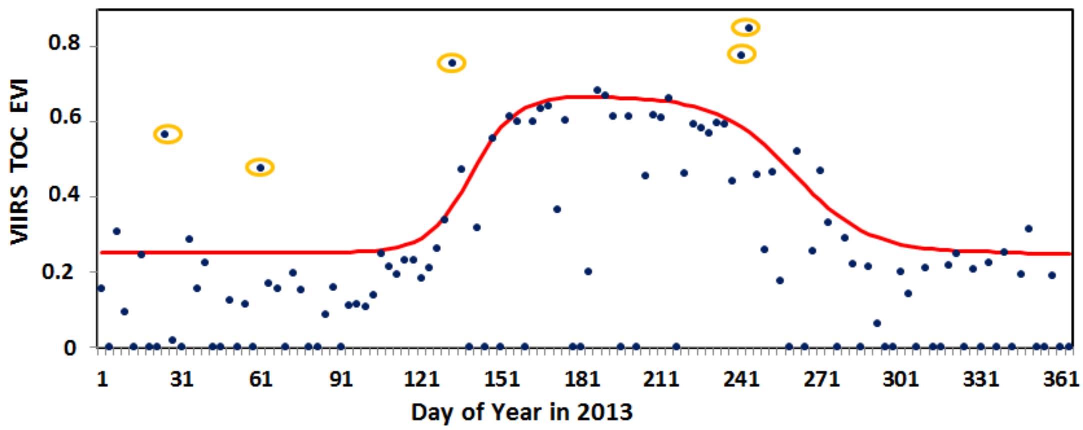



*Figure 1: Simulating annual time series EVI for detecting vegetation dynamics. The spuriously high EVI values are denoted using yellow circles and low EVI values are mainly associated with cloud cover. The latter were smoothed based on a set of filters.*

- 

- Phenology detection algorithm and C codes were updated for detecting phenological metrics in pixels with consecutively contaminated by clouds**.** The computer code was modified for reducing impacts from large gaps (good observations are consecutively missing for a period of longer than a month) by replacing observations using in preceding or succeeding year.

- Phenology detection algorithm was tested using 4km data and preliminary product was produced for North America**.** We tested our computer codes using 4km data, and further generated phenological metrics during a vegetation growing season. These metrics include the timing of greenup onset, maturity onset, senescent onset, and dormancy onset (Figure 3).

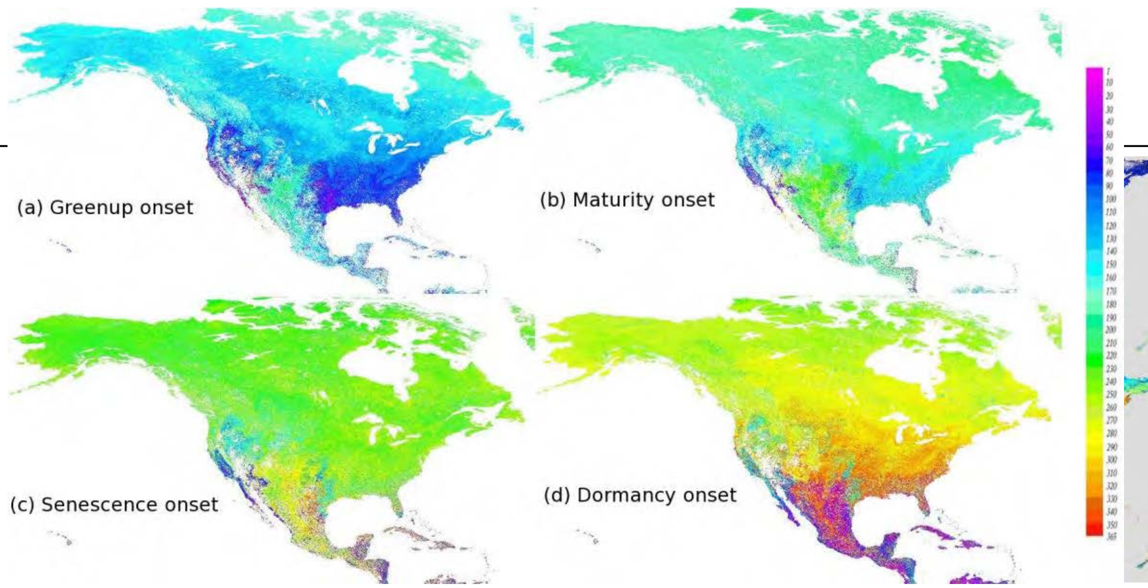



***Figure 3**: The timing of vegetation phenology detected across the globe (4km) across North America.*

***Figure 2**: Comparison of raw VIIRS EVI with simulated EVI at a spatial resolution of 4km. (a) and (b) are raw EVI, where missing values (dark gray color) are frequently observed and spuriously high values mainly occur in high latitudes. (c) and (d) are reconstructed VIIRS EVI using the logistic model, where gaps (missing observations) are filled and irregular outliers are smoothed.*

- VIIRS VI and snow data at 500m (gridded format) for the year 2013 were collected. Phenology detection requires annual time series of satellite observations. Because of the huge data seize, a single file of global dataset at a spatial resolution of 500m is not suitable to perform phenology detection directly. Thus, we divided the global coverage into 256 sub-regions equally. The daily observation was composited to 3 day data based on data quality flag. Each file of 3-day composite data contains NDVI, EVI, snow appearance, and LST. The annual time series of data at 500m is under processing.

- Phenological climatology in CONUS was under preparation. We have prepared daily MODIS Climate Modeling Grid (CMG) data from 2001-2013 across Contiguous United States. This dataset will be used to generate climatology of phenology for near real time phenology monitoring.

**PLANNED WORK**

- Complete documents for operation in OSPO
- Evaluate and assess the estimates of biomass burning emissions in OSPO

**PUBLICATIONS**

Zhang, X., Tan, B., and Yu, Y., 2014. Interannual Variations and Trends in Global Land Surface Phenology Derived from Enhanced Vegetation Index during 1982-2010, *International Journal of Biometeorology. (in press).*

**DELIVERABLES**

- Algorithm and computer codes for global phenology detection from VIIRS.
- Evaluation of phenology product output.

**PRESENTATIONS**

Zhang, X., Friedl, M. and Yu, Y., 2013, Interannual Variations in Global Land Surface Phenology Derived from a Long Term AVHRR and MODIS Data Record, *AGU Fall Meeting,* 9–13 December 2013, San Francisco, California, USA.

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

| | |
|---|---|
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

## *1.9 National Climate Assessments*

**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_PESC_12 & MKMK_RDIN_13 |
| **NOAA Sponsor** | Eric Locklear |
| **NOAA Office** | OAR/CPO |
| **Contribution to CICS Themes (%)** | Theme 1: 75%; Theme 2: 0%; Theme 3: 25% |
| **Main CICS Research Topic** | National Climate Assessments |
| **Contribution to NOAA Goals (%)** | Goal 1: 85%; Goal 2: 5%; Goal 3: 5%; Goal 4: 5% |

**Highlight**: Kenney is leading the development of an interagency indicator system to bring together data, observations, and indicator products in innovative ways to better assess climate changes, impacts, vulnerabilities, and preparedness. See http://tinyurl.com/melissakenney & http://orcid.org/0000-0002-2121-8135

**BACKGROUND**

Indicators are essential elements of information systems to provide information, both to inform understanding and decisions, about climate change to diverse audiences. The National Oceanic and Atmospheric Administration (NOAA) has a number of monitoring, observation, and indicator efforts that provide critical insights and are integrated into information systems (e.g., National Integrated Drought Information System (NIDIS; www.drought.gov)). These NOAA initiatives are relevant to a new, national scale effort to develop an interagency indicator system for the U.S. Global Change Program (USGCRP), National Climate Assessment (NCA), described below. Given the benefits of indicators to NOAA, USGCRP, and the NCA, it is critical to understand and test the extent to which NOAA and other federal agency indicator efforts and the development of additional indicators that would support ongoing NOAA information systems could additionally add value to a national interagency indicator platform.

This effort establishes a proof of concept system of indicators that communicates key aspects of the physical climate, climate impacts, vulnerabilities, and preparedness for the United States (Figure 1). We have brought together 150+ physical, natural, and social scientists, including NOAA experts, to develop pragmatic recommendations for a system of indicators. These collaborations will continue through the implementation of the prototype indicator system and associated scientific documents and manuscripts. The indicator system highlights critical NOAA and other federal datasets and products, supports interagency collaboration, and is a fundamental element of the sustained USGCRP National Climate Assessment.

**ACCOMPLISHMENTS**

We have developed this program with support from 9 of the 13 U.S. Global Change Research Program (USGCRP) agencies and 150+ physical, natural and social scientists from academia, government agencies, and the private sector. This effort supports the following existing interagency federal priorities: the four pillars of the strategic plan of the USGCRP to address the requirements of the Global Change Research Act (GCRA), foundational product of the National Climate Assessment (NCA) sustained assessment; USGCRP Office of Management and Budget (OMB) priority for 2013, 2014, and 2015; an activity to fulfill one of the data initiatives and decision tool kit requirements of the President's Climate Action Plan (CAP); and Executive Orders (EO) 13653, 13514, and 13642. This effort also builds on existing or develops new indicator and information system design and products developed through the USGCRP agency programs, participation by agency scientists and managers, and inclusion of indicators in existing Request for Proposals (RFPs). The system is currently under development; it will be launched in two phases: a pilot is slated for summer 2014 (funded by this task) and a full launch in 2015.

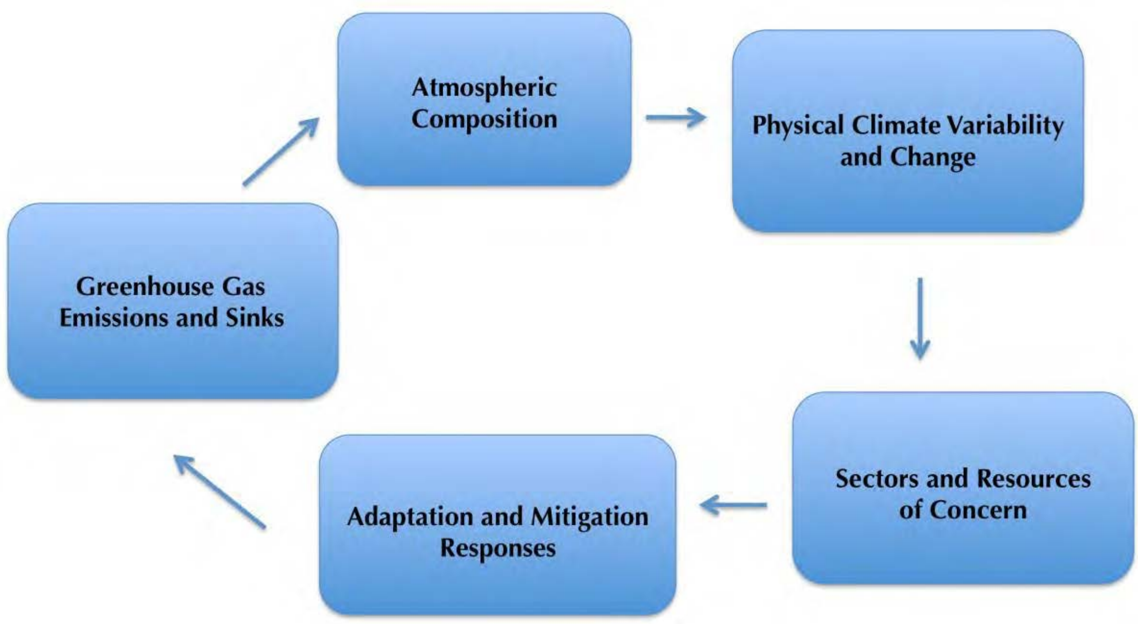
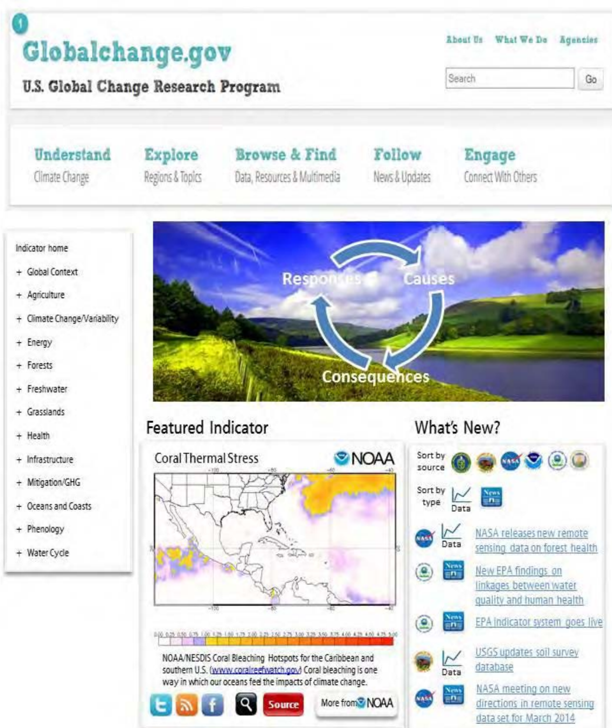
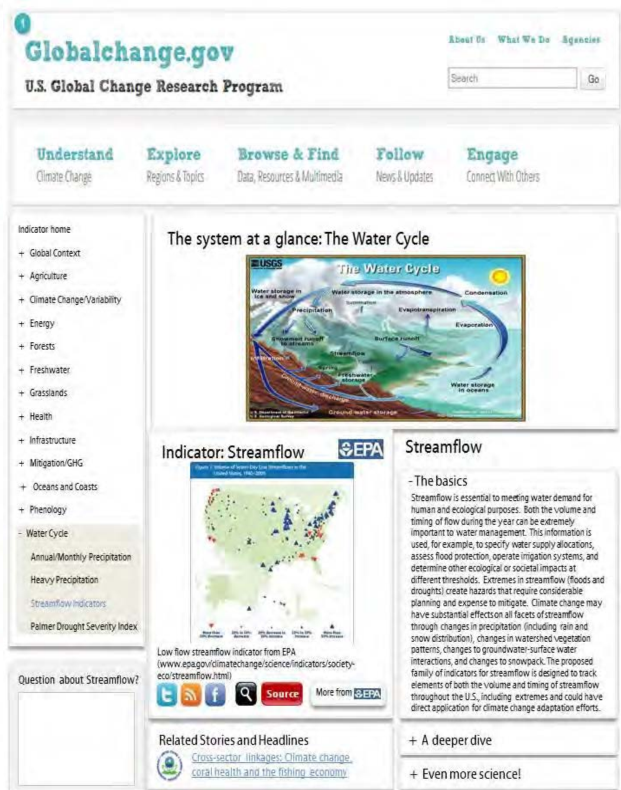



*Figure 1. Categories of Indicators: Framework for the National Climate Indicators System. Physical, ecological, and societal indicators could fall into different categories of this end-to-end framework. The framework includes the linkages between sources and sinks to impacts to responses, which over time can impact sources and sinks. Because this system is not designed for cause and effect research, indicators that are within a multi-stressor context where climate is one of many stressors can also be included.*

Over the past year, 12 Technical Teams developed reports that included draft conceptual models, indicator recommendations, and research priorities. Each report was peer-reviewed by at least 3 external scientists and revised given their comments. Each team was supported by scientists and students, who professionally coordinated meetings, worked with team leads to set agendas, and edited documents. Kenney worked with each of the teams and the support staff scientists to assure that the work of each of the multi-disciplinary (physical, natural, and social scientists) teams supported the larger indicators effort and would be scientifically rigorous enough to be considered for peer-reviewed publication. Janetos and Kenney developed a proposal for the Pilot National Climate Indicator System, on behalf of the NCADAC Indicator Work Group, which was vetted by this group, technical teams, and external reviewers, and the NCADAC. The NCADAC made a consensus decision to recommend to the USGCRP the development of a sustained indicator system, the first step of which is a pilot system.

As a result of the support received for the indicator effort, we have developed prototypes of the web interface (Figure 2) that could be used on the USGCRP website and the metadata documentation that would be required to assure full transparency of data and methods for the indicators. The purpose of the pilot system is evaluation, so that we can understand how decision makers would like to use the individual indicators and the system as a whole.




*The GCIS web platform: home page* *The GCIS web platform: Streamflow indicator page*

*Figure 2. GCIS Web Platform: The sample pages below provide examples of the globalchange.gov site concept for accessing and displaying Indicators information in GCIS.*

**PLANNED WORK**

*Note: This includes both work under this task as well as what is planned given additional funding.*

- Technical teams provide near-term and long-term research priorities
- Documentation for each of the indicator that would allow for replication of the product, including data, metadata, transformation, and indicator methodology
- **Implementation of Pilot Indicator System soon after the GCIS release (Summer 2014)**
- Test evaluation methods given the pilot of the indicators on the GCIS. Use lessons learned to improve the methods so that a robust procedure is developed for the launch.
- Write and submit manuscripts for special issue of a journal on the indicator system
- Internal, and external review of the system – data and methods
- Workshops: Adaptation and Hazards Indicators, Indicators using Citizen Science (co-sponsored with Wilson Center), Leading Indicators
- Work with GCIS team and graphic designers to develop the design of the indicator system
- **Launch indicator system on GCIS (2015)**
- Special issue of journal on the national indicator system (with release of indicator system)
- Evaluate and improve the indicator system; pilot indicators from research investments

**PUBLICATIONS**

Van Houtven, G., C. Mansfield, D.J. Phaneuf, R. von Haefen, B. Milstead, M.A. Kenney, K.H. Reckhow. (2014) Combining expert elicitation and stated preference methods to value ecosystem services from improved lake water quality. *Ecological Economics*. 99:40-52. doi:10.1016/j.ecolecon.2013.12.018

Moss, R., P.L. Scarlett, M.A. Kenney, H. Kunreuther, R. Lempert, J. Manning, B.K. Williams (in press) Decision support: Supporting policy, planning and resource management decisions in a climate change context. 3rd National Climate Assessment (currently draft).

Janetos, A.C. and M.A. Kenney (in revision) Indicators of Change and Consequence are Unmet Needs for Climate Change Assessments. *Nature Climate Change.*

Kenney, M.A., B.F. Hobbs, D. Mohrig, H. Huang, J.A. Nittrouer, W. Kim, G. Parker. (2013) Cost Analysis of Water and Sediment Diversions to Optimize Land Building in the Mississippi River Delta. *Water Resources Research*. 49. doi:10.1002/wrcr.20139

Kenney, M.A., A.C. Janetos, et al. (2014) Pilot National Climate Indicators System Report. National Climate Assessment Development and Advisory Committee. 155 pp.

**DELIVERABLES**

- Formal and informal support from 9 of the 13 USGCRP federal agencies (i.e., DOC NOAA, EPA, USDA, DOE, NASA, DOD USACE, HHS CDC, DOI, and NSF) and USGCRP Principals, given conversations and formal invited briefings, to develop a robust set of recommendations for a prototype indicators system in collaboration with experts from their agencies and utilizing indicators and data for the system developed by their agencies and other established organizations;
- Development of an Indicator Portal (indicators.globalchange.gov), which, given our direction, was developed by in-kind support from NOAA NCDC to facilitate collaboration among and between technical teams who will be providing recommendations of candidate indicators for the initial indicator system;

- Final multi-year implementation plan including the organizational structure, timeline, and deliverables to provide assurance that we can deliver on our ambitious goals;
- Developed policy memo, fact sheet, universal slide deck, poster, and other briefing materials to be used by anyone that is part of this effort;
- Draft inventory of physical, ecological, and societal indicators to support the initial work of the technical teams;
- Continued advisory leadership in indicators effort – Tony Janetos (system-wide leadership), Deke Arndt (physical indicators), Bob Chen and Richard Moss (societal indicators), and Rich Pouyat (ecological indicators)
- Confirmed, supported, and guided the scientific products from technical team leadership and team members for 13 teams and technical team members (approximately 10-20 members per team; 150+ professionals in total) with each team establishing an "NRC-like" panel of scientists and senior managers in academia, government, or private sector. Participation by the team leads or members was either supported by in-kind support their federal agency management or academic or private sector institution, as no financial support was provided for their recommendations.
    - Roger Griffis, Oceans and Coastal Team Co-lead (NOAA)
    - Laurie Mcgilvary, Coastal and Oceans Team Co-lead (NOAA)
    - Britta Bierwagen, Freshwater Ecosystems Team Lead (EPA)
    - Dennis Ojima, Grassland Team Co-Lead (Colorado State Univ.)
    - Nancy Cavallaro, Grassland Team Co-lead (USDA NIFA)
    - Jake Weltzin, Phenology Team Lead (USGS NPN)
    - Mike McGeehin, Health Team Lead (retired)
    - Tom Wilbanks, Energy Team Lead (ORNL)
    - Tom Wilbanks, Infrastructure Team Lead (ORNL)
    - Leon Clarke, Mitigation and GHG Team Lead (JGCRI)
    - Jerry Hatfield, Agriculture Team Lead (USDA)
    - Linda Heath, Forest Team Lead (USDA - USFS)
    - Deke Arndt, Physical Climate Change and Variability (NOAA NCDC)
    - Kathleen Tierney, Adaptation and Hazards Team Lead (University of Colorado-Boulder)
    - Pat Gober, Adaptation and Hazards Team Lead (Arizona State University)
    - Christa Peters-Lidard, Water Cycle and Management (NASA)
- 12 Technical Teams developed reports that included draft conceptual models, indicator recommendations, and research priorities. Each report was peer-reviewed by at least 3 external scientists and revised given their comments;
- Proposal for the Pilot National Climate Indicator System, written with the support of the NCADAC Indicator Work Group, which was vetted by this group, technical teams, and external reviewers, and the NCADAC. The proposal was adopted by the NCADAC, resulting in an official consensus recommendation for a sustained indicator effort, the first step of which is the implementation of a pilot, by the federal advisory committee to the federal government (specifically USGCRP);
- Each team was supported by scientists and students on my research team, who professionally coordinated meetings, worked with team leads to set agendas, and edited documents. I

worked with each of the teams and the support staff scientists to assure that the work of each of the multi-disciplinary (physical, natural, and social scientists) teams supported the larger indicators effort and would be scientifically rigorous enough to be considered for peer-reviewed publication;

- Continued leadership and support of the National Climate Assessment Development and Advisory Committee Indicator Work Group (advisory board of the indicators effort, which includes approximately 25 members);
- Mentored early career science policy fellows (7), graduate students (5), and undergraduate students (12) who provide unpaid research support and recruited additional research support for 2014;
- Worked with AOSC and ENSP to develop a research course on science policy for undergraduates in calendar year 2013 who would like to learn these research methods by working on the indicators effort;
- Hosted in-person meeting of indicator team leads at UMD JGCRI to discuss the development of conceptual models, 4 in-person technical team meetings to support the development of their recommendations and resulting reports, and 2 in-person meeting of the Indicator Work Group and technical team leads to provide a briefing of the recommendations and the resulting proposal (authored by me and Tony Janetos) for the pilot indicator system; and
- Developed prospectus (waiting response from journals) for a special issue on the National Climate Indicator System to be published in 2015.

**PRESENTATIONS**

Kenney, Melissa, 2013: Keynote Address: My non-linear path to a multidisciplinary career as a professor, *Preparing Future Faculty Fellow and Mentor Dinner*, Duke University, Durham, NC (November 4).

Kenney, Melissa, 2013: Developing a National Climate Indicators System to track climate changes, impacts, vulnerabilities, and preparedness, *2nd Annual CICS-MD Science Meeting*, College Park, MD (6-7 November), http://cicsmd.umd.edu/assets/1/7/8.2_Kenney_ab.pdf .

Kenney, Melissa, 2013: Developing a System of National Climate Assessment Indicators to track climate change impacts, vulnerabilities, and preparedness: Pilot Indicator System Proposal, *NOAA National Climate Adaptation Team Briefing*, Washington, DC (December 4).

Kenney, Melissa, 2013: Developing a System of National Climate Assessment Indicators to track climate change impacts, vulnerabilities, and preparedness: Pilot Indicator System Proposal, *NOAA National Climatic Data Center and National Climate Assessment Technical Support Unit Briefing*, Asheville, NC (December 5).

Kenney, Melissa, 2013: Developing a National Climate Indicators System to track climate changes, impacts, vulnerabilities, and preparedness [poster], *AGU Fall Meeting*, San Francisco, CA (December 9-13).

Kenney, Melissa, 2013: Pilot Indicator System to track climate changes, impacts, vulnerabilities and preparedness: Process and proposal, *U.S. Global Change Research Program Briefing*, Washington, DC (December 18).

Kenney, Melissa, 2014: Exploring career opportunities in academia, *AAAS Summit on Career Opportunities for Science & Technology Policy Fellows*, Silver Spring, MD (January 13).

Kenney, Melissa, 2014: National Climate Assessment Indicator System: Status and decisions, *National Climate Assessment Development and Advisory Committee Indicator Work Group Indicators Pilot Webinars*, Washington, DC (January 23–February 4).

Kenney, Melissa, 2014: National Climate Assessment Indicator System: Status and decisions, *National Climate Assessment Development and Advisory Committee Meeting*, Washington, DC (February 20–February 21).

Kenney, Melissa, 2014: A coalition of the willing: Building a National Indicators System*, NCSE Symposium and Workshop on the National Climate Assessment: Innovations in Science and Engagement*, Silver Spring, MD (January 28–29).

Kenney, Melissa, 2014: Indicators for Ecosystem Services and Adaptation*, NCSE Symposium and Workshop on the National Climate Assessment: Innovations in Science and Engagement*, Silver Spring, MD (January 28–29).

Kenney, M.A. and Janetos, A.C. (2013) National Climate Indicator System. Briefing of the U.S. Global Change Research Program Indicator Work Group Retreat. Washington, DC.

Patwardhan, A., R. Moss, M.A. Kenney, E. Fagley. (2013) Scenarios to Support Decision-making. Energy Modeling Forum, Climate Impacts and Integrated Assessment. Snowmass, CO.

Kenney, M.A., Moss, R., P.L. Scarlett, H. Kunreuther, R. Lempert, J. Manning, B.K. Williams, Janetos, A.C., R. Chen, D. Arndt, R. Pouyat. (2013) Supporting and Informing Decisions Through Assessments. National Climate Assessment Northwest Town Hall. Portland, OR.

Kenney, M.A. (2013) Supporting and Informing Decisions Through Assessments. American Association for the Advancement of Sciences. Boston, MA.

Janetos, A.C., M.A. Kenney, R. Chen, D. Arndt. (2013) Developing a System of National Climate Assessment Indicators to Track Climate Change Impacts, Vulnerabilities, and Preparedness. NOAA Climate Board. Washington, DC.

Kenney, M.A. (Summer 2013) What are the most cost-efficient coastal restoration approaches for the Mississippi River delta?: Integrating geosciences, economics, and policy analysis. Pardee Center for the Longer-Range Future, Boston University.

Kenney, M.A. (Spring 2013) Is urban stream restoration worth it?: Economic approaches to valuing the ecosystem services of restored streams. Carnegie Mellon University, Civil and Environmental Engineering. Invited Keynote Speaker

Kenney, M.A. (Spring 2013) Supporting and Informing Decisions Through Assessment. University of Maryland, Department of Atmospheric and Oceanic Sciences.

Kenney, M.A. (Spring 2013) National Climate Assessment: Science Informing Policymaking. University of Maryland, School of Public Policy

Kenney, M.A. (2013) Resilience Indicators: Ready or Not. (Co-organized Session with M. Davidson and E. Wallace) Natural Hazards Workshop. Broomsfield, CO.

Prava, V., R.T. Clemen, B.F. Hobbs, M.A. Kenney. (2013) Correcting Partition Dependence and Carryover Biases in Subjective Probabilities: A Web Survey. Institute for Operations Research and the Management Sciences. Minneapolis, MN.

Hobbs, B.F., M.A. Kenney, D. Mohrig, J. Nittrouer, W. Kim and G. Parker. (2013) What's the Most Efficient Use of our Limited Water and Money? Scale Economy Tradeoffs in Land Building Diversions in the Mississippi Delta. 2013 World Environmental & Water Resources Congress. Cincinnati, OH.

Kenney, M.A., A.C. Janetos, R.S. Chen, D. Arndt, R.V. Pouyat. (2013) Developing a system of National Climate Assessment indicators to track climate change impacts, vulnerabilities, and preparedness. Poster presented at Ecological Society of America. Minneapolis, MN.

Janetos, A.C., M.A. Kenney, R.S. Chen, D. Arndt, and R. Pouyat. (2013) Developing a System of National Climate Assessment Indicators to Track Climate Change Impacts, Vulnerabilities, and Preparedness. Poster presented at North American Carbon Program. Albuquerque, NM.

**OTHER**

Kenney, Melissa, 2014: Participant, *Climate Science Day Congressional Visits*, Washington, DC (January 29). [She distributed a fact sheet about the National Climate Indicators System].

*Honors:* Lead Author for Decision Support Chapter of the 3rd U.S. National Climate Assessment

*Grant Reviewer for*: National Science Foundation, Directorate of Social, Behavioral and Economic Sciences (2014); Belmont Forum, Freshwater Security (2013); National Science Foundation, SEES Fellows (2013); American Association for the Advancement of Sciences Policy Fellowship (2013)

*Reviewer*: *Integrated Environmental Assessment and Management* (2014); *Environment, Systems, and Decisions* (2013)

*Grants awarded in support of indicators:* Haimin, E., D. DeGroot, **M.A. Kenney**, T. Sheahan. (2014-2018) RCN-SEES: Sustainable Adaptive Gradients in the coastal Environment (SAGE): Reconceptualizing the Role of Infrastructure in Resilience. National Science Foundation, Research Coordination Network (RCN), Science, Engineering and Education for Sustainability (SEES). Awarded $750,000.

| **Performance Metrics** | **FY13** |
|---|---|
| # of new or improved products developed following NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 0 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 0 |
| # of peer reviewed papers | 3 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 18 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 5 |
| # of undergraduate students mentored during the year | 12 |

## *1.10 National Climate Model Portal*

**CWRF Model Development for Climate Services: Regional Enhancement of ISI Products**

| | |
|---|---|
| **Task Leader** | Xin-Zhong Liang |
| **Task Code** | XLXL_ARL_12 |
| **NOAA Sponsor** | Julian X.L. Wang |
| **NOAA Office** | OAR /ARL |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 20%; Theme 3: 80%. |
| **Main CICS Research Topic** | National Climate Model Portal |
| **Contribution to NOAA Goals (%)** | Goal 1: 60%; Goal 2: 20%; Goal 3: 0%; Goal 4: 10%; Goal 5: 10% |

**Highlight**: We have developed a new CFS-CWRF real time seasonal forecast system. The products of the system showed substantial improvement over CPC' operational CFS especially for precipitation.

**BACKGROUND**

This report summarizes the year-1 work of the ongoing NOAA project entitled "Regional enhancement of ISI products". A new seasonal forecast system has been developed and is generating summer climate outlooks. The system framework is a hybrid procedure that takes advantages of both global CFS and regional CWRF which producing significant skill improvement especially during seasons with weak planetary scale circulation anomalies. While NOAA relies on global models which have low skill especially for precipitation for operational seasonal prediction, the CFS-CWRF system is showed promising results and is the first-of-its kind to be developed at NOAA. Figure 1 presents the schematic of CFS-CWRF real time seasonal forecast system. Below are the accomplishments during the first year of the project, followed by future plans for the second year.

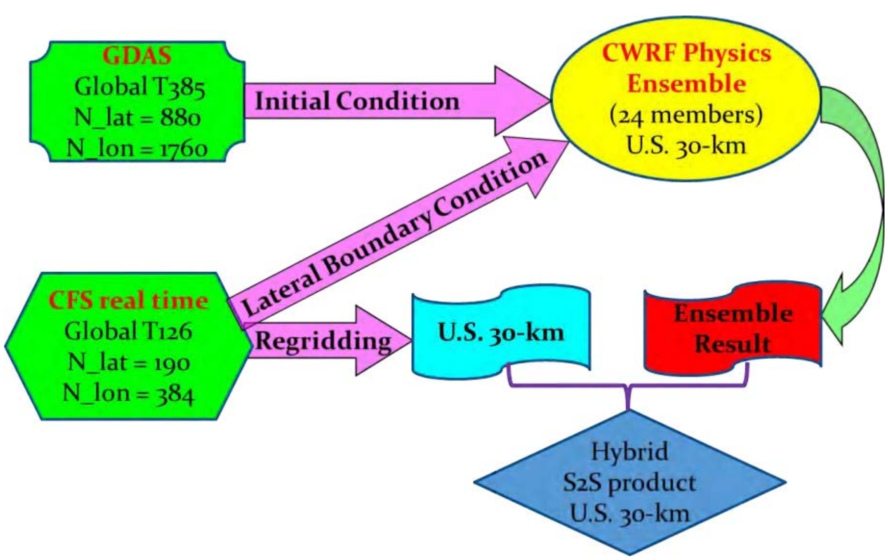



*Figure 1. Schematic of CFS-CWRF real time seasonal forecast system.*

**ACCOMPLISHMENTS**

The forecast system have been developed and tested. Figure 2 presents an example of the system generating seasonal forecast for precipitation over the U.S initialized at 00Z May 31st, 2012 and the forecast period is June-July-August. The CWRF was driven by CFS, and the ensemble (ENS in the figure) is the average of CWRF and CFS.

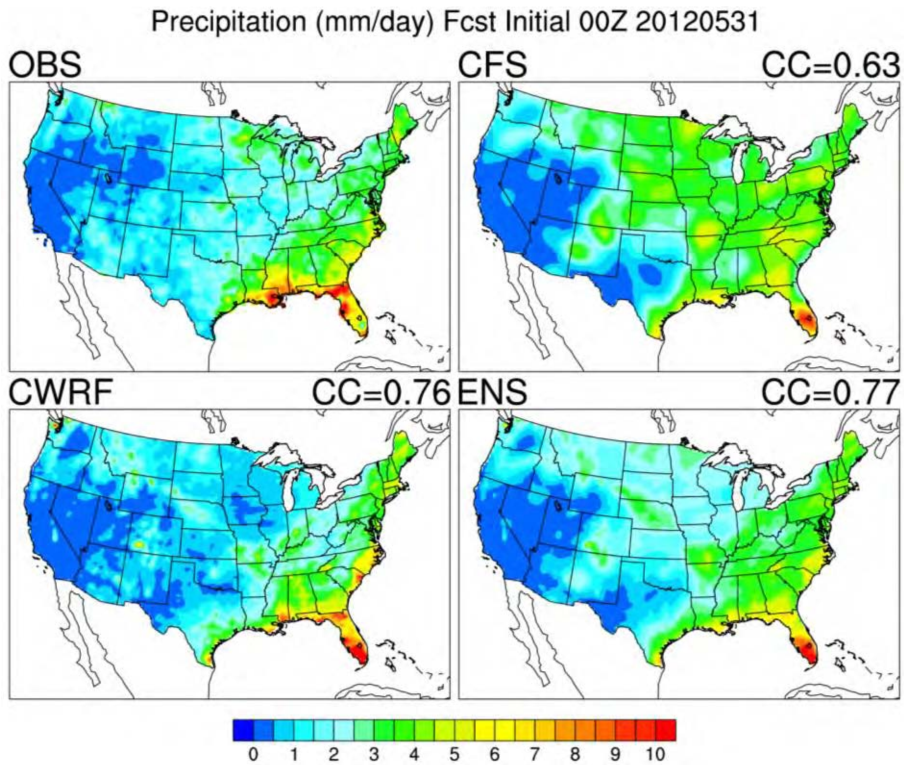



*Figure 2: An example of seasonal forecasts from the system. The initialization time is 00Z May 31st 2012 and forecast period is June-July-August. The ENS is the average of CFS and CWRF. Spatial pattern correlation coefficients (CC) of CFS/CWRF/ENS with observation (OBS) are also shown.*

All project deliverables (documentation and software) and milestones have been accomplished as planned. Currently, the forecast system is under further development.

**PLANNED WORK**

- Continue work to develop optimized physics ensemble for CWRF to improve the system's prediction skill
- Continue work to assess the performance of the system
- Transition the forecast system to operations

**PUBLICATIONS**

No publications yet.

**DELIVERABLES**

- CFS-CWRF forecast system for real time outlook
- Post-processing programs for precipitation and temperature analysis
- Algorithms for evaluation of the system performance
- Visualization tools for figure plotting
- Documentation for CFS-CWRF forecast system.

**PRESENTATIONS**

Liang, X.-Z, 2013: Advanced Regional Modeling to Improve Climate, Hydrology and Environment Prediction. *Seminar at the Department of Hydraulic and Ocean Engineering*, National Cheng Kung University, Taiwan, December 3.

Liang, X.-Z., J.X.L. Wang, and V. Morris, 2013: CWRF Present Climate Prediction and Future Climate Change Projection over North America. *Oral Presentation at the International Conference on Regional Climate: CORDEX (Coordinated Regional Downscaling Experiment),* Brussels, Belgium, November 4-7.

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

This year, we developed a new CFS-CWRF real time seasonal forecast system (1). Its development involved transferring our prior CWRF research to operations (1). We are preparing one journal article on the overall skill enhancement by the CFS-CWRF system than the operational CFS (1). Two presentations summarizing the modeling system and initial results have been made (3).

## 1.11 Education, Outreach, and Literacy

**Program Management at the Climate Program Office**

| | |
|---|---|
| **Task Leader** | Daniel Barrie |
| **Task Code** | DBDB_COEC_13 |
| **NOAA Sponsor** | Eric Locklear |
| **NOAA Office** | OAR/CPO |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 0%; Theme 3: 100%. |
| **Main CICS Research Topic** | Climate Literacy, Education, Outreach, and Engagement; Climate Research, Data Assimilation and Modeling; Land and Hydrology; National Climate Assessments; National Climate Model Portal. |
| **Contribution to NOAA Goals (%)** | Goal 1: 40%; Goal 2: 30%; Goal 3: 10%; Goal 4: 10%; Goal 5: 10% |

**Highlight**: Through engagement and the fostering of collaboration in carried out in this task, the University community has been more effectively connected with the NOAA scientific community. The results of this increased connectivity has been improved NOAA products and services including climate projections for North America, model components and performance, drought information, and improved understanding of extremes. Scientific progress has been fostered through new digital outreach techniques in addition to traditional facilitated community meetings. This outreach effort has helped coordinate and maximize the federal climate and Earth system model effort.

**BACKGROUND**

The NOAA Climate Program Office (CPO) focuses on developing a broader user community for climate products and services, provides NOAA a focal point for climate activities, leads NOAA climate education and outreach activities, and coordinates international climate activities. To achieve these goals, CPO will benefit significantly from a strong partnership with outside investigators. Building this partnership requires the involvement of personnel with strong backgrounds in scientific research in program management positions. This need for scientific expertise within CPO matches well with Dr. Barrie's training, talents, and career interests.

**ACCOMPLISHMENTS**

Three representative highlights from the task leader's previous year of activity are described below: 1) the success of a webinar series; 2) Task Forces covering a variety of topics and integrating the NOAA and external communities; 3) a report on the 2012 great plains drought; 4) CMIP5 Task Force interactions with modeling centers and the applications community.

1) The task leader has organized and hosted a webinar series, now in its third year, intend to communicate research results to the broader research and end-user community, connect funded investigators with each other, and to provide updates for program management on the progress of funded projects. In FY13, the webinar series entered its third year. Over 1000 individuals have attended the webinar series, with average attendance around 70 individuals. Attendance has grown

gradually over time. The webinar series is highlighted on a website co-created by the task leader, where information about the series, slides, and recordings are hosted.

2) The task leader has, with colleagues, fostered five Task Forces organized around the major topical areas covered by his program. Each Task Force is composed of approximately 30 researchers funded by the program doing research in the following titular areas:

- Climate Prediction Task Force
- Drought Task Force
- CMIP5 Task Force
- Climate Model Development Task Force
- Reanalysis Task Force

The purpose of the task forces is to maximize the impact of funded research projects for the purpose of improving NOAA products and services. NOAA's grants programs ultimately exist to improve NOAA's capabilities, and these task forces are envisioned as a way of creating dialogue and enabling the funded researchers to leverage off each other's projects to maximize their research outcomes. These task forces have achieved a number of notable accomplishments including:

- Providing input to the WCRP on CMIP plans based on CMIP5 experience (CMIP5 TF)
- Fostering a next-generation plan for the NCEP CFSv3 and integrating the external community into that development (CMD TF)
- Producing a major assessment of the 2012 Great Plains drought, its causes, its predictability, and the magnitude of the anthropogenic climate signal contributing to it (Drought TF)
- Organizing and publishing a special collection of papers that informed the IPCC WG1 Report (CMIP5 TF)
- Meeting and engaging with both modeling centers and the climate applications community on the utility of process-oriented model diagnostics for model development and improved regional understanding of model performance and fidelity (CMIP5 TF)
- Understanding and coordinating next directions on reanalysis research and development at NOAA (Reanalysis TF)
- Focusing on predictability in efforts to improve climate predictions at NOAA operational centers (CP TF)

3) Drought Task Force report on the 2012 Great Plains Drought
The task leader helped organize and carry out the Drought Task Force's efforts in assessing and better understanding the 2012 Great Plains Drought, its causal mechanisms, its predictability, and whether the climate change signal contributed significantly to the drought. Martin Hoerling of NOAA ESRL led the report with significant co-authorship and involvement from a broad cross-slice of the university research community.

The report received a significant amount of media attention, mostly focusing on the implied conclusion that climate change did not contribute significantly to the drought and that the primary hydrologic forcing of the drought was natural weather variability, and reduced moisture flux from the

Gulf of Mexico. The report involved novel modeling studies performed by a number of the co-authors, and it has been widely downloaded and read. A summary of the report is below:

*Historical Context - How do 2012 rainfall amounts and high temperatures compare to years past?*
Precipitation deficits for the period May through August 2012 were the most severe since official measurements began in 1895, eclipsing the driest summers of 1934 and 1936 that occurred during the height of the Dust Bowl. This prolonged period of precipitation deficits, along with above normal temperatures, resulted in the largest area of the contiguous United States in drought since the U.S. Drought Monitor began in January 2000. By early September, over three-quarters of the contiguous U.S. was experiencing at least abnormally dry conditions with nearly half of the region (the Central Plains in particular) experiencing unprecedented severe drought. *U.S. Drought Monitor, Sep 4, 2012* [http://droughtmonitor.unl.edu/](http://droughtmonitor.unl.edu/)

For a longer-term perspective, the Palmer Drought Severity Index (PDSI) for August 2012 is compared to a long-term PDSI average spanning from 1895 to 2000 (left) and identifies the core region of the drought to be the central Plains region, with the most extreme moisture deficits occurring over the western Plains (consistent with the Drought Monitor map). A central U.S. epicenter for the drought is also affirmed by the May-August standardized rainfall deficits (middle) with -2 standardized departures from the 1981 to 2010 long-term average being widespread from Colorado to Missouri. Much of the dry region also experienced hot temperatures (right). The combination of low rainfall and high temperatures is typically seen during summertime droughts over the central U.S.

*What caused the 2012 Central Great Plains Drought?*
The central Great Plains drought during May-August of 2012 resulted mostly from natural variations in weather. Moist Gulf of Mexico air failed to stream northward in late spring as cyclone and frontal activity were shunted unusually northward. Summertime thunderstorms were infrequent and when they did occur produced little rainfall. Neither ocean states nor human-induced climate change, factors that can provide long-lead predictability, appeared to play significant roles in causing severe rainfall deficits over the major corn producing regions of central Great Plains.

*The timing of the 2012 Central Great Plains Drought: Was it a "flash drought?"*
*The 2012 Central Great Plains drought developed suddenly, and did not appear to be just a progression or* a continuation of the prior year's record drought event that occurred over the southern Great Plains, but appeared to be a discrete extreme event that developed over the Central U.S. The figure to the left shows the rapid expansion of abnormally dry to exceptional drought conditions during June 2012 for the High Plains (Wyoming, Colorado, Kansas, Nebraska, South Dakota and North Dakota), an example of a flash drought. The x-axis extends from Mar 1, 2012 through Sep 30, 2012.

*Impacts of the Central Great Plains Drought*
*Along with the rapid development of the drought, impacts emerged quite swiftly. Loss estimates by the* end of July 2012, before drought severity peaked, were $12B. It remains to be seen if the economic effects of the 2012 drought will approach prior events, including the 1988 drought that inflicted $78 billion in losses and the 1980 event that caused $56 billion in losses (adjusted for inflation to 2012 dollars). Broad sectors were affected, and continue to be affected, by the 2012 drought. Notable for the swiftness of impacts was the reduction in crop yields caused by lack of timely rains. Also, curtailment of commerce on major river systems occurred owing to reduced water flow. It is expected that water supply reductions in the semi-arid western portions of the drought where reservoir storage was depleted by lack of rains will also have long-term impacts, as will livestock health and its long-term effect on herd stocks. Preliminary USDA estimates of farm and food impacts of the 2012 drought indicate corn yield (per acre of planted

crop) was about 123 bushels. This is 26% below the 166 bushel yield expectation that the USDA had at the commencement of the growing season.

*Was the extent and severity of this drought predicted?*
Official seasonal forecasts issued in April 2012 did not anticipate this widespread severe drought. Above normal temperatures were, however, anticipated in climate models, though not the extreme heat wave that occurred and which was driven primarily by the absence of rain.

4) The task leader has led the coordination and execution of the CMIP5 Task Force from the management side in collaboration with the Task Force leaders, Jim Kinter (Center for Ocean-Land-Atmosphere Studies), Eric Maloney (Colorado State University), and Justin Sheffield (Princeton University). This task force has an exceptional number of accomplishments in the past year, including organizing and publishing a 25+ paper special collection in the Journal of Climate. The 25 papers included three papers co-authored by the majority of the Task Force. These publications were well integrated into the IPCC WG1 Report, released in fall 2013. This in part was accomplished through efforts of the task leader, who served as a reviewer of the WG1 report.

The Task Force also hosted two meetings at the 2014 AMS annual meeting. The first meeting brought in a number of model development staff from NOAA GFDL and NCEP to discuss the concept and utility of process-oriented metrics for model development. The task force has been focused on process-oriented metrics recently, which are metrics to evaluate model performance that depend upon physical linkages (e.g., some phenomenon in the physical system responsible for the model's performance in simulating another phenomenon, such as the impact of modeled moist static energy above the Indian Ocean on the faithfulness of MJO simulation). These process oriented metrics represent a change form the status quo performance metrics (e.g., looking at differences between modeled and observed Z500, T2m, U, V, etc.). The idea behind this newer process-oriented thrust is that model developers can better diagnose model areas requiring improvement if there is an understanding of what phenomenological elements are not performing well in the model. The task force has developed a number of such metrics based on their research, and met with the modeling center staff to explore the possibility of integrating these metrics into the modeling center's development plans, diagnostic packages, and other efforts. The modeling centers were receptive to this and a number of pilot projects are underway.

Another parallel application of this effort is for the climate applications community, or those individuals engaged with stakeholders in better understanding climate impacts and helping communities and organizations plan and cope with a changing climate. These types of groups can include the RISAs or other regional entities that form a bridge between the climate research and stakeholder communities. The applications community is also interested in process-oriented diagnostics, as they don't only want to know whether the models are off (e.g., T2m is off by 5K in x model along the Southeast Coast); they also want to know why the model is off (e.g., the T2m is off because the Gulf Stream heat transport is 15% lower than observed). Thus, if a model performs well, the applications community can understand whether this is a accident of cancelled errors or whether that good performance represents exceptional model fidelity to the actual climate system.

Both of these process-oriented metrics directions will continue to be explored over the next year.

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

New products developed by the funded research community with the Task Leader's management guidance include the 2012 Drought Report (1), the CMIP5 Task Force Special Collection (2), the NMME experiment (3), the Climate Model Development Task Force (4), the Webinar series (5). One peer-reviewed paper has been published on the Drought Task Force efforts. One invited presentation was given at the Climate Diagnostics and Prediction Workshop.

**Climate Outreach and Education at the Climate Program Office**

| | |
|---|---|
| **Task Leader** | Dan Barrie/Will Chong |
| **Task Code** | DBWC_COEC_13 |
| **NOAA Sponsor** | Eric Locklear |
| **NOAA Office** | OAR/CPO/ASD |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 0%; Theme 3: 100% |
| **Main CICS Research Topic** | Climate Literacy, Education, Outreach, and Engagement |
| **Contribution to NOAA Goals (%)** | Goal 1: 55%; Goal 2: 5%; Goal 3: 0%; Goal 4: 0%; Goal 5: 40% |

**Highlight**: Increased collaboration and cooperation with scientist from NOAA, other agencies, Cooperative Institutes, and the external community fosters the net output of research for the general public. Outreach using web interface and communicative materials has helped maximize the promotion of scientific stewardship of climate related information.

**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 FY12, the primary scientist migrated the dated website to the new web interface content management system (CMS). The dated 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 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, 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 were co-created by the physical scientist for the distribution at meetings and conferences. 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 and in-person meetings 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. Research was completed to provide a new web conferencing tool that allows 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 and meetings
- Continue to develop communicative tools for outreach and education

**PUBLICATIONS**

N/A

**DELIVERABLES**

N/A

**PRESENTATIONS**

N/A

**OTHER** (e.g., awards; outreach; mentoring; advising)

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

New and improved products are described in the accomplishments section. Papers and graduate students are not applicable to the task.

## Interpretation of Real-Time Weather and Climate Data for Spherical Displays

| | |
|---|---|
| **Task Leader** | Stephanie Schollaert Uz |
| **Task Code** | EarthNow |
| **NOAA Sponsor** | Carrie MacDougall |
| **NOAA Office** | OED |
| **Contribution to CICS Themes (%)** | 0% |
| **Main CICS Research Topic** | Education, Outreach, and Literacy |
| **Contribution to NOAA Goals (%)** | Goal 1: 40%; Goal 2: 15%; Goal 3: 15%; Goal 4: 15%; Goal 5: 15% |

**Highlight**: We create videos about climate science topics distributed to the Science On a Sphere network: 100 museums and visitor's centers around the world. Working closely with the Maryland Science Center and other SOS sites, we evaluate the effectiveness of these stories with the general public and tailor our products to engage people with a variety of backgrounds on many levels.

### BACKGROUND

This report summarizes the year's progress on the informal education project funded by the NOAA Office of Education to interpret climate data for spherical displays. This project involves collaboration with the Cooperative Institute for Meteorological Satellite Studies in Wisconsin and the NOAA Environmental Visualization Lab to create content for the EarthNow blog and SOS network. We also partner with the Maryland Science Center to evaluate SOS content and conducted a case study on one of the EarthNow climate stories this year. In working closely with the Maryland Science Center and other museums to see how weather and climate stories are received by the SOS docents and the general public, we realized there is a need for short explanations of key concepts in Earth science. To address this, CICS-MD has launched ClimateBits, initial testing of which is promising and is leading to an additional partnership with NASA on this effort. Here we detail the accomplishments on this project at CICS-MD this year and then list planned work for next year.

### ACCOMPLISHMENTS

As we continue to develop and refine our method for informing the public about the latest findings in climate science through short videos displayed on Science On a Sphere as well as YouTube, we conducted a case study on what the public learned from one of our stories and had many opportunities to present our work at a variety of venues ranging from science meetings, educator workshops, and a briefing on Capitol Hill. The culmination of this year's efforts on the EarthNow project was the introduction of the new ClimateBits product led by CICS-MD. A chronological description of our accomplishments follows.

At the April 2013 NOAA Satellite Conference, we presented EarthNow within an invited talk on CICS outreach activities along with CICS-NC. Specifically, we highlighted EarthNow products as an example of how satellite data are being translated into useful messages for the general public and some ideas on how to addresses the challenges. At the NOAA STAR booth, we demonstrated EarthNow products on the Magic Planet spherical display, with a four-slide summary highlighting the project and our efforts to inform the public about current events in weather and climate.

A test of the effectiveness of various presentation methods of an EarthNow climate feature story was conducted at the Maryland Science Center (MSC). Four groups received the same information in different ways (live or auto-run SOS show, hands-on activity with SOS show, hands-on activity with no SOS show) and a control group did not hear the information. This test led to the conclusion that certain geoscience concepts can be more quickly and effectively learned with a spherical display. A summary of this case study has been accepted for publication in the peer-reviewed *Journal of Geoscience Education* special theme issue on outcomes from climate literacy efforts, with an anticipated publication date of August, 2014.

EarthNow was presented to more than 40 K-12 teachers from around the country attending the Smithsonian Science Education Academies for Teachers 2013 Biodiversity and Earth's History and Global Change workshops (Figure 1). Surveys of teachers indicated enthusiasm for using EarthNow stories to illustrate ecosystem changes and connections between ocean currents, atmospheric circulation and biodiversity, as well as climate-scale oscillations such as El Niño. The workshop organizers have asked us to participate again for their 2014 workshops.


*Figure 1: Schollaert Uz presenting an overview of the application of satellite data to biology for the Smithsonian Science Education Academy for Teachers Biodiversity Workshop. Additionally, she set up the Magic Planet in the back of the classroom so teachers could experience a spherical display.*

On July 11, Schollaert Uz briefed the U.S. House of Representatives Oceans Caucus on making NOAA data accessible to everyone through the use of spherical displays. This briefing was arranged in response to the president's proposed STEM realignment, which would have cut programs such as this project. Thankfully, our briefing appeared to have the desired effect and Congress did not support the proposed realignment.

For the 2nd annual CICS-MD Science Meeting in November, we shared our new effort on this project to address a need by museum docents and the general public to see and hear climate science concepts explained simply: ClimateBits (Figure 2). Museums can use these videos within an SOS show or anybody can use them online for background information, including links to more detailed information. An initial proof-of-concept video on Solar Radiation was tested on a variety of audiences (e.g. Maryland Science Center docents, K-12 teachers and students, Alliance for Climate Education team). Discussions with several museums about ClimateBits have been favorable: docents say they need such a tool. NASA likes this idea and is partnering with us to develop several.

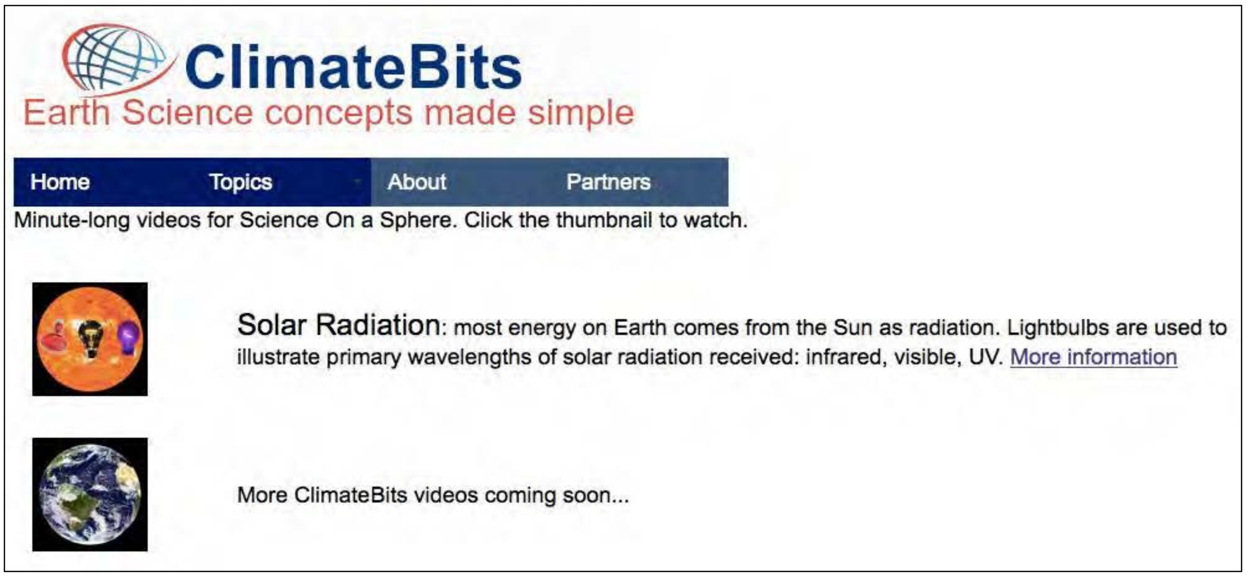



*Figure 2. ClimateBits website: http://climatebits.umd.edu launched 12-20-13, including an initial proof-of-concept video on Solar Radiation with more videos in development.*

In February, Schollaert Uz conducted training at the Bishop Museum, Honolulu, HI to learn how they use their sphere and show them interpreted products (EarthNow and ClimateBits). Although EarthNow products had automatically loaded to their SOS system, they had not noticed them before and were excited about updating their visitor-controlled kiosks to include these so visitors can select them. They also really like the idea of ClimateBits and said they will be helpful toward their effort to create 3rd-5th grade curriculum using the SOS, among other potential applications.

CICS-MD continued our support to the EarthNow project, including authoring three quarterly climate science feature stories on fracking, tropical widening, and El Nino's effect upon marine life around the Pacific. The fracking story received wide international praise for handling such a controversial issue in such a balanced and scientific way. One docent at MSC expressed concern that the story was not critical enough of wastewater disposal by fracking companies, which led to several beneficial discussions over e-mail and by phone. He later said that he was impressed with the level of research that went into creating the story and feels the story is accurate and a welcome addition to the MSC playlist, where it's been playing every hour since it was published. The other stories only received positive comments.

**PLANNED WORK**

- Continue to develop ClimateBits videos at CICS-MD and in partnership with others
- Work with climate communicators on the possibility of plugging ClimateBits videos into TV news (e.g. Zhou, Maibach, Gandy, Witte, Cullen, Klinger, Rowan, Witte and Pyle, 2014, Climate change education through TV weathercasts: results of a field experiment, BAMS).
- Work with Joe Witte to organize or attend TV weathercaster workshop to better understand how to collaborate with this community
- Present ClimateBits to the Climate Literacy and Energy Awareness Network (CLEAN) in a teleconference
- Increase outreach and collaboration on and off campus

**PUBLICATIONS**

C. W. Brown, S. Schollaert Uz, and B. H. Corliss, 2013: Seasonality of oceanic primary production and its interannual variability from 1998 to 2007, *Deep-Sea Research Part I* (submitted).

Schollaert Uz, S., C. W. Brown, A. Heidinger, T. Smyth, and R. Murtugudde, 2013: Detecting *Emiliania huxleyi* in 25 years of AVHRR imagery, in J. J. Qu, A. M. Powell, and M. V. K. Sivakumar (eds.), *Satellite Applications on Climate Change*. Springer, Dordrecht, pp. 277-288.

Schollaert Uz, S., W. Ackerman, J. O'Leary, B. Culbertson, P. Rowley, P.A. Arkin: The effectiveness of Science On a Sphere stories to improve climate literacy among the general public, *Journal of Geoscience Education*, (accepted).

**DELIVERABLES**

Authored EarthNow climate feature stories:

- Fracking: http://sphere.ssec.wisc.edu/20131024/
- Tropical Widening: http://sphere.ssec.wisc.edu/20130715/
- El Nino's impact on marine life around the Pacific: http://sphere.ssec.wisc.edu/20130315/

Created ClimateBits as a way to convey Earth science concepts to the general public on SOS:

- Established internet domain name; YouTube, Twitter and Facebook accounts;
- Located hardware to host site, designed, created and published website;
- Created initial ClimateBits video on Solar Radiation;
- Tested concept and received feedback from several audiences (Maryland Science Center and Bishop Museum docents, public school K-12 teachers and students, Alliance for Climate Education team);
- Established partnership with NASA on the development of ClimateBits videos, included in the 2014-2015 Aura Mission Education and Public Outreach Implementation Plan.

**PRESENTATIONS**

**Schollaert Uz, Stephanie**, 2013: Climate science education for the public using EarthNow, slideshow and demonstration on Magic Planet, *NOAA Satellite Conference*, College Park, MD (8-12 April).

**Dissen, Jenny, Stephanie Schollaert Uz**, Otis Brown, and Phil Arkin, 2013: Climate literacy and outreach using satellite data for the general public and the private sector: a CICS perspective, *NOAA Satellite Conference*, College Park, MD (8-12 April).

**Schollaert Uz, Stephanie**, 2013: Making NOAA data accessible to everyone, *U.S. Congressional House Oceans Caucus briefing on NOAA science transforming classrooms and communities*, Washington, DC (11 July).

**Schollaert Uz, Stephanie** and Phil Arkin, 2013: ClimateBits: Short, engaging videos on essential climate concepts, *2nd Annual CICS-MD Science Meeting*, College Park, MD (6-7 November), http://cicsmd.umd.edu/assets/1/7/8.3_Schollaert_Uz.pdf .

**Schollaert Uz, S.**, Busalacchi, A. J., Smith, T. M., Brown, C. W., Carton, J. A, 2014: Fifty years of statistically reconstructed chlorophyll patterns and their implications for higher trophic levels in the Tropical Pacific, *Ocean Sciences Meeting*, Honolulu, HI (February 23–28).

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