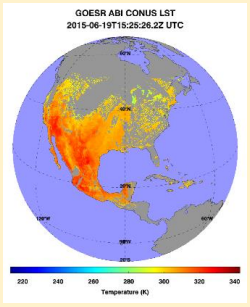
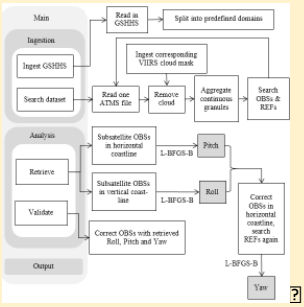




COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

Annual Scientific Report
VOLUME I: Activities Summary

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

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

Table of Contents

1 INTRODUCTION

This annual report of the Cooperative Institute for Climate and Satellites (CICS) is divided into three volumes. ***Volume I*** is a summary of all the activities of CICS including the administration and core tasks and the highlights of this year's scientific research and operational results, along with relevant appendices. ***Volume II*** (for CICS-MD) and ***Volume III*** (for CICS-NC) contain a compilation of reports on the over 100 individual CICS tasks that were undertaken this year for various National Oceanic and Atmospheric Administration (NOAA) funders, including the Center for Satellite Applications and Research (STAR); the National Centers for Environmental Information (NCEI); Office of Oceanic and Atmospheric Research (OAR); Climate Program Office (CPO); National Weather Service (NWS); and the Air Resources Laboratory (ARL). The acronyms in this report are compiled and defined in **Appendix 1**.

1.1 Background

The Cooperative Institute for Climate and Satellites (CICS) was formed in 2009 through a national consortium of academic, non-profit and community organizations, with leadership from the University of Maryland College Park (UMD) and North Carolina State University (NCSU) and principal locations in College Park, Maryland and Asheville, North Carolina. *The CICS Consortium* includes a wide range of research universities, non-profit organizations, and community groups. Its role is to augment the capabilities of CICS and to extend its ability to conduct innovative and original collaborative research with NOAA. CICS' cooperative agreement with NOAA was renewed for an additional five years in 2014.

CICS is administered as part of the NOAA/NESDIS/STAR Cooperative Research Program Institutes and was the first experiment by NOAA and academic institutions to engage a geographically dispersed, diverse set of more than 30 partner institutions across the United States to address environmental change, their prediction, and potential impacts.

Each of CICS' principal centers is collocated with or adjacent to its main NOAA partner**:** ***CICS-MD*** is adjacent to the NOAA Center for Weather and Climate Prediction (NCWCP). ***CICS-NC*** is collocated with the NCEI in Asheville, NC; CICS-NC is an Inter-Institutional Research Center with the UNC System, where it is known as the North Carolina Institute for Climate Studies. The physical proximity at both locations greatly facilitates extensive and productive collaboration between CICS and NOAA scientists.

The range of expertise needed to support NOAA is broad and varied. It ranges from basic and applied research on the natural climate system, through study of the coupling of the Earth system to societal responses, social science and policy research, to stakeholder engagement and communication with the general public. It is clear that no one institution or even a small number of institutions can provide all the necessary expertise. Thus CICS was implemented as a consortium of partners with expertise covering the breadth of NOAA's portfolio.

The CICS Consortium was developed to address the wide breadth of challenges associated with moving climate science research into a federal operational context for NOAA's NESDIS. Institutions were selected for demonstrated capabilities in climate research with a focus on observations, modeling and impacts. That is, institutions include both natural and social science expertise.

The current CICS Consortium membership consists of the University of Maryland College Park (UMD), the Joint Global Change Research Institute collocated with UMD, the University of North Carolina System (16 campuses, including NC State University), Land Surface Hydrology Group at Princeton University, Center for Hydrometeorology & Remote Sensing at University of California Irvine, the Climate and Radiation Group at Howard University, Columbia University/IRI, Institute for Global Environmental Strategies (IGES), City University of New York (CREST), University of Illinois at Urbana-Champaign, Oregon State University (CIOSS), University of Miami (RSMAS & CIMAS), University of Michigan, University of South Carolina (CISA & HVRI), the Barros Research Group at Duke University, Colorado State University, Remote Sensing Systems, Climate Central, North Carolina Arboretum, Centers for Environmental and Climatic Interaction, Renaissance Computing Institute (RENCI), Oak Ridge Associated Universities (ORAU), and, Oak Ridge National Laboratory (ORNL).

Due to the geographic and institutional diversity of the Consortium, maintaining institutional interest in it and coherence across it is challenging. Consortium coherence is fostered by annual meetings and site visits by the CICS Executive Director, while ongoing interactions associated with funded research and development activities, as well as proposed collaborations for competitive awards, help maintain institutional and principal investigator interest.

Consortium membership is driven by stated federal needs to CICS. As needs are communicated to CICS, Consortium members' expertise is reviewed to ascertain whether the need can be addressed internally. If not, then a broader search is initiated to find an institution with the required expertise through a competitive process. Once an institution with the appropriate expertise has been identified, it is invited to join the Consortium and author a task proposal to the federal partner for review and support through the cooperative agreement.

Federally funded Consortium activities are supported through the CICS Cooperative Agreement via a series of subcontracts between the University of Maryland and North Carolina State University and specific Consortium members, with UMD or NCSU taking the lead dependent on the specific collaboration.

CICS is arguably unique among NOAA Cooperative Institutes in its distributed configuration. The initial membership of the Consortium was chosen to ensure a broad spectrum of expertise and experience appropriate to the proposed institute vision. Since CICS was

established, some evolution in membership has occurred. A few of the initial members have found other methods to collaborate with NOAA, while others have been unable to identify a suitable niche. During the same period, several new partners have joined, extending the reach and capability of the Consortium.

The CICS Consortium provides NOAA with extraordinary opportunity to engage the extrafederal scientific and user communities on research, development, and outreach issues. It is a remarkably broad and flexible mechanism that enables NOAA to benefit from the collective capabilities of its members.

1.2 CICS Vision and Mission

CICS' vision and mission derive from the historical expertise of the lead institutions and partners that comprise the CICS Consortium, together with NOAA's requirements. The CICS vision and mission are closely tied to NOAA's Strategic Goals.

VISION

CICS' vision is to perform collaborative research aimed at enhancing NOAA's ability to use satellite and in situ observations and Earth System models to advance the national climate mission, including monitoring, understanding, predicting, and communicating information on climate variability and change.

MISSION

CICS' mission is to conduct research, education, and outreach programs in collaboration with NOAA to:

- Develop innovative applications of national and international satellite observations and advance transfer of such applications to enhance NOAA operational activities;
- Investigate observations and design information products and applications to detect, monitor, and understand the impact of climate variability and change on coastal and oceanic ecosystems;
- Identify and satisfy the climate needs of users of NOAA climate information products, including atmospheric and oceanic reanalysis efforts;
- Improve climate forecasts on scales from regional to global through the use of observation-derived information products, particularly through participation in the Climate Test Bed at the National Centers for Environmental Prediction (NCEP);
- Develop and advance regional ecosystem models, particularly aimed at the Mid-Atlantic region, to predict the impact of climate variability and change on such ecosystems; and
- Establish and deliver effective and innovative strategies for articulating, communicating, and evaluating research results and reliable climate change information to targeted public audiences.

The Research Themes for CICS are:

- **Theme 1: Climate and Satellite Research and Applications** incorporates the development of new observing systems, or new climate observables from current systems.
- **Theme 2: Climate and Satellite Observations and Monitoring,** focuses on: (a) development and improvement of climate observables from current systems, and (b) development of all continental and global fields of climate parameters that can be used for climate analysis and climate model initialization.
- **Theme 3: Climate Research and Modeling is** the research component that brings together (a) climate observables, modeling and validation in a comprehensive integrated whole, and (b) observational products with model development efforts to enable research into the improvement of forecasts of climate system variability on space scales ranging from regional to global, and time scales from a week or two to centuries.

Research is conducted through in situ and remotely sensed observations, together with component and coupled ocean-atmosphere-land modeling. This multi-pronged approach provides a foundation for understanding and forecasting changes in the global environment and regional implications. Data assimilation and regional downscaling are used to link the observations and models, enabling us to study the interactions between the physical climate system and biogeochemical cycles from global to regional scales.

The CICS Themes are unchanged from the original submitted proposal. As CICS research has evolved since 2009 in response to NOAA's needs, Topic Areas have been identified as useful organizing devices. **Figure 1** illustrates the relationship between the Themes and the Topic Areas. In **Figure 2,** we summarize graphically the stratification of active task funding by CICS Research Theme and by NOAA Strategic Goal.

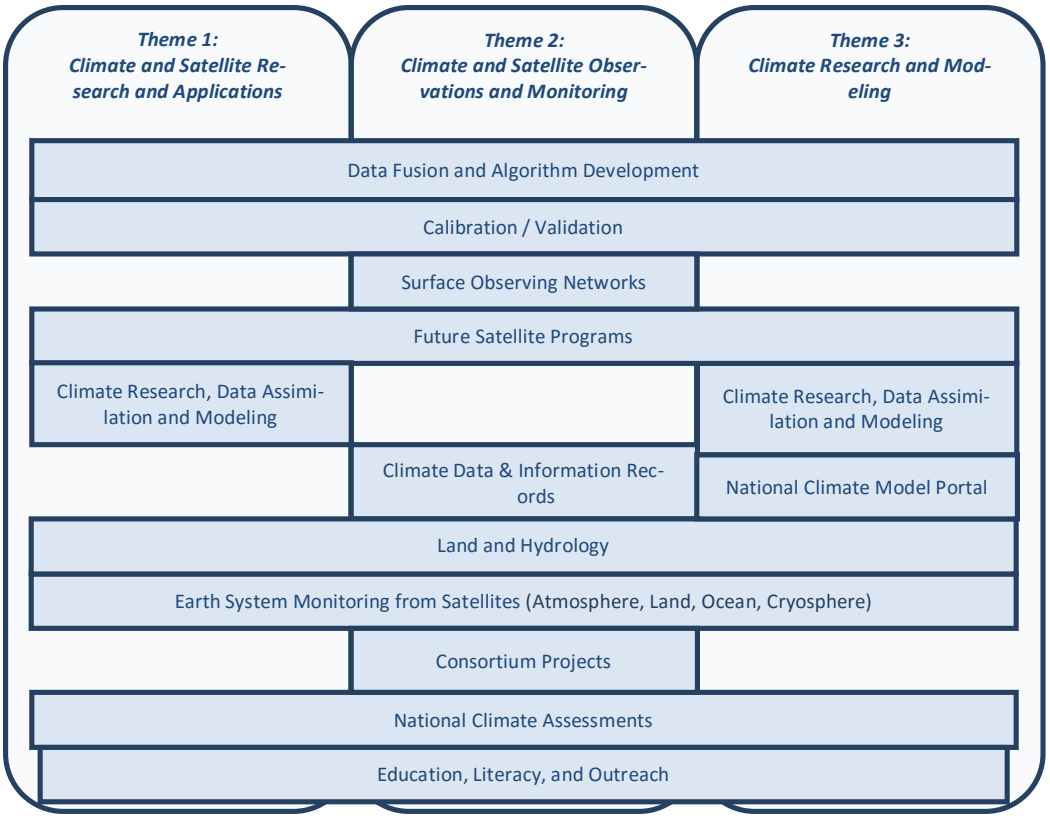
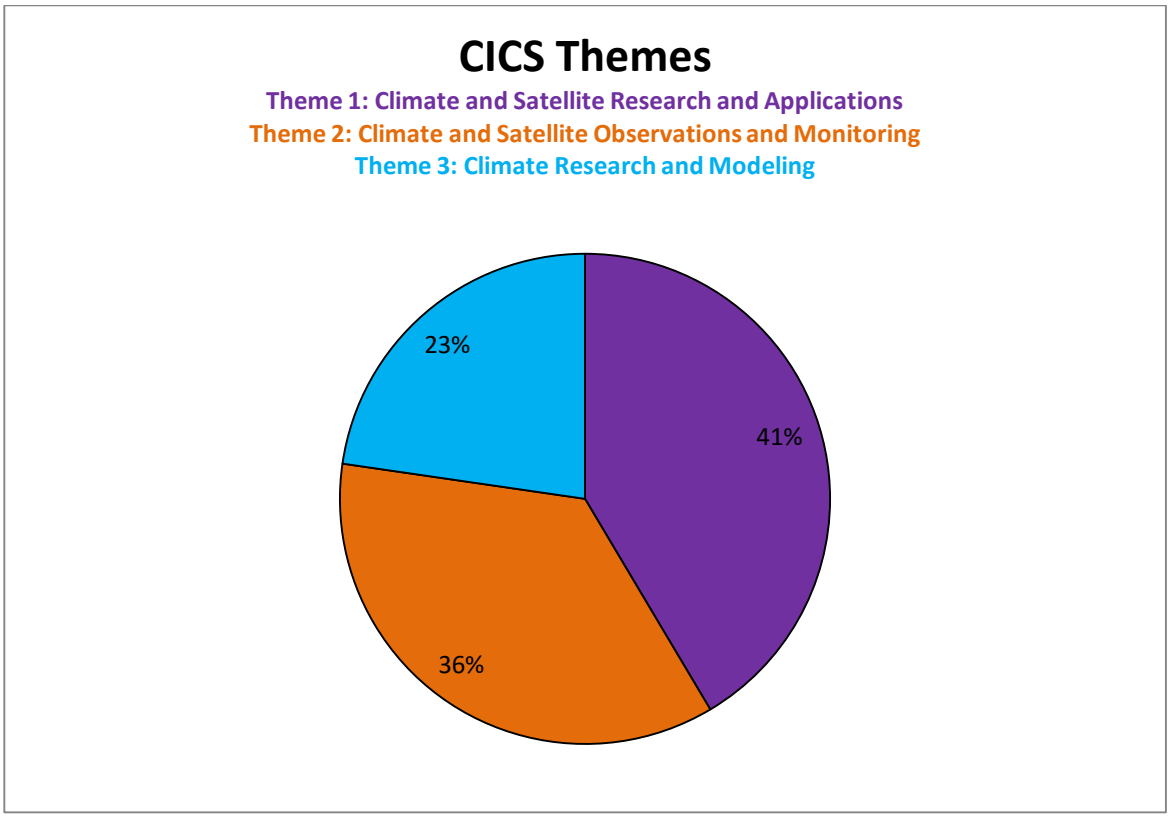


***Figure 1**: CICS Research Themes and Topic Areas*



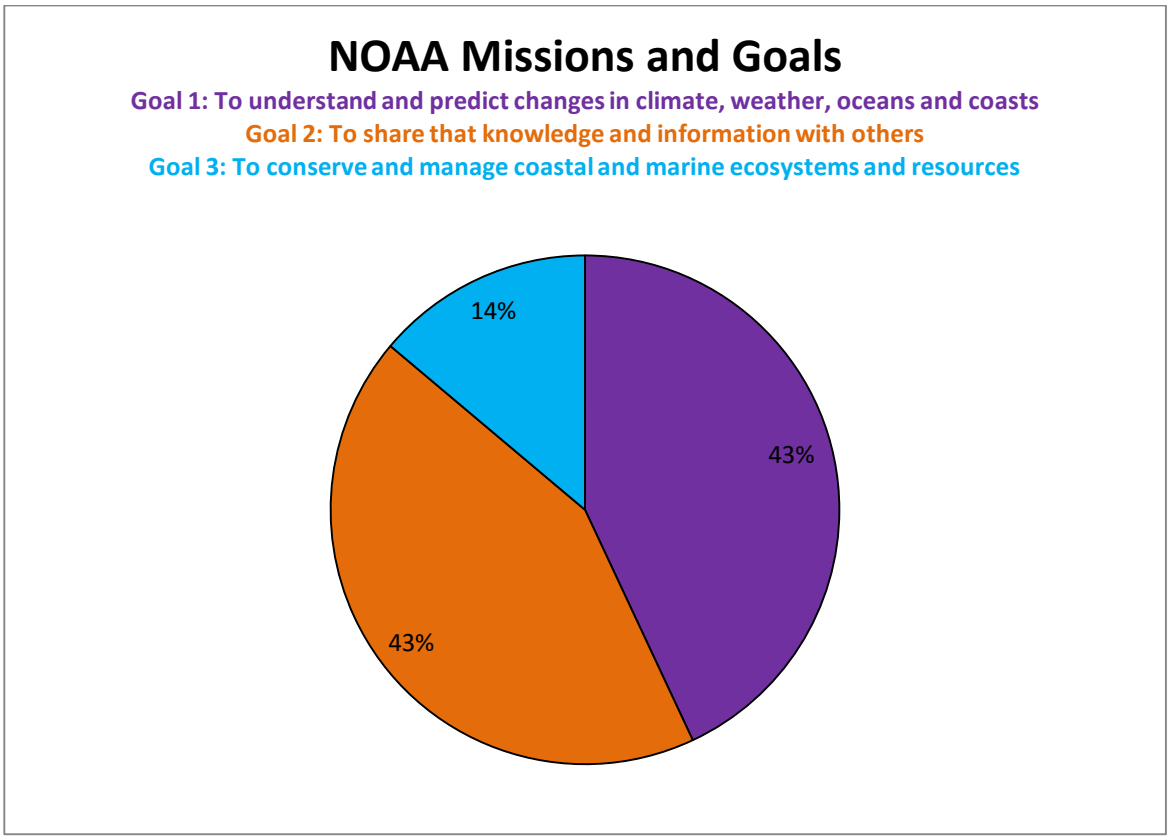


Figure 2: *Distribution of CICS funding during the reporting period.*

1.3 CICS-MD

CICS-MD is based upon the model and experience gained by UMD through its management of the Cooperative Institute for Climate Studies in collaboration with NOAA beginning in 1984. ***CICS-MD focuses on the collaborative research in satellite observations and Earth System modeling conducted by STAR, which is part of the NOAA National Environmental Satellite, Data and Information Service (NESDIS) and NOAA/NWS/NCEP.*** During the first several years of the award, CICS-MD has initiated additional collaborations with other NOAA units in the Washington, DC area, including NCEI and ARL.

CICS-MD's host organization is the Earth System Science Interdisciplinary Center (ESSIC), which is a joint center in the College of Computer, Mathematical, and Natural Sciences (CMNS) between the University of Maryland Departments of Atmospheric & Oceanic Science, Geology, and Geography, and the Earth Sciences Directorate at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC). ESSIC seeks to understand better how the atmosphere-ocean-land-biosphere components of Earth interact as a coupled system and how human activities influence this system through re-search that concentrates on four major areas: climate variability and change; atmospheric composition and processes; the global carbon cycle (including terrestrial and marine ecosystems/land use/cover change); and the global water cycle. ESSIC has fiduciary responsibility for CICS, provides the large majority of CICS-MD space, and hires and employs the majority of CICS-MD scientists and support staff. ESSIC has a cooperative agreement with NASA/GSFC that is in many respects similar to CICS.

Since CICS-MD includes UMD faculty, staff and students from several units, we have found it helpful to define CICS-MD members as faculty members who serve Task Leaders of a CICS task, individuals paid by a CICS task, and students and non-faculty employees who have been paid from a CICS task. The Satellite Climate Studies Branch (SCSB) of NESDIS/STAR is collocated with CICS-MD in ESSIC, and so we also include the federal employees in the SCSB as CICS-MD members.

1.4 CICS-NC

CICS-NC is an Inter-Institutional Research Center (IRC) of the UNC System, referred to as North Carolina Institute for Climate Studies (NCICS). It is administered by North Carolina State University (NCSU) and affiliated with all of the UNC academic institutions as well as a number of other academic and community partners. ***CICS-NC focuses primarily on the collaborative research into the use of in situ and remotely sensed observations in climate research and applications that is led by the National Climatic Data Center of NOAA/NESDIS.*** CICS-NC also is engaged in productive collaborative research with other NOAA elements, including the ARL Atmospheric Turbulence and Diffusion Division (ATDD). CICS-NC includes numerous partners from academic institutions with specific expertise in utilizing satellite observations in climate research, applications, and models.

1.5 CICS Consortium

The CICS Consortium includes a wide range of research universities, non-profit organizations, and community groups. Its role is to augment the capabilities of CICS and to extend its ability to conduct innovative and original collaborative research with NOAA. The CICS Consortium includes CICS-MD and CICS-NC. **Figure 3** shows geographic distribution of the current consortium partners (red diamonds are the principal nexuses. Black diamonds indicated CICS Consortium partners, and blue diamonds indicate the other NESDIS Cooperative Institutes).

CICS is arguably unique among NOAA Cooperative Institutes in its distributed configuration. The initial membership of the Consortium was chosen to ensure a broad spectrum of expertise and experience appropriate to the proposed institute vision. Since CICS was established in 2009, some evolution in membership has occurred. A few of the initial members have found other methods to collaborate with NOAA, while others have been unable to identify a suitable niche. During the same period, several new partners have joined, extending the reach and capability of the Consortium.

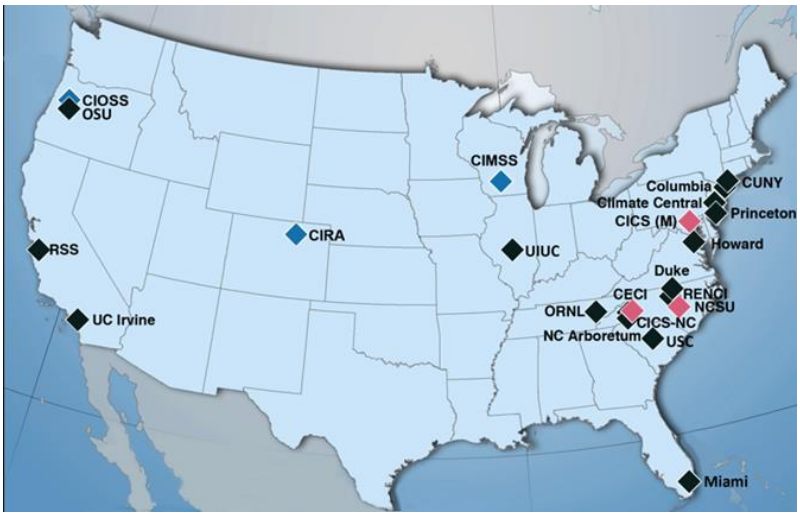


***Figure 3**: Spatial distribution of CICS Consortium institutions.*

The CICS Consortium provides NOAA with extraordinary opportunity to engage the extra-federal scientific and user communities on research, development, and outreach issues. It is a remarkably broad and flexible mechanism that enables NOAA to benefit from the collective wisdom and capability of its members.

1.6 Governance

A Memorandum of Agreement (MOA) governing CICS organization and operation was concluded between UMD and NOAA in 2011. The MOA describes the configuration and governance of CICS, and summarizes the functions of its several elements. The two prin-

cipal anchors, CICS-MD and CICS-NC, are described, and the initial membership of the Consortium is defined. This MOA will expire at the end of the initial 5-year term of CICS.

The CICS Executive Board comprises senior officials representing UMD, NCSU/UNC System, and NOAA and provides advice and direction to CICS leadership on strategic and executive issues. The CICS Council of Fellows is the primary planning and consultative body for CICS and provides scientific advice to the Directors. Council members are drawn from CICS task leaders, NOAA collaborating scientists, and other eminent scientists from CICS partners and Consortium members. The Executive Board current members are:

For UMD

- Dr. Patrick O'Shea - Vice President for Research
- Dr. Jayanth Banavar - Dean, College of Computational, Mathematical and Natural Sciences
- Prof. Antonio Busalacchi - Director, ESSIC

For NCSU/UNC System

- Dr. Mladen Vouk – Interim Vice Chancellor, Research, Innovation and Economic Development, NCSU
- Prof. Emeritus Ray Fornes - Professor of Physics, College of Physical and Mathematical Sciences, NCSU
- Dr. Chris Brown - Vice President for Research and Graduate Education, UNC

For NOAA

- Dr. Michael Kalb, Acting Director, NESDIS Center for Satellite Research and Applications (STAR)
- Dr. William Lapenta, Director, NWS/NCEP
- Dr. Michael Tanner, Director, NOAA Center for Weather and Climate (NCEI)
- Dr. Richard Artz/Dr. Bruce Baker OAR Air Resources Laboratory
- Dr. Margarita Gregg, NCEI Deputy Director

2 HIGHLIGHTS OF THIS YEAR'S RESEARCH

2.1 Summary of Achievements

This year we added new metrics to reflect the involvement of CICS in the development of research products, including those submitted to NOAA for consideration of their use in operations. Our efforts to communicate our scientific discoveries and technological innovations to other scientists are measured by publications and presentations. CICS also continues to train the next generation of NOAA scientists.

CICS CUMULATIVE PERFORMANCE METRICS

Performance Metrics 2015 (2014)	
# of new or improved products developed	**207 (231)**
# of products or techniques submitted to NOAA for consideration in operations use	**93 (110)**
# of peer reviewed papers	**201 (145)**
# of non-peered reviewed papers	**51 (46)**
# of invited presentations	**312 (250)**
# of graduate students supported by a CICS task	**20 (15)**
# of graduate students formally advised	**43 (25)**
# of undergraduate students mentored during the year	**44 (47)**

These metrics are an attempt to quantify the annual accomplishments of CICS. This table is a sum of the performance metrics reported by individual task leaders at CICS consortium member institutions. Performance metrics broken out for CICS-MD and CICS-NC and other consortium members are included in Appendix 2 of this report.

2.2 Research Highlights

In the following sections we summarize the research highlights from the past twelve months of this Cooperative Agreement. Details of each of the research activities highlighted below are presented in Volume 2 of this report.

a. CICS-MD

These highlights for CICS-MD are segmented according to topic and NOAA partner. Funders from NESDIS include STAR, NCEI, OSD (Office of Systems Development), GOESPO (GOES-R Program Office), JPSSO (JPSS Office), The NOAA Ice Center (NIC), the Office of

Satellite Ground Services (OSGS) the Joint Center for Satellite Data Assimilation (JCSDA) and the National Ocean Service (NOS). Other NOAA funders include ARL, CPO, CPC (Climate Predictions Center), and NWS.

Data Fusion & Algorithm Development

Monitoring and Day-2 Algorithms of AMSR2 EDRs: AMSR2 Environmental Data Records completed their initial evaluation and were declared operational by NESDIS. [**STAR**]

***Near Real-Time Precipitation Using Lightning*:** Applications of lightning data for precipitation remote sensing are being expanded at the CICS-MD Proving Ground and Training Center. [**STAR**]

JPSS Microwave Integrated Retrieval System (MiRS) Calibration and Validation: Delivery of updated MiRS Version 11.1 to NOAA operations for all NOAA operational microwave satellites/sensors. V11.1 includes numerous changes leading to significantly improved retrievals of atmospheric tem-perature, water vapor, land surface temperature, and hydrometeors. [**STAR**]

***Developing and Refining Microwave Integrated Retrieval System (MiRS) High Resolution Snow/Ice Products*:** Addition of snow grain size as preliminary operational product. Sea ice age (first year and multiyear ice) has been added as an operational product. Validation of both snow water equivalent and snow grain size performed by comparison with several reference data sets for a 6-month period in winter 2012-2013 season. All operational products generated at high-resolution. [**STAR**]

Validation of Operational AMSR2 SSTs: A third version of the GAASP AMSR-2 SST product, utilizing a different algorithm, has been evaluated and significant algorithm artifacts were identified. Further advice was passed back to the GAASP development team to inform their enhancements to the Day-1 SST algorithm. Validation has been redone for a 4th version of the product and results are now much improved. [**STAR**]

***Incorporation of Himawari-8 SST into 5-km Blended SST Analysis*:** The experimental version of the ACSPO Himawari-8 SST product has been successfully incorporated into the Geo-Polar Blended SST analysis. The Himawari-8 data are higher resolution and less noisy than those from the previous generation MTSAT-2 Imager. The results are encouraging for the prospect of including data from the upcoming GOES-R and, in the future, Meteosat Third Generation. [**STAR**]

***Development of Global Soil Moisture Product System (SMOPS)*:** CICS-MD Scientist Christopher Hain and his team have finished ingesting ASCAT soil moisture data from MetOp-B into SMOPS and the new SMOPS version (V1.20) has been operationally running since July, 2015 at OSPO. They have finished upgrading SMOPS to Version 2.0 that includes GCOM-W1 AMSR2 L2 orbital soil moisture retrievals and SMOS NRT soil mois-

ture retrievals. The code has been delivered to OSPO and the operational system is expected to be updated in Aprial, 2016. [**STAR**]

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

GCOM-W1 Soil Moisture Product Development and Validation: CICS-MD Scientist Jicheng Liu and his team have finished the development of GCOM-W1 AMSR2 soil moisture EDR product algorithm. The science code of the algorithm has been completed and delivered to GCOM-W1 team at NO-AA/NESDIS/STAR. The code is now operationally running there. A re-run of the production code has been done over the whole AMSR2 data period using the most recent version of brightness temperature inputs. This historical data set will be used for the validation work using the in-situ measurements. This product has been ingested into SMOPS Version 2.0. [**STAR**]

Calibration/Validation

Scientific Exchange Between DLR/Berlin and NESDIS/STAR Fire Scientists Using the German FireBird Small Satellite Constellation in Support of GOES-R/ABI and Suomi NPP/VIIRS Fire Product Validation: Through this collaborative work, the satellite retrieval of gas flares can be improved. This work is necessary for next generation NESDIS satellite architecture, pointing to the need for a constellation of "smallsats" to get the same VIIRS coverage in the future. [**STAR**]

Scientific Support for Joint Polar Satellite System (JPSS) CrIS, VIIRS and OMPS Calibration: CICS-MD Scientist Yong Chen continues work to improve the calibration algorithms, including optimization of the calibration equation, implement ringing artifact reduction algorithm updates into FSR-ADL software, further assess the spectral and radiometric accuracies of the SDR product from the FSR processing system, and analyze JPSS-1 pre-launch test data and derive parameters for CrIS spectral and radiometric calibration. [**STAR**]

The Ozone Mapping and Profiler Suite (OMPS) Sensor Data Record (SDR) Calibration and Validation**:** CICS-MD Scientist Chunhui Pan developed new comprehensive data analysis algorithms and models to evaluate and characterize sensor orbital stray light contamination, wavelength calibration and optical system stabil-ity. Numbers of milestone deliveries have been made to STAR, including sensor performance as-sessment, software tools, and weekly delivery of dark calibration tables. Four journal papers have been published in 2014. [**STAR**]

Scientific Support for JPSS CrIS and VIIRS Calibration*:* CICS-MD Scientist Likun Wang evaluates radiometric, spectral, and geometric calibration accuracy of Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR) on Suomi NPP satellite, improves the data

quality, and support operational use of numerical weather predication (NWP) data assimilation and Environmental Data Record (EDR) Team. [**STAR**]

Scientific Support for VIIRS Calibration: CICS-MD Scientist Slawomir Blonski presented the results of the VIIRS reflective solar bands radiometric calibration reprocessing at a major scientific conference and in a peer-reviewed publication. [**STAR**]

Science and Management Support for NPP VIIRS Snow EDR**:** We have maintained the S-NPP VIIRS Operational Binary and Fractional Snow Cover Algorithm at the NOAA IDPS. Intensive calibration and validation of both snow products has been conducted. It has been determined that the accuracy of the binary snow products satisfies the mission requirements. Both products are available to the users through NOAA CLASS. Two new snow fraction algorithms have been developed and tested in a quasi-operational mode. Both new snow fraction algorithms have been prepared for implementation within NOAA NDE system. [**JPPSO**]

NPP/VIIRS Land Surface Albedo Validation Research and Algorithm Refinement**:** We have completed a round of comprehensive evaluation of VIIRS albedo using both field measurements and high resolution albedo reference maps. We have updated the LUT to account for desert aerosol. We are developing a new daily gridded product of VIIRS albedo. [**STAR**]

GEOG Task 3 NPP/VIIRS Land Product Validation Research and Algorithm Refinement*: Science and Management Support for NPP VIIRS Surface Type EDR*: CICS-MD Scientist Chengquan Huang and his team developed a new global surface type classification map based on 2014 VIIRS data. [**JPPSO**]

Satellite Calibration and Validation (Cal/Val) efforts for STAR Precipitation Products**:** Daily and seasonal validation of satellite precipitation estimates continued, and a manuscript titled "Seasonal and Regional Validation of Operational Satellite Precipitation Estimates" was published in the *Journal of Operational Meteorology*. [**STAR**]

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

Continued Expansion, Enhancement and Evolution of the NESDIS Snowfall Rate Product to Support Weather Forecasting: The ATMS SFR algorithm was improved based on better MRMS radar data; A new satellite and radar merged product has been produced by a real-time system. [**STAR**]

Transition and Enhancement of ATMS Snowfall Rate Product and its Fusion with Weather Radar Data**:** The ATMS SFR algorithm was improved based on better MRMS radar data; A new satellite and radar merged product has been produced by a real-time system; SFR product assessment at NWS Weather Forecast Offices. [**STAR**]

Development of the Satellite Sea-Surface Salinity Quality Monitor System**:** We are developing the Satellite Sea Surface Salinity Quality Monitor (4SQM) system. In this system, satellite data will be monitored for self- and cross-platform consistency, as well as consistency with *in situ* data. [**STAR**]

GEOG Task 10: GOES-R Active Fire/Hot Spot Characterization: Validation and Refinement of GOES-R/ABI Fire Detection Capabilities: This task describes the GOES-R/ABI deep-dive active fire validation tool. USGS/Landsat-8 reference fire data set was published in 2015, alternative ESA/Sentinel-2 reference fire data test being developed. [**STAR**]

Lunar and Stellar Calibration for GOES-R Advanced Baseline Imager (ABI) in support of the Calibration Working Group**:** CICS scientists support Calibration and Validation work for GOES-R Advanced Baseline Imager (ABI) instrument through lunar calibration, stellar calibration, and Imagery Navigation and Registration (INR) of GOES-R ABI. [**STAR**]

J1-VIIRS and SNPP-VIIRS Calibration Support: CICS scientists provide prelaunch science support for JPSS-1 (J1) VIIRS instrument through support J1-VIIRS SDR look-up-tables (LUTs) preparation/testing/validation, analysis of J1-VIIRS DNB scan mode change due to DNB nonlinearity and support J1-VIIRS TEB band calibration/calibration. [**STAR**]

Support of SNPP VIIRS SDR Calibration and Team Management/Coordination**:** CICS scientists provides operational science support for Suomi-NPP VIIRS instrument through support radiometric calibration of VIIRS reflective solar bands by trending with lunar band ratio, vicarious methods and developing physics-based model of spectral dependent degradation of VIIRS solar diffuser; perform DNB stray light correction assessment with DNB observation under moon-light; support DNB radiometric and geolocation validation with nightlight sources and support VIIRS SDR team management and coordination. [**STAR**]

GOES-R Near-Surface Unmanned Aircraft System (UAS) Feasibility Demonstration Study: CICS scientists provide science, engineering and testing support for GOES-R near-surface Unmanned Aircraft System (UAS) feasibility demonstration study. In particular, this project supports GOES-R near-surface UAS design, performs hardware procurement for the prototype UASs, and supports the integration, initial testing and field campaign planning of GOES-R UAS. [**STAR**]

VIIRS Operational Calibration Science Support and JPSS-1 Prelaunch Test Data Analysis: CICS scientists provides operational science support for S-NPP VIIRS instrument through support on-orbit calibration of VIIRS using the onboard solar diffuser (SD), lunar observations and vicarious methods, as well as inter-comparisons with instruments on other satellite using SNOs, support DNB stray light correction software development, and support the prelaunch test data analysis of VIIRS on JPSS-1. [**STAR**]

Surface Observation Networks

Long-Term Changes in Cloudiness from Surface Observations*:* Cloud cover in four state-of-the-art global reanalysis products is compared with a homogeneity-adjusted dataset of total cloud cover from ground observations over the US. The reanalysis products generally capture in simulating the main characteristics of inter-annual variability of cloud cover for long-term means. However, the reanalysis products show lower cloud cover than visual weather station data and this underestimation causes to be overestimated in downward surface shortwave fluxes when compared with the Surface Radiation Network. In addition, the discrepancies in magnitudes of cloud cover trends are seen between the reanalysis products and weather station data. [**ARL**]

Future Satellite Programs

Year 5 GOES-R/JPSS Visiting Scientist Program: A CICS visiting scientist (VS) has lead the GOES-R and JPSS Proving Ground activities at the NOAA Center for Weather and Climate Prediction and the Tropical Analysis Branch of the National Hurricane Center since May 2011. These proving grounds allow forecasters and researchers the opportunity to evaluate new satellite technologies in every day operations.[**GOESPO**/**JPSSO**]

Facilitating Direct CICS Support for Satellite Proving Ground Efforts & Supporting Prob-Severe Developmen*t*: Following nearly three years of effort, a NOAAPORT Satellite Broadcast Network (SBN) antenna, receiver, and server have been installed at CICS-MD. The NOAAPORT will provide nearly identical feeds to those received at National Weather Service (NWS) offices, allowing CICS-MD to simulate operational environments for the first time. [**GOESPO**/**JPSSO**]

Scientific Support for the GOES-R Mission

GOES Evapotranspiration (ET) and Drought Product System (GET-D)**:** CICS-MD Scientist Christopher Hain and his team developed an operational evapotranspiration and drought monitoring system using GOES Land Surface Temperature product, meteorological data and other ancillary satellite remote sensing data. The GET-D product has been operational at NOAA OSPO. [**STAR**]

ATMS Derived Snowfall Rates to Support Weather Forecasting: ATMS snowfall detection and snowfall rate algorithms have been extensively evaluated using high quality in-situ and radar data. [**STAR**]

***Washington D.C. Lightning Mapping Array Maintenance and Outreach & Real-time Monitoring of Light-ning Detection Network Performance*:** Several recent projects have helped improve the visibility of the DCLMA and demonstrate its value for severe weather analysis and public outreach. [**STAR**]

***UAH GOES-R GLM Lightning Jump Algorithm: A National Field Test for Operational Readiness*:** Lightning Jump Algorithm tested at Hazardous Weather Testbed (HWT) in Spring 2015 across CONUS and will again shortly in Spring 2016. [**STAR**]

***Development of Algorithms for Shortwave Radiation Budget from GOES-R*:** CICS-MD Scientist Rachel Pinker and her team have developed and tested narrow-to-broadband transformation coefficients based on simulated ABI data in preparation for actual ABI observations. [**GOESPO**]

Scientific Support for the JPSS Mission

Analysis of an Observing System Experiment for the Joint Polar Satellite System: An Observing System Experiment was conducted to measure the impact of withdrawing data from the PM-orbit on global forecast skill; unique statistical processing reveals some quantitative impacts on risk assessment. **[NWS]**

Next-Generation Global Prediction System (NGGPS) Planning: The NGGPS planning involves strategic issues for model and data assimilation development and an explicit community-based plan for advanced physical (scale-aware) parameterizations with improved coupling of physical processes across radiation, boundary layer, deep and shallow convection and surface fluxes. This project contributes to planning for the next-generation physics package(s) and the next-generation coupled data assimilation system and forecast model. **[NWS]**

***NESDIS STAR Science Enterprise Support for Satellite Programs and JPSS Ground Project Transition Plan*:** CICS-MD Scientist Nai-Yu Wang is developing a JPSS risk reduction precipitation estimation algorithm for ATMS. **[STAR]**

***CUNY Development of Neural Network algorithms for retrieval of chlorophyll-a in the Chesapeake Bay and other coastal waters based on JPSS-VIIRS bands*:** Several multi band algorithms for retrieval of chl-a which include 745nm band on the JPSS/VIIRS sensor are explored demonstrating very good performance on the field and satellite data for the Chesapeake Bay and potentially other coastal waters, additional tests are currently planned at NOAA with the goal to make these algorithms operational. **[JPSSO]**

***OSU JPSS Data Products & Algorithms: Validation of VIIRS Ocean Color products for the coastal and open ocean*:** CICS Consortium Member OSU led by Task Leader Curtiss Davis developed a new procedure for above water reflectance measurements and validated it against HyperPRO data and Platform Eureka SeaPRISM data. We participated in the JPSS Ocean Color Validation Cruise in December 2015 further validating our remote

sensing reflectance measurement methods. We are analyzing a two year time series of VIIRS data for the Southern California Bight using Platform Eureka SeaPRISM for validation. **[JPSSO]**

GEOG Task 4: NPP/VIIRS Land Product Validation Research and Algorithm Refinement*: Active Fire Application Related Product*: This task supports the operational implementation of the Suomi-NPP/VIIRS Active Fire algorithm at NOAA. The input SDR data are routinely monitored, and reactive fire algorithm maintenance implemented in order to ensure highest product quality. Science algorithm updates are also ported into the operational system. Additional programmatic tasks (e.g., product maturity assessment/review) and algorithm/user guide documentation are regularly addressed. **[JPSSO]**

Validation of Cryospheric EDRs GCOM AMSR2**:** A suite of AMSR2 operational algorithms for the retrieval of snow cover, snow depth and Snow Water Equivalent has been developed and transitioned to operations. **[STAR]**

*I****mprovement of Cloud Ice Microphysics for ATMS Snowfall Rate Retrievals*****:** The ATMS SFR algorithm has been modified to generate product using non-spherical ice particle shapes. A method has also been developed that determines which ice shape to use based on weather conditions. **[STAR]**

Science and Management Support for S-NPP VIIRS Aerosol Optical Thickness (AOT), Aerosol Particle Size Parameter (APSP), and Suspended Matter (SM)**:** We have maintained and improved the S-NPP VIIRS Operational Aerosol Algorithm on the NOAA IDPS, conducted intensive Calibration and Validation of the VIIRS Aerosol Products, and provided the validated Products of daily global aerosol observations to user communities to support research and operational activities in weather, climate, and air quality. **[OSGS]**

Development and Implementations of Marine Isoprene Emission Product using Multiple JPSS Ocean Products to Support NAQFC Operations**:** 1) CICS scientists generated high-quality emission products to support day-to-day operations of NOAA O3 and PM2.5 real-time forecast; 2) CICS scientists have successfully developed a new satellite product of marine isoprene; 3) New projects launched to use fused satellite and ground observations to rapidly update anthropogenic emissions; 4) CICS and NOAA released new isoprene products to "early adopter" users. **[ARL/JPSSO]**

CUNY Validation of JPSS-VIIRS Data on Long Island Sound Coastal Site**:** The Project has continued to provide a consistent stream of data from the SeaPRISM instrument on the Long Island Sound Coastal Observatory (LISCO) to NASA – AERONET. This quality assured in-situ OC data stream permitted evaluation of the quality of VIIRS retrieved OC products for coastal waters conditions, statistical analysis of VIIRS, MODIS and AERONET-OC data, and the impacts of the different processing schemes NASA and NOAA MSL12. Possible applications of AERONET-OC data combined with RT simulations for the validation of the Sensor Data Records (SDRs) are considered. [**STAR**]

Scientific Support for Satellite Instrument Calibration and Application: Remote Sensing of Optically Thin Clouds from SNPP CrIS Data at Double CO2 Bands. [**STAR**]

Climate Research, Data Assimilation and Modeling

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

***CICS Support for NOAA's Climate Prediction Center*:** CICS-MD Scientist Li-Chuan Chen validated ENSO precipitation and temperature forecasts in the North American Multi-Model Ensemble (NMME) and found discrepancies between the model temperature composites and the observed. **[CPC]**

***Advances and Operational Implementation of Proactive QC (PQC) and Ensemble Forecast Sensitivity to R (EFSR) in the Atmosphere and the Ocean*:** CICS-MD Scientists Eugenia Kalnay and Tse-Chun Chen showed that Proactive Quality Control (PQC) improved five-day forecasts. [**JPPSO**]

Support for Diagnostic, Monitoring and Forecast Activities at the Climate Prediction Center: CICS-MD Scientist Augustin Vintzileos designed, developed, utilized in realtime applications and refined a Subseasonal Excessive Heat Outlook System (SEHOS). In its pilot phase, the SEHOS is targeting Week-2 using as input, predictions from the NCEP GEFS and the corresponding reforecast (from ESRL). Currently the refined baseline SEHOS is being augmented by using multi-model ensemble techniques, initially adding the ECMWF ensemble model and reforecast in the operational setting. This version of the SEHOS will be executed quasi-operationally in realtime during summer 2016 (beginning 1 May 2016) and evaluated by CPC forecasters. In parallel, the value added by the NMME suite of models is investigated for leads from Week-2 to Week-3&4. The Task Leader also developed and improving the product that uses Week-3&4 CFSv2 predictions to inform CPC forecasters. **[CPC]**

***Comparison of 4DVAR and LETKF in Assimilating JPSS-derived Sea-surface Temperature in the Chesa-peake Bay Operational Forecasting System*:** Comparison of 4DVAR and LETKF two data assimilation methods in the Chesapeake Bay Operational Forecasting System was completed. **[STAR]**

***Enhancing NCEP-NAM Weather Forecasts via Assimilating Real-time GOES-R Observations of Land Surface Temperature and Green Vegetation Fraction*:** We set up a fully coupled NASA LIS and WRF assimilation system (NU-WRF) in which EnKF DA algorithm is implemented to assimilate multiple land observations (SM and LST) into NWP model. We then tested the insertion of near real time (NRT) GVF observations into NUWRF and assessed the impact in weather forecast. We further evaluated the effectiveness of assimilating satellite SM product using EnKF technique and its impact on WRF weather forecast. **[STAR]**

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

***GMU Activities in Support of Forecasts sensitivity to Observation Impacts (FSOI) Evaluation and Scientific Improvement*:** Continuing study of satellite impacts on the weather forecasts. **[STAR/JCSDA]**

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

***Warm Anomalies in the Nordic Seas and the Role of Oceanic and Atmospheric Circulation*:** 1) Resolving the flow of Atlantic water from satellite altimetry and the transit time for warm anomalies to reach the Fram Strait (Chafik et al. 2015, JGR). These results were pre-sented at AGU (invited talk), conferences and national as well as international institutes. 2) The response of the global ocean circulation and ENSO to a high-latitude volcanic eruption (Pausata et al. 2015, PNAS). [**STAR**]

***Graduate Student Support: ENSO-related Precipitation in Recent Reanalyses and CMIP5 Models*:** CMIP5 models are able to simulate similar mean states and seasonal evolutions of ENSO-related precipitation as recent precipitation reanalyses, though the biases in the CMIP5 models precipitation climatology such as dry equator, “double-Intertropical Convergence Zones” and overly zonal Southern Pacific Convergence Zone exert major influences on simulating ENSO-like precipitation patterns. It is also very pos-

sible that the ENSO-related precipitation and drought extremes during the 2nd half of the 20th century are significantly larger than the 1st half. [**NESDIS**]

***Applying Snow Products from SNPP/JPSS and SNODAS to Streamflow Forecasting at the NWS National Water Center*:** The project is focused on the development of a snow data assimilation testbed for streamflow forecasting and on the basic research in snow data assimilation for streamflow forecasting. The later includes investigation of SNODAS, SNPP/JPSS satellite snow product error quantification, product fusion, and investigation of snow model error and DA methods. **[JPSSO]**

GMU Support of NOAA Air Quality Forecasting, Research and Operations: CICS scientists have (1) Validated MODIS-based marine isoprene retrieval algorithm; (2) Compared MODIS and VIIRS based marine isoprene products; and (3) Prepared to integrate and test the new Soumi-NPP VIIRS marine product in the NAQFC system. [**ARL**]

Climate Data and Information Records/Scientific Data Stewardship

***CICS Support for Ocean Data at the National Centers for Environmental Information (NCEI*):** In 2015, CICS played a significant role developing improved satellite data products, working with the ocean science community to provide global and regional ocean data, and validating new space-based ocean observing technologies. CICS researchers enhanced NOAA's abilities to understand, predict and communicate climate variability by data dissemination and public education, through web based in-situ and satellite data, and by detailed descriptions of these data. CICS team actively participated in the continued development, maintenance, and enhancement of the World Ocean Database, the World Ocean Atlas, and Regional Climatology Projects. **[NCEI]**

***Outgoing Longwave Radiation Monthly CDR – Software Rejuvenation*:** NOAA/NCEI CDR Program has decided to move Monthly OLR CDR production into the Full Operational Capability (FOC) model. Software package rejuvenation will review and revise the production code system for meeting the standards in computer program language, system maintenance and efficiency. Industry compliant procedures for software development are employed to ensure the comprehensive examination and documentation of the production system. **[NCEI]**

***HIRS OLR CDR Development, Sustainment and Maintenance*:** CICS is in charge of the development, sustainment and maintenance of the OLR CDR products for NCEI Climate Data Record Program, including two versions of the Monthly OLR CDR product (v02r02a and v02r07) and two versions of the Daily OLR CDR product (v01r02 and v01r02-interim). **[NCEI]**

***The Global Precipitation Climatology Project (GPCP) Data Products—Transfer to Operations at NCEI*:** The routine production of monthly, pentad and daily products from the Global Precipitation Climatology Project (GPCP) products will be transferred to NCEI for

archival and dissemination. The ICDR of monthly GPCP is being routinely produced and distributed. **[NCEI]**

***The Development of AMSU Climate Data Records (CDR's)*:** All Beta CDRs are online at http://cics.umd.edu/AMSU-CDR/home.html . **[NCEI]**

Land and Hydrology

CUNY Enhanced Operational System for the Mapping of River Ice Using SNPP VIIRS for River Ice-Jam Modeling and Forecasting: An enhanced operational river ice mapping system using VIIRS is developed. It supports NWS RFCs with timely information on river ice extent and concentration over wide river sections. [**JPSSO**]

***Hampton University/CUNY Developing an Orographic Adjustment for the GOES-R Rain Rate Algorithm*:** This project : (1) found that the developed orographic correction method for SCaMPR rainfall estimates consistently provided better performance than the previous correction techniques; (2) was able to reduce error up to 5% when correction is applied; (3) determined that the 35 km fetch length of upwind effect for orographic correction is the optimum fetch length; and (4) have identified other variables (precipitable water, relative humidity), which could improve performance if added to the correction equation. [**STAR**]

Earth System Monitoring from Satellites

***Towards Operational Arctic Snow and Sea ice Thickness Products*:** Multi-year sea ice continues to dominate the central Arctic Ocean, where mean ice thickness was ~3.5 m in winter 2015, while sea ice in the Beaufort/Chukchi Seas was a mix of multi- and first-year ice and mean thickness was ~ 2.4 m in winter 2015. **[STAR]**

***Utilization of M-T SAPHIR to monitor S-NPP ATMS and MiRS products*:** ATMS and SAPHIR data were intercompared and validated using radiosonde and GPS-RO data. **[STAR]**

***Leveraging Observations and Models to Improve Predictions of Convective Initiation*:** CICS & UAH Scientist John Mecilalski created and refined a 1-4 hour product for predicting new thunderstorm development. **[STAR]**

***CUNY: A New Technique for VIIRS Detection and Delineation of Karenia brevis Harmful Algal Blooms (HABS) in the West Florida Shelf without the Need for a Fluorescence Channel*:** CUNY developed a VIIRS neural network that can detect of *Karrenia Brevis* harmful algal blooms in the West Florida Shelf. [**JPPSO**]

***SDSU Real-Time Monitoring and Short-term Forecasting of Phenology from GOES-R ABI for the Use in Numerical Weather Prediction Models*:** We generated phenological datasets using SEVERI EVI2 from 2006-2013. Further, we conducted a detailed comparison between phenological detections from SEVERI EVI2 and MODIS EVI2 in the Congo

Basin where cloud cover frequently occurs. The results show that SEVERI EVI2 significantly improves the data quality for tropical forest observations relative to MODIS data. Moreover, the investigation also shows that wildfire has limited impacts on green vegetation fraction (GVF) because fires generally occurs during dry seasons. **[STAR]**

***SDSU Monitoring Land Surface Vegetation Phenology from VIIRS*:** CICS Scientist Xiaoyang Zhang developed algorithms and operational computer codes to monitor spring and fall foliage development from VIIRS data. The algorithms were tested using VIIRS data in 2014 across CONUS and extended to entire North America in 2015. They were implemented to monitor in real time and forecast in 10 days ahead the green leaf development. The results were routinely produced every 3-days and delivered to NOAA JPSS Environmental Data Records. Moreover, the phenological results were used for testing the Land Model in EMC. **[STAR]**

Decision Support Science

***Research, Development and Implementation of National and Regional Physical, Ecological, and Societal Climate Indicators for the NOAA and the USGCRP National Climate Assessment*:** Kenney is leading the development and research of an interagency climate indicator system to bring together data, observations, and indicator products in innovative ways to better assess climate changes, impacts, vulnerabilities, and preparedness and move the research products into operations for decision support. [**CPO**]

***International Decision Support Systems for Food Security*:** CICS-MD Scientist Miliaritiana Robjhon produced roughly twenty four weather and climate hazards outlooks over Africa, Central America and Hispaniola, and Central Asia and disseminated these climate information documents to the Famine Early Warning Systems Network partners and users. He also presented preliminary results on the investigation of recent droughts over Central America at the 40th Climate Diagnostics and Prediction Workshop in Denver, CO during late October 2015. In addition, he trained seven visiting scientists at the Climate Prediction Center's International Desks on the QGIS computer software application. **[CPC]**

Strengthening Coastal Community Resilience in the face of Climate Change: Science to Better Under-stand, Measure, and Value Coastal Ecosystem Services: The second year of this project has resulted in the publication of 5 papers on aspects of coastal resilience and the incorporation of ecosystem services into federal policy and decision making and has also contributed to significant progress in natural resource policy and climate policy goals for the U.S. **[NOS]**

Climate Science to Support Policy, Education, Literacy, and Outreach

***Climate Outreach and Education at the Climate Program Office*:** CICS-MD Scientist Will Chong increased collaboration and cooperation among scientists from NOAA, other agencies, Cooperative Institutes, and the external community to foster the net output of

research for the general public. Outreach using web interface and communicative materials has helped maximize the promotion of scientific stewardship of climate related information. **[CPO]**

Mentoring and Advising NWS Headquarters and Field Personnel on STI strategies: Mentoring by former NOAA employees can be a positive experience for younger managers and scientists as well as for the more experienced Federal employees as they adapt their workplace roles in a changing Federal environment. This project seeks to maximize the benefits of Dr. Lord's expe-rience in organizing and initiating major efforts to improve NOAA's operational models and data assimilation systems. **[NWS]**

b. CICS-NC

CICS-NC highlights are arranged by task stream with task sponsors noted in brackets [ ]. Primary NOAA support comes from NESDIS/NCEI; however, CICS activities are also funded by NWS and OAR's Climate Program Office (CPO), ARL's Atmospheric Turbulence and Diffusion Division (ATDD), and the Earth System Research Laboratory (ESRL). While CICS-NC activities remain primary, NCICS scientists are also engaged in research projects supported by non-NOAA sponsors that currently include: The National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Department of Defense (DoD), and EarthRisk/Riskpulse.

Administration (NCEI/NCSU)

Information Technology Systems Improvement, Management, and Maintenance*:* CICS staff require technological infrastructure and resources at a variety of levels. This task supports those needs by providing modern approaches to keep CICS-NC at the competitive edge of technology, as well as maintaining core technologies as a stable base for CICS-NC staff operations. These systems range from scientific computing to medium-scale office-oriented services. Improvements have been made in all aspects of CICS-NC's IT infrastructure towards a more reliable system that is both flexible and scalable while still supporting cutting-edge technologies that support the communication and computational needs of the administrative and research staff at CICS-NC.

Access and Services Development (CPO/NCEI)

Programming and Applications Development for Climate Portal*:* Staff from UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with the continued development and redesign of the *U.S Climate Resilience Toolkit* (www.toolkit.climate.gov), the design of the new Climate Widget for climate projection information, and the redesign of the *Climate Explorer* application (http://toolkit.climate.gov/climate-explorer). In addition, NEMAC led the implementation of the *Steps to Resilience* in the *Toolkit* redesign and led several workshops in this

effort. These products and services support the overall advancement and progression of the NOAA's Climate Services Portal (NCSP) program.

NCEI Website Information Architecture Development and User Interface Design Support: The new NCEI website, launched in April 2015 following the merger of NOAA's three data centers, provides the opportunity to update and enhance current services to customers with a more user-friendly design and interface to enable current and future users to more easily identify, locate, and access specific data products and services. CICS-NC web development and program staff are working to identify the best research partner to support the development of an updated information architecture, redesigned user interface, and an implementation plan for the NCEI website.

Assessment Activities (NCEI/CPO)

Building on the support provided for the Third U.S. National Climate Assessment (NCA3) released in May 2014, the NOAA Assessment Technical Support Unit (TSU), staffed largely by CICS-NC personnel, is providing the same level of scientific, editorial, graphic design, metadata, project management, programming, and web design support for the U.S. Global Change Research Program's report on the impacts of climate change on human health. The TSU delivered two major review drafts of the report, with the final report due to be released in April 2016.

CICS-NC staff in the TSU are also providing an expanded range of support for U.S. Global Change Research Project (USGCRP) activities, including taking over development and management of the www.globalchange.gov website and continuing development work on author collaboration and report development tools.

Web Development for Assessments: Planned, designed, and built the Climate and Human Health Assessment (http://health2016.globalchange.gov) and began redevelopment/redesign work of the USGCRP Resources/Collaboration websites.

National Climate Assessment Scientific Support Activities: A NOAA Technical Report comparing CMIP3 and CMIP5 model simulations and the implications for the National Climate Assessment was published, and draft climate assessment summaries on an individual U.S. state scale have been completed for all 50 states.

Sustained Assessment Data Processes: Information Quality Act compliance and assessment production support: Continued development and operation of a unique Product Suite and production processes to collect, curate, and display the metadata for five assessments products. The efforts remain compliant with the Information Quality Act and include traceability of data, contributors, and scientific analysis methods across graphics, visualizations, references, and photos at a level of detail to satisfy a requirement to also be reproducible.

An investigation into current and future trends in severe thunderstorms and their environments: An 11- year (2000–2011) MRMS radar based hail climatology using variables such as Maximum Expected Size of Hail (MESH) and Severe Hail Index (SHI) was developed, with subsequent analysis comparing the hail based climatology to a hail day climatology using NARR, developed based on environmental parameters which signify hail. Detection of long-term trends in the NARR hail day climatology looking for similarities in hail day frequency, the observed decrease in the number of tornado days in the U.S., and any subsequent increase in hail and tornado outbreaks.

Climate Data Records and Scientific Data Stewardship (NCEI)

Expansion of CDR User Base (e.g., Obs4MIPs): The aim of this project is to make NOAA Climate Data Records (CDRs) from observational platforms (*e.g.* satellite, in situ datasets) easily available for evaluating climate model outputs produced for the Coupled Model Intercomparison Project Phase 5 (CMIP5). Results from analyses from CMIP5 were used for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

Optimum Interpolation Sea Surface Temperature (OISST) Transition to Operations: The OISST production software is being refactored to meet Climate Data Record Program requirements for operation readiness. https://www.ncdc.noaa.gov/cdr/oceanic/sea-surface-temperature-optimum-interpolation.

High-resolution Infrared Radiation Sounder (HIRS) Monthly Outgoing Long-wave Radiation (OLR) Climate Data Record (CDR) Software Refactoring: The HIRS Monthly OLR software refactoring effort has produced noticeable improvements in data and software quality. https://www.ncdc.noaa.gov/cdr/atmospheric/outgoing-longwave-radiation-monthly

Common Ingest Agile Development Team: Evaluation and testing of the NCEI-CO Common Ingest software for use at NCEI-NC was completed and software implementation is in progress at NCEI-NC.

Reanalyzing Tropical Cyclone Imagery with Citizen Scientists: CycloneCenter.org has collected more than 500,000 tropical cyclone classifications from citizen scientists, and results published in the *Bulletin of the American Meteorological Society* show that this crowdsourced data can help address uncertainties in the historical record of these storms.

NOAA PERSIANN-CDR Support for Hydrologic and Water Resource Planning and Management: The PERSIANN Precipitation Climate Data Record (PERSIANN-CDR) processed precipitation dataset at daily 0.250 lat-long scale covering from 60°S to 60°N and 0° to

360° longitude from 1983 to June 2015. Application of PERSIANN-CDR to hydro-climatological studies is demonstrated.

Broadband radiation budget at TOA and surface at high Spatial and Temporal Resolution from Multi- Sensor Data Fusion: Techniques are being developed to estimate broadband top-of-atmosphere (TOA) and surface radiation components, at high spatial and temporal resolution, in the short wave and long wave from geostationary imagers.

Calibration of the Visible Channel of the International Satellite Cloud Climatology Project (ISCCP) B1 data for the extended period (2010-2015): Calibration of the Geostationary Earth Orbit (GEO) visible channel in the ISCCP B1 data stream, completed for all meteorological satellites for the period 1979–2009, is being revised for use by the Geostationary Surface Albedo (GSA) project and extended for years beyond 2009.

Transitioning the International Satellite Cloud Climatology Project (ISCCP) Process to NCEI: The transfer of the ISCCP Cloud products processing from the ISCCP team (at CCNY and NASA-GISS) to NOAA/NCEI, is nearly complete with delivery of code, ancillary data and necessary documentation. This will result in a higher resolution ISCCP product (so-called H-series), an extended period of record, and an expanded user-base, with easier data access and availability.

Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES data: The GSA algorithm is being implemented as the American contribution of an international collaboration between Europe, Japan, and the U.S. to produce a joint, global climate data record of land surface albedo.

HIRS Temperature and Humidity Profiles: The team is developing a global temperature and humidity profile dataset for the time period of 1978–present. A neural network analysis approach is applied to High-resolution Infrared Radiation Sounder (HIRS) observations to produce the global dataset.

Evaluation and Characterization of Satellite Data Products: This effort focused on the evaluation and characterization of satellite climate data records (CDRs) in various stages of development and application. The accuracy of the NCEI High-resolution Infrared Radiation Sounder (HIRS) near-surface temperature product was evaluated in the Arctic using the quality-controlled SHEBA dataset. Analysis lays the foundation for a long-term remote sensing near-surface air temperature product in the Arctic.

Scientific data stewardship for digital environmental data products: This effort focuses on research in scientific stewardship of individual digital environmental data products. Leading, coordinating, and participating in NCEI and across-agency DSMM (data stewardship maturity matrix) use-case studies and development of tools for integrating DSMM results for enhanced data discovery and decision-making support. Introducing

roles of data, scientific, and technology stewards and their responsibilities and other major stakeholders for effectively ensuring and improving data quality and usability.

Merging long-term high-resolution quantitative precipitation estimates Quantitative Precipitation Estimates from the high-resolution NEXRAD reanalysis over CONUS with rain-gauge observations: The objective of this work is to provide long-term high-temporal and spatial resolution quantitative precipitation estimates (QPEs) suitable for hydrological, meteorological, and climatological applications. The radar-only National Mosaic and Multi-sensor QPE (NMQ/Q2) Precipitation Reanalysis is adjusted using a suite of in situ datasets at various temporal resolutions (GHCN-D, HADS, ASOS, CRN).

Toward the development of Reference Environmental Data Records (REDRs) for precipitation: Global evaluation of satellite based Quantitative Precipitation Estimates (QPEs): This project uses a suite of quantitative precipitation estimates (QPEs) derived from satellite observations to derive long-term global precipitation characteristics at high spatial and temporal resolution. The work is part of a broader effort to evaluate long-term multi-sensor QPEs, with the goal of developing Reference Environmental Data Records (REDRs) for precipitation.

Identifying Tropical Variability with CDRs: Tropical variability identified through Climate Data Records can be leveraged for numerous end users, including climate monitoring, the energy sector, and the U.S. military.

Hydrometerological Automated Data System (HADS): Effort to recreate and automate quality control processes for in situ rain gauge data: This project works to port algorithms developed at NCEI into a more operational framework. This involves streamlining, debugging, and automating code to run in a more autonomous way.

Reanalysis of archived NEXRAD data using NMQ/Q2 algorithms to create a high-resolution precipitation dataset for the continental U.S.: The reanalysis product is in the process of being entered into the NCEI archive. Project lead worked closely with Big Data partners to make raw data available.

Ingest Archive System Agile Development Team: Provided modifications to NCEI ingest system in support of new center needs, system stability, and operational issues.

Evaluation of a new spatial interpolator to estimate land surface precipitation over the contiguous U.S. region: Estimations of land surface precipitation climatologies at 2.5-minute resolution using a new spatial interpolator were evaluated and compared with estimations from Cressman's traditional interpolator, NCEI/NOAA, and PRISM.

Estimation of topographic variables at different resolutions: DEM information from GTOPO30 is being used to estimate topographic variables (elevation, latitudinal and lon-

gitudinal components of slope and exposure to orography) at different resolutions for contiguous U.S. and global scale.

Global Surface Temperature Portfolio: Evaluation of NOAA Temp/MLOST Land Surface Temperature using ERA Interim: The purpose of this task is to use ERA Interim as a benchmark for NOAATemp/MLOST land surface temperature evaluation. A comparison of the spatial and temporal variability of global surface temperature trends for different datasets (e.g. University of York, GISTEMP, and NOAATemp/MLOST), identifying regions, and periods of discrepancies was completed.

Surface Observing Networks

Evaluation of U.S. Climate Reference Network (USCRN) Soil Moisture and Temperature Observations: This research focuses on an analysis of USCRN soil observations to develop an understanding of spatial and temporal variability of soil moisture and temperature. The goal of this project is to determine the changes in soil observations to improve USCRN for drought monitoring and satellite calibration.

Expansion and Development of U.S. Climate Reference Network (USCRN) Soil Moisture Observations: The addition of soil instrumentation to the United States Climate Reference Network (USCRN) provides an opportunity to evaluate national signals for changes in soil climate. This research involves modeling of the USCRN soil observations to develop a historical soil moisture record for improved drought monitoring.

Climate Monitoring and Research Support for NOAA's Air Resources Laboratory (ARL) Atmospheric Turbulence and Diffusion Division (ATDD): Oak Ridge Associated Universities (ORAU) contractor personnel completed two additional USCRN station installations in Alaska and 16 annual station maintenance visits, surveyed 5 sites for future installations, and tested a small Unmanned Aerial System platform in support of the VORTEX SE research program. http://www.arl.noaa.gov/sUAS_CIstudy.php

Development and verification of U.S. Climate Reference Network (USCRN) Quality Assurance Method: A new revised precipitation algorithm was accepted by the USCRN configuration management and NCEI science council and deployed operationally. The National Ecological Observatory Network was provided help to adopt a variant of the precipitation algorithm for their quality control needs.

Development of an Extra-Tropical Cyclone Track dataset: Extra-tropical cyclone (ETC) tracks were generated from a 56-member ensemble of the 20th century reanalysis. Ensemble mean and member ETC tracks were placed within a database for public dissemination. ETC track densities since 1950 were analyzed by MJO phase, which revealed tracks favoring heavier Northeast snowfall were more likely in MJO phases 7-8.

Analysis of hydrological extremes from the U.S. Climate Reference Network (USCRN): Analyzed changes to USCRN precipitation patterns over the 2012 drought and compared

USCRN soil conditions to a commonly used reanalysis model; the North American Regional Reanalysis (NARR). These two studies highlighted the severity of the 2012 drought and the model's capacity to simulate the evolution of hydrological extremes. The development of a soil product for the USCRN that can monitor both sides of hydrological extremes (droughts and floods) is currently underway.

Maintenance and Streamlining of the Global Historical Climatology Network – Monthly (GHCN-M) Dataset: Using an open and transparent databank of land surface stations, the next iteration of NOAA's global temperature product has been developed and released as a public beta. This new version includes more stations, along with enhancements to the data quality and homogenization algorithms.

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool: Steps have been taken to create a sub-monthly tool for monitoring impacts of temperature extremes in the United States. Using existing NCEI products, station data is aggregated on the State, NCA region, and contiguous U.S. levels to analyze current temperatures against its period of record. A dataset has been produced internally, with plans to undergo research to operation status.

Building a Climatology of Extreme Snowfall Events in the United States: A joint NOAA/FEMA project is underway to validate snowfall extremes for every county in the United States. This will help mitigate future snowfall events and build better spatial quality algorithms for weather station data products.

Global Surface Temperature Portfolio: Land Surface Temperature Analysis and Assessment of HIRS Surface Temperature Collocated with USCRN Observed Surface Temperature and Global Land Surface Temperature Datasets: The goal of this task is to provide a detailed assessment of HIRS surface temperature with high-quality USCRN observed surface temperatures. Bias and RMSE were calculated for HIRS surface temperatures vs. the USCRN observation network from 2006–2013 for the N17 and M02 satellites. This effort applies a calibration scheme that results in improved and reduced bias and RMSE when compared to USCRN, especially for the western United States.

Workforce Development (NCEI)

Workforce development is long-term investment in NOAA's future workforce. NCEI has a continuing number of research and workforce requirements that necessitate collaboration with the best climate science practitioners in the nation. This requires the hiring of outstanding scientific staff with unique skills and backgrounds in Earth System Science and the use of observations for defining climate and its impacts. To meet this demand, CICS-NC has hired a cadre of dedicated research staff and is actively working to identify and train the next generation of scientifically and technically skilled climate scientists. Junior and/or aspiring scientists, including students and post-doctoral researchers, play an important

role in the conduct of research at CICS-NC. While consistent funding remains a challenge, CICS-NC is nevertheless working to identify prospective future scientists, to nurture interest in climate applications, and to provide opportunities for training and mentorship on various levels.

Senior CICS-NC scientists hold research faculty positions in the Marine, Earth, and Atmospheric Sciences Department (MEAS) in the College of Sciences (COS) at NCSU and provide mentorship to junior scientists and students both in CICS-NC and MEAS. Several junior scientists have also secured adjunct appointments in pertinent NCSU departments as well as other universities to gain experience and exposure with their academic peers and mentor graduate students. CICS-NC scientists are also engaged in various outreach activities to promote awareness and pique interest in science and climate studies at the K-12 level.

CICS-NC initiated its program in workforce development through the hiring of an initial cadre of post- doctoral research scholars working on applied research topics in Climate Data Records and Surface Observing Networks. Senior scientists from NOAA and CICS-NC provide mentoring for these post-docs. The expectation is a 2-3 year commitment, dependent on circumstances and individual interests.

Meanwhile, CICS-NC has been successful in recruiting and involving local high school students and UNC Asheville undergraduates in temporary student internships, providing an opportunity for the students to explore their interest in science and/or apply their ongoing education to current projects within the institute under the oversight of CICS-NC and NCEI mentors.

Climate Literacy, Outreach, Engagement and Communications (NCEI/NCSU)

CICS-NC climate literacy, outreach, engagement, and communication activities are interdisciplinary in nature, with both formal and informal activities that reach various stakeholders across the public, private, and academic areas, ultimately to advance climate information and activities in adaptation and resilience. https://www.cicsnc.org/events/

CICS-NC is currently co-hosting a webinar series on impacts of a changing climate and opportunities in adaptation and resilience with the Research Triangle Foundation (RTF) that will culminate in the next Executive Forum on Business and Climate (EFBC) focused on resiliency and adaptation for RTF's member companies.

In collaboration with the Economic Development Coalition for Asheville-Buncombe County Coalition (Asheville EDC), CICS-NC co-sponsored the *2016 AMS Annual Meeting* Asheville information booth, which showcased climate activities and companies advancing climate services in Western North Carolina.

CICS-NC also helped design and host an NCEI engagement forum, "Moving from Environmental Data to Resilience: Forging Public-Private Partnerships in the Energy Sector" in New Orleans with energy industry participants following the AMS Annual Meeting.

Engagement capacity in the energy sector was enhanced through service on the NOAA Energy Team and the Executive Advisory Council (EAC) for the *Utility Analytics Institute*, a membership-based group for energy industry professionals looking at strategic analytics issues. CICS-NC staff are building industry partner collaborations on uses and applications of environmental data for decision making.

Worked with the Asheville-Buncombe Sustainable Community Initiative to develop the *Collider*—an event and business center in downtown Asheville intended to advance climate/environmental literacy and development of climate services business. The Collider opened March 2016. http://www.thecollider.org/

CICS-NC staff participated in K–12 educational outreach events in conjunction with the celebration of the state-wide 2015 and 2016 North Carolina Science Festival by providing information about the Cyclone Center citizen science project and the Third National Climate Assessment at the *Mountain Science Expo* at the North Carolina Arboretum and at Isothermal Community College's *Science and Technology Expo.* CICS-NC also coordinated numerous outreach events in Fall 2015 and Winter 2016.

Communications activities serve to highlight CICS-NC/NCICS research activities and facilitate distribution of relevant information to CICS-NC/NCICS' various stakeholders. Past year activities included thirteen press releases/website stories, development of a new institute brochure, issuance of the 3rd edition of the institute newsletter, *Trends*, and initiation of a redesign of the institute website to improve navigation and incorporate updated NCSU branding.

Other CICS PI Projects

Research dealing with the impacts of climate on health: This report illustrates current collaboration and interaction with the Centers for Disease Control and Prevention on issues related to climate and health. The goal of this interaction is to increase the understanding of climate on human health and assist with projects that can further this knowledge. **[NCEI/CDC]**

The Partnership for Resilience: A public–private partnership consortia organization was instituted to foster collaborative activities and a dynamic environmental change solution-provider industry for environmental analytics and adaptation strategies. http://www.partnershipforresilience.org/ **[NCSU]**

Water Sustainability and Climate Change: A Cross-Regional Perspective: Model simulations from the CMIP5 hindcast/predictive experiment were found to reproduce observed temperature trends for six regions of the U.S. for the period 1981–2010 and 2006–2035. Trends in the number of extreme monthly temperatures are simulated well

for most regions, but not for the northwest. The very large-scale features of historical trends in extreme daily precipitation are simulated moderately well. **[NSF]**

Incorporation of climate change into Intensity-Duration-Frequency Design Values: A comprehensive analysis of historical trends in extreme precipitation found larger increasing trends for the shortest durations and longest return periods. A candidate metric for identifying North American Monsoon heavy rainfall events has been identified. **[DOD / SERDP]**

Role of Kelvin Waves in Tropical Cyclogenesis: Kelvin waves encourage tropical cyclogenesis by closing the midlevel circulation in the predecessor easterly waves. **[NASA]**
German Wind Power Model Development Support: Wind power generation over Germany can be statistically forecast out to 30 days using teleconnections, including tropical diagnostics of outgoing longwave radiation. **[EarthRisk/Riskpulse]**

Relationship between occurrence of precipitation and incidence of traffic fatalities using high-resolution NEXRAD reanalysis: This project is using the recently completed NMQ/Q2 NEXRAD reanalysis to study the impact of precipitation on the frequency of fatal auto accidents across the United States. The new product has the ability to determine the intensity of precipitation (if any) within five minutes and one kilometer of a crash. **[NCEI/CDC]**

Trends and Projections of Northern Hemisphere Blocking Highs: Analysis of 20th Century Reanalysis data provides a 141-year climatology of blocking high events—a period longer than any previous analysis. **[NOAA/CPO]**

Trends and Projections of Northern Hemisphere Extratropical Cyclones: Analysis of CMIP5 future projections indicates a decrease in weak ETCs and an increase in strong ETCs. A northward shift in the mean track is also projected. **[NOAA/CPO]**

3 NOAA/CICS CORE ACTIVITIES

CICS core activities include education, coordination, scientific computing, outreach, management and administration related to CICS-MD, CICS-NC and Consortium efforts. During the past 12 months, CICS leaders have continued to establish the essential administrative and management activities required to support the collaborative science and research. Activities include institute administration, office administration, accounting and finance, proposal development/support, contracts and grants management, human resources, information technology, international linkages, and education and outreach. In addition, further progress has been achieved on the full suite of core activities, as described below.

3.1 Management and Administration

CICS is led by its Executive Director, Dr. Fernando Miralles-Wilhelm at the University of Maryland, and is hosted by ESSIC. The primary mechanisms that support the Executive Director in ensuring coherent collaboration across the entire Consortium, including the Council of Fellows, the Science Meeting(s), and the support of the CICS-MD and CICS-NC Directors.

CICS-MD is led by Dr. Hugo Berbery of UMD. CICS-MD includes research and professorial faculty members from ESSIC and the Department of Atmospheric and Oceanic Science (AOSC), the Department of Geographical Sciences (GEOG), and the Department of Astronomy (ASTR), and supports a number of Research Associate and Faculty Research Assistant positions in each unit. In addition, CICS-MD supports a number of graduate research assistants. CICS-MD financial and personnel operations are supported by each employing unit. Administrative work is handled by the CICS-MD Coordinator, Debra Baker. ESSIC Assistant Director Andrew Negri also provides support on personnel and other matters. The ESSIC Business Office, directed by Mr. Jean La Fonta, manages the UMD funding and accounting efforts as well as the subcontracts for CICS-NC and Consortium members.

CICS-NC is led by Dr. Otis B. Brown, Director of the North Carolina Institute for Climate Studies (NCICS) and is hosted by NCSU on behalf of UNC System. CICS-NC collocated within the National Climatic Data Center in Asheville, NC. The CICS-NC administrative team includes:

- Janice Mills, Business Manager
- Theresa Stone, Program Specialist
- Jenny Dissen, Director of Climate Literacy, Outreach and Engagement
- Jonathan Brannock, Network/Systems Analyst
- Scott Wilkins, Operations/Systems Specialist

3.2 Coordination

A continuing challenge for CICS is to ensure that collaboration and communication across the entire Consortium contributes effectively to advancing NOAA's research mission. Several mechanisms are utilized to this end, ranging from direct discussions among the Directors to participation in the annual Cooperative Research Program (CoRP) Symposium to facilitating visits among students and scientists associated with CICS and other Cooperative Institutes.

3.3 Education

CICS supports NOAA's commitment to the development of a society that is environmentally responsible, climate resilient and adaptive and utilizes effective, science-based problem-solving skills (e.g. STEM based learning) in education. CICS scientists and educators participate in NOAA's climate education programs to advance the development of strong and comprehensive education and outreach activities about climate and oceanic and atmospheric sciences.

Through CICS education, outreach, and engagement activities, CICS scientists involve students in climate science and enable students and teachers to explore and understand the large volumes of climate data that NOAA collects about the Earth. Working collaboratively with other academic and public partners, stakeholders, and the private sector, CICS supports and engages in various educational and outreach-related activities to advance the following areas:

i. Increase awareness of climate science and changes in the climate system
ii. Grow the understanding of how climate data is collected, observed, analyzed, and used in research purposes
iii. Increase awareness of climate datasets and products, and how educational teachers/professors can make use of climate data products for teaching climate science
iv. Demonstrate capacity building on the various impacts of climate change across public, private, and academic arenas
v. Increase private sector understanding and use of climate data and information for their strategic and operational use

Education, outreach and engagement are all important elements of the CICS mission. CICS engages in the improvement of both formal and informal education approaches to these areas of foci, as both of these approaches are important to the development of climate-literate citizens and a climate-adaptive society. These activities are broadly grouped within K-12 Education, Undergraduate Education, Graduate and Postdoctoral Education, Opportunities in Education Outreach, and Private Sector Engagement. Below are descriptions of the various activities CICS has tackled in the past year.

K-12 Education

CICS reaches out through various activities to K-12 students to help advance climate science, literacy and education particularly focusing in on STEM skillsets. Over the past several years, CICS scientists have given presentations, led lectures, taught courses, developed curricula, lent equipment, and mentored high-school students.

Staff from CICS conducted outreach activities across K-12, higher education, and the general public to advance environmental information and increase climate literacy throughout the year:

4/11/2015: NC Science Week Mountain Science Expo, NC Arboretum, Asheville, NC. Theresa Stone, Laura Stevens, Jared Rennie manned a booth with NCEI and showcased Cyclone Center and the Third National Climate Assessment.

4/17/2015: NC Science Week ICC Science and Technology Expo, Isothermal Community College, Spindale, NC. Theresa Stone and Scott Stevens gave presentations to elementary school groups demonstrating the Cyclone Center and the National Climate Assessment.

6/29/2015: Montreat College Myles of Science (middle school) summer camp, Purchase Knob, NC. Scott Stevens presented, "What is Climate Change, and How Do We Know It's Real?".

7/24/2015: Asheville Science Tavern, Asheville, NC. Jenn Runkle and Jim Fox presented, “Report on the Impacts of Climate Change on Human Health in the United States: At a Glance.”

9/12/2015: Immanuel Village retirement community, Omaha, NE. Tom Maycock gave a presentation on climate change and the National Climate Assessment.

11/3/2015: Mitchell County High School STEM Expo, Bakerville, NC. Scott Stevens presented, "Climate Change: What is it, and how do we know it's real?"

11/4/2015: Sand Hill-Venable Elementary School Career Day, Asheville, NC. Jared Rennie and Carl Schreck gave a presentation on Tropical Cyclones and other CICS-NC activities.

11/13/2015: Jenny Dissen served as a panelist at the Lenoir Rhyne University Sustainability Program Asheville Bioneers conference, addressing topics in “Adaptation and Resilience,” “Food, Race, and Justice,” and “Climate Change and Clean Energy.”

11/16/2015: Apple Valley Middle School, Hendersonville, NC. Jared Rennie discussed software coding and how it is used at NCEI on a video chat with science club students.

11/16/2015: Heather Glen at Ardenwoods, assisted living facility, Arden, NC. Tom Maycock gave a presentation on NOAA NCEI and a 2014 National Climate Assessment overview.

12/01/2015 - 12/04/2015: Hour of Code week, Isaac Dickson Elementary School, Asheville, NC. Jared Rennie and Jim Biard talked with students about how CICS-NC and software developers use code, and assisted students with exercises to help them learn about developing software.

12/11/2015: Bethel Middle School, Waynesville, NC. Jared Rennie gave a presentation on climatology and coding at NCICS and NCEI.

12/15/2015: In collaboration with NCEI, Jenny Dissen developed a poster presentation that portrays how NCEI's data reaches the general public for the Dec. 2015 American Geophysical Union conference, presented by NCEI's Information Services Division Chief, Tim Owen.

2/26/2016: Asheville Museum of Science (AMOS) Pub Science Friday, Asheville, NC. Jake Crouch (NCEI) gave a presentation on the 2015 State of the Climate.

3/8/2016: Bell Elementary School STEAM Festival, Asheville, NC. Theresa Stone hosted a CICS-NC booth focused on careers in climate science, the Cyclone Center, and climate literacy.

3/12/2016: Asheville Museum of Science Super Science Saturday, Asheville, NC. Theresa Stone and Laura Stevens provided Extreme Weather events and Climate Change information and hands-on activities including "Make your own rain gauge," "Be a climate scientist with the Cyclone Center," and "Extreme Weather arts and crafts."

3/19/2016: UNC-Charlotte WeatherFest, Charlotte, NC. Theresa Stone hosted a booth focused on extreme weather and Cyclone Center demonstrations.

Figure 4*: Jared Rennie with students at Bethel Middle School in Waynesville, NC, Dec. 2015.*

Undergraduate Education

CICS supports education, literacy and outreach to university-level students by providing internship opportunities, mentoring and advising for graduating college seniors, undergraduate and graduate student researchers who have a strong desire to enhance their research and analysis skills by working with NOAA and CICS. CICS' competitive internship program is very comprehensive and designed to prepare a young meteorologist or climatologist for an entry-level data analysis position or provide desirable research skills in preparation for graduate studies. Students will learn professional "tools of the trade" such as scientific software engineering best practices with Python-based scientific programming, High-Performance Grid Computing, GIS, and Adobe Creative Suite.

CICS-MD is closely linked to University of Maryland's undergraduate programs. For instance, the Department of Atmospheric and Oceanic Science (AOSC), where many CICS scientists are either members or affiliated researchers has an undergraduate program (BS). The program has been designed to teach broad based knowledge in meteorology, oceanography, climate and air pollution. The degree satisfies the requirements for federal service positions as a meteorologist or oceanographer, and also follows the American Meteorological Society's statement on bachelor's degrees in Atmospheric Science. The emphasis of the program is on preparing undergraduates to become generators of knowledge, or researchers, instead of idle consumers of knowledge that others produce. Undergraduates are already working on thesis projects with their CICS advisors, and the close partnership between the AOSC department and CICS is a major recruiting tool for

the undergraduate program. For the last two summers, CICS has hosted undergraduate students in Maryland (**Figure 5**) to provide training in scientific methods applied to climate studies. Given the growing interest in students as well as scientists, the intent is to expand this activity.

Figure 5*: (a) Jim Carton, AOSC Chair, during an undergraduate ocean science class. (b) An undergraduate student presents her poster with results of her summer research at the CICS-MD Science meeting*

AOSC also offers a Professional Masters degree. The graduate degree is designed for working professionals who need cutting-edge skills and knowledge in atmospheric and oceanic science, air quality and computational methods. It offers the rigor required to understand scientific advances in the field and the flexibility needed by individuals to customize the curriculum towards their educational goals. The professional masters is organized into three certificate tracks. A certificate is earned after the completion of four classes, and two certificates plus two classes from the third track earns the student a masters degree. The plan is especially attractive to working students who may have to relocate for their jobs before finishing an entire masters program. In the professional masters, students can keep the certificates they earn should they need to leave early. This is in marked contrast to academic masters programs where students keep nothing but classroom credit if they must leave early. We anticipate that the program will be especially attractive federal employees and contractors needing additional training for their jobs or for a promotion.

CICS personnel are involved in teaching courses like Geography 415 (Land Use, Climate Change, and Sustainability), AOSC 432 (an undergraduate atmospheric dynamics course), and AMSC 460 (an undergraduate scientific computation course). Other CICS researchers are engaged in teaching courses and classes at other universities. For example, James Reagan has helped create an alumni mentorship program at Cornell University for Atmospheric Science undergraduates, while Cezar Kongoli has mentored one undergraduate student at American University during her admission and one-year study abroad academic program at Oxford University, UK. He is currently mentoring another undergraduate student from American University on her graduate degree program in environmental management at Oxford University, UK.

Mentoring undergraduate students in ***science policy research*** is an important goal of our research program. Such experiences provide opportunities to do research that uses and supports NOAA mission science and helps the students to hone their science interests, skills, and talents outside of the classroom. Thus, we take the education of student interns and fellows very seriously and develop a robust set of opportunities to develop their skills in science policy coordination and research methods. We actively engage the students in meetings and provide them with opportunities to learn the process of effective technical team and research coordination. We hone their skills in science editing and research through report preparation and editing, drafting policy memos, writing professional emails, developing and managing datasets, and assessing scientific literature and writing reviews. Additionally, we regularly hold professional development sessions to help the interns and fellows learn about networking, writing cover letters and resumes, and providing professional introductions. We invite the students to attend scientific conferences, congressional briefings, seminars, and informal networking receptions with scientists and practitioners.

During the summer, the policy program brings in a cohort of 5-10 undergraduate students because we find that the students are able to work together to address questions, they can learn from each other's strengths, we can build professional development programs for the entire group, and they have more fun and a better research experience. Historically about half of our summer policy students have been from UMD and the other half from other universities around the U.S. We also include Ph.D. and Masters students (who have their own support through programs such as the Washington State University IGERT) who would like to work part of their time on Indicators activities and part of their time on a science policy research project, thesis, or dissertation chapter that would support the long-term Indicators goals and lead to a peer-reviewed manuscript. The addition of graduate students has been very successful because it provides the undergraduate students additional mentors and allows them the opportunity to participate in a greater diversity of research projects by assisting the graduate students.

CICS task leaders have taught special **summer courses** at CREST on topics such as Geographical Information Systems and MatLab for students from Summer REU and Education Outreach Programs for High School and Senior Students. Four undergraduate students from the CE department learned how to download, read, and process GOES IR, CALIPSO, and CloudSat data for use in a GOES-R project in the summers of 2011 and 2012. One REU undergraduate and one high school student learned how to acquire, read, and process satellite (GOES & MODIS) data, as well as to understand some of the cloud physical properties.

CICS-MD has launched a summer program to provide training and outreach opportunities for both graduate and undergraduate students. The ***CICS-MD Summer Initiative (CSI)*** pairs students with mentors to conduct original scientific research and help train future NOAA scientists. The CSI provides a framework that includes software tutorials, informal student presentations, weather/climate discussions, and interactions with other institutions to maximize the student experience. The CSI not only focuses on training this year's students, but also works to recruit future CICS-MD students. Summer interns

hail from a wide variety of backgrounds, including UMD undergraduates, Hollings Scholars from other states, and UMD graduate students. These students (**Figure 6**) are sponsored through various projects, but the availability of funding often becomes a limiting factor. The number of students (10+) and proximity to their mentors lead to an extremely successful 2015 CSI, and lessons learned will be applied to future summer initiatives.

Figure 6: *The Summer 2015 cohort of the CSI.*

Graduate and Postdoctoral Education

CICS-MD is located in College Park MD and centered on the Earth System Science Interdisciplinary Center (ESSIC). ESSIC is a joint center between the University of Maryland Departments of Atmospheric & Oceanic Science (AOSC), Geology (GEOL), Geography (GEOG), and the Earth Sciences Directorate at the NASA/Goddard Space Flight Center. ESSIC's goal is to enhance understanding of the coupled interactions of the atmosphere, ocean, land, and biosphere components of the Earth and the influence of human activities on this system. This is accomplished via studies of the interaction between the physical climate system (*e.g.*, El Nino) and biogeochemical cycles (*e.g.*, greenhouse gases, changes in land use and cover). The major research thrusts of the center are studies of Climate Variability and Change, Atmospheric Composition and Processes, the Global Carbon Cycle (including Terrestrial and Marine Ecosystems/Land Use/Cover Change), and the Global Water Cycle. This research is accomplished is via analyses of in situ and remotely sensed observations together with component and coupled ocean-atmosphere-land models. Together these provide a foundation for understanding and forecasting changes in the global environment and regional implications. Data assimilation and regional downscaling provide the means by which the observations and models are linked to study the interactions between the physical climate system and biogeochemical cycles from global to regional scales.

CICS-MD has entered in an agreement with STAR/NESDIS to establish the provision for scientists (Visiting Scientists, Research Scientists and Research Associates/Postdoctoral

Fellows) to be appointed as NOAA/STAR temporary scientific staff. These positions will be located at STAR headquarters (University of Maryland Research Park, College Park, Maryland) and in other locations as deemed appropriate by the NOAA/STAR program manager. CICS-MD is located at the same research park, thus facilitating exchanges and visits without any additional expenses. Support for these positions will be from NOAA/NESDIS Center for Satellite Applications & Research (STAR) via (a) STAR central funding or (b) STAR science projects.

Professional interactions will be fostered among the CICS-MD and NESDIS/STAR Postdoctoral fellows and resident scientists in both groups by 1) scientific collaborations, 2) working visits, 3) scientific conferences, workshops, and seminars, 4) sharing of facilities, software, and data sets, and 5) other means required to foster this working agreement.

Graduate degrees for CICS-MD students are granted by the Departments, and many ESSIC faculty members have joint appointments and affiliations with AOSC, GEOL and GEOG. CICS-MD scientists include numerous faculty members from ESSIC and from the partner Departments. CICS-MD is able to draw on the extensive heritage of collaboration between UMD and NOAA that has enable numerous NOAA scientists to take courses in the physics of the atmosphere and ocean, and to obtain advanced degrees, as illustrated by the (until recently) Executive Director of CICS, Phillip Arkin, and Mitch Goldberg, the Chief of the Satellite Meteorology & Climatology Division.

CICS-MD scientists often provide lectures or teach courses, and several new courses have been developed specifically to enhance the University's educational program in the areas of most relevance to CICS and NOAA research. For example, Introduction to Earth System Science (AOSC 680) presents an introduction to the study of the earth as a system, including the atmosphere, oceans, land, cryosphere, solid earth, and humans. It covers cycling of materials and energy in the earth system: the energy cycle, the hydrologic cycle, the carbon cycle, the nitrogen cycle, as well as climate processes and variability, including land-atmosphere, ocean atmosphere, biosphere-climate, and human interactions, and short- and long-term variability in climate.

CICS-NC is located within a University of North Carolina Inter-Institutional Research Center in Asheville NC and administered by NCSU through the Department of Marine, Earth and Atmospheric Sciences (MEAS). MEAS includes approximately 40 faculty, 100 graduate students and 150 undergraduates involved in basic and applied studies of Earth Systems. Principal concentrations include weather prediction, air quality, air-sea interactions, storm and climate modeling, hydrology, geochemistry, oceanography, surface processes and regional geology. The NCSU Department of Statistics is among the nation's oldest and most prestigious, having been founded by renowned statistician Gertrude Cox in 1941. It receives support from both the College of Physical and Mathematical Sciences and the College of Agriculture and Life Sciences. Their graduate program is the largest in the country, with about 170 graduate students with an undergraduate program that is the second largest in the country with about 100 students.

As part of enhancing and supporting graduate students and postdoctoral students, CICS engages in several activities, including support of postdoctoral fellows in innovative re-

search, mentoring of graduate students and early career staff, support through fellowships, and advancing research efforts through delivering seminars and presentations.

CICS scientists offer early career mentoring of students and participate in advisory panels. CICS has an extensive mentoring program for graduate students where they participate in reviews of students' research, provide supervisory and mentorship support, and aid in early career development areas. CICS supports postdoctoral fellows working in Maryland and North Carolina, and through selected support, enable postdoctoral fellows to travel and present at a variety of state and national conferences, e.g., the American Geophysical Union Annual Meeting, the American Meteorological Society Annual Meeting, and the Climate Diagnostics and Prediction Workshop that is part of CPC activities. Over the past few years, CICS-NC has supported a total of 6 post-doctoral students to work in various research capacities supporting both CICS-NC and NCEI staff, as part of the broader workforce development. Research topics included the development of a next generation integrated global surface temperature analysis, global surface albedo calculations, scientific programming and visualization of satellite data information, climate variability of tropical cyclones and water vapor, quantitative precipitation estimation, temperature extremes analysis, amongst others.

CICS also engaged in interdisciplinary activities for education and outreach support. For example, Cezar Kongoli (CICS-MD) has supervised two students at the Department of Environmental Studies of American University (Washington DC) in the areas of remote sensing of coastal wetlands and statistical modeling and analysis of marine ecosystem health. Ms. Dissen served on a panel on energy, environment, and climate at Harvard University for their Science Policy Careers Symposium, held in May 2012, to provide support and share career experience with postdoctoral students about careers in science policy.

Many CICS scientists support and advice PhD students in different programs at the Universities in Maryland and North Carolina. In Maryland, there are about 20 graduate students involved in CICS research, while in North Carolina approximately 5 graduate students are working on CICS themes.

The National Research Council's 2010 ranking of PhD programs places the AOSC department firmly in the top ten Earth Science programs nationwide and higher than any other institution on the East Coast. Approximately 20% of the graduate students have been employed by NOAA.

The Department of Atmospheric and Oceanic Science of the University of Maryland has created a Graduate Fast-Track program for accomplished scientists. Graduate students with exceptional scientific achievements may, through written petition to the Graduate Director, replace the written portion of the Comprehensive Exam with a seminar followed by an oral examination. Approximately six NOAA scientists have already taken advantage of this program. About twenty civil servants and contractors have returned for their PhDs following the normal path.

CICS scientists often provide lectures, deliver seminars, and give presentations on their research areas. Since 2009, CICS researchers have published more than 300 peer-reviewed papers and given hundreds of presentations at a large number of conferences/meetings/workshops on the topics of climate research and applications, satellite and observation monitoring, and climate modeling. Staff members also serve on proposal review boards and have conducted many reviews of papers for journals. For a full list of seminars and scientific visitors, please refer to the Appendix H; for a full list of presentations and invited talks, please refer to Appendix I.

CICS scientists participate in the annual CoRP Symposium, and CICS helps to support CUNY/CREST graduate students participation as well. CICS also facilitates summer visits by CUNY/CREST students to NESDIS Cooperative Institutes, providing them with hands-on experience with software and techniques relevant to their research projects. This summer exchange program has led to increased visibility and employment opportunities for students and early career scientists, and provides excellent candidates for open positions at NOAA and the CIs.

3.4 Outreach and Engagement

There is a need to advance climate science and climate change literacy for decision makers as they explore practical and cost-effective approaches to leverage available resources. Provision of climate data for applications and decision capabilities, which can factor into strategic, planning, and operational decisions, requires partnerships across public, private, and academic organization. CICS will engage in several meaningful climate engagement and outreach activities to the private sector as well as the general public. CICS will contribute to enhancing NOAA's efforts to communicate research results to the scientific community, decision-makers and the general public using several methods. We will present our collaborative research results at appropriate scientific meetings and other fora, and will publish them in the scientific literature once they are sufficiently complete. Scientists at all the participating institutions have excellent publication records, including substantial published work describing the results of collaborative research with NOAA scientists.

Since scientific publication tends to reach the scientific community more effectively than other target audiences, we propose to utilize other innovative approaches as well. These activities are often more effective when carried out in conjunction with CICS partners who have particular areas of expertise. To this end we will establish an *Outreach Enterprise Team* that will identify opportunities for the necessary activities. Critical expertise and connectivity for this effort will come from the Asheville *Buncombe*

Sustainable Communities Initiative (ABSCI), an Asheville NC-based non-profit group that brings together important community elements with an interest in climate research, innovation and entrepreneurial activities. ABSCI will be particularly valuable to the efforts of CICS to enhance the effectiveness of climate information products that result from research into satellites and climate. Another crucial contribution to the Outreach Enterprise Team is provided by *Climate Central*, a non-profit organization established by a team of eminent climate scientists to ensure that critical climate information is made available in accessible form to decision-makers and the general public. *Climate Central* and CECI are both members of the CICS Consortium, ensuring that NOAA will benefit effectively from their expertise and networking capabilities.

CICS engagement and outreach activities require developing frameworks, delivering presentations, engaging in relationship-building and capacity-building activities, enabling catalytic support of innovation in uses of climate data, engaging in individual and executive-level roundtable discussions, as well as providing ongoing operational support to NOAA organizations like NCEI, and NWCPC.

Key highlights of proposed activities in outreach are framed under these areas:

- Advancing climate literacy for private sector partnerships through interdisciplinary activities, including outreach to energy industry, insurance industry, plant-based sector, and executive roundtable sessions
- Engagement and outreach to local and national TV meteorologists and other media interested in climate information
- Providing operational support to activities in NOAA organizations like NCEI in advancing their engagement activities in collaboration with the Climate Services and Monitoring Division and the Sectoral Engagement Team, communication with the Communications Officer, and literacy with the Education Lead
- Engagement and outreach and literacy activities to the general public

  Developing communication and informational materials on the CICS activities and progress to share with CICS partners, and to inform the general public

Training Operational Forecasters

Several CICS Scientists work closely with operational meteorologists to implement their science and products, in what is usually called Satellite Proving Ground Activities. For example, CICS Research Associate Michael Folmer works as the "Satellite Liaison" at the OPC/HPC/SAB Proving Grounds (PGs), helping to coordinate their PG activities. Satellite PGs connect NOAA with its partners to bridge the gap between research and operations, provide unique sources of information, and support end-user education and training. The PG approach ensures communication between product developers and operational forecasters, allowing end users to contribute expertise to the final products (i.e., how it is displayed and integrated into operations). User feedback during algorithm develop-

ment affords a wealth of information that helps focus research activities on end-user applications. This feedback mechanism also supports the development of effective education and training tools early in the product development process.

CICS currently develops satellite products and provides indirect support for Satellite PG efforts, but has no direct method for implementing new or existing experimental products. An ongoing project seeks to develop an operational framework which allows CICS to maximize its Satellite PG contributions by creating a variety of gateways to the public. The four major components are to install and implement McIDAS and AWIPS-II, build a Local Data Manager (LDM), improve the CICS-led STAR Precipitation Calibration and Validation center, and expand education, training, and outreach activities. This research will allow CICS to become a stronger, more diverse, and more direct PG provider, which will enhance collaboration, improve operational products, and simplify the feedback mechanism.

CICS provides satellite education and training materials through e-learning modules, seminars, weather event simulations, and special case studies. NOAA, collaboratively through the NESDIS and the NWS, partners with the COMET, VISIT, and SPoRT to develop and deliver training on the new features, operations, and capabilities of future satellite missions. The academic community is another important user of satellite data, for informational, educational, and research purposes. Some specific academic institutions collaborate with NOAA/NESDIS to develop and implement PG demonstration products. The planned implementation of McIDAS and AWIPS-II at CICS also will provide a valuable education and training opportunity for UMD graduate and undergraduate students. Such activities will help develop students with remote sensing experience who then can enter the work force to staff future NESDIS activities as support contractors and civil servants.

Figure 7: *Michael Folmer engaged in Forecaster Trainingon on "GOES-R Series Program Update and User Readiness"*

Engagement and Outreach to the General Public

CICS reaches out to the general public and relevant communities in a variety of ways. The University of Maryland sponsors an annual event called Maryland Day (**Figure 8**; **Figure 9**; http://www.marylandday.umd.edu/) that enables CICS-MD to reach a large audience, on the order of 70,000 visitors, in a campus-wide open house. For the last several years, CICS has contributed significantly to the ESSIC exhibit at Maryland Day, permitting CICS to "show off" many of its talented researchers and promote the NOAA mission to the general public.

Figure 8*: Images of Maryland Day (April 25, 2015)*

CICS-MD has been using a visualization technique called "The Magic Planet" to reach out to the public. The Magic Planet displays datasets of weather and climate moving across its surface. The images displayed are used to educate visitors of all ages, earth systems and how they relate to the environment. CICS makes presentations at Maryland Day,

the Maryland Science Center in Baltimore, and the National Zoo. Furthermore, a supplemental target was to promote the use of *Earthnow,* a web-based blog operated by the same research institutes, among docents (staff and volunteers) that carry out presentations at SOS sites in museums and science centers across the country (and around the globe).

Figure 9*: Images of Maryland Day (April 25, 2015)*

To fulfill this task, training sessions were held bi-weekly at the Maryland Science Center (MSC) in Baltimore, Maryland. The project identified supplemental methods to promote public learning, interest, and focus on earth science, short-term weather, and long-term climate change. These methods included (a) podcasting some of the *Earthnow* content and including it in automatic SOS playlists, (b) promoting the use of local stories and topical events in SOS presentations and *Earthnow* posts (by using local sources, working closely with museum staff and data providers and developers) and (c) creating future docent training material based on feedback received in an online survey of docents, as well as on the systematic observation of the public's engagement and perception (opinion) of the SOS live presentations.

CICS recently supported the launch of *CycloneCenter.org*, a joint activity with NCEI, UNC Asheville, and Zooniverse that enables the public to help analyze the intensities of past tropical cyclones around the globe. The general public is able to log in and answer questions about images as part of a simplified technique for estimating the maximum surface wind speed of tropical cyclones. This example of public collaboration allows for the completion of a large number of classifications in just a few months—something that would take a team of scientists more than a decade to accomplish. The end product will be a new global tropical cyclone dataset that provides tropical cyclone intensity estimates, confidence intervals, and a wealth of other metadata that could not be realistically obtained in any other fashion.

Outreach at CICS-MD has the potential to grow into a major resource for raising climate awareness around College Park, MD, the Washington D.C. metropolitan area, and beyond. For the past three years, CICS scientists have been conducting outreach and informal education through a NOAA Office of Education project to interpret global climate and satellite products at museums using the *Science On a Sphere (SOS)*. This project involves close collaboration with the Maryland Science Center in Baltimore to understand public perception of stories displayed on SOS and how to improve the effectiveness of this tool. Museum staff and their public audience often need background information to provide context. To address this, CICS-MD has launched a new website (climatebits.umd.edu) to serve as a tool for SOS museums as well as a resource for anybody interested in minute-long videos on Earth Science concepts. Over the next five years, we will grow this resource and increase our collaboration with related outreach efforts.

ClimateBits will serve as the focus of CICS outreach efforts to the general public, including its website, online videos, twitter, and facebook accounts. These tools are tailored to the SOS community, consisting of more than 100 sites in 15 countries attended by more than 33 million visitors each year according to the NOAA SOS website. Yet this resource will have broader impact with a dynamic web and social media presence. The internet is now the top source of information world-wide, half of all Americans own a smartphone, and two thirds of these Americans use smartphones to access the internet. Social media accounts for 17% of all time spent online. Additionally, younger generations look for organizations on social media and lose interest in organizations without an active web presence. Facebook alone reaches more than 1 billion people or 72% of internet users, with 48% of users under the age of 30 using it as their primary news source. Additional distribution of this tool as resource will be accomplished through collaboration with other agencies (e.g. NASA, NOAA) and organizations (e.g., the Smithsonian), and by working more closely with UMD to increase our visibility on and off campus.

CICS-NC supports access to climate information for opportunities through its partnership with the Asheville Buncombe Sustainable Community Initiatives (ABSCI), a NC 501 (c) 3 with a mission to support and catalyze a resilient and enduring prosperity for the community within the context of a rapidly evolving and increasingly complex world. ABSCI has a long history of projects that support sustainability of the long-term economic, environmental and cultural values that make NC vital and unique. ABSCI project portfolio includes the Collider Innovation Center, where ABSCI manages and runs The Collider, a catalyst environment for building relationships and collaborations across economic and community sector. The Collider offers small offices, co-working, conference rooms and event and workshop spaces as a platform within downtown Asheville to stimulate business and community engagement. Through the intentional creation, nurturing and maintenance of this workplace and learning environment ABSCI leverage the resources of a multitude of partners to offer activities that support business commercialization, community engagement and lifetime learning, with a specific focus on the climate and resilience sector.

Communication and Informational Updates on CICS

In 2015, CICS-NC significantly invested in improving its communications efforts for delivering institute science and program information and technical services for varied audiences and a wide range of stakeholders across public, private and academic enterprises.

CICS-NC brought on a communications specialist (Tom Maycock) who elevated the presence of CICS-NC across its stakeholders to share information related to the progress of the institute's work. Starting with building a communications strategic plan for CICS-NC, the communications activities included following significant updates that have helped the general public improve their understanding of not only the research institute but also progress in climate research:

- A refined, updated CICS-NC website with content that is updated frequently of both science and engagement activities
- Development of a science fact sheets that translated the scientific content into user-friendly materials for the general public and the CICS-NC stakeholders
- Improved inter-institutional communications with NC State University across the College of Sciences, Marine, Earth and Atmospheric Sciences Department and Office or Research, Innovation and Economic Development, as well as with the University of Maryland ESSIC and CICS-MD
- Improved CICS-NC's presence across social media (e.g. through an improved and updated Facebook)_as well as issue relevant press releases with media contacts as appropriate.

In addition, CICS-NC developed a new brochure as well as an overview, science and engagement poster that is broadly used and shared across conferences, meetings and workshops.

CICS-MD and CICS-NC each distribute semiannual publications entitled *Circular* and *Trends,* respectively (**Figure 10**), that report on CICS-MD / CICS-NC vision and mission, research themes and provide brief descriptions of selected research projects at the institute. These publications are shared with the respective business communities, consortium partners, other organizations as part of the engagement effort, and university partners across the various offices to keep the department heads and faculty updated on research progress. They are also shared with participants at CICS-organized workshops or science meetings.

***Figure 10**: Recent CICS-MD and CICS-NC Newsletter issues*

CICS web sites continue to be developed to enhance CICS outreach to all interested sectors. CICS has a dedicated web page that serves as a focused presentation of CICS-specific research projects and results. An independent website, climateandsatellites.org, intended to provide a comprehensive description of the CICS Consortium, has been established and is in the process of being enhanced. This site provides the background, mission, and vision statements for CICS, as well as links to Consortium participants.

Both CICS-MD and CICS-NC maintain dedicated sites for their own activities that also include cross-links with other CICS sites using a consistent "look and feel.

CICS website: http://climateandsatellites.org

CICS-MD website: www.essic.umd.edu/cics-md/

CICS-NC website: www.cicsnc.org

In addition, CICS contributes news items to the ESSIC and AOSC web pages and blogs, where significant research accomplishments are described.

A new blog created by CICS-MD and SCSB scientists titled “It’s Severe – Unique Perspectives on Extreme Weather” was recently launched on the ESSIC website. This outreach effort aims to introduce the public to the unique methods and datasets that CICS/ESSIC scientists use to examine extreme weather events (thunderstorms, fires, floods, blizzards, etc.). The blog also serves as a seed for NESDIS, CICS, and ESSIC scientists to begin exploring new multi-sensor, multi-platform applications.

The College of Computer, Mathematical, and Natural Sciences (CMNS), of which CICS is a part, issues a quarterly newsletter to a wide audience, and CICS, when appropriate, contributes items describing notable accomplishments and events.

Additional outreach through communication occurs through seminar participation. CICS scientists participate in the AOSC, ESSIC, and NCSU MEAS seminar series, as well as give seminars and presentations at other institutions. Volume 2 of this Annual Report contains a sampling of CICS Researchers’ invited talks and their participation in giving seminars.

Appendix 1: Acronym List

Acronym	Definition
4D-Var	Four-Dimensional Variational (data assimilation system)
4SQM	Satellite Sea Surface Salinity Quality Monitor
ABI	Advanced Baseline Imager
ACSPO	Advanced Clear-Sky Processor for Oceans
ADL	Algorithm Development Library
AERONET	Aerosol Robotic Network
AERONET-OC	Aerosol Robotic Network-Ocean Color data
AF	Active Fire
AGU	American Geophysical Union
AL	Albedo
ALEXI	Atmosphere-Land Exchange Inverse model
AMS	American Meteorological Society
AMSR2	Advanced Microwave Scanning Radiometer 2
AMSR-E	Advanced Microwave Scanning Radiometer - EOS
AMSU	Advanced Microwave Sounding Unit
AMSU-A	Advanced Microwave Sounding Unit-A
AMSU-B	Advanced Microwave Sounding Unit B
AOSC	Department of Atmospheric and Oceanic Science (UMCP)
AOT	Aerosol Optical Thickness
APSP	Aerosol Particle Size Parameter
AR5	Fifth Assessment Report (IPCC)
ARL	Air Resources Laboratory (OAR)
ASCAT	Advanced Scatterometer
ASTR	Department of Astronomy (UMCP)
ATDD	Atmospheric Turbulence and Diffusion Division (ARL)
ATMS	Advanced Technology Microwave Sounder
AWIPS-II	Advanced Weather Information Display System, version 2
BDI	Blended Drought Index
CDR	Climate Data Record
CFS	Coupled Forecast System
Chl-a	Chlorophyll-a
CHRS	Center for Hydrometeorology and Remote Sensing
CICS	Cooperative Institute for Climate and Satellites
CICS-MD	Cooperative Institute for Climate and Satellites-Maryland
CICS-NC	Cooperative Institute for Climate and Satellites-North Carolina
CIMAS	Cooperative Institute for Marine and Atmospheric Studies (University of Miami)
CIOSS	Cooperative Institute for Oceanographic Satellite Studies (OSU)
CIRUN	Climate Information Responding to User Needs
CISA	Carolinas Integrated Sciences & Assessments (USC)
CLASS	Comprehensive Large Array-data Stewardship System

CMIP3	Coupled Model Intercomparison Project, Phase 3
CMIP5	Coupled Model Intercomparison Project, Phase 5
CMNS	College of Computer, Mathematical and Natural Sciences (UMD)
CONUS	Continental United States
CoRP	Cooperative Research Program Division (STAR)
CPC	Climate Prediction Center (NCEP)
CPO	Climate Program Office (OAR)
CREST	Cooperative Remote Sensing Science and Technology Center (CUNY)
CrIMSS	Cross-track Infrared Microwave Sounder Suite
CrIS	Cross-Track Infrared Sounder
CRTM	Community Radiative Transfer Model
CUNY	City University of New York
CWG	Calibration Working Group (GOES-R)
DA	Data Assimilation
DCLMA	District of Columbia Lightning Mapping Array
DLR	German Aerospace Center
DNB	Day/Night Band
DoD	Department of Defense
ECMWF	European Centre for Medium-Range Weather Forecasts
EDR	Environmental Data Record
EFSO	Ensemble Forecast Sensitivity to Observations
EFSR	Ensemble Forecast Sensitivity to R
EMC	Environmental Modeling Center (NCEP)
EnKF	Ensemble Kalman filter (data assimilation system)
ENSO	El Niño Southern Oscillation
ERB	Earth Radiation Budget
ESA	European Space Agency
ESRL	Earth System Research Laboratory
ESSIC	Earth System Science Interdisciplinary Center (UMD)
ET	Evapotranspiration
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EVI2	Enhanced Vegetation Index, version 2
FCDR	Fundamental Climate Data Record
FOV	Field of View
RP	Fire Radiative Power
FSOI	Forecasts Sensitivity to Observation Impacts
FSR	Full Spectral Resolution
GAASP	GCOM AMSR2 Algorithm Software Processor
GCOM	Global Change Observation Mission (JAXA)
GCOM-W1	Global Change Observation Mission 1st - Water
GCOS	Global Climate Observing System
GEFS	GFS Ensemble Forecast System
GEO	Geostationary Orbits
GEOG	Department of Geographical Sciences (UMCP)

GET-D	GOES Evapotranspiration and Drought product system
GFS	Global Forecast System
GISS	Goddard Institute for Space Studies (NASA)
GLDAS	Global Land Data Assimilation System
GLM	Geostationary Lightning Mapper
GMU	George Mason University
GOES	Geostationary Orbiting Environmental Satellite
GOESPO	GOES-R Program Office (NESDIS)
GOES-R	Geostationary Orbiting Environmental Satellite – R-Series
GPCP	Global Precipitation Climatology Project
GPM	Global Precipitation Measurement Mission
GPROF	Goddard Profiling Algorithm
GPSRO	Global Positioning System Radio Occultation
GRAVITE	Government Resource for Algorithm Verification, Independent Testing
GridSat	Gridded Satellite Data
GRUAN	GCOS Reference Upper Air Network
GSA	Geostationary Surface Albedo
GSFC	Goddard Space Flight Center (NASA)
GSI	Gridpoint Statistical Interpolation (data assimilation system)
GSICS	Global Space-based Inter-Calibration System
GVAR	GOES Variable Format
GVF	Green Vegetation Fraction
HAB	Harmful Algal Blooms
HIRS	High-Resolution Infrared Radiation Sounder
HOT	Hawaii Ocean Time-series
HVRI	Hazards & Vulnerability Research Institute (USC)
HWT	Hazardous Weather Testbed
HyperPRO	Free-falling Optical Profiler (HOT)
ICDR	Interim Climate Data Record
ICESat	Ice, Cloud and Land Elevation Satellite
IDPS	Integrated Data Processing Segment
IGES	Institute for Global Environmental Strategies
IMS-V3	Interactive Multi-Sensor Snow and Ice System, Version 3
INR	Imagery Navigation and Registration
IPCC	Intergovernmental Panel on Climate Change
IR	Infrared
IRC	Inter-Institutional Research Center (UNC)
IRI	International Research Institute for Climate and Society (Columbia University)
ISCCP	International Satellite Cloud Climatology Project
IT	Information Technology
JAXA	Japan Aerospace Exploration Agency
JCSDA	Joint Center for Satellite Data Assimilation
JGR	Journal of Geophysical Research

JPSS	Joint Polar Satellite System
JPSSO	JPSS Office (NESDIS)
LAI	Leaf Area Index
LETKF	Local Ensemble Transform Kalman Filter
LIS	Land Information System
LISCO	Long Island Sound Coastal Observatory
LMA	Lightning Mapping Arrays
LSM	Land Surface Model
LST	Land Surface Temperature
LUT	Look-Up Table
MESH	Maximum Expected Size of Hail
METEOSAT	Meteorological Satellite
Metop-B	Meteorological Operational Polar Satellite-B
MHS	Microwave Humidity Sounder
MiRS	Microwave Integrated Retrieval System
MOA	Memorandum of Agreement
MODIS	Moderate Resolution Imaging Spectroradiometer
MRMS	Multi-Radar Multi-Sensor precipitation product suite
MSG	METEOSTAT Second Generation
MSL12	Multisensor Level-1 to Level-2 (NOAA-MSL12) ocean color data processing
MSPPS	Microwave Surface and Precipitation Products System
MSU	Microwave Sounding Unit
M-T	Megha-Tropiques satellite
MTSAT-2	Multi-Function Transport Satellite #2 (Japan)
NAM	North American Mesoscale model
NAQFC	National Air Quality Forecast Capability
NARR	North American Regional Reanalysis (NCEP)
NASA	National Aeronautics and Space Administration
NCA3	Third U.S. National Climate Assessment
NCEI	National Centers for Environmental Information (NOAA)
NCEP	National Centers for Environmental Prediction (NOAA)
NCICS	North Carolina Institute for Climate Studies
NCSP	NOAA Climate Service Portal
NCSU	North Carolina State University
NCWCP	NOAA Center for Weather and Climate Prediction
NDE	NPOESS Data Exploitation
NEMAC	National Environmental Modeling and Analysis Center (UNC)
NESDIS	National Environmental Satellite, Data and Information Service (NOAA)
NGGPS	Next Generation Global Prediction System (NWS)
NIC	NOAA Ice Center (OSPO)
NIDIS	National Integrated Drought Information System
NLDAS	North American Land Data Assimilation System
NMME	National Multi-Model Ensemble

NM	Nadir Mapping
NN	Neural Network
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service (NOAA)
NP	Nadir Profile
NPOESS	National Polar Orbiter Environmental Satellite System
NPP	NPOESS Preparatory Project
NRT	Near Real Time
NSF	National Science Foundation
NU-WRF	NASA-Unified Weather Research and Forecasting
NWP	Numerical Weather Prediction
NWS	National Weather Service (NOAA)
OAR	Office of Oceanic and Atmospheric Research (NOAA)
Obs4MIPS	Observations for Model Intercomparisons Project
OISST	Optimum Interpolation Sea Surface Temperature
OLR	Outgoing Longwave Radiation
OMPS	Ozone Mapping and Profiler Suite
ORNL	Oak Ridge National Laboratory
ORAU	Oak Ridge Associated Universities
OSD	Office of Systems Development (NESDIS)
OSGS	Office of Satellite Ground Services (NESDIS)
OSPO	Office of Satellite and Product Operations (NESDIS)
OSSE	Observing Systems Simulation Experiment
OSU	Oregon State University
PERSIANN	Precipitation Estimation from Remote Sensing Information using Artificial Neural Network (CHRS)
$PM_{2.5}$	Particulate Matter less than 2.5 microns in diameter
PNAS	Proceedings of the National Academy of Sciences
PQC	Proactive Quality Control
PSDI	Palmer Drought Severity Index
POES	Polar Orbiting Environmental Satellites
QA	Quality Assurance
QC	Quality Control
QGIS	A free and open source Geographic Information System
QPE	Quantitative Precipitation Estimates
RENCI	Renaissance Computing Institute (UNC)
RFC	River Forecast Centers (NWS)
RMSE	Root Mean Square Error
RSMAS	The Rosenstiel School of Marine and Atmospheric Science (University of Miami)
RT	Real-Time
SAPHIR	Spectrometer Arrangement for Photon Induced Reactions
SBN	Satellite Broadcast Network
SCaMPR	Self-Calibrating Multivariate Precipitation Retrieval

SCAN	Soil Climate Analysis Network (USDA)
SCSB	Satellite Climate Studies Branch (CoRP)
SD	Solar Diffuser
SDR	Sensor Data Record
SDSU	South Dakota State University
SeaPRISM	SeaWiFS Photometer Revision for Incident Surface Measurements
SeaWiFS	Sea-viewing Wide Field of View Sensor
SEHOS	Subseasonal Excessive Heat Outlook System
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SHI	Severe Hail Index
SM	Suspended Matter or Soil Moisture
SMAP	Soil Moisture Active Passive satellite (NASA)
SMOPS	Soil Moisture Operational Products System
SMOS	Soil Moisture and Ocean Salinity satellite
SMOS NRT chain	Soil Moisture and Ocean Salinity satellite: Near Real Time processing
SFR	Snowfall Rate
SNODAS	Snow Data Assimilation System
S-NPP	Suomi-National Polar-Orbiting Partnership
SSMIS	Special Sensor Microwave Imager/Sounder
SST	Sea Surface Temperature
ST	Surface Type
STAR	Center for Satellite Applications and Research (NESDIS)
STI	Science, Technology, and Infusion program (NWS)
SW	Shortwave
TEB	Thermal Emissive Bands
TET-1	Technology Experiment Carrier satellite (DLR)
TMPA	TRMM Multisatellite Precipitation Analysis
TOA	Top of the Atmosphere
TPW	Total Precipitable Water
TRMM	Tropical Rainfall Measuring Mission
TSU	Technical Support Unit (National Climate Assessment)
UAH	University of Alabama in Huntsville
UAS	Unmanned Aircraft System
UMCP	University of Maryland, College Park
UMD	University of Maryland
UNC	University of North Carolina
USC	University of South Carolina
USDA	United States Department of Agriculture
USDM	United States Drought Monitor
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
VI	Vegetation Index
VIIRS	Visible/Infrared Imager Radiometer Suite

VS	Visiting Scientist
WRF	Weather Research and Forecasting model