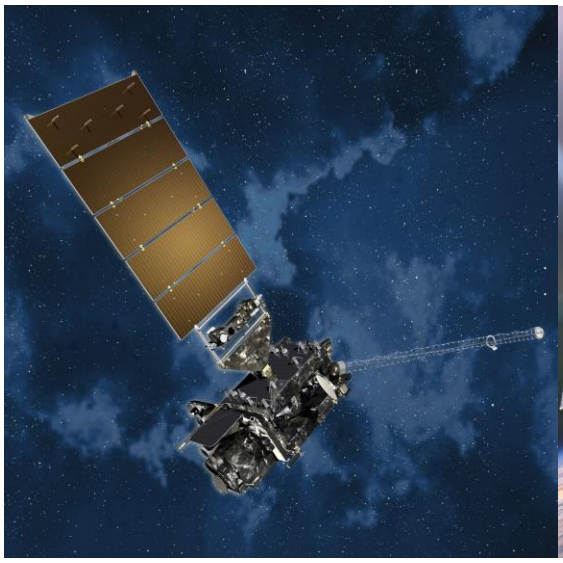

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COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

Annual Scientific Report

VOLUME I: Activities Summary

For the period:
April 1, 2016 – March 31, 2017
NOAA Grant NA14NES4320003

Dr. Fernando Miralles-Wilhelm, Director
April 30, 2017

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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.

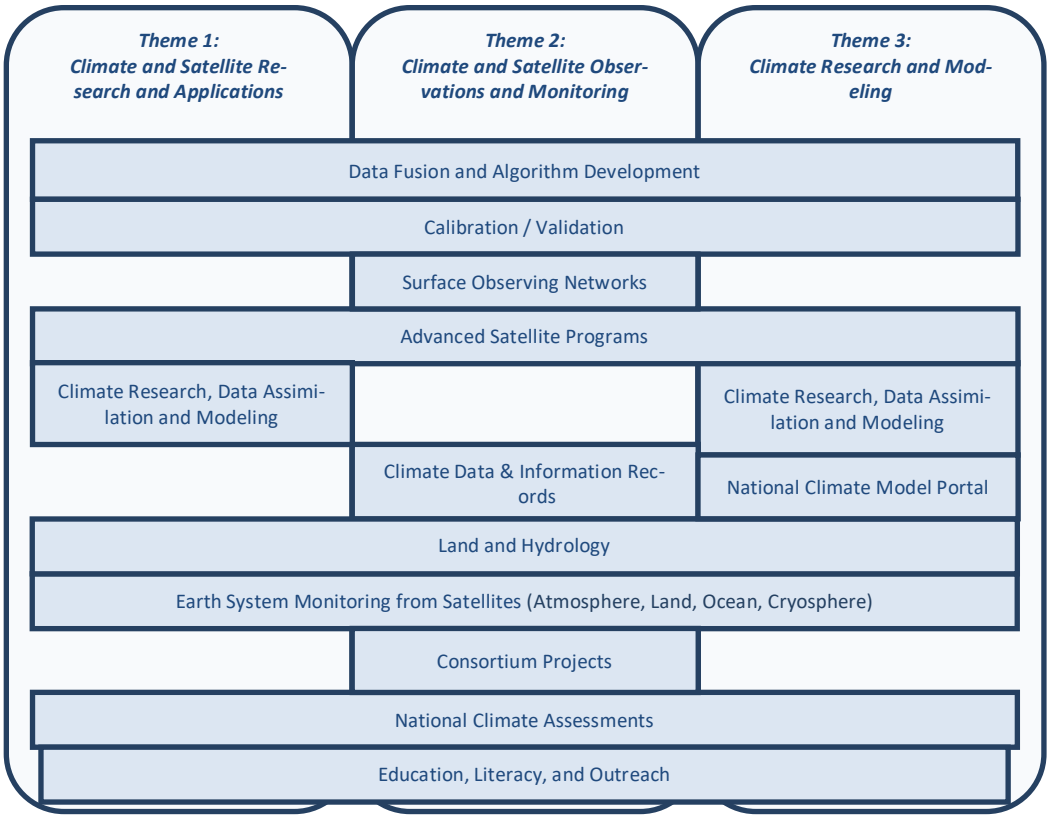
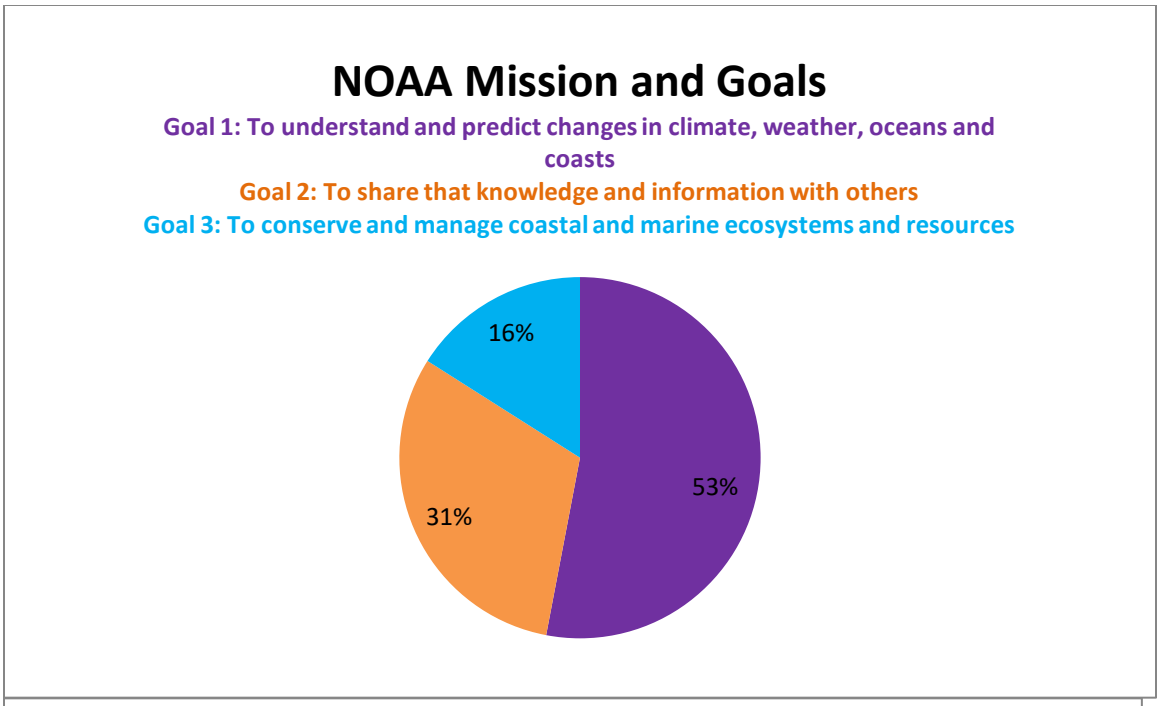


***Figure 1**: CICS Research Themes and Topic Areas*



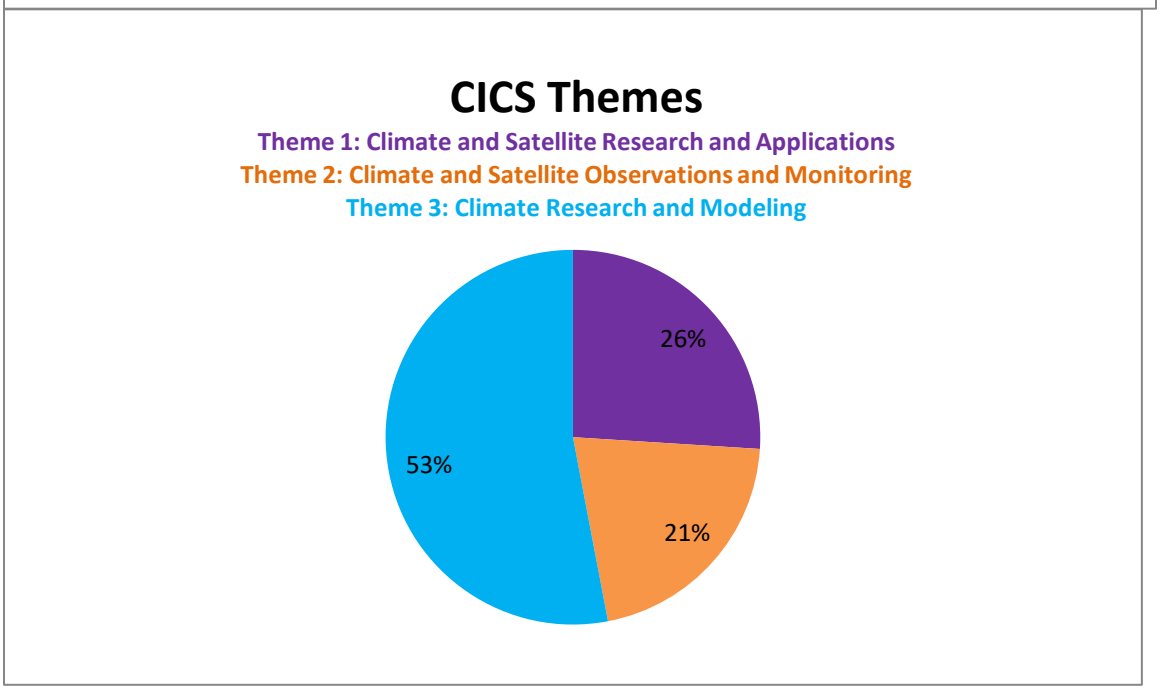


Figure 2: *Distribution of CICS funding during the reporting period.*

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 of the University of North Carolina 9UNC) 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.

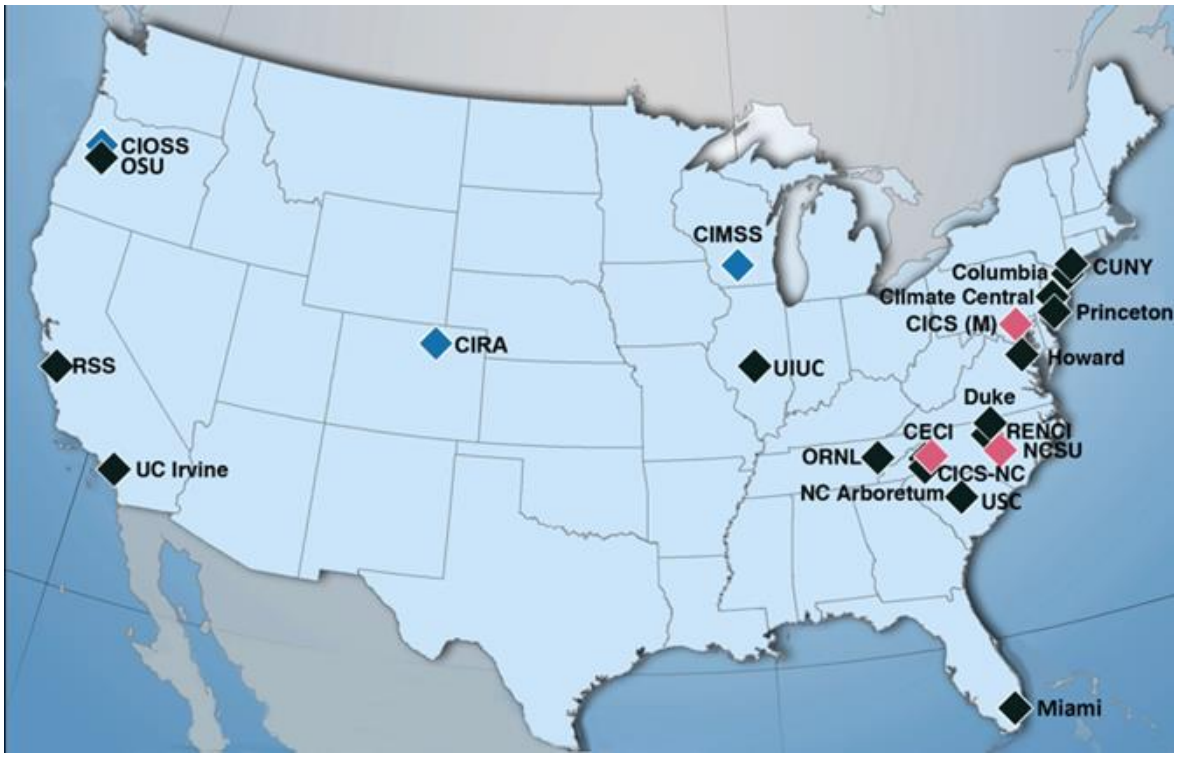


***Figure 3**: Spatial distribution of CICS Consortium institutions.*

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 principal 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

- Amitabh Varshney – Interim Vice President for Research
- Jayanth Banavar - Dean, College of Computational, Mathematical and Natural Sciences
- Fernando Miralles-Wilhelm – Interim Director, ESSIC

For NCSU/UNC System

- Alan H. Rebar – Vice Chancellor, Research, Innovation and Economic Development, NCSU
- Ray Fornes - Professor Emeritus of Physics, College of Physical and Mathematical Sciences, NCSU
- Michael Todd – Executive Director, NC Research Campus

For NOAA

- Harry Cikanek, Acting Director, NESDIS Center for Satellite Research and Applications (STAR)
- William Lapenta, Director, NWS/NCEP
- Michael Tanner, Director, NOAA Center for Weather and Climate (NCEI)
- Richard Artz/Dr. Bruce Baker OAR Air Resources Laboratory
- 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 2016* (2015)	
# of new or improved products developed that became operational	**160 (207)**
# of products or techniques submitted to NOAA for consideration in operations use	**80 (93)**
# of peer reviewed papers	**174 (201)**
# of NOAA Technical Reports	**93 (51)**
# of invited presentations	**357 (312)**
# of graduate students supported by a CICS task	**31 (20)**
# of graduate students formally advised	**59 (43)**
# of undergraduate students mentored during the year	**72 (44)**

(*) Figures for 2016 are reported for the period of April 1, 2016-March 31, 2017.

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

Validation of Operational AMSR2 SSTs: The 4th version of the GAASP product has been used as the basis for development of a GHRSST Level-2P AMSR-2 product which will commence production in the NDE. This has required the development of a sensor-specific error statistics function, which reduces regional biases and improves accuracy. [**STAR**]

***Incorporation of Himawari-8 SST into 5-km Blended SST Analysis*:** Investigations continue on the available version of the ACSPO Himawari-8 SST, which has been successfully incorporated into the Geo-Polar Blended SST analysis. Tests have included the effect of a diurnal adjustment for the H-8 SSTs during the input gridding. Since the SPO retrieval algorithm utilizes direct regression, patterns of bias are somewhat different from the previous MTSAT-2 Imager. However, the AHI instrument has more channels, lower noise, improved spatial resolution and better calibration. This permits a more linear solution and makes the choice of algorithm less critical. The results are encouraging for the prospect of including data from the GOES-R ABI and, in the future, Meteosat Third Generation. [**STAR**]

An Investigation into the Feasibility of Accurate Lake Surface Temperatures: Investigations into the utility of the existing ACSPO VIIRS SST product show that, for the Great Lakes, using only data defined with a quality level of "good" results in the exclusion of large areas of observations that are actually valid. This exclusion is both substantial and asymmetric, i.e. use of "good" data results in coverage that is both poor and biased warm with respect to the full distribution of valid temperatures. In order to allow the many good observations of cooler water, it is necessary to relax the quality level to include data flagged as "bad" which means that some truly cloud-contaminated observations are also allowed to pass the threshold. Further investigations into coverage for a representative target lake show that observations are almost absent during winter-time. Optimization of the cloud detection will be the first step in obtaining a viable automated lake surface temperature product from the VIIRS mission. [**STAR**]

An Assessment of Existing 1-km Sea Surface Temperature Analyses: Investigations into the utility of the existing ~1-km SST analyses demonstrate that accuracy and coverage are likely to be significantly worse than obtained for the current ~5-km Geo-Polar Blended SST analysis. The anticipated benefit of moving to a higher resolution SST analysis is therefore unlikely to be realized without dedicated effort into development of regional analyses tailored to the needs of Coral Reef Watch. [**STAR**]

***Development of Global Soil Moisture Product System (SMOPS)*:** We have finished ingesting NOAA AMSR2 and NASA SMAP soil moisture data into SMOPS, ingesting NRT SMOS, GMI and SMAP brightness temperatures into SMOPS for its own soil moisture retrievals and the new SMOPS version (V3.0) has been under testing at OSPO. The new version of SMOPS is expected to go operational in the summer of 2017. [**STAR**]

JPSS Microwave Integrated Retrieval System (MiRS) Calibration and Validation: An updated MiRS Version 11.2 was delivered to NOAA operations for all NOAA operational microwave satellites/sensors. The primary enhancement in V11.2 is the extension of operational processing capability to GPM/GMI measurements. V11.2 is also backwards compatible with all other operational satellites.. [**STAR**]

Developing and Refining Microwave Integrated Retrieval System (MiRS) High Resolution Snow/Ice Products: A significant update was done to snow water equivalent (SWE) algorithm for all ATMS and AMSU/MHS satellites, which optionally allows for the use of a vegetated forest fraction correction. Validation results over the U.S. using SNODAS analyses show significant improvements in snow cover detection and SWE, particularly over forested regions of eastern and northern U.S. [**STAR**]

GCOM-W1 Soil Moisture Product Development and Validation: We have finished the development of GCOM-W1 AMSR2 soil moisture EDR product algorithm. The science code of the algorithm has been completed and delivered to GCOM-W1 team at NOAA/NESDIS/STAR. The code is now operationally running there. A re-run of the production code has been done over the whole AMSR2 data period using the most recent version of brightness temperature inputs. This historical data set will be used for the validation work using the in-situ measurements. This product has been ingested into SMOPS Version 2.0 and after. Algorithm refinement has been intensively conducted to improve both the spatial coverage and the quality of the retrievals. [**STAR**]

Science and Technology Infusion Strategy for the Next-Generation Global Prediction System (NGGPS) Planning: A successful Science and Technology Infusion Strategy for the NGGPS planning involves strategic issues for model and data assimilation development and an explicit community-based plan for ad-vanced physical (scale-aware) parameterizations with improved coupling of physical processes across radiation, boundary layer, deep and shallow convection and surface fluxes. Mentoring current NWS and other NOAA staff is an important contribution to add perspective to a very complex undertaking. Moreover, efficient and effective use of High Performance Computing (HPC) resources through careful software design and HPC system planning is essential for providing new and improved products to users through the NGGPS Program. A comprehensive diagnostic system is essential to identifying systematic forecast errors and to measuring progress toward minimizing these errors. This project contributes to building such a system. [**NWS**]

Calibration/Validation

Science and Management Support for NPP VIIRS Surface Type EDR: Passed Validated 1 maturity review. [**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. 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: A new Snowfall Detection algorithm was developed, which combines current operational algorithm and weather forecast model; Supercool liquid water effect was modeled in the 1D VAR satellite snowfall rate retrieval algorithm. [**STAR**]

Transition and Enhancement of ATMS Snowfall Rate Product and its Fusion with Weather Radar Data: The ATMS snowfall rate algorithm was updated with the new snowfall detection algorithm. [**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. [**STAR**]

NPP/VIIRS Land Surface Albedo Validation Research and Algorithm Refinement: We developed an algorithm to estimate daily mean albedo from VIIRS. We developed a new VIIRS gridded product of land surface albedo. We comprehensively evaluated VIIRS albedo data using newly collected data and we have also been routinely monitoring VIIRS albedo product. [**STAR**]

GOES-R Active Fire/Hot Spot Characterization: Validation and Refinement of GOES-R/ABI Fire Detection Capabilities: *Deep-dive* fire validation tool was expanded, tested with DOE data and applied to post-launch ABI data. [**STAR**]

Radiometric Calibration for Jason 2 and 3 Advanced Microwave Radiometer: We have monitored the stability of Jason-3 Advanced Microwave Radiometer by comparing with

Jason-2 AMR using vicarious site methods, SNO method, and coldest ocean method. A comparison of AMR radiance at 23.8 GHZ between Jason-3 and ATMS is also carried out. [**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**]

Pre- and Post-Launch Calibration/Validation Support for J1 and Suomi-NPP VIIRS: CICS scientists provide operational science support for Suomi-NPP and J1 VIIRS instrument through support radiometric calibration and validation of VIIRS by providing pre-launch Support for J1 VIIRS, performing lunar calibration, characterizing spectral degradation of solar diffuser due to space radiation exposure, supporting DNB radiometric validation with nightlight sources for SNPP VIIRS, DNB stray light correction LUT generation tool development for Suomi-NPP and J1 VIIRS, and supporting VIIRS SDR team management and coordination.. [**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) validation, analysis of J1-VIIRS DNB scan mode change, developed tool to validate the VIIRS Day/Night Band geolocation accuracy and for DNB radiometric validation with nightlight sources, and support J1-VIIRS TEB band calibration/calibration.. [**STAR**]

Support of SNPP VIIRS SDR Calibration and Team Management/Coordination: CICS scientists provide operational science support for Suomi-NPP VIIRS instrument through support radiometric calibration of VIIRS by trending with lunar model and vicarious methods; perform VIIRS IDPS data quality assessment; 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 of GOES-R UAS.. [**STAR**]

Developing Front-End-Processing for Mitigating JPSS ATMS Radiance Striping and Radio- Frequency Interference: A modification successfully made to the striping noise mitigation algorithm, which worked for ATMS sounding channels, so that artefacts generated by the striping noise mitigation in the window channels are successfully removed while the striping noise is mitigated as desired. [**JPSSO**]

Scientific Support for Joint Polar Satellite System (JPSS) CrIS, VIIRS and OMPS Calibration: CICS Scientist Yong Chen continued 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. CICS scientists evaluate radiometric, spectral, and geometric calibration accuracy of Cross-track Infrared Sounder (CrIS) Sensor Data Records (SDR) on Suomi NPP and future JPSS satellites, improve the data quality, and support operational use of numerical weather predication (NWP) data as-similation and Environmental data record (EDR) Team. Chunqiang Wu is a visiting research scholar from China under the support of Dr Yong Chen. Dr Wu mainly focus on the field of nonlinear (NL) correction in the Cross-track infrared Sounder (CrIS) re-lated calibration procedure. Some tools to derive NL parameters from various data sets are developed , which would benefit the optimization of the calibration of J1 Cris. CICS Scientist Hui Xu works to improve the calibration algorithms, including assess the accuracies of CrIS algorithms and updates CrIS SDR algorithms into ADL software. [**STAR**]

Surface Observation Networks

Support for Air Quality Projects at the Air Resources Laboratory*:* 1) CICS scientists generated high-quality emission products to major updates in the NOAA O3 and PM2.5 forecasts; 2) CICS scientists conducted validation of VIIRS isoprene product using measurements from two new cruises; 3) CICS scientists investigated the impact of the 2008 economic recession on US air quality; 4) CICS scientist co-authored UN report on global assessment of sand and dust storms. [**ARL**]

Advanced Satellite Programs

Year 6 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)*:** We have developed an operational evapotranspiration and drought monitoring system using the GOES Land Surface Temperature product, meteorological data and other ancillary satellite remote sensing data. The GET-D product has been made operational at NOAA OSPO. [**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**]

***Development of Algorithms for Shortwave Radiation Budget from GOES-R*:** We have tested narrow-to-broadband transformation coefficients based on heritage radiative transfer simulations implemented with simulated ABI data; developed new transformation based on updated models of radiative transfer for implementation with the operational versions of ABI and H-8/AHI. [**GOESPO**]

Scientific Support for the JPSS Mission

Ocean Color LISCO (AERONET site) Cruise Data and Matchup: 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. Reflectance data from VIIRS validation cruises 2014, 2015 and 2016 are analyzed and compared with satellite data demonstrating good performance of CCNY instruments on board. [**STAR**]

***Validation of Cryospheric EDRs GCOM AMSR2*:** A blended AMSR-2 snow depth algorithm using optimal interpolation of *in-situ* surface Snow Depth has been developed. [**STAR**]

Continued Monitoring and Day-2 Algorithms of AMSR2 EDRs: GCOM-W/AMSR2 rain rate product achieved "Validated Maturity" under the JPSS program. [**STAR**]

NESDIS STAR Science Enterprise Support for Satellite Programs and JPSS Ground Project Transition Plan: Develop a JPSS risk reduction precipitation estimation algorithm for ATMS. [**STAR**]

***Development and Implementations of Marine Isoprene Emission Product using Multiple JPSS Ocean Products to Support NAQFC Operations*:** 11) CICS scientists have acquired new field campaign data that allow in-situ product validation; 2) CICS scientists have VIIRS isoprene validation using SPACES/OASIS and ASTRA-OMZ observations; 3)

CICS scientists proposed and tested new improvement of isoprene retrieval algorithms in light of the new validation results. [**ARL**/**JPSSO**]

Land Product Validation Research and Algorithm Refinement Science and Management Support for the S-NPP/VIIRS Active Fire Product: Baseline VIIRS 750 m fire data have been produced routinely at NDE, and distributed via the NOAA/CLASS archive. Algorithm has been ported to Community Satellite Processing Package (CSPP) managed by the Cooperative Institute for Meteorological Satellite Studies (CIMMS). Refined VIIRS 375 m fire algorithm was ported to NOAA/NESDIS. [**JPSSO**]

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

Climate Research, Data Assimilation and Modeling

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

Enhance Agricultural Drought Monitoring Using NPP/JPSS Land EDRs for NIDIS**:** 1) Evaluated the improvements of real time green vegetation fraction (GVF) on Noah model-based soil moisture and soil temperature simulations, and near real time green vegetation fraction and albedo products are suggested to be used for better model performance; 2) Offer a viable approach for addressing the issues that merging microwave soil moisture retrievals to improve agricultural drought estimation is hampered by the uncertainty propagation of satellite data rescale-match and quality control; 3) Relative to subjectively equal weighted-average blending technique-based drought index, developed a objectively integrational drought blended index.. [**STAR**]

Enhancing NCEP-NAM Weather Forecasts via Assimilating Real-time GOES-R Observations of Land Surface Temperature and Green Vegetation Fraction**:** Based on the land data assimilation framework and evaluation tool implemented in previous funding cy-

cles, we accomplished two major tasks in the current funding cycle, 1) conducted data assimilation of both directly GOES/GOES-R LST observations and LST-based ALEXI SM data into weather forecast model; 2) evaluate the effectiveness and efficiency of the two assimilation approaches and reported data as-similation evaluation statistics. [**STAR**]

Improve HYSPLIT Mercury Code: Implemented Parallelization, improved model precision, developed Regional Eulerian Model within HYSPLIT-Hg; and created a new set of HYSPLIT meteorological input fields. [**ARL**]

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

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

Graduate Student Support: ENSO-related Precipitation in Recent Reanalyses and CMIP5 Models**:** This year, we have distinguished the better and worse performing models from total 30 CMIP5 models, in an ENSO perspective, by comparing the models with recent reanalyses and observations. The better performing model group can simulate more realistic spatial patterns, mean magnitude and seasonal variability of ENSO-related precipitation, as well as ENSO-related SST, diabatic heating and circulation structures that resemble those of the reanalyses. We have also studied the connections between ENSO-related precipitation biases in the models and model biases in SST, atmospheric diabatic heating and circulations. The results show that models with stronger cold tongue bias in the SST have more severe negative bias of the equatorial precipitation

anomalies over the Pacific, combined with less atmospheric diabetic heating and lower (upper) level convergence (divergence). The bias of double positive anomaly bands over the eastern Pacific in the ENSO-related precipitation is also related to the ENSO-related SST biases in the models. [**NESDIS**]

GMU Support of NOAA Air Quality Forecasting, Research and Operations: 1) GMU scientist helped develop the NOAA unified dust forecasting system; 2) GMU scientist developed a new emission data assimilation algorithm to assess the impact of the 2008 economic recession on US air quality. [**ARL**]

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

Improving Hurricane and Coastal QPFs through Direct Assimilation of GOES-R ABI Radiances in Regional Models: A new infrared-only cloud mask algorithm was developed for AHI/ABI data assimilation, which is critical when visible and near-infrared channels are not inputted to NWP systems. [**GOESPO**]

Advance CrIS Radiance Assimilation in GSI to Improve Forecasts of High-Impact Weather Events: An innovative double CO2 cloud detection algorithm was developed for improving CrIS data assimilation. [**JPSSO**]

CRTM Upgrades and Applications for GOES-R Program: An action was taken to correct a mistake found in CRTM that it failed to incorporate the new spectral response functions of AHI after the launch of Himawari-8. [**STAR**]

Development and Improvement of Satellite Data Applications for Global and Regional Weather Monitoring and Forecasting: A new convective initiation (CI) algorithm was developed and delivered to NOAA for AHI data. [**STAR**]

Climate Data and Information Records/Scientific Data Stewardship

World Ocean Database Updates and Seasonal Estimates of Ocean Temperature, Salinity, Heat Content, and Steric Sea Level: From April 2016 through March 2017 the World Ocean Database (largest publicly available quality controlled ocean profile database) was updated four times, with over 200,000 profiles added by CICS staff. Additionally,

the Northwest Atlantic Regional Climatology (high-resolution decadal climatol-ogy of the Northwest Atlantic) was released in the summer of 2016. [**NCEI**]

Improving the Inventory, Discoverability, and Delivery of Oceanographic Data at the National Centers for Environmental Information: Through this project, we have greatly improved ocean profile datasets (WOD, ARGO, GTSPP, GOCD, led by James Beauchamp) and an ocean surface dataset's (ICOADS, led by Zhankun Wang) discov-erability and de-livery through the National Centers for Environmental Information (NCEI) geoportal and THREDDS server. Z. Wang also developed the THREDDS access to the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) modelling data archived at NCEI-NC. [**NCEI**]

Ocean Data Stewardship: Development of a Global Thermosalinograph (TSG) Data-base: CICS-MD Scientist Zhankun Wang I have constructed a Global Thermosalinograph Database (NCEI-TSG) to facilitate access to the in situ sea surface salinity and tempera-ture measurements. This database provides a comprehensive set of quality-controlled in situ sea surface salinity (SSS) and temperature (SST) measurements collected from over 200 vessels during the period 1989 to the present. I also worked with NCEI personnel to develop a NCEI Thermosalinograph Portal to improve the discoverability of the data-base. [**NCEI**]

Outgoing Longwave Radiation - Monthly CDR – Software Rejuvenation**:** NOAA/NCEI CDR Program is in the process of migrating the Monthly OLR CDR production towards the Full Operational Capability (FOC). Software package rejuvenation efforts reviewed and revised the production code system for meeting the standards in computer pro-gram 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**]

O&M for OLR-Monthly and OLR-Daily Climate Data Records**:** CICS is responsible for the development, sustainment, maintenance and operational production of the OLR CDR products for NCEI Climate Data Record Program, including the Monthly OLR CDR prod-uct (v02r02a and v02r07) and the Daily OLR CDR product (v01r02-final and v01r02-interim). [**NCEI**]

Ocean Acidification Data Stewardship (OADS) Project: New study on the global distri-bution of pH, mechanisms and regression. [**NCEI**]

NOAA Video Data Management System Modernization: In 2016, CICS played a signifi-cant role developing improved ocean data products, working with the ocean science community to provide global and regional ocean data, and validating new ocean-based observing technologies. CICS researchers enhanced NOAA's abilities to understand, pre-dict and communicate climate variability by data dissemination and public education, through web based in-situ data, and by detailed descriptions of these data. CICS team

actively participated in the continued development, maintenance, and enhancement of the OER Video Portal, the NCEI Collection Level and Granule Level Geoportals, the World Ocean Database, the World Ocean Atlas, and Regional Climatology Projects. [**NCEI**]

CICS Support for the management of Ocean and Climate Data originating from member Regional Associations of the US Integrated Ocean Observing System (IOOS): : In 2016, CICS played a significant role working with the ocean science community to provide regional ocean data to the NCEI archive. CICS researchers enhanced NOAA's abilities to understand, predict and communicate climate variability by data dissemination and public education. CICS researchers provided resources to the community, which has assisted numerous data providers throughout the oceanographic environment. [**NCEI**]

CICS Support for the National Centers for Environmental Information (NCEI): Pathfinder Sea Surface Temperature (PFSST), Ocean Surface Salinity Investigation (OSSI), Ocean Color Reprocessed Data (OCRD), and Jason 3 Stewardship Archive: In 2016 CICS played a significant role developing improved satellite data products, working with the ocean science community to provide global and regional ocean data, and contributing to the validating new space-based ocean observing technologies. CICS researchers enhanced NOAA's abilities to understand, predict and communicate climate variability by data dissemination and public education, through web based in-situ and satellite data, and by detailed descriptions of these data. [**NCEI**]

Land and Hydrology

CICS Support for Hydroclimatological Activities at Climate Prediction Center: CICS researcher developed a new weighting system to objectively combine multiple seasonal probabilistic forecasts in the North American Multi-Model Ensemble (NMME). The new system improves prediction skill of precipitation and temperature from baseline, equally weighted forecasts. [**CPC**]

GOES-R Water Cycle Products & Services to Support the National Weather Service: We held a workshop in October with National Weather Service (NWS) and National Ocean Services (NOS) stakeholders to learn about their current and future needs for satellite hydrology products. They set snowfall rate and evapotranspiration/soil moisture products as our first priorities. [**GOESPO**]

Earth System Monitoring from Satellites

***Towards Operational Arctic Snow and Sea ice Thickness Products*:** Novel measurements of snow on Arctic sea ice now routinely available using FMCW Snow Radar system mounted on aircraft platform. Since Operation IceBridge measurements began in 2009, we find that snow depth on first-year sea ice is ~ 70 % of that on multi-year sea ice at the end of winter, with some inter-annual variability observed. [**STAR**]

SDSU Global Biomass Burning Emissions (GBBEP) Product: We developed a global biomass burning emissions product (GBBEPx) that combines fire detection and fire radiative power (FRP) from a network of geostationary satellites and polar-orbiting satellites. [**STAR**]

***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 and investigated the impacts from rainfall. Further, we conducted investigations of AHI time series observations for phenology detections. The AHI, SEVERI, and VIIRS data were used as proxy data of GOES-R for the real-time monitoring of phenology development. The results show that SEVERI EVI2 and AVHI significantly improves the data quality for tropical forest observations relative to MODIS data. Moreover, the investigation also shows that wildfire has limited impacts on green vegetation fraction (GVF) because fires generally occurs during dry seasons. [**STAR**]

***SDSU Monitoring Land Surface Vegetation Phenology from VIIRS*:** We developed algorithms and operational computer codes to monitor spring and fall foliage development from VIIRS data. The algorithms were extended to entire northern hemisphere in 2016. They were implemented to monitor in real time and forecast in 10 days ahead the green leaf development. The results were routinely produced every 3-days and delivered to NOAA JPSS Environmental Data Records. Further, the product was evaluated using PhenoCam data. Moreover, the phenological results were used for testing the Land Model in EMC. [**STAR**]

Decision Support Science

***Identifying Users, Diagnosing Understandability Challenges, and Developing Prototype Solutions for NOAA Climate Prediction Center's Seasonal Climate Temperature and Precipitation Outlooks*:** The goals of this research are to understand how climate outlooks are understood and used in decision-making. By assessing both individual visualizations and overall design of the forecast products, we aim to suggest pragmatic improvements that will improve the understandability and use of the products by decision-makers. [**CPC**]

***Research, Development and Implementation of National and Regional Physical, Ecological, and Societal Climate Indicators for the NOAA and the USGCRP National Climate Assessment*:** Kenney's research team is leading the development of prototypes and the evaluation 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**]

Strengthening Coastal Community Resilience in the face of Climate Change: Science to Better Under-stand, Measure, and Value Coastal Ecosystem Services: The third year of

this project has resulted in the publication of 4 papers on aspects of coastal blue carbon, the incorporation of ecosystem services into federal policy and decision making, and the connections between ecosystem services and human health, and has also contributed to significant progress in natural resource policy and climate policy goals for the U.S. [**NOS**]

Education, Literacy and Outreach

Summer Training of Undergraduate students: The CICS-MD Summer Initiative series provides training and outreach opportunities for both graduate and undergraduate students. The 2016 season involved a group of about 22 students with their corresponding mentors. In some cases, the internship was extended to the rest of the year.

Climate Outreach, Education, and Community Engagement at the Climate Program Office: CICS-MD Scientist Alison Stevens' accomplishments support more effective dissemination of research results and program accomplishments from NOAA to the broader national and international research and climate-interested communities. Additionally, her efforts help strengthen relationships with funded scientists and increase the visibility of the scientists, their research, and ultimately CPO as a result. Through enhanced access to climate-related information, Ms. Stevens work supports greater opportunities for collaboration and linkages among researchers and other user groups. [**CPO**]

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 Department of Energy, and the U.S. Department of Defense (DoD).

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.

***Website Information Architecture Development and User Interface Design for NOAA's National Centers for Environmental Information**:* After researching NCEI's target audience and current site analytics, Medicacurrent identified key performance indicators for tracking success, prioritized features based on user and stakeholder needs, and created a big-picture roadmap for user interaction. The outcome of this process was an end-to-end strategy, a fully designed interactive prototype, and a Drupal Functional Specification, which outlines technical requirements for building the new Drupal 8 site.

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 a set of 50 State Summary reports (a NOAA contribution to the National Climate Assessment); the U.S. Global Change Research Program's (USGCRP) Climate Science Special Report (CSSR), scheduled for release in late 2017; and the Fourth National Climate Assessment (NCA4), scheduled for release in late 2018.

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

***TSU Software Support**:* The National Climate Assessment integrates, evaluates, and interprets the findings of the U.S. Global Change Research Program (USGCRP) into a single cohesive report for policymakers and private entities to inform their decision-making and planning for the future. Given that these analyses are implemented with computer software, this task focuses on ensuring the integrity and portability of the programs developed for the NCA and assisting the lead scientist in their creation and development.

***TSU Graphics Support**:* CICS-NC staff provided editorial, graphics, and production support for the Climate and Health Assessment (released in April 2016), the State Climate Summaries, the Climate Science Special Report (CSSR), and NCA4. Given the intended

audience, it is essential that figures and other graphical representations in these reports are designed to be easily understood by a broad audience while maintaining the highest possible standards of accuracy and transparency.

U.S. – India Partnership for Climate Resilience (PCR) Workshop Support: Development of state-of-the-art climate products and analysis tools for resilience planning and sustainable development and provision to U.S. – India Partnership for Climate Resilience (PCR) collaborators including practitioners and researchers.

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

TSU Science Writing, Editorial, and Project Management Support: CICS-NC staff provided editorial, graphics, and production support for NOAA's Technical Support Unit to the National Climate Assessment. Efforts this year focused on the release of, and follow-up support for, the USGCRP assessment report, "The Impacts of Climate Change on Human Health: A Scientific Assessment," editorial support for the Climate Science Special Report currently under development, and input into the early development of the Fourth National Climate Assessment.

Analytical Support for the Fourth National Climate Assessment: LMI's proprietary ClimateIQ toolkit is being used and tailored to develop climate scenario products for the Fourth National Climate Assessment regional and sectoral chapter authors.

An investigation into current and future trends in severe thunderstorms and their environments: A 12 year (2000-2011) MRMS radar based hail climatology using the hail proxy Maximum Expected Size of Hail (MESH) was completed at a basic level. This required implementation of several quality control measures, and development of "severe hail outbreak" criteria using MESH hail climatology. Through comparison to MESH data, "severe hail" and "severe hail outbreak" criteria were developed based on environmental parameters within the NARR. An analysis of short term trends in the MESH climatology and long term trends in the NARR-based hail environments, specifically trends in severe hail outbreaks, will be performed.

Climate Data Records and Scientific Data Stewardship (NCEI)

Climate Data Record (CDR) Integrated Product Team (IPT) Subject Matter Expertise Support: Climate Data Record (CDR) IPTs are multidisciplinary teams comprised of members from offices and organizations supporting the transition of research-grade CDRs into an initial operational capability (IOC) status. The IPTs are formed for the purpose of efficient and effective collaboration, coordination and execution, and reporting of member's office/organization tasks required to transition the CDR to an IOC state.

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 Inter-comparison 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

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.

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 was demonstrated.

Spatial-Temporal Reconstruction of Geostationary Land Surface Temperature for Multi-Sensor Data*:* Geostationary Earth Orbit thermal infrared data combined estimates of net surface solar radiation (or surface solar absorption) derived from the visible channel is used in reconstructing the temporal evolution of LST even under partially cloud-contaminated conditions.

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 D-series ISCCP cloud product has not been updated since 2009 and its current resolution is somewhat antiquated at 2.5-degrees latitude. NCEI routinely and regularly received customer requests for updated ISCCP data. Launch of the H-series production at NOAA/NCEI fulfills this long-awaited need through providing the knowledge and capability to maintain this important climate data record.

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.

Scientific data stewardship for digital environmental data products: This effort focuses on cutting-edge research in and application of scientific stewardship of individual digital environmental data products and promoting scientific data stewardship. The data stewardship maturity matrix (DSMM) has been applied to more than 700 individual NCEI datasets, and about 668 of those DSMM assessment ratings are to be integrated into the new NOAA OneStop Search and Discovery portal. Lead-authored two peer-review journal articles, chaired several conference sessions, and lead/co-authored several conference presentations.

***Regional Variability of Sea Ice Coverage**:* This effort focuses on examining temporal and spatial variability of sea ice coverage and sensitivity of their trends and projections. Long-term, consistent time series of monthly sea ice area and extents are computed for the period of 1979–2015. Regional temporal variability of Arctic sea ice coverage and its decadal trends are examined for the whole Arctic and 15 sub-regions with the implication of spatial variability. Lead-authored two manuscripts to be submitted to peer-reviewed journals.

***Toward the development of Reference Environmental Data Records (REDRs) for precipitation**: Global evaluation of satellite based Quantitative Precipitation Estimates (QPEs):* The project team conducted a long-term assessment of the different Satellite based precipitation products from the Reference Environmental Data Records (PERSIANN-CDR; GPCP; CMORPH-CDR; AMSU A-B Hydro-bundle) and derived long-term global precipitation characteristics at fine spatial and temporal resolution. This work is part of a broader effort to evaluate long-term multi-sensor QPEs and to develop 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.

***Hourly Precipitation Dataset (HPD) Quality Analysis**:* Prior to the release of a new version of the Hourly Precipitation Dataset (HPD), quality checks are necessary to ensure that the data are of good, consistent quality, comparable to existing datasets.

***Obs4MIPs Processing**:* In order to facilitate the use of NCEI datasets by the modelling community, a multi-year effort is underway to reformat several gridded, mostly satellite-based datasets into a standardized form.

Surface Observing Networks

Analysis of U.S. Climate Reference Network (USCRN) Soil Moisture Observations*:* This research is an analysis of USCRN soil observations for developing an understanding of spatial and temporal variability of soil moisture and temperature. The goal of this work is to determine the changes in soil conditions to improve USCRN for drought monitoring and satellite calibration.

Climate Monitoring and Research Support for NOAA's Air Resources Laboratory (ARL) Atmospheric Turbulence and Diffusion Division (ATDD): ORAU/ATDD performed annual maintenance at 12 Alaskan USCRN sites and completed one additional Alaska site installation in Yakutat bringing the current Alaska site total to 19. http://www.atdd.noaa.gov/research/

Extension of the Great Smoky Mountain Rain Gauge Mesonet and Exploration of the Origins of Extreme Precipitation Events in the Southern Appalachian Mountains and their Signatures as Observed by GOES-R: Completed Fall 2016 maintenance and data collection gauge visits as part of this collaborative research effort to extend the period of observations of the Duke University Great Smoky Mountains National Park Rain Gauge Network (Duke GSMRGN). Details of every gauge visit along with precipitation raw and CSV files: https://drive.google.com/open?id=0B9P8oUaRiBOweG5VcU9wMVE3TDg

Development and verification of U.S. Climate Reference Network (USCRN) Quality Assurance Method*:* Completed the adoption work of USCRN precipitation algorithm with colleagues at the National Ecological Observatory Network (NEON). In addition, the precipitation algorithm was used in the World Meteorological Organization (WMO) Solid Precipitation Inter-Comparison Experiment (SPICE) study. This task also developed a methodology to capture spurious precipitation estimates from USCRN stations, which led to the flagging of over 248,000 observation hours.

Development of an Extra-Tropical Cyclone Track dataset*:* This task worked to develop processes to associate extra-tropical cyclone (ETC) low pressure centers and frontal boundaries. These methods promote the temporal analysis of ETC systems (low pressure centers and fronts) over their lifespan, and linking of synoptic systems with weather and climate observations. The approach is being evaluated with the National Weather Service's (NWS) coded weather surface bulletins, which document ETC systems in the U.S. every 3 hours. In an effort to overlay NWS fronts with precipitation data, the daily Global Historical Climatology Network (GHCN-D) observations times were convert from local standard time to UTC, and linked with the closest frontal boundary for each daily observation.

Analysis of hydrological extremes from the U.S. Climate Reference Network (USCRN): Completed a comparison between USCRN and the North American Regional Reanalysis (NARR) soil moisture datasets, which revealed that despite offsets in precipitation and soil moisture conditions, modeled data had similar temporal trends to observed data. A

preliminary analysis evaluating USCRN precipitation extremes for various temporal durations was completed along with the development of an approach to standardized USCRN soil moisture observations.

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 project has been completed with both NOAA and FEMA to validate snowfall extremes for every county in the United States. This will help mitigate future snowfall events, and also build better spatial quality algorithms in our weather station data products.

Simplified and Optimal Analysis of NOAA Global Temperature Data: Data Validation, New Insights, Climate Dynamics and Uncertainty Quantification*:* Developed a suite of modern big data and computing tools for delivering NOAA environmental data to schools, households, and the general public.

Night Marine Air Temperature Near Real-Time Dataset Development*:* Night marine air temperatures have been extracted from ICOADS data along with several other variables including SST and thermometer heights aboard ships/buoys. Missing heights are filled in using Pub. 47 data to give a more global representation.

Workforce Development (NCEI)

CICS-NC actively works 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. High School, Undergraduate, and Graduate level students and recent post-docs support projects across the CICS-NC task streams.

Water Sustainability and Climate Change*: A Cross-Regional Perspective:* Model simulations from the CMIP5 hindcast experiment were found to generally reproduce observed regional trends in the number of monthly precipitation extremes for the period 1981–2010. The NE and MW showed the largest differences in extreme precipitation Trends.

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 staff participated in K–12 educational outreach events in conjunction with the celebration of the state-wide 2016 and 2017 North Carolina Science Festival by providing climate and weather handouts and classroom activity ideas 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 2016 and Winter 2017. Engagement with higher education institutions is also a CICS-NC focus area being served through mentorship of undergraduate and graduate students, invited speaking engagements with university student and faculty audiences, and through development of a distance education course.

Communications activities emphasize CICS-NC/NCICS research activities and facilitate distribution of relevant information to CICS-NC/NCICS' various stakeholders. CICS-NC communication activities serve to raise awareness and highlight the accomplishments of the Institute and its staff, including research findings of CICS-NC scientists and their NOAA/NCEI colleagues. Other activities include working to improve the science communication capabilities of CICS-NC staff, expanding the social media reach of the institute, and providing editorial and communications support to NCEI.

"Spot the Rip": Rip Current Documentation for Education and Research*:* Rip currents are among the leading causes of beach injuries along coastal United States waters. While there have been significant outreach efforts (e.g., "Break the Grip of the Rip") related to informing the public on methods for self-rescue and survival once in a rip, relatively little effort has been placed on educating the public to identify rips in advance of getting into the water. A comprehensive documentation of rip current events with high definition video and photography from a variety of typical visitor views and aerial views could then be used as educational collateral as part of a nationwide educational campaign to "Spot the Rip" and prevent instances in which beach visitors get themselves into potentially dangerous swimming conditions.

Other CICS PI Projects

Collaboration with the Centers for Disease Control on Issues Related to Climate and Health*:* Interactions with the Centers for Disease Control and Prevention to build collaboration on issues related to climate and health and increase the understanding of the impact of climate on human health. **[CDC]**

The Urban Resilience to Extremes Sustainability Research Network (UREx SRN): Analyzed a suite of downscaled climate model projections and developed "Scenarios Lite," a summary of climate extremes for seven of the UREx SRN pilot cities. **[NSF]**

Incorporation of climate change into Intensity–Duration–Frequency Design Values*:* An algorithm to automatically identify the location and type of fronts in reanalysis data was developed and tested against a dataset of manually analyzed fronts from NOAA coded surface bulletins. **[DOD / SERDP]**

Climate indicators to track the seasonal evolution of the Arctic sea ice cover to support stakeholders*:* This project utilizes the NOAA/NSIDC (National Snow and Ice Data Center) Sea Ice Concentration Climate Data Record (CDR) to develop a consistent, high quality suite of sea ice climate indicators that track the seasonal evolution of the Arctic sea ice cover from spring through fall, in addition to commonly used sea ice coverage indicators. CICS-NC contributes to this effort by assisting with the CDR fields and integration of the fields with the melt/freeze and advance/retreat parameters. **[NASA]**

Synthesis of Observed and Simulated Rain Microphysics to Inform a New Bayesian Statistical Framework for Microphysical Parameterization in Climate Models*:* This research project aims at comprehensively investigating the representation and associated uncertainties of rain microphysical processes in weather and climate models. In order to quantify those uncertainties in microphysical formulations, we develop an innovative Bayesian statistical framework that combines the extensive radar and ground-based data from ARM field campaigns, bin microphysical modeling, and a new bulk parameterization. **[DOE]**

Role of Kelvin Waves in Tropical Cyclogenesis*:* Kelvin waves encourage tropical cyclogenesis by closing the midlevel circulation in the predecessor easterly waves. **[NASA]**

Drought Data for Human Health Studies*:* A project has been completed to provide county level drought information to the Centers for Disease Control and Prevention (CDC). The data has been organized to satisfy needs of CDC, and it has been sent to their website for public dissemination. Data is currently being used to build a statistical climatology of drought information, going back to 1895. **[CDC]**

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 Ms. June Sherer, 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-NC conducts outreach activities across K–12, higher education, and the general public to advance environmental information and increase climate literacy. This year's outreach activities included:

- 4/9/2016: Mountain Science Expo, Asheville, NC . Theresa Stone, Laura Stevens and Scott Stevens, represented CICS-NC at a booth with NCEI as part of the larger NC Science Festival events. This event was open to the public, with ~1500 attendees. The booth showcased the Cyclone Center, the National Climate Assessment, and NOAA educational materials.
- 4/15/2016: ICC Science and Technology Expo, Isothermal Community College, Spindale, NC. Theresa Stone gave a 20 minute presentations on the NCA, climate change, and the Cyclone Center to 8 groups of 6th graders (~160 students) from Polk County.
- 4/21/2016: Climate and Weather at NCEI/CICS, Asheville, NC. Theresa Stone, Scott Stevens, Paula Hennon, and Jared Rennie, partnered with NCEI to provide an overview of NCEI activities, and give presentations on "What is Climate Change and How do we know it's real", the Cyclone Center website, and "Coding in Climate Science" to 30 students and their parents.
- 4/23/2016: "Celebrate STEM" Buncombe County Schools, Nesbitt Discovery Academy (STEM HS), Asheville, NC. Theresa Stone hosted a CICS-NC booth with ~500 K-5 students and their parents. Participants received NOAA climate materials, info on the Cyclone Center, and climate literacy and built rain gauges as a hands-on activity.
- 4/27/2016: East Yancey Middle School, Burnsville, NC. Scott Stevens gave a presentation on climate change to all 7th grade science classes.
- 05/20/2016: Environmental Educators of North Carolina (EENC) Western Section, NCEI/CICS, Asheville, NC. Theresa Stone and Tom Maycock coordinated presentations by Jake Crouch (NCEI) on the Climate Monitoring branch and their activities, Greg Hammer (NCEI) gave a tour of building with focus on IT capabilities and the archive, and Jeff Robel (NCEI) gave a presentation on the customer service branch activities to 12 EENC participants.
- 6/16/2016: Brevard HS, Brevard, NC. Scott Stevens, Jenn Runkle, and Jessicca Griffin gave presentations to 15-20 high school science students participating in an intensive year-long program that allowed them to conduct original research into their own questions.
- 06/20/2016: St. Mark's Lutheran Church Vacation Bible School, Asheville, NC. Carl Schreck taught science lessons, made anemometers, and provided weather related handouts.
- 10/11/2016-10/13/2016: Asheville Middle School, Asheville, NC. Scott Stevens, Laura Stevens, and Jared Rennie each took a day of classes (four 7th grade classes each day), speaking about what NCEI does, and how we safeguard all of the nation's weather and climate observations.

- 11/22/2016: North Buncombe Elementary School Career Day, Asheville, NC. Carl Schreck presented on hurricanes and rain gauges to the special needs classrooms (K-4).
- 12/9/2016: Isaac Dickson Elementary School, Asheville, NC. Linda Copley and Jared Rennie supported the Hour of Code outreach event on Dec. 9th for Kindergarten, 1st, 2nd, and 3rd grades.
- 12/9/2016: Ira B. Jones Elementary, Asheville, NC. Jared Rennie gave a presentation to ~75 5th graders on "Weather, Climate, and Code.".
- 02/14/2017: Imagine Collegiate Invest (charter school), Asheville, NC. Scott Stevens gave three presentations centered on the value of keeping 150 years of weather data to ~50 7th grade science classes.
- 02/17/2017: Etowah Elementary School Career Day, Etowah, NC. Scott Stevens gave three presentations to ~40 students ranging from 3rd to 5th grade about meteorology as a career.
- 03/24/2017: UNC-Charlotte Weatherfest, Charlotte, NC. Theresa Stone manned a CICS-NC booth giving out weather activity handouts and demonstrating the Cyclone Center.
- 03/29/2017: Franklin School of Innovation Career Day, Asheville, NC. Laura Stevens was a presenter to ~60 6th to 11th grade students.
- 03/31/2017: Isothermal Community College STEM Expo, Spindale, NC. Theresa Stone gave presentations to ~160 6th graders on the use of satellites and radar in climate science and used NCEI's Magic Planet to show satellite tracking and images of hurricanes around the globe.

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

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 Mas-

ters 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. 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 2016 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 research, 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, "Mathematics of Climate Science" is a new course to satisfy the need for training graduate-level researchers in how mathematics contributes to the study of the Earth's climate. We will teach this course remotely from a key climate research hub,

NOAA's National Centers for Environmental Information in Asheville, NC, through NCSU's North Carolina Institute for Climate Studies. This will be the first graduate-level mathematics course offered in an online environment. Students can be located in the Asheville location, on main campus, or participate via distance education. This course is being developed by Dr. Matthews in collaboration with NCSU Distance Education and Learning Technology Application (DELTA) staff as supported by the award of a competitive grant in August 2016.

The Statistical and Applied Mathematical Sciences Institute (SAMSI) is a partnership of Duke University, North Carolina State University, University of North Carolina at Chapel Hill, and the National Institute of Statistical Sciences. It is part of the Mathematical Sciences Institutes program of the Division of Mathematical Sciences and the National Science Foundation. Upcoming for the 2017–18 academic year is their "Program on Mathematical and Statistical Methods for Climate and the Earth System." This program will bring together new and experienced researchers from around the country and the world to evaluate climate data, climate models, and the impacts of climate change on the Earth and its human inhabitants. This course will be offered for credit, in conjunction with the 2017-2018 program, at SAMSI's partner universities (i.e. Duke, NCSU, UNC-CH).

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

The public's awareness and understanding of climate variabilities and change continues to grow, and decision-makers are exploring innovative ways to advance research, observations and apply the information in a decision-context or to build resilience. This in turn improves the collective understanding of how environmental information is used in design, planning, engineering, operations, investments, etc. As the information exchange builds, improved analytics on users, their applications, and their needs help inform areas like advancement in scientific research, assessments, and the need for new and different data. The exchange between practitioners, solution providers, applied scientists, and scientists requires engagement and collaboration across a wide range of stakeholders, as well cataloging and analyzing that exchange. To that end, CICS-NC engages in targeted and interdisciplinary literacy, engagement, and outreach activities for business and industry, academia, other scientists, and the general public through various modes. The efforts are intended to build and analyze the information exchange and case studies and thus build vast network of experts in different disciplines that incorporate climate information in their context. These activities are often in conjunction with NCEI, CICS-NC partners and collaborators, and other university partners.

The various 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, and providing ongoing operational support to NOAA NCEI to advance their science and services capabilities.

CICS-NC supports and advises NCEI's Climatic Information Services Branch (ISB) on strategic and operational stakeholder engagement activities. CCS-NC also supported the Climatic Analysis and Synthesis Branch (CASB). Work effort and initiatives are primarily in building capabilities within NCEI information services, engagement with business and industry, and other interdisciplinary activities that advance NCEI and NOAA mission goals with partners.

CICS-NC led and advised in the design and development of a customer relationship management solution (CRM), which would identify, track, and store customer information gathered by engagement personnel at NCEI. It included an analysis and requirements phase and the design and deployment of a Phase I Google form solution that tracked and analyzed 15,000+ entries. Phase II of the solution involved analyzing CRM vendor solution providers, development of the decision process, and the procurement

of the Salesforce CRM tool. CICS-NC was involved in the detailed implementation of the Salesforce solution, ranging from technical integration needs to training needs for the NCEI users. The Salesforce solution is expected to go live in April 2017 and will provide NCEI a customer database, insights into uses and applications of NCEI data, and requirements from users. The previous year's efforts in sectoral analysis using the US Census Bureau of Economic Analysis sectors (NAICS codes) is being implemented in the cataloguing and categorization of the data.

Jenny Dissen represented CICS-NC on the organization committee of the 2016 Carolinas Climate Resilience Conference, held in Charlotte, NC. Along with NCEI Engagement colleagues, Dissen presented on the "Engagement with the Energy Sector: Our Experience" and moderated the session titled "Adaptation Support for Energy Utilities." This NCEI engagement activity was to share information about ongoing research, efforts and partnerships in the Carolinas. (http://www.cisa.sc.edu/ccrc/schedule.html#wednesday)

CICS-NC was engaged in the planning of the NCEI engagement side panel event at American Meteorological Society's 97th Annual Meeting in January 2017 called "Wildfires in Alaska and Hawaii: A Dialogue on Building Disaster Resilience." The discussion included panelists from the wildfire hazard and risk communities, scientists, and forecasters and focused on the role of environmental data in wildfire management and climate change impacts on wildfires in the OCONUS region. (More information: https://annual.ametsoc.org/2017/index.cfm/programs/town-hall-meetings/side-panel-discussion-wildfires-in-alaska-and-hawaii-a-dialog-on-building-disaster-resilience/)

CICS-NC provides strategic input and review of engagement case studies, most recently in the reinsurance, retail, and manufacturing industries, provided by NCEI subcontractor Acclimatise. The case studies are intended to inform NCEI about how industries use NCEI's climate and weather information as well as the economic and societal benefits generated by environmental information in those sectors. Case studies available upon request.

CICS-NC continued engagement with the Research Triangle Foundation (RTF) and held a second webinar in September 2016 that facilitated executive-level engagement on environmental information with corporate leaders from companies located at RTP. Speakers included Johanna Jobin, Global Sustainability Director of Biogen; Andrew Hoffman, University of Michigan; Scott Shuford, Planning and Code Enforcement Services Director, City of Fayetteville; and Amanda Rycerz from Acclimatise. Ken Kunkel and Jenny Dissen, both from CICS-NC, NC State University, and NOAA NCEI, also presented.

As part of the Executive Advisory Council (EAC) for the Utility Analytics Institute (UAI), CICS-NC collaborated with Terri Thompson of LMI to continue discussions on how downscaled climate information impacts energy generation. Dr. Thompson presented at the Utility Analytics conference on "Merging NOAA Climate Data with Energy Infrastructure Data for Climate Risk Analysis" and presented on "Applying NOAA Big Data to Utilities" during the fall Utility Analytics week conference. In 2017, Utility Analytics (UAI) will

support a future energy forum discussion in collaboration with CICS-NC that examines environmental information in the context of renewables.

CICS-NC led the coordination of the "Workshop on Development and Applications of Downscaling Climate Projections" held at the Indian Institute of Tropical Meteorology (IITM), March 7–9, 2017 (**Figure 7**). As part of the INDO-U.S. Partnership for Climate Resilience announced by Prime Minister of India Modi and U.S. President Barack Obama, the workshop successfully achieved its objectives in sharing expertise in climate modeling and downscaling between CICS-NC, Texas Tech University, IITM, and users in various sectors. The workshop included presentations and hands-on exercises involving NASA NEX-GDDP, downscaling methods from the U.S. Asynchronous Regional Regression Model (ARRM), and applications of climate information in India state actions plans and other sectors. Details of the workshop are available at the IITM website (http://cccr.tropmet.res.in/home/workshop/indo-us2017/index.jsp) and the NCICS website (https://ncics.org/cics-news/u-s-india-climate-downscaling-workshop/).

***Figure 7**: Participants from the "Workshop on Development and Applications of Downscaling Climate Projections" at IITM in India (March 2017).*

CICS-MD researcher Alison Stevens accomplished several tasks to support communication and outreach efforts of CPO. She developed several internal communication products including Hot Items and Three Things Memos to inform OAR, NOAA, and DOC leadership of research and program accomplishments and upcoming events. To reach the external community, including funded scientists and the climate-interested public, she produced news articles for the CPO website and liaised with the CPO CEE Division and OAR communications to share higher impact items on climate.gov and the NOAA Research website. She also developed concise info sheets, including one about the newly funded NOAA S2S Prediction Task Force, as a handout for conferences, workshops, and as a source of information on the CPO website. Furthermore, she helped edit, format, and print reports developed and organized by CPO and CPO-funded scientists to share and distribute at conferences, workshops, meetings, and on the CPO website. To reach

broader and less technical audiences, Ms. Stevens worked with the CEE Division to produce Featured Image Stories for climate.gov highlighting CPO-funded research. These stories include a key image representative of the research findings. Ms. Stevens applied her data visualization skills to help develop easily digestible and visually pleasing maps to accompany the Featured Image Stories.

To better engage CPO-funded scientists, Ms. Stevens initiated a targeted outreach plan in FY16. With the help of the Program Managers, she identified key scientists to reach out to. She scheduled interviews with the identified scientists to cultivate a personal relationship with each of them, learn more about their research, and inform them of the types of communication support she can provide. Using the information she gathered during the interviews, she began developing Meet Our Scientist profiles highlighting the CPO-funded scientists, their backgrounds, and their currently funded research. These profiles have been published on the NOAA Research website, increasing the visibility of CPO and its funded scientists (**Figure 8**).

***Figure 8**: Screenshot of Meet Our Scientist profile highlighting Jason Otkin on the NOAA Research website.*

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 (**Figure 9**) 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 development 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 9: *Michael Folmer engaged in Forecaster Training 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 10**; 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 10**: Images of Maryland Day (April 2016)*

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).

Dr. Jessica Matthews from CICS-NC was an invited speaker at SAMSI’s Workshop for Women in Math Sciences in April 2016, **Figure 11.** (https://www.samsi.info/programs-and-activities/education-and-outreach/2016-spring-opportunities-workshop-for-women-in-math-sciences-april-6-8-2016/). The goals of this workshop, geared towards graduate students and postdoctoral scholars, were: 1) to familiarize women and/or under-represented minorities in the mathematical sciences with professional opportunities in academia, industry, and government, and 2) to focus on challenges currently faced by women or minorities in mathematical sciences. Following the workshop, she was asked by organizers to write a blog post summarizing her reflections on the event (https://samsiatrtp.wordpress.com/2016/06/14/what-does-it-mean-to-be-a-woman-in-mathematics/).

***Figure 11**: SAMSI's Workshop for Women in Math Sciences, April 6-8, 2016.*

Throughout the year, Dr. Matthews continued engagement with university students and faculty via a variety of mechanisms including giving several invited talks regionally. She also served as a mentor for the 2016 Industrial Math/Stat Modeling Workshop for graduate students, which is an intensive 10-day interdisciplinary group work experience (https://www.samsi.info/programs-and-activities/education-and-outreach/2016-industrial-mathstat-modeling-workshop-for-graduate-students-july-17-27-2016/). The project was done in collaboration with the US EPA and entitled "Fusing surface and satellite-derived PM observations to determine the impact of international transport on coastal PM2.5 concentrations in the western U.S."(**Figure 12**).

***Figure 12**: Dr. Matthews presenting on her research applications at the US EPA in July 2016.*

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 13**)*,* 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 13**: 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)
ABI	Advanced Baseline Imager
AERONET	Aerosol Robotic Network
AERONET-OC	Aerosol Robotic Network-Ocean Color data
AF	Active Fire
AL	Albedo
ALEXI	Atmosphere-Land Exchange Inverse model
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
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
CDR	Climate Data Record
Chl-a	Chlorophyll-a
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
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
DNB	Day/Night Band
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
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
GEOG	Department of Geographical Sciences (UMCP)
GET-D	GOES Evapotranspiration and Drought product system
GFS	Global Forecast 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
GPM	Global Precipitation Measurement Mission
GPROF	Goddard Profiling Algorithm
GPSRO	Global Positioning System Radio Occultation
GRUAN	GCOS Reference Upper Air Network
GSA	Geostationary Surface Albedo
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
ICDR	Interim Climate Data Record

ICESat	Ice, Cloud and Land Elevation Satellite
IMS-V3	Interactive Multi-Sensor Snow and Ice System, Version 3
IR	Infrared
IRC	Inter-Institutional Research Center (UNC)
ISCCP	International Satellite Cloud Climatology Project
IT	Information Technology
JAXA	Japan Aerospace Exploration Agency
JCSDA	Joint Center for Satellite Data Assimilation
JPSS	Joint Polar Satellite System
JPSSO	JPSS Office (NESDIS)
LAI	Leaf Area Index
LETKF	Local Ensemble Transform Kalman Filter
LISCO	Long Island Sound Coastal Observatory
LMA	Lightning Mapping Arrays
LSM	Land Surface Model
LST	Land Surface Temperature
LUT	Look-Up Table
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 ocean color data processing
MSPPS	Microwave Surface and Precipitation Products System
MSU	Microwave Sounding Unit
NAM	North American Mesoscale model
NAQFC	National Air Quality Forecast Capability
NARR	North American Regional Reanalysis (NCEP)
NCEI	National Centers for Environmental Information (NOAA)
NCEP	National Centers for Environmental Prediction (NOAA)
NCSU	North Carolina State University
NCWCP	NOAA Center for Weather and Climate Prediction
NESDIS	National Environmental Satellite, Data and Information Service (NOAA)
NGGPS	Next Generation Global Prediction System (NWS)
NIDIS	National Integrated Drought Information System
NOS	National Ocean Service (NOAA)
NPOESS	National Polar Orbiter Environmental Satellite System
NPP	NPOESS Preparatory Project
NRT	Near Real Time
NSF	National Science Foundation
NWP	Numerical Weather Prediction

NWS	National Weather Service (NOAA)
OAR	Office of Oceanic and Atmospheric Research (NOAA)
OISST	Optimum Interpolation Sea Surface Temperature
OLR	Outgoing Longwave Radiation
OMPS	Ozone Mapping and Profiler Suite
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
$PM_{2.5}$	Particulate Matter less than 2.5 microns in diameter
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
RFC	River Forecast Centers (NWS)
RMSE	Root Mean Square Error
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
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
SFR	Snowfall Rate
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
TMPA	TRMM Multisatellite Precipitation Analysis
TOA	Top of the Atmosphere
TPW	Total Precipitable Water
TRMM	Tropical Rainfall Measuring Mission
UAS	Unmanned Aircraft System
UMCP	University of Maryland, College Park
UMD	University of Maryland
UNC	University of North Carolina
USDA	United States Department of Agriculture
USDM	United States Drought Monitor
USGS	United States Geological Survey
VI	Vegetation Index
VIIRS	Visible/Infrared Imager Radiometer Suite
VS	Visiting Scientist
WRF	Weather Research and Forecasting model