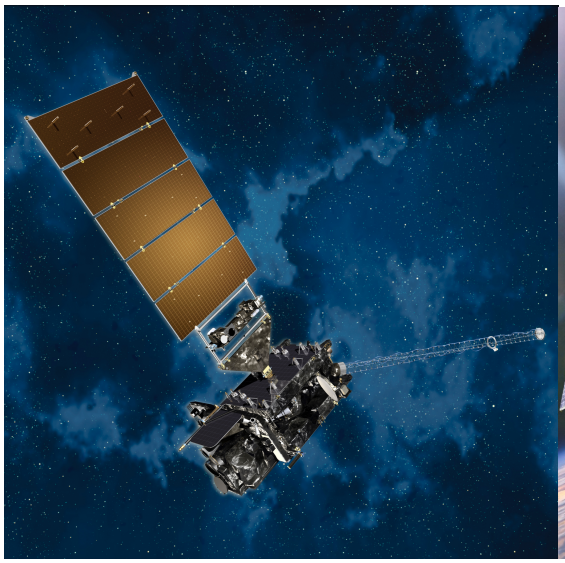


GOES-R

JPSS

COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

Annual Scientific Report

VOLUME III: CICS-NC TASK REPORTS

For the period:
April 1, 2019 – March 31, 2020
NOAA Grant NA14NES4320003

Dr. Fernando Miralles-Wilhelm, Director
April 30, 2020

Table of Contents

CICS-NC Overview

The operation of a NOAA Cooperative Institute (CI) is the primary activity of the North Carolina Institute for Climate Studies (NCICS), an Inter-Institutional Research Center (IRC) of the University of North Carolina (UNC) System. From 2009–2020, NCICS has managed the North Carolina site of the Cooperative Institute for Climate and Satellites (CICS-NC). NCICS/CICS-NC is hosted by North Carolina State University (NCSU) and affiliated with the UNC academic institutions as well as a number of other academic and community partners. CICS-NC is collocated with the NOAA/NESDIS National Centers for Environmental Information (NCEI) in Asheville, NC, and focuses primarily on collaborative research on utilizing satellite and surface observations, understanding the Earth system, and climate products and applications. CICS-NC also engages in collaborative research and other climate activities with other NOAA line offices and units, including the National Weather Service (NWS), Oceanic and Atmospheric Research's (OAR's) Climate Program Office (CPO), and the Air Resources Laboratory's (ARL's) Atmospheric Turbulence and Diffusion Division (ATDD), as well as other federal agency collaborators with NOAA/NCEI, including the United States Global Climate Research Program (USGCRP), the Federal Emergency Management Agency (FEMA), the National Aeronautics and Space Administration (NASA), the U.S. Department of Defense, and the U.S. Department of State.

CICS-NC is led by the Director of the IRC and includes numerous partners from academic institutions with specific expertise in the challenges of utilizing remotely sensed and in situ observations in climate research and applications and related science expertise. NCSU provides CICS-NC with access to a strong graduate program in Earth, engineering, and life sciences, and many of the CICS partners offer complementary programs. A variety of needed skills and/or information sets have been requested by NOAA that were not originally envisaged in the original CI proposal, and additional partners have been added to the CICS Consortium. Additions include Oak Ridge Associated Universities (ORAU), the Institute for Global Environmental Strategies (IGES), the University of South Carolina, the University of Michigan, the Center for Climate and Energy Solutions (C2ES), the University of Illinois at Urbana–Champaign, the University of Alabama in Huntsville, and the University of Nebraska Medical Center. Additional collaboration and support for community engagement and outreach are provided by the North Carolina Arboretum, an affiliate member of the UNC System, and the Economic Development Coalition for Asheville-Buncombe County (Asheville EDC).

CICS's scientific vision centers on observation, using instruments on Earth-orbiting satellites and surface networks, and prediction, using realistic mathematical models of the present and future behavior of the Earth System. Observations include the development of new ways to use existing observations, the invention of new methods of observation, and the creation and application of ways to synthesize observations from many sources into a complete and coherent depiction of the full system. Prediction requires the development and application of coupled models of the complete climate system, including atmosphere, oceans, land surface, cryosphere, and ecosystems. Underpinning all of these activities is the fundamental goal of enhancing our collective interdisciplinary understanding of the state and evolution of the full Earth System. This vision is consistent with NOAA's Mission and Goals and CICS scientists' work on projects that advance NOAA objectives. CICS conducts collaborative research with NOAA scientists in three principal Research Themes: Satellite Applications, Observations and Modeling, and Modeling and Prediction.

CICS-NC's mission focuses on collaborative research on the use of in situ and remotely sensed observations, the Earth system, and climate products and applications; innovation of new products and

the creation of new methods to understand the state and evolution of the full Earth System through cutting-edge research; preparation of the workforce needed to address continuing science, technology, and application development; engagement with corporate leaders to develop climate-literate citizens and a climate-adaptive society; and the facilitation of regional economic development through its engagement activities.

CICS-NC activities primarily support NCEI activities and enterprise services. Main collaborative activities are currently organized, and CICS is structured thematically, by the following task streams:

1) Administration (Task I)
2) Access and Services Development
3) Assessments
4) Climate Data Records and Scientific Data Stewardship
5) Climate Literacy, Outreach, Engagement, and Communications
6) Surface Observing Networks
7) Workforce Development
8) Consortium and/or Other Projects

These streams are currently supported by different divisions in NCEI; by NOAA Line Offices including the National Environmental Satellite, Data, and Information Service (NESDIS), Oceanic and Atmospheric Research (OAR), and the National Weather Service (NWS); and by North Carolina State University. Other Projects led by CICS-NC Principal Investigators are generally funded by other federal or private (non-NOAA) sponsors but reflect broader Institute research efforts that complement CICS mission goals.

Highlights

CICS-NC

CICS-NC highlights are arranged by task stream with task sponsors noted in brackets [ ]. Primary NOAA support comes from NESDIS/NCEI; however, the past year's activities were also supported by NESDIS/STAR, OAR's Climate Program Office (CPO), and the NOAA Office of the Chief Information Officer (OCIO). While CICS-NC activities remain primary, NCICS scientists are also engaged in research projects (Other CICS PI Projects) supported by other sponsors that currently include: The National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy (DOE), the U.S. Department of Defense (DoD), and the National Institute Institutes of Health (NIH).

Administration [NCSU/NOAA]

***Institute Information Technology Systems Improvement, Management, and Maintenance*:** Institute IT staff provide modern, scalable approaches to keep CICS-NC at the competitive edge of technology advances, as well as maintaining core technologies as a stable base for staff operations. This year's

Access and Services Development [OCIO/CPO/NCEI]

***NOAA Big Data Project Support*:** Utilizing the CICS-NC-designed data hub/broker architecture, the project team moved multiple NCEI and other NOAA datasets to the cloud this year and backfilled HRRR data from archive sources. https://ncics.org/data/noaa-big-data-project/

***Common Ingest Agile Development Team*:** This software development team works in concert with NCEI staff to enhance, modify, and deploy the new Common Ingest (CI) system at NCEI-NC. This year the team supported the NCEI-NC operations team in completing the migration of datasets from the legacy ingest system to the new CI system, enhancing existing functionality, and hardening the system to provide greater resilience to network errors.

***Programming and Applications Development for Climate Portal*:** In support of the overall advancement of the NOAA Climate Services (NCS) Portal program, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with the continued development of the U.S. Climate Resilience Toolkit (CRT) and the new Climate by Location design (part of Climate Explorer). NEMAC also provided graphics and GIS support for the USGCRP Indicators project and the National Climate Assessment, as well as design and content support for the NIDIS drought.gov redesign.

***Scientific Data Stewardship for Digital Environmental Data Products*:** This effort focuses on cutting-edge research on, and application of, scientific stewardship of individual digital environmental data products and promoting scientific data stewardship. Communication efforts aimed at raising the awareness of the Data Stewardship Maturity Matrix (DSMM) and of curated data quality descriptive information included a peer-reviewed paper and multiple presentations at national and international conferences.

***NCEI Infrastructure Architecture Planning and Implementation*:** This project team and its collaborators drive NCEI and Institute IT infrastructure and architecture innovation that will support a modern, flexible, distributed approach to data science, archive, and access capabilities.

Assessment Activities [NCEI/CPO/DOS]

***National Climate Assessment Scientific and Data Support Activities*:** The science/data team was integral to the initial development of the North Carolina Climate Science Report, including working with the state's Department of Environmental Quality and other stakeholders to gather requirements, authorship contributions to several chapters, and development of numerous specialized scientific analyses and graphs**.**

***National Climate Assessment Technical Support Activities*:** The Technical Support Unit released updates to the Fourth National Climate Assessment that enhanced the accessibility of the report and addressed errata, produced new websites for two major reports—the Scientific Assessment of Ozone Depletion: 2018 and the State of the Carbon Cycle Report 2018—and produced updates to seven State Climate Summaries.

***North Carolina Climate Science Report*:** In support of the North Carolina Governor's Executive Order 80 (EO80), which called for various actions in response to the challenge of climate change, CICS-NC began the development of a climate change assessment for North Carolina. Initial actions included establishing a science advisory panel, recruiting an author team, and supporting several regional resiliency workshops.

***Climate Change Indicators*:** The Technical Support Unit (TSU) assisted in the efforts of the U.S. Global Change Research Program (USGCRP) to maintain a comprehensive suite of climate change Indicators. Work focused on updating Indicators and completing Indicator metadata. The full suite of Indicators can be found on the USGCRP Indicator Platform: globalchange.gov/indicators.

***U.S. – India Partnership for Climate Resilience (PCR) Workshop Support*:** In support of the U.S.–India Partnership for Climate Resilience (PCR), Texas Tech University (TTU) scientists continued a collaboration with the Environment Protection Training and Research Institute in India in the development of a web interface designed to facilitate the provision and use of climate model downscaling tools with a non-specialist audience.

Climate Data Records and Scientific Data Stewardship [NCEI]

Scientific Subject Matter Expertise Support: CICS-NC scientists served as subject matter experts on six Climate Data Record Integrated Product Teams, as Product Leads for 25 products, and as Product Area Leads for three product areas. https://www.ncdc.noaa.gov/cdr

Spatial–Temporal Reconstruction of Land Surface Temperature (LST) from Daily Max/Min Temperatures: The approach for reconstructing LST has been revised, including the addition of new constraints for the descending leg of the daily solar cycle (time of max LST to sunset) based on climatologically developed LST values near sunset.

Transitioning of the International Satellite Cloud Climatology Project (ISCCP) Process to NCEI-NC: The ISCCP team released an ISCCP H-series cloud product (ICDR) for July 2017 through December 2018 that employed climatological nnHIRS profiles. Extensive planning for the FY2022 reprocessing is under way. https://www.ncdc.noaa.gov/isccp

Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES Data: The GSA algorithm is being implemented as the U.S. contribution of an international collaboration between Europe, Japan, South Korea, and the United States to produce a joint climate data record. A pilot study of reprocessing

satellite data in the cloud was completed, with results published in a June 28, 2019, Amazon Web *Services* blog post. http://www.scope-cm.org/projects/scm-03/

HIRS Temperature and Humidity Profiles: The team is developing a global temperature and humidity profile dataset for the time period of 1978–present. The data are produced by applying neural networks to High-resolution Infrared Radiation Sounder (HIRS) Data. Results of intercomparisons of long-term atmospheric temperature and humidity profile retrievals were published *in* Remote *Sensing*.

Regional Variability of Sea Ice Coverage: This effort focuses on examining and characterizing temporal and spatial variability of Arctic sea ice coverage, sensitivity of trends, and statistical projections. Climate normals for sea ice concentration, area, and extent for the Arctic and sub-Arctic were evaluated and transitioned to NOAA.

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 four Climate 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. A book chapter incorporating project results was finalized.

Developing blended in situ and satellite global temperature dataset: This project explores using machine learning to integrate in situ measurements and satellite-derived surface temperature from HIRS to create a sub-daily gridded temperature dataset since 1978. During data preprocessing, a data availability issue was identified in the earlier version of HIRS-derived temperature data that resulted from conservative cloud screening. The team completed most of the HIRS temperature reprocessing.

Identifying Tropical Variability with CDRs: This project resulted in several publications on monitoring and prediction of tropical cyclones using the OLR-Daily CDR and the International Best Track Archive for Climate Stewardship (IBTrACS). The new IBTrACS version 4 is being utilized to produce the "Hurricanes and Tropical Storms" report for NCEI's monthly State of the Climate report.

El Niño–Southern Oscillation (ENSO) Normals: A paper documenting the project's unique methodology for developing U.S. Normals from nClimGrid–Monthly conditioned on both climate change and the phase of ENSO was published.

Calibration of High-resolution Infrared Radiation Sounder (HIRS) Brightness Temperatures: High-resolution Infrared Radiation Sounder (HIRS) measurements of brightness temperature must be calibrated in order to provide a consistent dataset for use as a Climate Data Record (CDR). Preliminary work identified a subset of the data that can be used for calibration of HIRS brightness temperature between satellites.

Climate Literacy, Outreach, Engagement, and Communications [NCEI/NCSU]

Climate Literacy, Outreach, Engagement, and Communications: CICS-NC provided operational customer engagement support to NCEI's Center for Weather and Climate (CWC), helped plan and host the 2019 NCEI Users' Conference, increased the number of targeted sector- and topic-specific engagement discussions, and participated in regional outreach activities promoting STEM and environmental information

CICS-NC Communications: CICS-NC communication efforts promote the Institute and its research activities to its stakeholders and advance the external and internal communications efforts of NCEI. Key accomplishments included communications related to the new cooperative institute announcement, a blog post on cloud computing published by *Amazon*, and graphic design and visual communication support for NCEI's annual State of the Climate Report.

Surface Observing Networks [NCEI/ATDD]

***Drought-related health impacts: advancing the science for public health applications*:** The University of Nebraska Medical Center (UNMC) and the National Integrated Drought Information System (NIDIS) convened a National Drought and Public Health Summit in June 2019. The Summit provided a forum for stakeholders to discuss drought and its impacts on human health and highlight current drought research and preparedness activities.

Software Development of a Cloud-Based Data Processing Prototype for GHCN-D: This project reexamines the Global Historical Climatology Network-Daily (GHCN-D) data pipeline to deliver a functional prototype that can operate on any cloud computing platform. Automation, scalability, and efficiency will be demonstrated and compared against 1) the existing in-house process and 2) the existing process if ported over to the commercial cloud.

Optimum Interpolation Sea Surface Temperature (OISST) algorithm upgrades: The task team has successfully aided in upgrading OISST dataset. This upgrade corrected a loss of buoy data due to data-transmission formatting changes, corrected bias errors with ship-derived temperature data, and streamlined the overall processing pipeline. In addition, the team is studying how best to incorporate data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instruments on the NOAA-20 and Suomi-NPP satellites into a subsequent version of the OISST product. https://www.ncdc.noaa.gov/oisst

U.S. Climate Reference Network (USCRN) Applications and Quality Assurance: CICS-NC assisted in the evaluation and initial transition from the *HydraProbe* to *Acclima* soil sensor, which also involved streamlining the manual quality control (QC) process. Validation and verification of the reconstructed hourly land surface temperature dataset at USCRN and Surface Radiation Budget Network (SURFRAD) stations was also completed.

Standardization of U.S. Climate Reference Network (USCRN) Soil Moisture Observations: The operational standardized soil moisture product was compared with other hydrological indicators, including the standardized precipitation index (SPI), standardized precipitation–evapotranspiration index (SPEI), and the U.S. Drought Monitor. These comparisons revealed that combining standardized soil moisture conditions with other indicators can provide insight on drought onset and amelioration.

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 the Spring 2019 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).

Development of the United States Climate Reference Network (USCRN) National Precipitation Index: An algorithm to build a national precipitation index (NPI) using 100+ stations from the United States Climate Reference Network has been in development and updated to 2019. A white paper has been completed, and the team is working to make the NPI operational at NCEI.

Maintenance and Streamlining of the Global Historical Climatology Network-Monthly (GHCNm) Dataset: The next iteration of NOAA's global temperature product has been developed and is operational. Updates are ongoing and provided as necessary. www.ncdc.noaa.gov/ghcnm/

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool: A sub-monthly tool for monitoring impacts of temperature extremes in the United States has been created and described in an article in an American Meteorological Society journal. The resulting dataset can be used to assess heat extreme events in the United States from 1895–2018 and can be compared against other relevant data.

International Comprehensive Ocean–Atmosphere Data Set (ICOADS): The International Comprehensive Ocean–Atmosphere Data Set (ICOADS) is the most complete and heterogeneous collection of surface marine data in existence. The high-impact scripts and workflow used to retrieve and process this data were migrated to a new, more robust computation environment.

Workforce Development [NCEI / NSF / NASA / NCSU]

CICS-NC actively works to identify and train the next generation of scientifically and technically skilled climate scientists. Junior and/or aspiring scientists, including post-doctoral researchers and students, 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.

Other CICS PI Projects

***Climate indicators to Track the Seasonal Evolution of the Arctic Sea Ice Cover to Support Stakeholders*:** This project examined the long-term average and temporal variability of the new sea ice climate indicators, including snow melt onset and sea ice retreat, advance, and freeze-up dates. A dataset was released by the National Snow and Ice Data Center.

***Synthesis of Observed and Simulated Rain Microphysics to Inform a New Bayesian Statistical Framework for Microphysical Parameterization in Climate Models*:** This multi-institutional research project comprehensively investigated the representation and associated uncertainties of rain microphysical processes in weather and climate models. The team developed an innovative Bayesian statistical framework that combines the extensive radar and ground-based data from the Department of Energy Atmospheric Radiation Measurement (ARM) field campaigns, bin microphysical modeling, and a new bulk parameterization.

***Climate Change Impacts on Human Health*:** Exploratory research and pilot studies were conducted to examine the impact of climate change—a known environmental determinant—on health risks for vulnerable persons (e.g., pregnant women, persons with a mental health condition).

***Multiscale Convection and the Maritime Continent*:** Project results show that the Madden–Julian Oscillation (MJO) modulates rainfall over the Maritime Continent during the afternoon peak of the diurnal cycle but has little impact on the morning minimum. Results exploring the skill of a novel Fourier filtering of combined observations and model hindcasts in the region were published and presented at two seminars. ncics.org/mjo

Administration

Administrative, or Task I, activities provide a central shared resource for CICS-NC staff and partners. Primary Task I activities include institute and office administration, accounting and finance, proposal development/support, contracts and grants management, human resources, information technology, international linkages, internal and external communications, oversight and management of CICS-NC-initiated consortium projects, and coordination with National Centers for Environmental Information (NCEI) administration and leadership. Other Task I activities include coordination of student intern opportunities and K–12 outreach activities.

Under the current NOAA Cooperative Agreement, CICS-NC serves as one of two CICS campuses and is collocated with NCEI in the Veach-Baley Federal Complex in Asheville, NC. The operation of CICS-NC is the primary activity of the North Carolina Institute for Climate Studies (NCICS), an Inter-Institutional Research Center (IRC) of the University of North Carolina (UNC) System. NCICS/CICS-NC is hosted and administered by North Carolina State University (NCSU) as an administrative unit under NCSU's Office of Research and Innovation (ORI). The NCICS/CICS-NC Director reports to the NCSU Vice Chancellor for ORI. CICS personnel are hired as NCSU employees and serve under NCSU policies and administrative guidelines. CICS-NC administrative staff implement, execute, and coordinate administrative activities with pertinent CICS-MD, UNC, NCSU, ORI, NOAA, and NCEI administrative offices.

The CICS-NC Director, in coordination with the Business Manager and University Program Specialist, is responsible for the operations of CICS-NC. Administrative operations are primarily supported by NCSU, with additional support from NOAA via the Task I cooperative institute allocation. The NOAA Task I allocation currently provides partial support for the Director (2 summer months), a Business Manager (20%), a Program Specialist (10%), IT operations and systems support (10%), and travel funds, primarily for the Director, for administration and research facilitation purposes with the diverse climate science and applications community. NCSU provides support for the Director and administrative staff, basic office and Institute operations, and a substantial investment in IT infrastructure associated with the goal of providing state-of-the-art visualization and connectivity (including Wi-Fi access and telepresence) tools for the Asheville-based staff.

CICS-NC/NCICS administrative activities are currently led by Dr. Otis B. Brown, Director, and are implemented and executed by the following administrative team:

Janice Mills, Business Manager
Erika Wagner, Program Specialist
Jonathan Brannock, IT Systems Administrator II
Steven Marcus, IT Network Administrator II
Scott Wilkins, IT Systems Administrator II

Institute Information Technology Systems Improvement, Management, and Maintenance	
Task Team	Jonathan Brannock, Steven Marcus, Scott Wilkins
Task Code	NC-ADM-01-NCICS-JB/SM/SW
NOAA Sponsor	Task I (partial support)
NOAA Office	NESDIS/NCEI (and other line offices)
Contribution to CICS Research Themes	Theme 1: 33.3%; Theme 2: 33.3%; Theme 3: 33.3%
Main CICS Research Topic	Data Access and Services Development
Contribution to NOAA goals	Goal 1: 45%; Goal 2: 45%; Goal 3: 8%; Goal 4: 2%
NOAA Strategic Research Priorities	All

Highlight: Institute IT staff provide modern, scalable approaches to keep CICS-NC at the competitive edge of technology advances, as well as maintaining core technologies as a stable base for staff operations. This year's accomplishments include security and monitoring improvements, network upgrades, and transitioning data storage to the *Ceph* file system.

Background

CICS-NC IT staff support a well-rounded set of IT resources and services and maintain the necessary infrastructure required to do so. Institute IT services are organized into three areas: the user network, cluster and computing resources, and network and disk infrastructure (Figure 1). The user network consists of wireless network services, *Google* telecommunications services, and end-user software on *Apple* desktops and laptops. The cluster and computing resources are centered on a high-performance computing cluster with 528 processing cores and 3 terabytes of memory. The cluster head node is a powerful server where users can prototype ideas and perform light work tasks, including coding and testing. The head node can then queue heavy workloads onto the cluster, where a number of different processing queues are available to suit computing requirements.

CICS-NC provides distributed *Ceph* file systems for concurrent system-wide access to high-speed storage. *Amazon S3* and *Glacier* provide offsite backup and disaster recovery for all data.

A building-wide wireless network provides both CICS-NC and other building partners with strong-signal, fast wireless coverage. This allows CICS-NC to quickly integrate and work side by side with its NCEI partners. There are 37 access points covering areas on the 1st through 3rd floors, fitness center, and NCEI archive, as well as full coverage on the 4th and 5th floors. The most populous areas utilize 802.11AX or gigabit Wi-Fi. Heat maps and simulations were used to optimize access point locations.

CICS-NC IT staff utilize a suite of monitoring tools, including *Casper Suite*, *Puppet OSE, Zabbix*, *Elasticsearch*, *Kibana*, *Ganglia*, and *Monitis*. These and other open source and proprietary tools allow IT staff to quickly address issues and efficiently monitor and maintain systems.

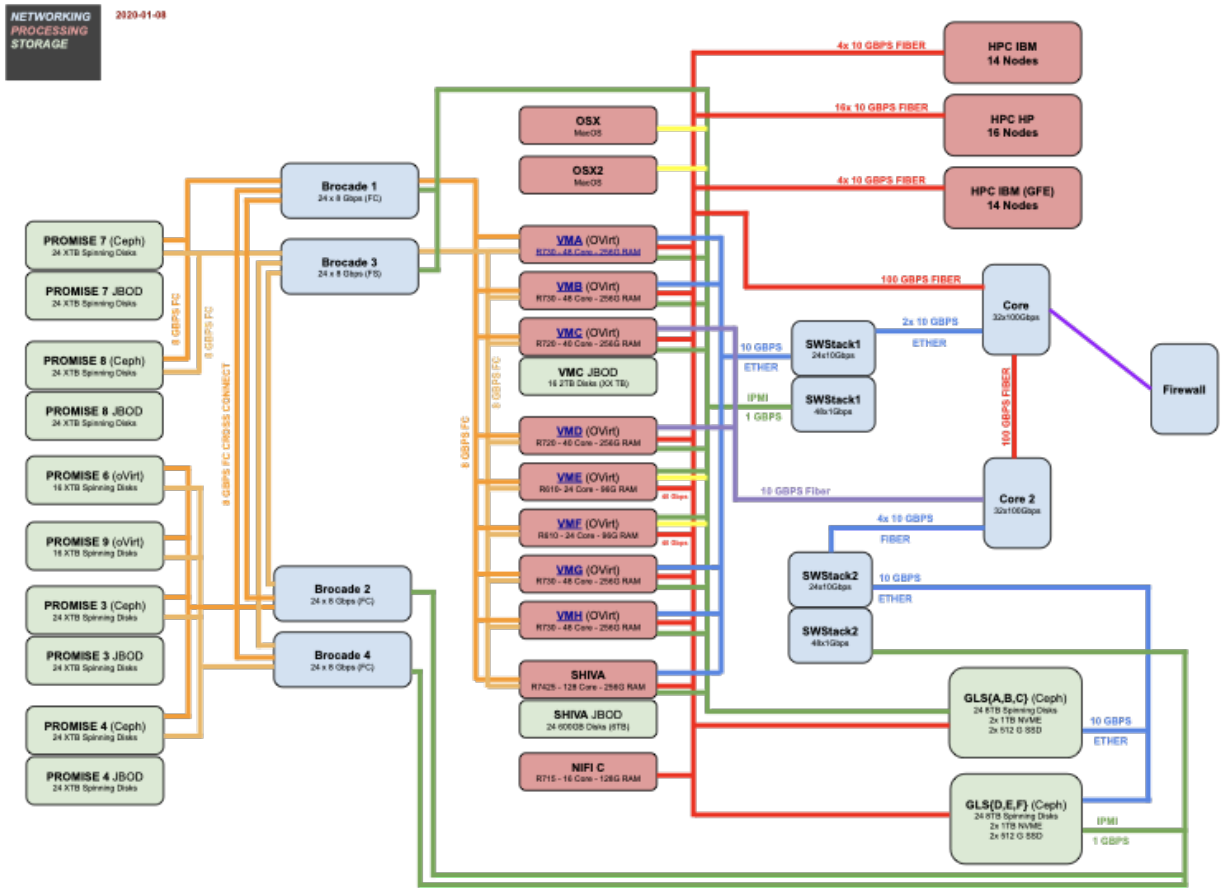


***Figure 1**. Network and System Diagram.*

Accomplishments

Security and monitoring improvements. The vulnerability scanner, *OpenVAS*, was upgraded and moved onto a virtual machine for easier management. Previously, most monitoring and alerting was done with *Nagios*, and most logs were managed by *Cacti*. This year, *Zabbix* was implemented this year, which performs both of these functions while providing some newer functionality and a more modern user interface. *Ansible* was also implemented for system management, which, in conjunction with *Git* for revision management, creates a way to ensure system configuration. On the desktop support side, University-mandated Endpoint Protection Standards were put in place, including *Malwarebytes* for all endpoints. Security exceptions were requested and approved for use of Institute inventory tracking and management systems separate from the university-managed systems.

Network upgrades. The wireless network has been improved with the addition of 802.11AX access points (APs). This keeps the wireless network up to date with the latest standards and performance. The core network infrastructure was also improved with the addition of a second 100 gigabit switch. This switch was provisioned as a second network route to all critical resources. The network can now more easily survive the loss of switches, network interface cards, and network links.

Ceph file systems. The *Gluster* file systems were replaced with *Ceph Reliable Autonomic Distributed Object Store (RADOS) Block Device (RBD)* file systems. After encountering response and data-corruption issues with the *Gluster* infrastructure, the existing *Gluster* hardware was reconfigured to host *Ceph*. The *Ceph RBD* file systems have been very stable and much more performant. To maximize performance, the input datasets were placed on our older *Promise Storage Area Network (SAN)* systems. These slower drives are still very responsive in read-intensive operations. The *Ceph* infrastructure allows CICS-NC researchers to transition their code from file systems to object stores on-premises in preparation for cloud deployment.

NOAA and other building tenant support. The Institute provides IT support to its partners in the federal building, including regular Wi-Fi access, audiovisual and video conferencing support of various meetings and engagements, and support to augment existing resources and provide the required functionality to make NCEI meetings and events possible. The Institute typically provides workstations, Wi-Fi, video conferencing, virtualization, and high-performance computing resources in support of various workforce development programs within the building, including the NASA DEVELOP and NOAA Hollings internship programs. Interns are often without access to federal resources until they are halfway through the program due to the short internship period (10–12 weeks). Institute-provided equipment enables a fully productive internship.

Planned work

Institute IT services and resources will continue to be provided under the successor CI, the Cooperative Institute for Satellite Earth System Studies (CISESS).

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

Access and Services Development

Access and Services Development activities support improvements to access mechanisms to the expansive data and product holdings of NOAA and NCEI. NOAA daily generates terabytes of data from satellites, radars, ships, weather models, and other sources. NCEI has ongoing requirements to improve the delivery of data products and services to its stakeholders and clients. Current NCEI services include interacting with data users, providing data products to users, and communicating unmet user needs to the science and stewardship components of NCEI. Increasing and improving access requires the input, guidance, and expertise of scientific data management staff, software engineers, and other technical specialists. Access improvements include the design of new tools and the enhancement of existing mechanisms. This work not only improves access to NCEI's data and product holdings but also contributes to the objectives of climate change resilience.

CICS-NC continues to support the enhancement and expansion of NOAA's Climate Services Portal applications under this task umbrella. The U.S. Climate Resilience Toolkit website (toolkit.climate.gov) was launched in November 2014, and work continues on enhancement of the site as well as other related tasks and climate interactive tools. Capitalizing on this current tool and application development, CICS-NC also expanded its work to identify synergies and integrate products and tools (data visualization capabilities, online mapping applications, etc.) across programs including the Climate Services Portal, the National Climate Indicators, the National Climate Assessment, and the National Integrated Drought Information System (NIDIS) U.S. Drought Portal. The NCEI website, which launched in April 2015 following the merger of NOAA's three data centers, offered the opportunity to update and enhance current services to customers with a more user-friendly design and interface to enable current and future users to more easily identify, locate, and access specific data products and services. The development of the NOAA OneStop portal, launched in late 2017, provided yet another opportunity to enhance and expand data access services. To meet this demand, CICS-NC provides experts in data architecture, management, web services, and user interface design and development. The NOAA Big Data Project (BDP) was created in 2015 to explore sustainable models to increase access to NOAA open data. In support of the BDP, CICS-NC designed and implemented a pilot data hub architecture to facilitate transfer of key NOAA environmental datasets to public cloud providers.

NOAA Big Data Project Support	
Task Leader	Otis Brown, Jonathan Brannock
Task Code	NC-ASD-01-NCICS-OB/JB
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/OCIO
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Data Access and Services Development
Contribution to NOAA goals	Goal 1: 40%; Goal 2: 40%; Goal 3: 15%; Goal 4: 5%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: Utilizing the CICS-NC-designed data hub/broker architecture, the project team moved multiple NCEI and other NOAA datasets to the cloud this year and backfilled HRRR data from archive sources. https://ncics.org/data/noaa-big-data-project/

Background

NOAA's environmental data holdings include more than 30 petabytes of comprehensive atmospheric, coastal, oceanographic, and geophysical data. While these datasets are publicly available, accessing and working with such large datasets can be difficult. NOAA's Big Data Project (BDP) is designed to facilitate public use of key environmental datasets by providing copies of NOAA's environmental information in the cloud, making NOAA's data more easily accessible to the general public, and allowing users to perform analyses directly on the data. Figure 1 provides an overview of this process.

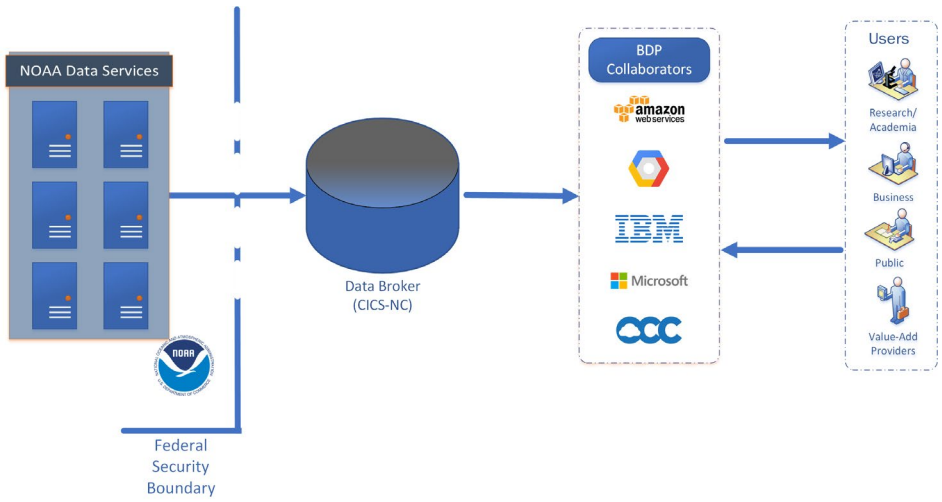


***Figure 1**. Data Hub/Broker Overview.*

CICS-NC is a partner in the BDP and acts as a broker between NOAA and the public cloud providers. CICS-NC data and information technology experts work to help transfer and certify multiple NOAA datasets to several cloud platforms, including *Amazon Web Services* (*AWS*), *Google Cloud Platform*, *IBM*'s *NOAA Earth Systems Data Portal*, and the *Open Commons Consortium* (OCC).

The CICS-NC high-performance computing cluster serves as a critical gateway for the near-real-time transfer of several datasets, including NEXRAD Level 2 radar data; NOAA-20, GOES-16, GOES-17 satellite data; and others.

Accomplishments
This year's BDP efforts focused on broadening the availability of NOAA datasets while maintaining performance and on using cloud-based agents to mediate transfers. Datasets were added from various NOAA data holdings, including the Automated Surface Observing System, the Integrated Surface Database, and Global Surface Hourly data (NCEI); Global Hydro-Estimator, fire/hotspot data (NOAA Product Distribution and Access); and almost every other Level 2 product for GOES-16 and GOES-17, including the ABI, GLM, and SUVI instruments.

Expanding the available datasets and maintaining performance required changing some dataset formats, working with several NOAA partners to gain access and obtain data missing from the existing BDP datasets, and exploring options to maintain and/or enhance data transfer workflows.

Format conversion. Emergency Response Imagery (covering storm events from Katrina to the present) was converted from non-Cloud Optimized GeoTIFF (COG) and JPEG data to COG-compliant data.

High-Resolution Rapid Refresh (HRRR) data backfill. This task required approved access to NOAA's Research and Development High Performance Computing System to backfill HRRR data from the Fairmont, WV, tape silo. While it took some time to identify the missing HRRR data and secure access, the actual data transfer to the *Google Cloud Storage* platform was facilitated utilizing the new *Niagara* system with *Globus GridFTP* untrusted data transfer nodes.

Google* Cloud Local Data Manager (LDM) *data transfer. In response to *Google* requests, the data broker set up LDM servers and installed a side-by-side installation of *NIFI* to load the LDM data into the cloud as soon as the LDM data are written to disk. NEXRAD Level 2 and Level 3 were configured, as well as a selection of NOAA Port data products.

Planned work
BDP support will continue under the successor Cooperative Institute for Satellite Earth System Studies.

Presentation
Brown, O., and **J. Brannock**, 2019: BDP Data Broker Update. *ESIP 2019 Summer Meeting*, Tacoma, WA, July 16, 2019.

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

Common Ingest Agile Development Team	
Task Leader	Linda Copley
Task Code	NC-ASD-02-NCICS-LC
NOAA Sponsor	Scott Hausman
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Data Access and Services Development
Contribution to NOAA goals	Goal 1: 40%; Goal 2: 40%; Goal 3: 20%
NOAA Strategic Research Priorities	**Environmental Observations**

Highlight: This software development team works in concert with NCEI staff to enhance, modify, and deploy the new Common Ingest (CI) system at NCEI-NC. This year the team supported the NCEI-NC operations team in completing the migration of datasets from the legacy ingest system to the new CI system, enhancing existing functionality, and hardening the system to provide greater resilience to network errors.

Background

Common Ingest (CI) is the solution delivered by the CI Agile development team for the ingest and archive of environmental information at NCEI. CI is being deployed at NCEI-NC to ingest and archive up to 6.7 terabytes per day of weather and climate data archives—processing more than 150,000 files, stored in as many as 13,000 archive information packages.

The CI system implements a modern software architecture and provides a browser-based interface for configuration and monitoring. The system is composed of an Ingest Manager and multiple Ingest Engines. Ingest Manager is responsible for submitting granules through the system for processing and monitoring the result of these submissions. Ingest Engines are responsible for processing granules as they pass through the system. Some engines are capable of routing processing to the next engine, removing the necessity to pass all processing through the Manager.

All desired file processing steps are stored as they traverse the system, resulting in persistent system status and full file provenance throughout the ingest process. CI employs a centralized message broker for asynchronous routing of processing control and status throughout the system.

Common Ingest is built so that data streams can be user-configured by defining the processing steps using multiple processing engines, as in a workflow system. This allows CI to be configured to handle multiple, complex data streams without the need for additional programming.

Accomplishments

As members of an agile software development team, CICS-NC staff work in concert with federal employees and contractors to enhance, modify, and deploy CI components at NCEI-NC. This year, the team supported the operations team in the completion of dataset migration to the CI system. As the migration progressed and new requirements were identified, the team designed and developed solutions in ways that could be generically applied for the ingest of current and future datasets.

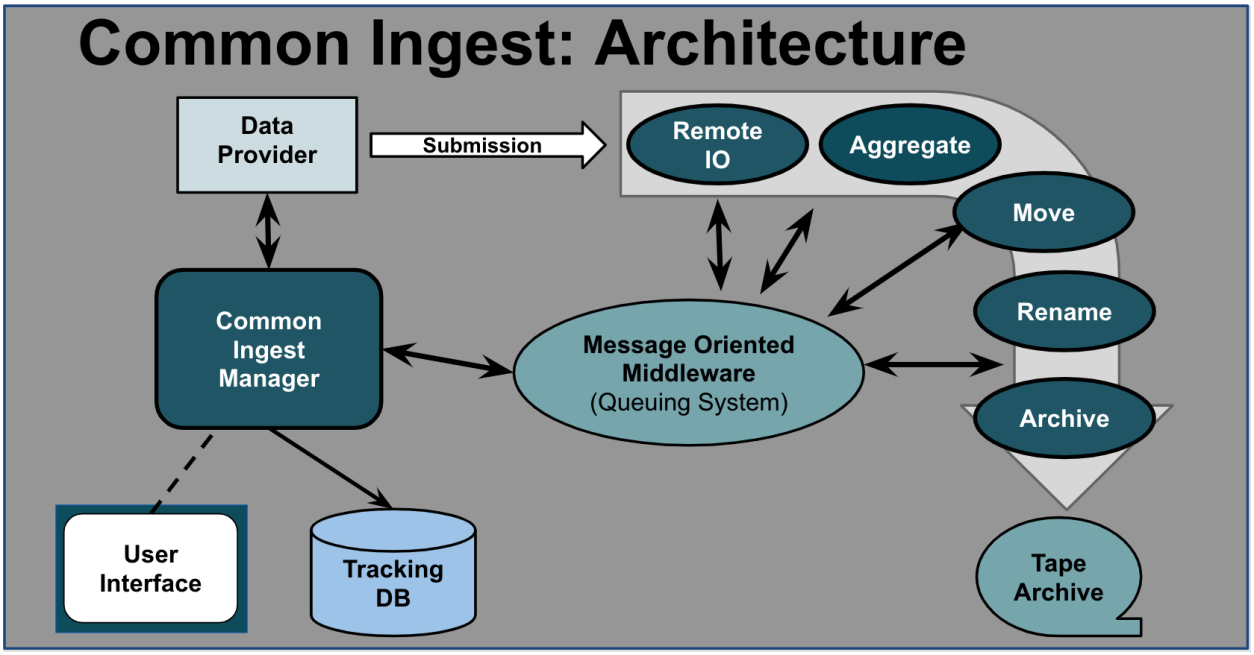


Figure 1. *CI Architecture.*

Several CI engines were upgraded to support sharding and scaling. The remote-io and fetch-processor engines that retrieve files for ingest, and the tar-creator engine that packages file aggregations, were enhanced to allow files to be partitioned over various input queues using the *RabbitMQ* central queueing component. This new functionality provides the operators with the ability to load balance the input and processing of files by separating the processing by input source or file size.

The CI team modified the HPSS and CLASS archive components of the system to communicate with Inventory Manager in support of the Common Data Services end-to-end test. NCEI has targeted Common Data Services as the preferred direction for near-term servicing of data at NCEI. This test included all Common Data Services system components and demonstrated that all components, including CI, could be successfully integrated to archive, discover, and deliver archive products.

A frequently used processing step in CI involves packaging large groupings of files into daily and monthly aggregations. The method of processing aggregations was refactored to provide more operator control of the process, greater visibility into the process for the operator, and a more reliable retention of files for archive. This new capability allows operators to collect files in a file system folder and retain them for later packaging. Files can be added to the folder from multiple sources using automated or manual methods. A new addition to the web-based graphical user interface provides the operator visibility into the state of files awaiting aggregation.

Frequent network errors beyond the control of the CI development team have caused errors in processing of files that had to be manually corrected by the operations team. Once all functionality required for processing ingest streams was complete, the team focused on hardening the CI system to provide greater resilience. Improvements included

- Implementing a new engine to fetch files from internal and external providers. The new fetch processor has a smaller memory footprint and provides a framework for more efficient ingest of data into CI.
- Using automated retries when fetching, moving, aggregating, and archiving files.
- Moving the interface with an automatic scheduling component to a persistent queue to ensure scheduled items were not lost and are guaranteed to be serviced under heavy system load.
- Upgrading all processing engines to ensure the persistence of messages pulled from the central queueing component.
- Correcting an issue that sometimes caused huge messages to compromise the queueing system.
- Modifying the system to detect and verify some file errors that were incorrectly reported by the file system.

Products

The following Common Ingest components were deployed in NCEI production:

- Common Ingest v2. 17.0 Complete chooseTar algorithm processing; operationalize object-storer
- Common Ingest v2.16.1 Persist *RabbitMQ* message in all engines
- Common Ingest v2.16.0 Tar-creator create tarball in new working directory
- Common Ingest v2.15.8 Partition tar-creator
- Common Ingest v2.15.7 Add ingest report scraper
- Common Ingest v2.15.5 Fixed missing variable declaration in Ftpser
- Common Ingest v2.15.4 Include *RabbitMQ* thread option for engines
- Common Ingest v2.15.2 Close temporary manifest files
- Common Ingest v2.15.1 Allow checksums to begin with zero
- Common Ingest v2.15.0 Allow aggregation stream name change
- Common Ingest v2.14.0 Create fetch-processor light engine
- Common Ingest v2.13.0 Retry on tar and untar failures
- Common Ingest v2.12.0 Remote-io retry with queues
- Common Ingest v2.11.1 Fix tar-creator message too large
- Common Ingest v2.11.0 Cleanup for chooseTar processing algorithm

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**15**
# of products or techniques submitted to NOAA for consideration in operations use	**15**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Delivered 15 Common Ingest components (see "Products") that are deployed in the NCEI production environment.

Programming and Applications Development for Climate Portal	
Task Leader	James Fox
Task Code	NC-ASD-03-UNCA
NOAA Sponsor	David Herring/Dan Berrie/David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50% Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Decision Science, Risk Assessment and Risk Communication

Highlight: In support of the overall advancement of the NOAA Climate Services (NCS) Portal program, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with the continued development of the U.S. Climate Resilience Toolkit (CRT) and the new Climate by Location design (part of Climate Explorer). NEMAC also provided graphics and GIS support for the USGCRP Indicators project and the National Climate Assessment, as well as design and content support for the NIDIS drought.gov redesign.

Background

To address the increasing need to incorporate climate services across NOAA and enhance NOAA's web presence in response to customer requirements, the NCS Portal has a continuing need for expertise and resources to support programming work for applications development and data visualization in support of the following tasks:

- *Drupal* Content Management System for climate.gov
- U.S. Climate Resilience Toolkit
- Global Climate Dashboard
- Climate Explorer and online map viewers (Climate Explorer 1 & 2)
- Climate Interactive tools
- Maps and Data Section Leadership for climate.gov

Supplemental task areas for coordinated development and integration with current task areas include

- Graphics for Indicators and the National Climate Assessment (NCA)
- GIS/climate projections for NCA
- Regional, state, local products
- Internal management portals
- Decision support and user engagement
- NIDIS support for drought.gov

Accomplishments

Project support was provided for four programs: the NOAA CPO Climate Portal (including the CRT and Climate Explorer), the National Climate Assessment, the USGCRP Indicators Working Group, and NIDIS.

Drupal CMS for climate.gov. NEMAC provided general programming, maintenance, and development-site support for the climate.gov team, including section support and maintenance for Data Snapshots and feedback on climate.gov redesign.

U.S. Climate Resilience Toolkit (CRT). NEMAC contributed to ongoing CRT development and editorial/content management, including 1) Great Lakes regional section case studies development; 2)

new Midwest regional section author team coordination and content development; 3) initial planning for development of new Southeast and U.S. Caribbean regions; 4) update of topic, subtopic, and regional narratives and other content to reflect key messages/content of the Fourth National Climate Assessment (NCA4); 5) initial implementation of editorial initiative to review, identify, and develop NCA4 case studies for the CRT to solidify ties between the two products; 6) exploration of better integration of story maps into the CRT site; 7) programming related to the migration of the CRT website from *Drupal 7* to *Drupal 8*; 8) troubleshooting and working with CRT editorial team members and *webLyzard* representatives to improve website search results; 9) general maintenance and update of site content; 10) two new case studies (total of 149); and 11) seventeen additional tools (total of 421).

Climate Explorer. The project team planned, designed, and conducted Climate Explorer 3.0 user testing during the April 2019 National Adaptation Forum (NAF), then planned and designed needed/desired interface changes based upon the NAF user testing. Work included coordination with the CRT editorial team to ensure proper navigation and an improved user experience, with expected deployment in winter 2019/2020.

Interactive climate tools/maps and data. NEMAC worked with NOAA personnel to create *Drupal* code in support of the Climate by Location tool project and hosted and maintained a development server to allow developers to test and review the code.

Static indicator graphics. Updates to the static indicator graphics design and data on the USGCRP Indicators website were completed in collaboration with the CICS-NC/NCEI Indicators team. Updated graphics include Start of Spring, Ocean Chlorophyll Concentrations, Terrestrial Carbon Storage, Sea Surface Temperature, Global Surface Temperatures, Frost-Free Season, U.S. Surface Temperatures, Atmospheric Carbon Dioxide, Arctic Sea Ice Extent, and Annual Greenhouse Gas Index. NEMAC helped update the Indicators Style Guide to meet new design requirements and implement these changes in the graphics.

Interactive graphics for NCA4. NEMAC supported the development of interactive graphics for the NCA Technical Support Unit and the NCA4 website, including Indicators of a Warming World, Impacts by Sector, Causes of Temperature Increase, Warmest Years, Arctic Sea Ice Extent, and Projected U.S. Sea Level Rise.

Decision support/user engagement. Project team members participated in a number of local, regional, and national forums, including steering and program committee contributions, poster presentations, and prototype Climate Explorer 3 user testing at the NAF (April 2019); service on panels, presentations, and/or workshop facilitation at The Collider's Climate City Expo (April 2019); participation in the NCEI 2019 Users' Conference (May 2019), the NOAA Climate Prediction Applications Science Workshop (June 2019), the 2019 North Carolina Coastal Resilience Summit (June 2019), and the National Center for Atmospheric Research's "Envisioning Risk of Hurricane Storm Surge and Sea Level Rise" workshop (July 2019). Several team members also worked with NOAA CPO's David Herring to research and prepare an economic impact white paper for NOAA CPO leadership.

National Integrated Drought Information System (NIDIS) support. NEMAC supported the NIDIS team with the redesign of drought.gov and its simultaneous migration from *Drupal 7* to *Drupal 8*, including programming and web development and facilitation of planning meetings. NEMAC also created first drafts of By Sector and Data and Maps/Topic content for review and approval by NIDIS staff and stakeholders.

Planned work

This project ended in September 2019. Development work on the various tools and websites will continue under the new Cooperative Institute for Satellite Earth System Studies (CISESS).

Products

- Data snapshots on Climate.gov (https://www.climate.gov/maps-data/data-snapshots/start)
- U.S. Climate Resilience Toolkit (https://toolkit.climate.gov)
- Climate Explorer 1 (http://climate-explorer.nemac.org)
- Climate Explorer 2 (CE2.5) (https://crt-climate-explorer.nemac.org/)
- USGCRP Indicator graphics (http://www.globalchange.gov/browse/indicators)

Publications

Moss, R.H., S. Avery, K. Baja, M. Burkett, A.M. Chischilly, J. Dell, P.A. Fleming, K. Geil, K. Jacobs, A. Jones, K. Knowlton, J. Koh, M.C. Lemos, J. Melillo, R. Pandya, T.C. Richmond, L. Scarlett, J. Snyder, M. Stults, A. Waple, J. Whitehead, D. Zarrilli, **J. Fox**, A. Ganguly, L. Joppa, S. Julius, P. Kirshen, R. Kreutter, A. McGovern, R. Meyer, J. Neumann, W. Solecki, J. Smith, P. Tissot, G. Yohe, and R. Zimmerman, 2019: "A Framework for Sustained Climate Assessment in the United States." *Bulletin of the American Meteorological Society*, **100**, 897–907. https://doi.org/10.1175/BAMS-D-19-0130.1.

Moss, R.H., S. Avery, K. Baja, M. Burkett, A.M. Chischilly, J. Dell, P.A. Fleming, K. Geil, K. Jacobs, A. Jones, K. Knowlton, J. Koh, M.C. Lemos, J. Melillo, R. Pandya, T.C. Richmond, L. Scarlett, J. Snyder, M. Stults, A.M. Waple, J. Whitehead, D. Zarrilli, B.M. Ayyub, **J. Fox**, A. Ganguly, L. Joppa, S. Julius, P. Kirshen, R. Kreutter, A. McGovern, R. Meyer, J. Neumann, W. Solecki, J. Smith, P. Tissot, G. Yohe, and R. Zimmerman, 2019: "Evaluating Knowledge to Support Climate Action: A Framework for Sustained Assessment. Report of an Independent Advisory Committee on Applied Climate Assessment." *Weather. Climate, and Society*, **11**, 465–487, https://doi.org/10.1175/WCAS-D-18-0134.1.

Presentations

Rogers, K., 2019: Scaling Technology with a Lens on Equity. *Climate City Expo*, The Collider, Asheville, NC, April 3, 2019.

Rogers, K. and N. Hall, 2019: Focusing the Frame: Engaging and Connecting with Your Resilience Audience, *National Adaptation Forum 2019*, Madison, WI, April 23, 2019.

Hutchins, M., **J. Fox**, J. Hicks, **K. Rogers**, and N. Hall, 2019: After the assessment: Informing and prioritizing projects and strategies to build resilience, *National Adaptation Forum 2019*, Madison, WI, April 23, 2019.

Fox, J., 2019: Climate Resilience: Moving From Data to Decisions. *NCEI 2019 Users' Conference*, The Collider, Asheville, NC, May 14, 2019.

Fox, J., 2019: Building Resilience Through Risk Management of Climate-Related Coastal Hazards. *Climate Prediction Applications Science Workshop*, Charleston, SC, June 13, 2019.

Other

Two UNC Asheville undergraduate students were mentored in writing/editing internships for the U.S. Climate Resilience Toolkit.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**4**
# of products or techniques submitted to NOAA for consideration in operations use	**4**
# of peer-reviewed papers	**2**
# of NOAA technical reports	**0**
# of presentations	**5**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**2**

Products improved and/or redesigned: the U.S. Climate Resilience Toolkit, the Climate Explorer 2 (CE2.5), and the Climate by Location tool (3). Several products were generated including graphics (static and interactive) for the USGCRP (1).

Scientific Data Stewardship for Digital Environmental Data Products	
Task Leader	Ge Peng
Task Code	NC-ASD-04-NCICS-GP
NOAA Sponsor	Kenneth Casey
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Data Access and Services Development
Contribution to NOAA goals (%)	Goal 1: 80%; Goal 3: 20%
NOAA Strategic Research Priorities	Other

Highlight: This effort focuses on cutting-edge research on, and application of, scientific stewardship of individual digital environmental data products and promoting scientific data stewardship. Communication efforts aimed at raising the awareness of the Data Stewardship Maturity Matrix (DSMM) and of curated data quality descriptive information included a peer-reviewed paper and multiple presentations at national and international conferences.

Background

U.S. governmental directives (e.g., the Information Quality Act of 2001, the Federal Information Security Management Act of 2002, and the Foundations for Evidence-Based Policymaking Act of 2019) and recommendations from other expert bodies require that environmental data be

- scientifically sound and utilized,
- fully documented and transparent,
- well preserved and integrated, and
- readily obtainable and usable.

Data stewardship begins with preservation and includes documenting data sources and quality-control procedures for data product traceability, lineage, and provenance. Any improvement process requires knowledge of the current stage as well as what needs to be done to improve to the next stage. To address this need, NCEI and predecessor cooperative institute scientists and subject matter experts jointly developed a unified framework for measuring stewardship practices for a specific dataset. In collaboration with the NOAA OneStop program, NCEI's Data Stewardship Division, and NCEI's Center for Weather and Climate, the Data Stewardship Maturity Matrix (DSMM) has been applied to over 800 individual datasets to assess the quality of stewardship practices applied to digital environmental datasets, with the goal of providing consistent information, such as the state of data integrity and usability, to users and stakeholders. The DSMM is also garnering international attention. For example, the Committee on Earth Observation Satellites' Working Group on Information System and Services Data Stewardship Interest Group has adapted the DSMM for more global use in 2017.

Accomplishments

This year's accomplishments included a peer-reviewed paper describing the practical application of DSMM to NOAA's OneStop project and multiple presentations at national and international conferences to raise awareness of the DSMM and of curated data quality descriptive information, for both human and machine end-users (e.g., Figure 1). Other work included supporting the application of DSMM to the OneStop project, coordinating the development of a data use/service maturity matrix, and organizing and leading conference sessions on systematically curating and presenting data quality information to users.

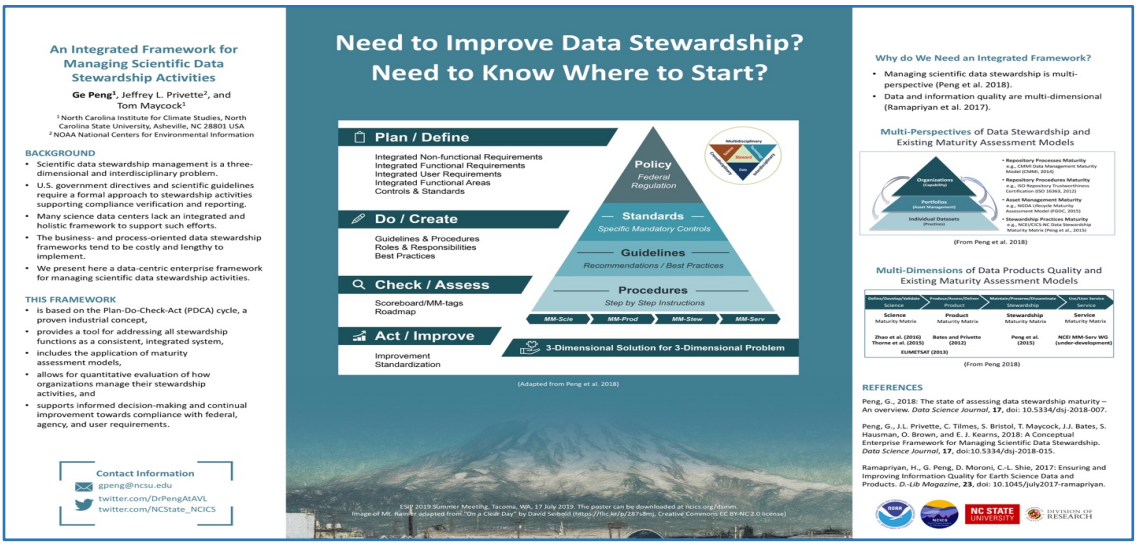


Figure 1*. This poster, which describes an integrated framework for managing scientific data stewardship activities, was presented at the 2019 ESIP summer meeting (Peng et al. 2019). https://doi.org/10.6084/m9.figshare.9171830*

Publications

Moroni, D. F., H. Ramapriyan, **G. Peng**, J. Hobbs, J.Goldstein, R. Downs, R. Wolfe. C.-L. Shie, C. J. Merchant, M. Bourassa, **J. L. Matthews**, P. Cornillon, L. Bastin, K. Kehoe, B. Smith, J. L. Privette, A. C. Subramanian, **O. Brown**, and I. Ivanova, 2019: Understanding the Various Perspectives of Earth Science Observational Data Uncertainty. (link)

Peng, G., A. Milan, N. A. Ritchey, R. P. Partee II, S. Zinn, E. McQuinn, K. S. Casey, P. Lemieux III, R. Ionin, P. Jones, A. Jakositz, and D. Collins, 2019: Practical Application of a Data Stewardship Maturity Matrix for the NOAA OneStop Project. *Data Science Journal*, **18**, 41. http://doi.org/10.5334/dsj-2019-041

Presentations

Peng, G., A. Milan, N.A. Ritchey, and others, 2019: Providing Structured, Evidence-Based, Content-Rich, Machine and Human Readable Dataset Quality Information – Practical Application of a Stewardship Maturity Matrix. Poster. *Research Data Alliance's 13th Plenary Meeting*, Philadelphia, PA, April 2, 2019.

Lief, C., **Peng, G.,** O. Baddour, W. Wright, V. Aich, and P. Siegmund, 2019: WMO Stewardship Maturity Matrix for Climate Data (SMM-CD) Developed under the High-Quality Global Data Management Framework for Climate. Poster. *EGU General Assembly 2019*, Vienna, Austria, April 9, 2019.

Peng, G., N. Ritchey, and I. Maggio, 2019: Establishing Trustworthiness and Suitability of Data Products and Services with Content-Rich, Interoperable and Findable Quality Descriptive Information. Session. *EGU General Assembly 2019*, Vienna, Austria, April 9, 2019.

Peng, G., 2019: An Introduction to Stewardship Maturity Matrix for Climate Data. *WMO Catalogue on Assessed Climate Datasets Expert Meeting*, Geneva, Switzerland, April 12, 2019.

Peng, G., 2019: What is the WMO Stewardship Maturity Matrix for Climate Data? Why need one? Why now? *WMO Catalogue on Assessed Climate Datasets Expert Meeting*, Geneva, Switzerland, April 12, 2019.

Peng, G., 2019: A Brief Update on the Activity of the RDA FAIR Data Maturity Model Working Group. *47th Committee on Earth Observation Satellites (CEOS) Meeting of the Working Group on Information Systems & Services,* Silver Spring, MD, May 1, 2019.

Peng, G., 2019: WMO Stewardship Maturity Matrix for Climate Data (SMM-CD) – An Update and Possible Collaboration. *47th Committee on Earth Observation Satellites (CEOS) Meeting of the Working Group on Information Systems & Services,* Silver Spring, MD, May 1, 2019.

Ramapriyan, H., D. Moroni, **G. Peng**, and Y. Wei, 2019: Conveying Information Quality – Recent Progress. Session. *The ESIP 2019 Summer Meeting*, 16–19 July 2019, Tacoma, WA, USA.

Peng, G., A. Milan, N. Ritchey, et al, 2019: Providing Rich and Structured Dataset Quality Information – Practical Application of a Data Stewardship Maturity Matrix. Poster. *DataONE Community Meeting*, Tacoma, WA, July 15, 2019.

Peng, G., 2019: A Framework for Curating Rich and Structured Data Quality Descriptive Information. *DataONE Community Meeting*, Tacoma, WA, July 15, 2019.

Peng, G., 2019: Update on Maturity Matrix Related Activities. Session: Conveying Information Quality – Recent Progress. *ESIP 2019 Summer Meeting,* Tacoma, WA, July 16, 2019.

Peng, G., J.L. Privette, and **T. Maycock**, 2019: An Integrated Framework for Managing Scientific Data Stewardship Activities. Poster. *ESIP 2019 Summer Meeting*, Tacoma, WA, July 17, 2019.

Moroni, D., H. Ramapriyan, **G. Peng**, 2019: Community Whitepaper on Uncertainty Quantification. *2019 US CLIVAR Summit,* Long Beach, CA, August 6, 2019.

Peng, G., J. L. Privette, E. J. Kearns, N. Ritchey, O. Brown, C. Tilmes, S. Bristol, H. K. Ramapriyan, and **T. Maycock**, 2019: A Holistic Framework for Supporting Evidence-Based Institutional Research Data Management. *CODATA 2019 Conference*, Beijing, China, September 19, 2019.

Peng, **G**., H. Ramapriyan, and D. Moroni, 2019: Introducing ESIP Information Quality Cluster. *Barcelona Supercomputing Center and Copernicus Data Store*, Barcelona, Spain. September 23, 2019.

Peng, G., 2019: An overview of maturity models for consistent dataset quality ratings. *Barcelona Supercomputing Center and Copernicus Data Store*, Barcelona, Spain. September 26, 2019.

Other

- Chief Editor – Earth Science System Data (ESSD) journal
- ESIP Data Stewardship Committee and co-chair of ESIP Information Quality Cluster
- WMO Stewardship Maturity Matrix for Climate Data Working Group – lead
- RDA FAIR Data Maturity Model Working Group

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**1**
# of NOAA technical reports	**0**
# of presentations	**16**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

NCEI Infrastructure Architecture Planning and Implementation	
Task Leader	Lou Vasquez
Task Code	NC-ASD-05-NCICS-LV
NOAA Sponsor	Scott Hausman/Drew Saunders
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: 33%; Theme 2: 33%; Theme 3: 34%
Main CICS Research Topic	(Data) Access and Services Development
Contribution to NOAA goals	Goal 1: 25%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%;
NOAA Strategic Research Priorities	Environmental Observations

Highlight: This project team and its collaborators drive NCEI and Institute IT infrastructure and architecture innovation that will support a modern, flexible, distributed approach to data science, archive, and access capabilities. This project supported the test-tier deployment of NCEI's Common Data Services (CDS) and integration with Common Ingest (CI) and demonstrated the ability to support metadata at NCEI.

Background

Existing NCEI architecture supporting data science, archive, and access is based on block storage, virtual machine servers, integration framework business logic, and service-oriented solutions. This does not scale proficiently or reconfigure quickly and cannot be shifted to readily available, robust alternatives without redesign.

In addition to the general need to stay current and have effective infrastructure, specific new projects such as CDS and NESDIS Cloud Framework make new approaches a requirement. Meanwhile, existing projects such as CI are experiencing the limitations of current NCEI infrastructure and processing approaches.

This project both explores and deploys modern, industry-accepted approaches used to avoid these pitfalls. It includes Infrastructure as a Service (IaaS) for resource management, containers for processing, object store for data, scalable workflow automation for data and metadata processing, and architecture that ties them together in a flexible, effective way for NCEI.

Because tying these pieces together requires an understanding of NCEI processes, from science to hardware, this project's collaborators include staff with backgrounds in science, architecture, software, and hardware. As it also must support many projects and NCEI architectural components, including the Open Archival Information System framework and NESDIS Big Data Interoperability Framework, the group interacts with staff involved in data ingest, archive, management, preservation, and access. This cross-disciplinary approach is a new way to develop NCEI architectural solutions.

Accomplishments

This project supported the test-tier deployment of CDS, integration with CI, and the demonstration of its ability to support metadata at NCEI. It is awaiting NCEI resources for its transition to the production tier.

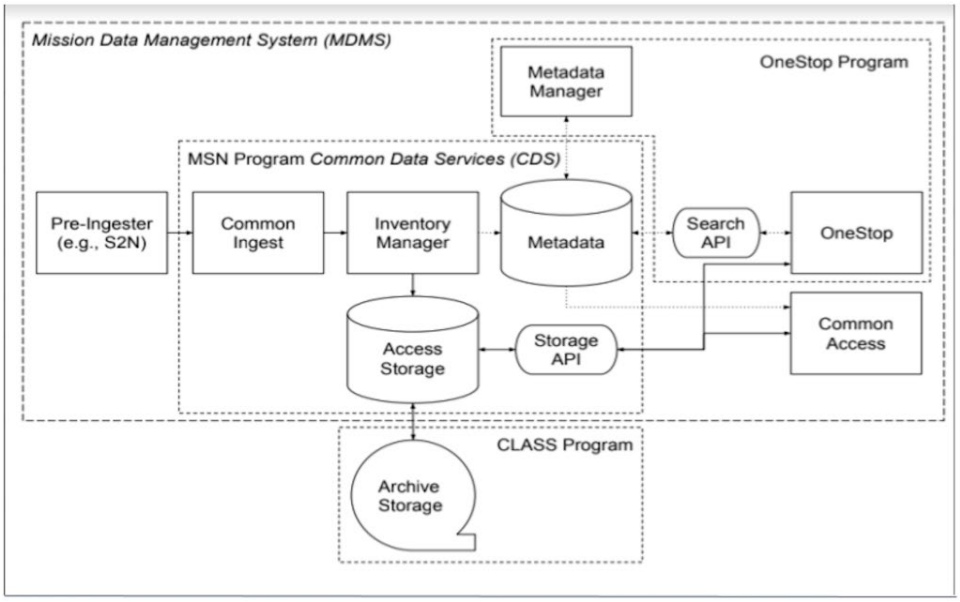


Figure 1. *CDS and MDMS Architecture.*

The CDS system at NCEI (Figure 1) brings together tools that exhibit desired infrastructure qualities. *Kafka*, at the center of CDS, is scalable, containerize-able, workflow driven, and widely deployed in the cloud.

Planned work
Project support will continue under the successor Cooperative Institute (the Cooperative Institute for Satellite Earth System Studies).

Product

- CDS system architecture design

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

Assessment Activities

Assessment efforts support interagency activities for global, national, and regional assessments of climate change. NOAA has a number of global, national, regional, and sectoral-level climate assessment activities underway and a sustained assessment process that includes ongoing engagement with public and private partners and targeted, scientifically rigorous reports, as well as participation in the high-level, legally mandated National Climate Assessment (NCA) process, which is responsive to greater emphasis on user-driven science needs under the auspices of the U.S. Global Change Research Program (USGCRP). USGCRP is a federation of 13 federal agencies (including NOAA) that conduct research and develop and maintain capabilities supporting the Nation's response to global change. National climate assessments, based on observations made across the country in comparison to predictions from climate system models, are intended to advance the understanding of climate science in the larger social, ecological, and policy systems to provide integrated analyses of impacts and vulnerability.

NCEI and other parts of NOAA have provided leadership on climate assessment activities for over a decade. Decisions related to adaptation at all scales, as well as mitigation and other climate-sensitive decisions, will be supported through an assessment design that is collaborative, authoritative, responsive, and transparent. NOAA is working through an interagency process and investing in partnerships across many scales to support this comprehensive assessment activity. The agency is also investing in core competencies including modeling, data management, visualization, communication, web management, and other expertise.

The Third National Climate Assessment (NCA3), released in May 2014, was the result of four years of development and production involving a team of 300+ experts guided by a 60-member Federal Advisory Committee. Under the preceding and current projects, CICS-NC established an assessment task group, the Technical Support Unit (TSU), that contributed to many aspects of the report by providing scientific, editorial, graphics, project management, metadata, software engineering, and web design expertise. CICS-NC also coordinated an outside evaluation of the NCA3 process, which helped inform the Fourth National Climate Assessment (NCA4) process and its release in November 2018. The NCA process has emerged as a template for other interagency assessments and for other countries/nations looking to implement their own comprehensive climate assessments at the national, regional, and local scale. CICS-NC and its consortium partners are leveraging the experience and capacity gained during the development of NCA3 and NCA4 to continue to address assessment priorities—including the sustained assessment process, interim assessments, and technical and special reports—and to provide ongoing support to other interagency assessment efforts, international assessment activities, and USGCRP activities.

National Climate Assessment Scientific and Data Support Activities	
Task Team	Kenneth Kunkel (Lead), James Biard, Sarah Champion, Katharine Johnson, Laura Stevens, Liqiang Sun
Task Code	NC-CAA-01-NCICS-KK/JB/SC/KJ/LS/LS
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI and OAR/CPO
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50% Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Decision Science, Risk Assessment and Risk Communication

Highlight: The science/data team was integral to the initial development of the North Carolina Climate Science Report, including working with the state's Department of Environmental Quality and other stakeholders to gather requirements, authorship contributions to several chapters, and development of numerous specialized scientific analyses and graphs**.**

Background

NOAA is participating in the high-level, visible, and legally mandated National Climate Assessment (NCA) process, and is responding to a greater emphasis on user-driven science needs under the auspices of the U.S. Global Change Research Program (USGCRP). National climate assessments are intended to advance the understanding of climate science in the larger social, ecological, and policy systems to provide integrated analyses of impacts and vulnerability. NCEI, along with many other parts of NOAA, has provided leadership on climate assessment activities for over a decade. A renewed focus on national and regional climate assessments to support improved decision-making across the country continues to emerge. Decisions related to adaptation at all scales as well as mitigation and other climate-sensitive decisions will be supported through an assessment design that is collaborative, authoritative, responsive, and transparent. NOAA is working through an interagency process and investing in partnerships across many scales to support this comprehensive assessment activity.

To support these activities, CICS-NC formed a technical support unit (TSU). Within the TSU, a group focused on scientific support was assembled, consisting of a Lead Senior Scientist (Kenneth Kunkel), Deputy Scientist (Liqiang Sun), Support Scientist (Laura Stevens), Data Lead (Sarah Champion), and Software Engineer (James Biard). The Lead Senior Scientist provides scientific oversight for the development of NOAA's assessment services supporting the NCA and broader assessment activities based on foundational climate science information. The Data Lead directs Foundations for Evidence-Based Policymaking Act (EBPA) and Information Quality Act (IQA) compliance efforts.

Accomplishments

CICS-NC led the initial development of a North Carolina Climate Science Report (NCCSR) in support of the North Carolina Governor's Executive Order 80 (EO80: "North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy"). This report provides an independent, peer-reviewed scientific contribution to the EO80. CICS-NC recruited an author team and established the Climate Science Advisory Panel, composed of North Carolina university and federal research climate experts to provide oversight and review of the report. The report will include an overview of the physical science of climate change and detailed information on observed and projected changes in temperature and precipitation

averages and extremes, hurricanes and other storms, sea level, and other relevant climate metrics for the state.

In an ongoing effort to comply with the EBPA and IQA, and as part of the sustained assessment process, work continued on improved design and capabilities of a content management system. Team staff led a collaboration with NOAA General Counsel and the NOAA/Department of Commerce Chief Data Officer on EBPA and IQA applications to the NCA enterprise.

The State Climate Summaries of Alabama, Louisiana, Mississippi, New Mexico, North Carolina, Ohio, and Utah were updated to include information through 2018. Updates included figure development, textual revisions, graphical layout, and web deployment.

Products

- Improved interactive, web-based metadata viewer, providing additional downloadable content, most notably including direct access to TSU derived datasets
- NOAA State Climate Summaries for Alabama, Louisiana, Mississippi, Utah, New Mexico, Ohio, and North Carolina

Publications

Runkle, J., K. Kunkel, L. Stevens, and **R. Frankson**, 2017: Alabama State Climate Summary. *NOAA Technical Report NESDIS 149-AL*, March 2019 Revision, 4 pp. http://statesummaries.ncics.org/al/.

Runkle, J., K. Kunkel, S. Champion, R. Frankson, and **B. Stewart**, 2017: Mississippi State Climate Summary. *NOAA Technical Report NESDIS 149-MS,* March 2019 Revision, 4 pp. http://statesummaries.ncics.org/ms/.

Frankson, R., K. Kunkel, and **S. Champion**, 2017: Louisiana State Climate Summary. *NOAA Technical Report NESDIS 149-LA,* March 2019 Revision, 4 pp. http://statesummaries.ncics.org/la/.

Frankson, R., K. Kunkel, L. Stevens, and D. Easterling, 2017: New Mexico State Climate Summary. *NOAA Technical Report NESDIS 149-NM*, May 2019 Revision, 4 pp. http://statesummaries.ncics.org/nm/.

Frankson, R., **K. Kunkel, L. Stevens**, D. Easterling, W. Sweet, A. Wootten, and R. Boyles, 2017: North Carolina State Climate Summary. *NOAA Technical Report NESDIS 149-NC*, May 2019 Revision, 4 pp. http://statesummaries.ncics.org/nc/.

Frankson, R., **K. Kunkel, S. Champion,** and D. Easterling, 2017: Ohio State Climate Summary. *NOAA Technical Report NESDIS 149-OH,* September 2019 Revision, 4 pp. http://statesummaries.ncics.org/oh/.

Frankson, R., K. Kunkel, L. Stevens, and D. Easterling, 2017: Utah State Climate Summary. *NOAA Technical Report NESDIS 149-UT,* September 2019 Revision, 4 pp. http://statesummaries.ncics.org/ut/.

Kunkel, K. E., and S. M. Champion, 2019: An assessment of rainfall from Hurricanes Harvey and Florence relative to other extremely wet storms in the United States. *Geophysical Research Letters*, **46**, 13500– 13506, http://dx.doi.org/10.1029/2019GL085034.

Kunkel, K. E., T. R. Karl, M. F. Squires, X. Yin, **S. T. Stegall**, and D. R. Easterling, 2020: Precipitation Extremes: Trends and Relationships with Average Precipitation and Precipitable Water in the Contiguous United States. *Journal of Applied Meteorology and Climatology*, **59**, 125–142, https://doi.org/10.1175/JAMC-D-19-0185.1.

Lee, J., D. Waliser, H. Lee, P. Loikith, and **K. E. Kunkel**, 2019: Evaluation of CMIP5 ability to reproduce twentieth century regional trends in surface air temperature and precipitation over CONUS. *Climate Dynamics*, **53**, 5459–5480, https://doi.org/10.1007/s00382-019-04875-1.

Peng, G., **J. L. Matthews**, M. Wang, R. Vose, and **L. Sun**, 2020: What Do Global Climate Models Tell Us about Future Arctic Sea Ice Coverage Changes? *Climate*, **8**, https://doi.org/10.3390/cli8010015.

Rennie, J., **J. E. Bell**, **K. E. Kunkel**, S. Herring, H. Cullen, and A. M. Abadi, 2019: Development of a submonthly temperature product to monitor near-real-time climate conditions and assess long-term heat events in the United States. *Journal of Applied Meteorology and Climatology*, **58**, 2653–2674, http://dx.doi.org/10.1175/JAMC-D-19-0076.1.

Russell, B. T., M. D. Risser, R. L. Smith, and **K. E. Kunkel**, 2019: Investigating the association between late spring Gulf of Mexico sea surface temperatures and U.S. Gulf Coast precipitation extremes with focus on Hurricane Harvey. *Environmetrics*, **In press**, e2595. http://dx.doi.org/10.1002/env.2595.

Presentations

Kunkel, K., 2019: Climate Science in the National Climate Assessment. *Osher Lifelong Learning Institute*, Raleigh, NC, April 9, 2019.

Kunkel, K. E., 2019: Hydroclimatic Extremes Trends and Projections: A View from the Fourth National Climate Assessment. *4th Annual NRC Probabilistic Flood Hazard Assessment Workshop*, Rockville, MD. May 2, 2019.

Kunkel, K., 2019: Probabilities of Extreme Climate Events. *NCSU MEA 593 "*Quantitative *Analysis of Climate Change" class*, Raleigh, NC, September 3, 2019.

Kunkel, K., 2019: Extreme precipitation and climate change: Observations and projections. *Association of State Dam Safety Officials* Dam Safety 2019 Conference, Orlando, FL, September 9, 2019.

Kunkel, K., 2019: Effects on anthropogenically-forced global warming on the risks of extreme rainfall and flooding. *Association of Environmental and Engineering Geologists 62nd Annual Meeting*, Asheville, NC, September 18, 2019.

Stevens, L., 2019: Highlights from the Fourth National Climate Assessment Volume II: Impacts, Risks, and Adaptation in the United States. *Association of Environmental and Engineering Geologists 62nd Annual Meeting*, Asheville, NC, September 18, 2019.

Other

Kenneth Kunkel serves as graduate advisor and/or committee member for the following students:

- TSU staff members Brooke Stewart and Sarah Champion, NCSU Department of Marine, Earth, and Atmospheric Sciences (MEAS; PhD advisor)
- Mike Madden, NCSU/MEAS (PhD committee)
- Qing Dong, visiting international PhD student, Hohai University (advisor)

Liqiang Sun is a Climate Explorer team member. The Climate Explorer offers customizable graphs, maps, and data downloads of observed and projected climate variables for every county in the United States

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**7**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**6**
# of NOAA technical reports	**7**
# of presentations	**6**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**3**
# of undergraduate students mentored during the year	**0**

NOAA State Climate Summaries for Alabama, Louisiana, Mississippi, New Mexico, North Carolina, Utah, and Ohio

National Climate Assessment Technical Support Activities	
Task Team	Jim Biard, Jessicca Griffin, Katharine Johnson, Angel Li, Tom Maycock, Andrea McCarrick, Brooke Stewart-Garrod
Task Code	NC-CAA-02-NCICS-JB/JG/KJ/AL/TM/AM/BS
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI and OAR/CPO
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities	Decision Science, Risk Assessment and Risk Communication

Highlight: The Technical Support Unit released updates to the Fourth National Climate Assessment that enhanced the accessibility of the report and addressed errata, produced new websites for two major reports—the Scientific Assessment of Ozone Depletion: 2018 and the State of the Carbon Cycle Report 2018—and produced updates to seven State Climate Summaries.

Background

The National Climate Assessment (NCA) is conducted under the auspices of the U.S. Global Change Research Program (USGCRP). The NCA is intended to provide the President, Congress, other stakeholders, and the general public with a report on the current state of climate change science, the impacts of climate change, and the effectiveness of mitigation and adaptation efforts. It is essential that the report be written in clear language and graphically represented in a way that is easily understood by a broad audience while maintaining the highest possible standards of accuracy and transparency. The Technical Support Unit (TSU) at NCEI serves as a major part of NOAA's contribution to the program as one of USGCRP's 13 agency members and provides technical expertise to support the development, production, and publication of the NCA and other associated products. TSU technical staff work collaboratively with the TSU Assessment Science team and in coordination with NCA authors, NCEI, and USGCRP.

The TSU editorial team—Brooke Stewart-Garrod, Tom Maycock, Andrea McCarrick, and Tiffany Means—provides scientific editing and writing services to the NCA authors as well as to in-house scientists/authors. They also provide technical writing/editing, copy editing, and coordination of scientific figure development; coordinate in-house publication across multiple teams; and provide substantive input to product rollout and communications plans. The team provides similar support for related assessment products that are created as part of the sustained assessment process. Team members assist CICS-NC and NCEI management as well as USGCRP management and staff with project planning and coordination, including development of the overarching NCA project timeline. They also help develop guidance documents for NCA authors.

Jessicca Griffin serves as the CICS-NC liaison between the TSU and NCEI's Communication and Outreach Branch to provide *graphics design and production* support for the NCA and other publications. Graphics support includes image creation and editing for accuracy and readability, preparing graphics for various pre-release drafts, and graphics design.

The web team—Angel Li and Katharine Johnson, with support from Jim Biard—designs, develops, and implements online climate assessment reports (websites) with mobile device (e.g., phones and tablets) access, as well as web-based tools that support assessment processes.

Accomplishments

Volume II of the Fourth National Climate Assessment: Impacts, Risks, and Adaptation in the United States (NCA4): Accessibility and Errata Updates

In compliance with Section 508 of the Rehabilitation Act, the TSU editorial team wrote alternative text for more than 330 non-text elements in NCA4. Alternative text is a brief yet comprehensive description of a visual (such as a graph, map, diagram, or photograph) and is used primarily by people who are blind or have visual impairments. These alternative text scripts were applied to the PDF and HTML versions of the report—a task made easier by a tool developed by Jim Biard of the TSU that automatically applies alternative text scripts to the appropriate images in PDF files. The TSU also implemented revisions to report text and figures to address several errors identified since the release of the report. The alternative text and errata updates were released in fall 2019.

Scientific Assessment of Ozone Depletion: 2018

The web team worked with NOAA Earth System Research Laboratory (ESRL) and David Easterling (NOAA NCEI) to produce a website for this report, which is prepared quadrennially by the Scientific Assessment Panel (SAP) of the Montreal Protocol on Substances that Deplete the Ozone Layer. The report website can be accessed here: https://www.esrl.noaa.gov/csd/assessments/ozone/2018/

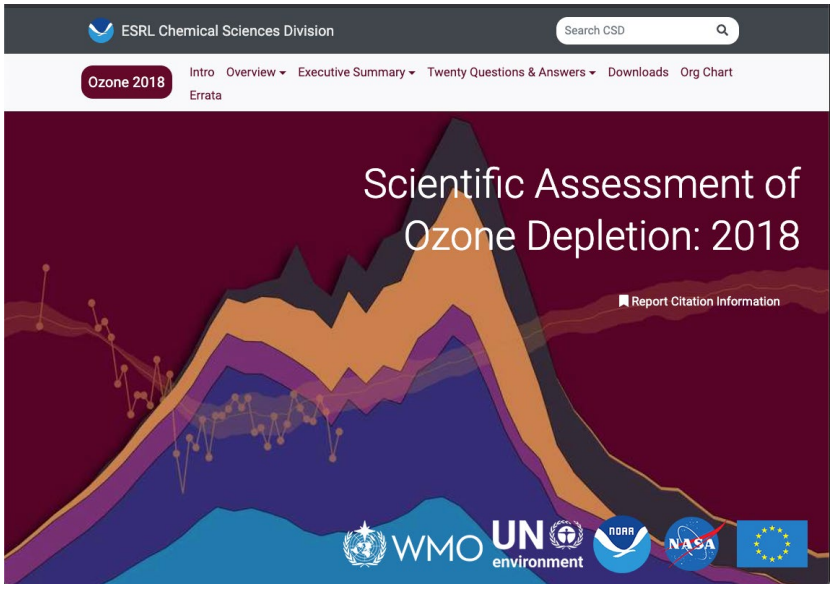


Figure 1. *The TSU developed the report website for the 2018 Ozone Assessment.*

State of the Carbon Cycle Report 2018

The web team worked with members of USGCRP and the U.S. Carbon Cycle Science Program Office to build a website for this report, which is produced every ten years and is part of the USGCRP sustained assessment process. The report website can be accessed here: https://carbon2018.globalchange.gov/

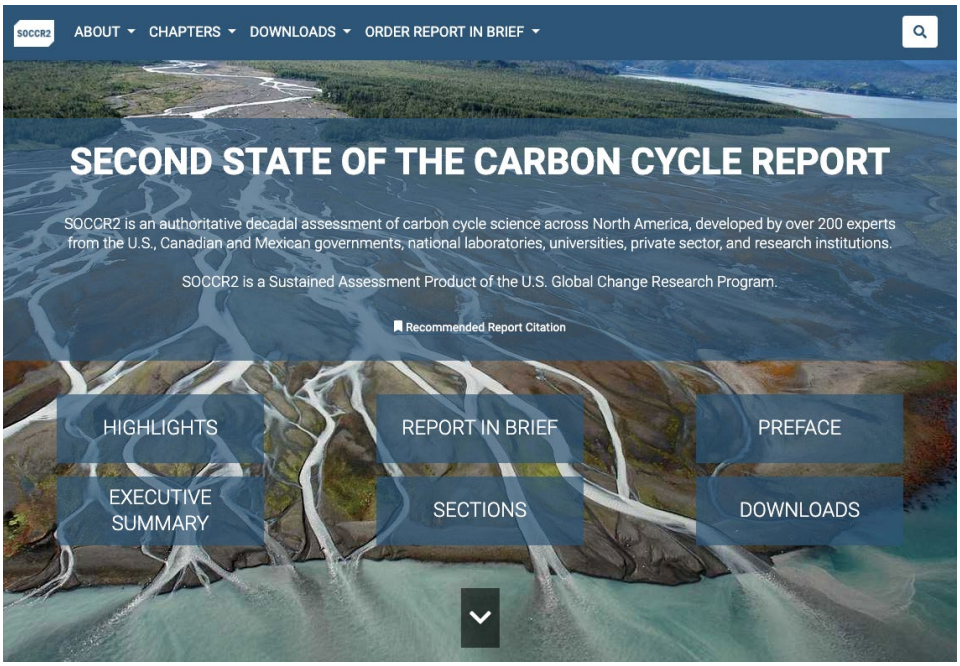


Figure 2. *The TSU built a new website for the 2018 State of the Carbon Cycle Report, providing the full content of the report in HTML format in addition to the PDF files that were available in the earlier version of the website.*

State Climate Summaries Updates

The TSU editorial team provided support for the ongoing 2019/2020 update of the 2017 NOAA State Climate Summaries. Each summary includes state-level information regarding historical and projected climate variations and trends. There are summaries for each of the 50 states, as well as Puerto Rico and the U.S. Virgin Islands and the Western Pacific Islands. Seven state summaries have been updated so far.

- Editorial support included proofreading and copy editing each summary, as well as writing alternative text for each state's core and supplemental graphics (approximately 35 figures per state).
- The web team implemented several UI modifications and added updated content to the website. Metadata for the updated states were synced to the Global Change Information System in coordination with the team at USGCRP.
- Graphics support included updating approximately 70 figures and the PDF versions of seven summaries. Graphics are edited for report consistency (e.g., size, fonts, colors) and enhanced for accessibility per Section 508 of the Rehabilitation Act (e.g., color-blind-friendly colors, readable font size, addition of alternative text).

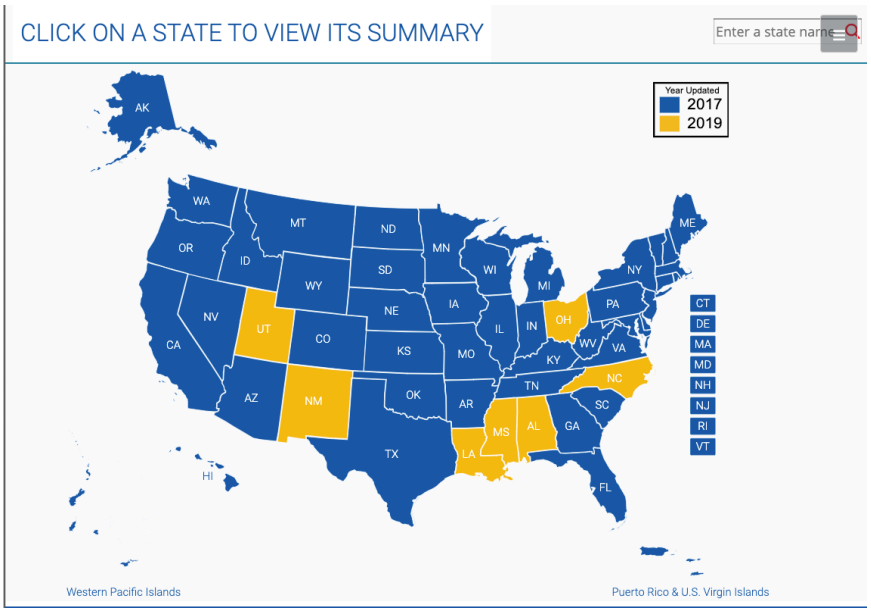


Figure 3. *The TSU is in the process of updating all 50 state climate summaries. To date, seven states have been updated. The summaries are available at stateclimatesummaries.globalchange.gov.*

Products

- ***Fourth National Climate Assessment, Volume II*** – accessibility and errata updates https://nca2018.globalchange.gov
- ***The Scientific Assessment of Ozone Depletion: 2018*** – https://www.esrl.noaa.gov/csd/assessments/ozone/2018/
- ***State of the Carbon Cycle Report 2018*** – version 2.0 – https://carbon2018.globalchange.gov/
- ***PDF Alternative Text Tool*** – *new software tool for automatically applying alternative text to figures in PDFs*

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

NCA updates, ozone report website, carbon cycle report website, and PDF alternative text tool (state summary updates are included in science/data team report)

North Carolina Climate Science Report	
Task Leader	Kenneth Kunkel, Jenny Dissen
Task Code	NC-CAA-01-NCICS-KK/JD
NOAA Sponsor	David R. Easterling
NOAA Office	NESDIS/NCEI

Highlight: In support of the North Carolina Governor's Executive Order 80 (EO80), which called for various actions in response to the challenge of climate change, CICS-NC began the development of a climate change assessment for North Carolina. Initial actions included establishing a science advisory panel, recruiting an author team, and supporting several regional resiliency workshops.

Background

In October 2018, North Carolina (NC) Governor Roy Cooper issued Executive Order 80 (EO80), "North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy," that directed all cabinet agencies to integrate climate adaptation and resiliency planning into their policies, programs, and operations. The order specifies a number of emissions-reduction and clean-energy goals, establishes an interagency council on climate change, and calls for a range of other specific actions across the state government. One EO80 provision directed the NC Department of Environmental Quality (DEQ) to develop a risk assessment and resilience plan. The DEQ and other state agencies recognized the need for an objective and credible climate science analysis to support the EO80 activities and the risk assessment and resiliency plan development.

With their established scientific environmental assessment expertise and experience, NC State University's NC Institute for Climate Studies (NCICS) and CICS-NC were invited to support the EO80 activities and lead the development of a climate science report for North Carolina, which serves as a key input to the state's risk assessment and resiliency plan.

Accomplishments

CICS-NC staff members Dr. Kenneth Kunkel and Jenny Dissen initiated engagement with DEQ in April 2019. They received input from Department Cabinet Designee members to identify climate stressors and topics of interest and to determine the most relevant climatological information to address the diverse state agency needs. With this initial information, CICS-NC drafted a plan for the development of a North Carolina Climate Science Report (NCCSR) to provide an independent scientific assessment of observed and projected climate change in North Carolina and to inform North Carolina citizens about important climate trends and potential future changes.

Author team. Carolina-based climate experts were recruited to draft the NCCSR. While some authors (including those from CICS-NC) are employed by state universities and although state agency needs informed the selection of report topics, the authors based their analysis of the science on their own climate expertise, informed by 1) the scientific consensus on climate change represented in the U.S. Fourth National Climate Assessment and the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2) the latest research published in credible scientific journals, and 3) information in the CICS-NC North Carolina State Climate Summary.

Science advisory panel. To provide scientific overview and review, North Carolina academic and federal research scientists with national and international reputations in their specialty areas of climate science were asked to serve on the NCCSR Climate Science Advisory Panel.

Regional resiliency workshops. CICS-NC staff supported several workshops to get input on regional stakeholder needs and address questions about the climate science report.

Communications. Weekly meetings with DEQ staff were established to update DEQ on progress. Additional updates were provided to the North Carolina Climate Change Interagency Council.

Planned work

Project oversight and effort transitioned to the successor CI, the Cooperative Institute for Satellite Earth System Studies (CISESS), in December 2019.

Presentations

Kunkel, K. E., 2019: Overview of the Climate Science in the National Climate Assessment and Support for the NC Assessment. *NC DEQ Climate Council Meeting on EO80*, Raleigh, NC, April 8, 2019.

Kunkel, K. E., D.E. Easterling, **J. P. Dissen**, and **O.B. Brown,** 2019**:** Initial Perspective on the NC Climate Science Activities. *NC DEQ Climate Change Interagency Council Meeting*, Raleigh, NC, April 26, 2019.

Whitehead, J., and **J. P. Dissen**, 2019. Bringing Academic and Scientific Assessment to Decisions. *NC DEQ Climate Change Interagency Council Meeting*, Raleigh, NC, April 26, 2019.

Kunkel, K. E., D.E. Easterling, **S. M. Champion**, **J. P. Dissen**, and **O.B. Brown,** 2019: North Carolina Climate Science Report Activities and Updates. *NC Interagency Council Meeting*, Winston-Salem, NC, July 16, 2019.

Kunkel, K. E., D.E. Easterling, **S. M. Champion**, **J. P. Dissen**, and **O.B. Brown,** 2019: North Carolina Climate Science Report Update. *Regional Resiliency Workshops*, Sylva, NC, October 15, 2019.

Kunkel, K. E., D.E. Easterling, **S. M. Champion**, **J. P. Dissen**, and **O.B. Brown,** 2019: North Carolina Climate Science Report Update. *Regional Resiliency Workshops*, Hickory, NC, October 16, 2019.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**4**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate (high school) students mentored during the year	**0**

Climate Change Indicators	
Task Leader	Laura Stevens
Task Code	NC-CAA-04-NCICS-LS
NOAA Sponsor	David Easterling/Derek Arndt
NOAA Office	OAR/CPO
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 75%
	Theme 3: Climate Research and Modeling 25%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50%
	Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: The Technical Support Unit (TSU) assisted in the efforts of the U.S. Global Change Research Program (USGCRP) to maintain a comprehensive suite of climate change Indicators. Work focused on updating Indicators and completing Indicator metadata. The full suite of Indicators can be found on the USGCRP Indicator Platform: globalchange.gov/indicators.

Background

Indicators are observations or calculations that can be used to track conditions and trends. Indicators of climate change can communicate key aspects of the changing environment, point out vulnerabilities, and inform decisions about policy, planning, and resource management. Such indicators are an important part of the vision for the sustained National Climate Assessment (NCA).

A set of climate change indicators, initially intended as a prototype for evaluation by scientists and user communities, exists to inform the development of a more comprehensive, dynamic system encompassing climate changes, impacts, and responses. This suite of indicators is managed by the U.S. Global Change Research Program (USGCRP), a consortium of 13 federal agencies that deal with global change. Currently, 16 indicators reside online within the USGCRP Indicator Platform, which serves as an authoritative resource highlighting data, research, and indicators-related activities. Uniting and building on efforts from across USGCRP agencies, the Indicator Platform will support future NCA reports and provide scientific data that can help decision-makers understand and respond to climate change. The USGCRP Indicators Interagency Working Group (IndIWG) serves as an interagency forum to support and facilitate the development of a USGCRP indicators effort.

CICS-NC and NCEI continued working with the IndIWG in order to better broker and administer the Indicator set, based on the synergy with, and similarity to, the work of the NCA Technical Support Unit (TSU). Laura Stevens (CICS-NC) and Jessica Blunden (NCEI) are supporting the overall USGCRP effort with scientific and technical expertise. Other CICS-NC staff aid with specific components, including data/metadata (Sarah Champion), editing (Tom Maycock), and website support (Katharine Johnson and Angel Li).

Accomplishments

TSU staff members participate in monthly calls with the IndIWG and an annual in-person meeting. Over the past year, efforts focused primarily on a comprehensive update of the full Indicator suite, which included updating data, completing metadata collection, and revising textual descriptions (e.g., Figure 1).

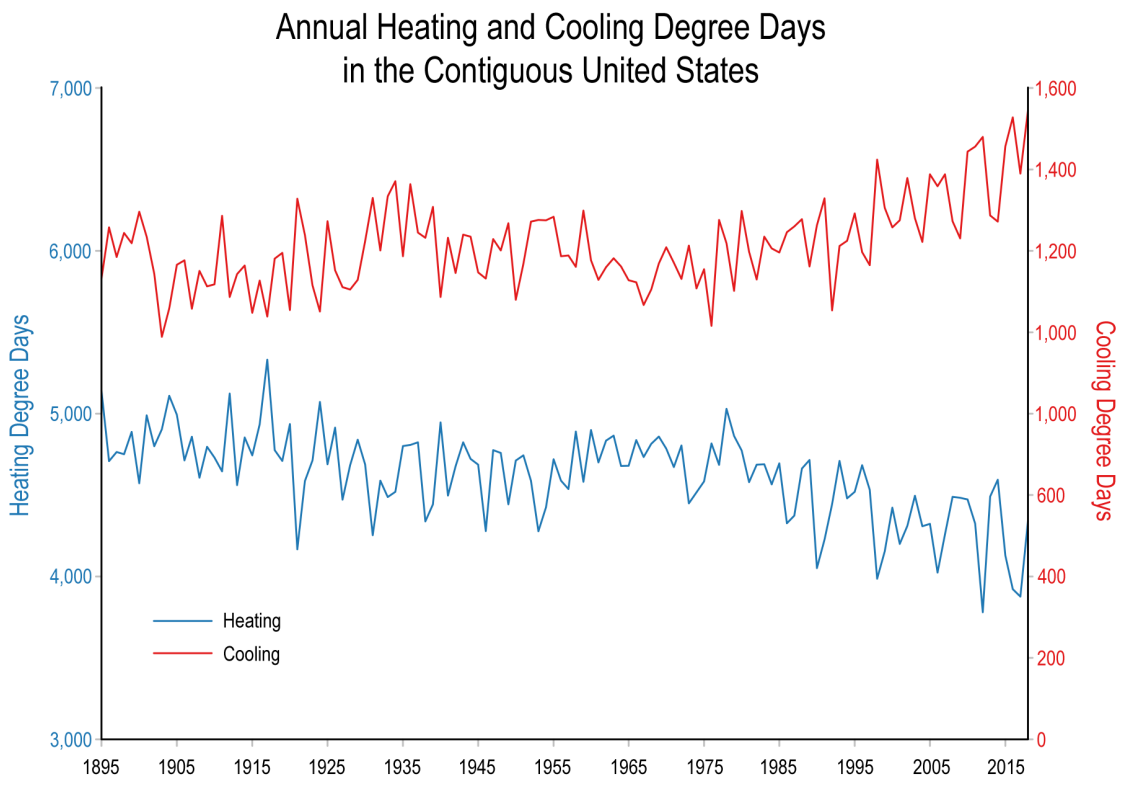


Figure 1. *The Heating and Cooling Degree Days Indicator, updated through 2018 and with a revised presentation. These time series show the total annual number of cooling degree days (red) and heating degree days (blue) for the contiguous United States. Since 1980, the number of cooling degree days has increased and the number of heating degree days has decreased. These changes impact the demand for energy use and increase net electricity demand nationwide.*

The update of an Indicator is multistep process. The TSU works directly with Indicator "champions" (members of partner agencies designated as experts responsible for a given Indicator) throughout this process in order to

- gather the most relevant and up-to-date data,
- facilitate the development of the updated Indicator,
- update the informative description of the Indicator,
- gather comprehensive metadata,
- present the updated Indicator to the Indicator champion for approval,
- deploy the Indicator online, and
- implement timely updates going forward.

As part of this update process, the TSU also works with CICS consortium partner UNC Asheville's National Environmental Modeling and Analysis Center in the creation of indicator graphics.

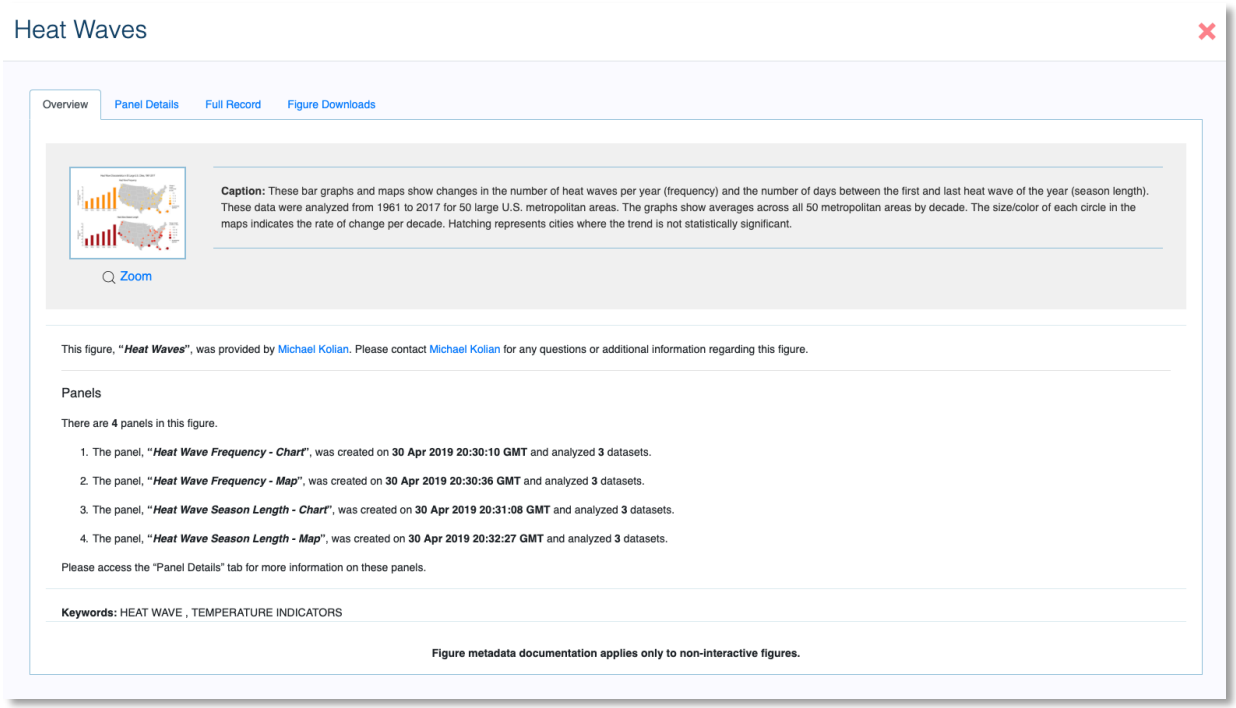


Figure 2. *The metadata viewer, as implemented for the Heat Waves Indicator. A series of tabs display comprehensive information regarding datasets, methods, and points of contact.*

Comprehensive metadata are collected for each Indicator in order to provide full transparency, traceability, and reproducibility, in line with NCA efforts to satisfy the Information Quality Act (IQA). Due to the successful use of the NCA metadata collection system, a logical step was to expand the NCA metadata viewer for use with USGCRP Indicators (Figure 2). This allows users to learn more about the data sources, methods, and experts associated with each Indicator and significantly enhances the credibility associated with the Indicators. The metadata viewer was successfully incorporated into the Indicator Platform, and 100% metadata completion was achieved across all 16 Indicators.

Planned work

Indicators activities will continue under the successor cooperative institute, CISESS.

Products

- Updated 15 of the 16 USGCRP Indicators: Annual Greenhouse Gas Index, Arctic Glacier Mass Balance, Arctic Sea Ice Extent, Atmospheric Carbon Dioxide, Billion Dollar Disasters, Frost-Free Season, Global Surface Temperatures, Heat Waves, Heating and Cooling Degree Days, Ocean Chlorophyll Concentrations, Sea Level Rise, Sea Surface Temperatures, Start of Spring, Terrestrial Carbon Storage, U.S. Surface Temperatures.

Presentations

Stevens, L.E., J. Blunden, and D.S. Arndt, 2019: Curating a multi-agency set of Federal climate indicators, *2019 National Adaptation Forum*, Madison, WI, April 23, 2019.

Stevens, L.E., J. Blunden, and D.S. Arndt, 2019: Curating a multi-agency set of Federal climate indicators, *ESRL 47th Global Monitoring Annual Conference*, Boulder, CO, May 21, 2019.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**15**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**2**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

15 updated USGCRP indicators: Annual Greenhouse Gas Index, Arctic Glacier Mass Balance, Arctic Sea Ice Extent, Atmospheric Carbon Dioxide, Billion Dollar Disasters, Frost-Free Season, Global Surface Temperatures, Heat Waves, Heating and Cooling Degree Days, Ocean Chlorophyll Concentrations, Sea Level Rise, Sea Surface Temperatures, Start of Spring, Terrestrial Carbon Storage, U.S. Surface Temperatures.

U.S.–India Partnership for Climate Resilience (PCR) Workshop Support	
Task Leader:	Katharine Hayhoe
Task Code	NC-CAA-03-TTU
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI (DOS)
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment, and Risk Communication

Highlight: In support of the U.S.–India Partnership for Climate Resilience (PCR), Texas Tech University (TTU) scientists continued a collaboration with the Environment Protection Training and Research Institute in India in the development of a web interface designed to facilitate the provision and use of climate model downscaling tools with a non-specialist audience.

Background

In September 2014, former U.S. President Obama and Indian Prime Minister Modi agreed to a new and enhanced strategic partnership on energy security, clean energy, and climate change. The resulting U.S.–India Partnership for Climate Resilience (PCR) aims to advance capacity for climate adaptation planning by supporting climate resilience tool development. Joint activities include downscaling global climate models for the Indian subcontinent to a much higher resolution than currently available, assessing climate risks at the subnational level, working with local technical institutes on capacity building, and engaging local decision-makers in the process of addressing climate information needs and informing planning and climate resilient sustainable development, including for India's State Action Plans. NCEI, CICS-NC, and CICS-NC subcontractors (including Texas Tech University [TTU]) are providing key technical support for the PCR bilateral activities in collaboration with the U.S. State Department.

Accomplishments

TTU's Katharine Hayhoe, a lead author for the U.S. National Climate Assessments since 2007, and TTU Climate Science Center researchers Anne Stoner, Ian Scott-Fleming, and Ranjini Swaminathan have supported multiple PCR workshops and associated research activities over the project's duration. The TTU team completed all of its originally anticipated project outcomes, which included 1) developing a suite of state-of-the-art climate products and analysis tools to inform sustainable development and hazard mitigation in India; 2) contributing to and participating in the design and implementation of three regional workshops to disseminate these datasets and tools to academic, federal, and nonprofit experts; and 3) building long-term collaborations with Indian practitioners, researchers, and other experts to expand on the original products, a collaboration that has led to a plan to build online training and data resources that will be made available to practitioners and researchers across the country. The TTU team also expanded the scope and capability of the data products available to share with Indian practitioners and researchers and participated in the development of a web interface designed to facilitate the provision and use of these products with a non-specialist audience.

The final months of the project period were spent in collaboration with the Environment Protection Training and Research Institute staff, reviewing and providing guidance for the web-based interface development activities.

Planned Work
This project ended in May 2019.

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

Climate Data Records and Science Data Stewardship

Climate Data Records (CDRs), also known as Reference Environmental Data Records (REDRs), provide climate-quality satellite and in situ observing datasets that document the Earth's climate and are part of the vast data holdings of NCEI. CICS–NC staff support NCEI's efforts to preserve, steward, and maximize the utility of NCEI's environmental data, focusing on the development and transition from research to operations (R2O) of CDRs. While some of this effort is in-house, a significant part of it is accomplished by CICS partner institutions, which include some of the Nation's leading climate science practitioners working in basic and applied research endeavors.

An appreciation for the functional development from concept to mature observation and agency roles is provided by a slide updated from Bates et. al. (2008), excerpted in the figure below.

CDR Name Here

maturity level as of mm/dd/yyyy

Climate Data Record (CDR) Maturity Matrix

Maturity	Software Readiness	Metadata	Documentation	Product Validation	Public Access	Utility
1	Conceptual development	Little or none	Draft Climate Algorithm Theoretical Basis Document (C-ATBD); paper on algorithm submitted	Little or None	Restricted to a select few	Little or none
2	Significant code changes expected	Research grade	C-ATBD Version 1+ ; paper on algorithm reviewed	Minimal	Limited data availability to develop familiarity	Limited or ongoing
3	Moderate code changes expected	Research grade; Meets int'l standards: ISO or FGDC for collection; netCDF for file	Public C-ATBD; Peer-reviewed publication on algorithm	Uncertainty estimated for select locations/times	Data and source code archived and available; caveats required for use.	Assessments have demonstrated positive value.
4	Some code changes expected	Exists at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset	Public C-ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed publication on algorithm; paper on product submitted	Uncertainty estimated over widely distributed times/location by multiple investigators; Differences understood.	Data and source code archived and publicly available; uncertainty estimates provided; Known issues public	May be used in applications; assessments demonstrating positive value.
5	Minimal code changes expected; Stable, portable and reproducible	Complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset	Public C-ATBD, Review version of OAD, Peer-reviewed publications on algorithm and product	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Record is archived and publicly available with associated uncertainty estimate; Known issues public. Periodically updated	May be used in applications by other investigators; assessments demonstrating positive value
6	No code changes expected; Stable and reproducible; portable and operationally efficient	Updated and complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets current international standards for dataset	Public C-ATBD and OAD; Multiple peer-reviewed publications on algortihm and product	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation; quantified errors	Record is publicly available from Long-Term archive; Regularly updated	Used in published applications; may be used by industry; assessments demonstrating positive value

1 & 2	Research
3 & 4	IOC
5 & 6	FOC

CDRP-MTX-0008 V4.0 (12/20/2011)

Figure 1. *Updated Bates et. al. (2008) CDR Maturity Matrix.*

CICS-NC provides climate and instrument researchers and scientific staff with specialized scientific and technical experience in supporting the life cycle of CDRs at NCEI, providing necessary skills in areas including the following:

- Coordination and development of calibration and validation activities and approaches for high-quality baseline climate datasets from satellite and in situ observations

- Development, refinement, and implementation of algorithms for daily, global, multi-sensor, optimally interpolated CDRs; characterization of the sources and magnitudes of errors and biases in the CDRs and development of methodologies for reducing these errors and biases
- Development of high-quality baseline climate datasets from satellite and in situ climate data and development of the relationship(s) between tropospheric and stratospheric trends derived from ground-based and satellite observations
- Software engineering to support coding, code refactoring, and code review; database development; and the transition of scientific codes into operationally executable and maintainable processes
- Development of scientifically based quality control algorithms for in situ climate data of various time scales (hourly, daily, monthly, annually), methods to detect and adjust for inhomogeneities due to issues such as instrumentation changes or observing station relocations, and scientific analyses of structural uncertainty due to these methods
- R2O transitions
- Transitions management of various externally developed CDRs to NCEI
- Interim CDRs development and implementation for early use of climate-relevant observations
- Stewardship of archival and current climate observations and enhancement of data curation, standards-based data management, metadata, and other data documentation
- Enhancement of all aspects of NCEI data discovery and access services, including data interoperability, semantic technologies, *no-SQL* and graph database technologies, linked open data standards, and other related technologies and standards
- Exploration of methods for more effective data ingest, quality assurance, product processing, and data archival

Scientific Subject Matter Expertise Support	
Task Team	Jessica Matthews (Lead), Jenny Dissen, Anand Inamdar, Ronnie Leeper, Ge Peng, Olivier Prat, Jared Rennie, Carl Schreck
Task Code	NC-CDR/SDS-01-NCICS-JM/JD/AI/RL/GP/OP/JR/CS
NOAA Sponsor	Jay Lawrimore/Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 50%; Theme 2: Climate and Satellite Observations and Monitoring 50%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: CICS-NC scientists served as subject matter experts on six Climate Data Record Integrated Product Teams, as Product Leads for 25 products, and as Product Area Leads for three product areas. https://www.ncdc.noaa.gov/cdr

Background

Climate Data Record (CDR) Integrated Product Teams (IPTs) are multidisciplinary teams composed 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, execution, and reporting of office/organization tasks required to transition each CDR to an IOC state.

Science management practices at NCEI are evolving towards a new product portfolio planning approach that borrows from the best practices used widely in both public and private sectors. The objective of this approach is to ensure the focus on stakeholder priorities and to align with today's government environment and expectations. To support this initiative, CICS-NC staff have been enlisted to act as Product Leads for 25 of NCEI's 214 products, and as Product Area Leads for 3 of 15 product areas.

Accomplishments

CICS-NC scientists participated in the ***IPTs*** of the following CDRs during this reporting period:

- Total Solar and Solar Spectral Irradiance (Inamdar)
- Land Surface Bundle (Matthews)
- Global Surface Albedo (Matthews)
- Sea Ice Concentration – Annual (Peng)
- Ocean Surface Bundle (Peng)
- Precipitation – CMORPH (Prat)

Subject Matter Expert IPT responsibilities include

- leading and scheduling IPT meetings needed for resolving technical issues on the products with Principal Investigator (PI),
- conducting initial assessment of CDR readiness for transition from scientific perspective,
- reviewing PI-submitted draft products against IOC requirements,
- providing feedback to PI on draft products,
- verifying that PI-submitted final products conform to IOC requirements,
- participating in management and technical meetings as required,

- working with PI, IPT, and the Operations and Management Project Manager to complete each change request and route for signatures
- attending Change Control Board meetings, when needed,
- reviewing PI-submitted documents delivered as part of the work agreement (Climate Algorithm Theoretical Basis Document, Maturity Matrix, Data Flow Diagram, Implementation Plan) and providing feedback,
- reviewing PI-submitted documents delivered as part of the work agreement (QA procedure, QA results, version description documents, annual reports) for information only, and
- presenting to the NCEI User Engagement Branch on the CDR.

CICS-NC scientists acted as ***Product Lead*** for the following products during this reporting period:

- Sectoral Engagement (Dissen)
- ISCCP-FH (Inamdar)
- AVHRR Radiances – NASA CDR (Inamdar)
- AVHRR Cloud Properties – NASA CDR (Inamdar)
- Total Solar Irradiance CDR (Inamdar)
- Solar Spectral Irradiance CDR (Inamdar)
- CRN Science: Drought indices (Leeper)
- CRN Science: Precipitation Extremes (Leeper)
- Blended Soil Moisture (Leeper)
- AVHRR Surface Reflectance CDR (Matthews)
- Normalized Difference Vegetation Index CDR (Matthews)
- Leaf Area Index and FAPAR CDR (Matthews)
- GOES Albedo CDR (Matthews)
- Precipitation – CMORPH (Prat)
- Standard Precipitation Index using CMORPH (Prat)
- Extreme Snowfall (Rennie)
- ISTI (Rennie)
- Outgoing Longwave Radiation – Monthly CDR (Schreck)
- Outgoing Longwave Radiation – Daily CDR (Schreck)
- Sea Surface Temperature – WHOI CDR (Peng)
- Near Surface Atmospheric Properties over Ocean CDR (Peng)
- Heat Fluxes over Ocean – CDR (Peng)
- Sea Ice Concentration CDR (Peng)
- Sea Ice Normals (Peng)
- Gridded In Situ Normals (Peng)

The objective of a Product Lead is management of the product, which includes

- coordinating the following product phases (as appropriate)
    - development
    - assessment of maturity
    - transition to operations
    - sustainment in operations
    - upgrades, succession, and retirement
- for operational products, sustaining the product if internally generated or serving as the liaison to external providers

- maintaining technical knowledge of the product, including characteristics, status, algorithmic approach, dependencies, limitations, sustainment activities, and uses and user requirements, as appropriate
- drafting annual work agreements or statements of work, as appropriate, for non-federal product development, transition and/or sustainment activities
- providing regular status reports and participating in technical meetings

CICS-NC scientists acted as Product Area Leads for the following product areas during this reporting period:

- Land surface properties (Matthews)
- Snow and ice (Peng)
- Extreme Storms (Schreck)

The objective of a Product Area Lead is strategic and coherent planning and management of the product portfolio, which includes:

- maintaining a coherent strategic portfolio vision and plan, including potential new work activities, which are responsive to evolving user needs
- maintaining a life cycle management plan for portfolio products and maintaining a high-level schedule to accomplish plans
- maintaining status and priority ranking of each product in portfolio
- reviewing and providing input on product change requests
- reviewing and recommending annual work agreements, as needed, for product development, improvement, sustainment, and/or support.

Planned work

NCICS staff will continue participating on CDR IPTs and acting as Product Leads and Product Area Leads under the successor cooperative institute CISESS.

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

**AVHRR Surface Reflectance CDR, Normalized Difference Vegetation Index CDR, and Leaf Area Index and FAPAR CDR all underwent a version change to version 5.0. Precipitation – CMORPH transitioned to operations.*

Spatial–Temporal Reconstruction of Land Surface Temperature (LST) from Daily Max/Min Temperatures	
Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-02-NCICS-AI
NOAA Sponsor	Jeff Privette/Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50%
	Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: The approach for reconstructing LST has been revised, including the addition of new constraints for the descending leg of the daily solar cycle (time of max LST to sunset) based on climatologically developed LST values near sunset.

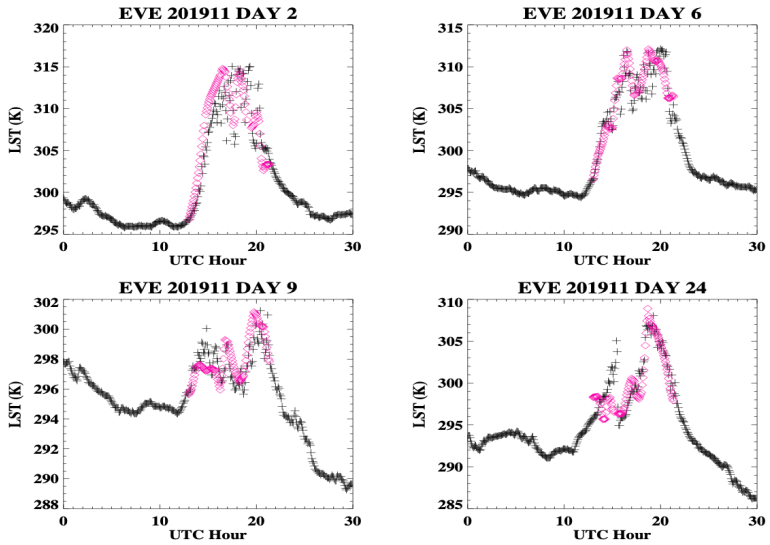
Background

Land surface temperature (LST) and its diurnal variation play a major role in the study of land–atmosphere interactions, climate change, hydrological cycle, vegetation, and soil moisture conditions. They are also critical in the study of epidemiology, agriculture, urban heat island effects, and varying demands on energy consumption. Physically based approaches that use thermal infrared measurements from remote sensing satellites and a combination of harmonic and exponential decay functions to model daytime and nighttime variation of LST are applicable only under clear-sky conditions. Missing LST values due to the presence of clouds limits the potential application of available satellite LST products. Diurnal evolution of the LST is strongly correlated with the diurnal pattern of surface absorbed solar radiation. Results from a companion study on the diurnal variation of net surface solar radiation suggest a promising option for filling in the spatial and temporal gaps in LST values, even under partially cloud-contaminated conditions.

Accomplishments

The algorithm developed was tested against the surface solar absorption (SSA) values retrieved in near real time from the GOES-R sensor for recent months in 2019. The SSA values were retrieved by employing a simplified form of the approach developed earlier, but using the near-real-time data provided by the CERES FLASHFLUX (Fast longwave and shortwave radiative fluxes) system developed at the NASA Langley Research Atmospheric Sciences Data Center.

The approach for reconstructing LST has been revised further from the one reported previously involving application of the non-linear Levenberg–Marquardt least square fit technique. The modifications implemented recently include new constraints for the descending leg of the daily solar cycle (time of max LST to sunset) based on climatologically developed LST values near sunset. Figure 1 shows the performance of the LST reconstruction scheme for a more recent period (November 2019) for the USCRN site in Everglades City, FL, for different days characterized by a challenging mix of clear and cloudy conditions.



Error Stats for Nov 2019 for Everglade City (FL)

Mean Bias (K) (RMS, K)

0.63 K (1.6 K) Ascending

-0.12 K (1.62 K) Descending

Figure 1. *The figure shows in situ measurements of LST at Everglades City, FL (+ symbols) and reconstructed LST (magenta diamond symbols) for the four days indicated in the subtitles. The error statistics are shown at right.*

Planned work

Work will continue under the successor cooperative institute, CISESS.

Product

- Updated algorithm to reconstruct LST from daily max/min temperatures and Surface Solar Absorption retrieved in near real time from GOES-R data

Presentation

Inamdar, A., and **R. Leeper**, 2019: Extracting Surface Absorbed Solar Radiation in Near Real-time from GOES-R. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

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

Updated algorithm to reconstruct LST from daily max/min temperatures and near-real-time surface solar absorption.

Transitioning of the International Satellite Cloud Climatology Project (ISCCP) Process to NCEI-NC	
Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-03-NCICS-AI
NOAA Sponsor	Jeff Privette/Ken Knapp
NOAA Office	NESDIS/NCEI; NESDIS/STAR
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50%
	Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: The ISCCP team released an ISCCP H-series cloud product (ICDR) for July 2017 through December 2018 that employed climatological nnHIRS profiles. Extensive planning for the FY2022 reprocessing is under way. https://www.ncdc.noaa.gov/isccp

Background

The International Satellite Cloud Climatology Project (ISCCP) began in 1983 under the leadership of Dr. William Rossow (City College of New York and Goddard Institute for Space Studies) as an activity of the Global Energy and Water Exchanges (GEWEX) core project of the World Climate Research Programme. ISCCP's objective is to derive an Earth cloud climatology by pooling the radiances from the suite of geosynchronous meteorological satellites around the globe and the polar orbiting Advanced Very-High-Resolution Radiometer (AVHRR) sensors. ISCCP is one of the longest-lived and most widely used satellite climate datasets and has been extensively cited in the peer-reviewed literature. An example of its widespread application is the ISCCP simulator, an algorithm developed to mimic ISCCP observations from global climate models in order to evaluate model simulations of the current environment. Moreover, ISCCP data (and its derivative datasets) have been used to study and understand a wide array of weather and climate phenomena, including clouds, Earth's radiation budget, aerosols, surface radiation budgets, renewable energy, hurricanes, tropical cyclone genesis, climate modeling, stratospheric moisture, weather states, cloud forcing and cloud feedbacks, and the relationship of clouds with numerous other phenomena.

The ISCCP H-series cloud product has several improvements over its predecessor, the ISCCP D-series. These include higher-resolution input satellite data, an expanded period of record (1983–2015 and continuing beyond), temporally stable atmospheric profiles derived through a neural network approach, higher-resolution (1 degree) gridded products, and radiances and cloud information available at pixel level (10 km every 3 hours).

Accomplishments

Production operations suffered delays and setbacks during the first half of year owing to IT migration. Production beyond 2017 June was completed using the neural network High-Resolution Infrared Sounder (nnHIRS) climatology. Principal Investigator Rossow noted calibration-related problems for some of the Geostationary positions (GOES-EAST, GOES-West and GMS) which are being addressed. After production completion, files will be archived as Interim Climate Data Records (ICDRs). More detailed statistics on the impact of using climatological profiles (in ICDR production) in lieu of the actual profiles have been generated and are provided on the NOAA ISCCP web page (https://www.ncdc.noaa.gov/isccp). A sample table for one of the parameters (cloud amount) is provided below.

Month	Stdev(dif)	using nnHIRS	Stddev	Using CLIM	Stdev
1	1.08254	63.9933	1.10950	63.9508	1.10372
2	0.723456	64.0804	1.59056	64.0237	1.59387
3	0.721442	64.9265	1.42121	64.8769	1.45613
4	0.572309	65.2001	1.52936	65.1528	1.53831
5	0.460216	64.1396	1.61989	64.0997	1.59281
6	0.547642	63.6367	1.40483	63.5906	1.43083
7	0.732027	64.0118	1.44974	63.9597	1.50551
8	0.778585	64.0315	1.07101	63.9683	1.07907
9	0.723594	64.0520	1.31776	63.9857	1.33838
10	0.952273	64.9530	1.03179	64.8992	1.07247
11	0.560348	65.0373	1.33390	64.9949	1.35606
12	0.623911	65.6415	1.32846	65.5571	1.31555

Table 1. Impact of using nnHIRS and ozone climatology on cloud amount versus actual data for all months of year 2012. Columns 3 and 5 show the result of actual nnHIRS profiles versus climatological profiles on mean cloud fraction.

Planned work

Work will continue under the successor cooperative institute, CISESS.

Presentation

Inamdar, A., 2019: Status of ISCCP H-Series Data; 35 Years and Counting. *AMS 2019 Joint Satellite Conference*, Boston, MA, October 1, 2019.

Products

- H-series cloud product for the extended period (2015–2017), including the new NOAA-19 sensor from 2013
- H-series cloud product (ICDR) for 2017 July–2018 December using the nnHIRS climatology
- HBT Calibration (counts to radiance) tables for the period 2017 July–2018 December, including for the new sensors NOAA-19, HIMAWARI-8, and GOES-16 and for MSG-1 (INS segment), MSG-2, and MSG-3

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

Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES Data	
Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-04-NCICS-JM
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: The GSA algorithm is being implemented as the U.S. contribution of an international collaboration between Europe, Japan, South Korea, and the United States to produce a joint climate data record. A pilot study of reprocessing satellite data in the cloud was completed, with results published in a June 28, 2019, *Amazon Web Services* blog post. http://www.scope-cm.org/projects/scm-03/

Background

Surface albedo is the fraction of incoming solar radiation reflected by the land surface and therefore is a sensitive indicator of environmental changes. To this end, surface albedo is identified as an Essential Climate Variable (ECV) by the Global Climate Observing System. In support of the Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM), NCEI is implementing the GSA algorithm for GOES data to contribute to an international effort in collaboration with EUMETSAT, JMA, KMA, and MeteoSwiss. Currently, the GSA algorithm generates products operationally at EUMETSAT using geostationary data from satellites at 0° and 63°E and at JMA using 140°E geostationary data. To create the stitched global Level 3 product as illustrated in Figure 1, NCEI is tasked with implementing the algorithm for GOES-E (75°W) and GOES-W (135°W).

Previously, as part of the SCOPE-CM agreement, the GSA algorithm was run with GOES data for a pilot period of 2000–2003. A project charter was developed in July 2014 describing the implementation of a related land surface albedo product, the so-called Albedo of the Americas. This product will be focused on the Americas, the primary user base of the CDR program, and will provide greater temporal resolution and historical extent than other available albedo datasets. In short, the scope of the plan is to process 1995–2018 GOES-GVAR data (GOES-8 through 15) using the SCOPE-CM algorithm with a unified approach to calibration, handling of numerical weather prediction inputs, and cloud masking.

This project is one of 10 selected by the SCOPE-CM Executive Panel from open competition. The team proposed extending the international collaboration to include activities such as a common cloud mask approach, a common intercalibration method, exploration of different temporal resolutions and formats of output, and validation of Level 2 products.

Accomplishments

As a look forward to the reprocessing effort, a pilot study was undertaken using this project to explore satellite data reprocessing in the cloud. Bleeding-edge computing techniques were implemented to replicate traditional high-performance cluster computing in the cloud environment. Careful cost comparisons, in terms of both dollars and time, were calculated to understand the scale of future reprocessing of massive next-generation remote sensing data. Results were published in an *Amazon Web Services* blog: https://aws.amazon.com/blogs/publicsector/embracing-the-cloud-for-climate-research/

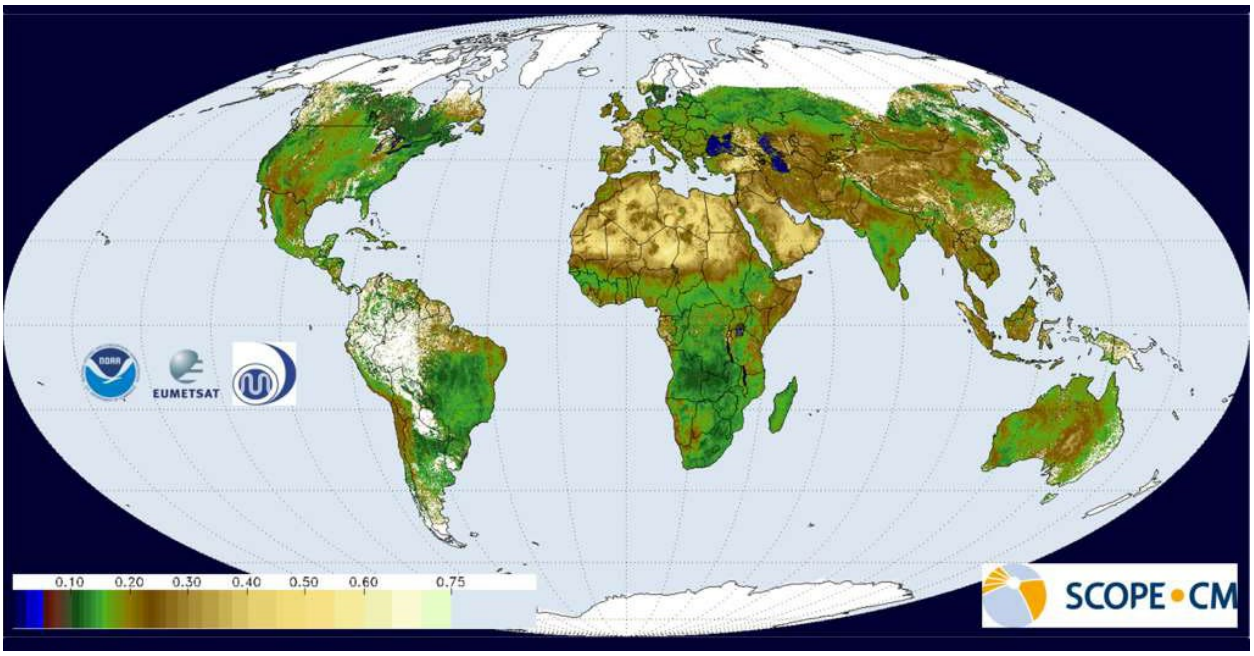


Figure 1. *Broadband black sky albedo spatial composite product for the period 1–10 May 2001.*

Planned work
Work will continue under the successor cooperative institute, CISESS.

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

HIRS Temperature and Humidity Profiles	
Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-05-NCICS-JM
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research Applications 50%
	Theme 1: Climate and Satellite Observations and Monitoring 50%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: The team is developing a global temperature and humidity profile dataset for the time period of 1978–present. The data are produced by applying neural networks to High-resolution Infrared Radiation Sounder (HIRS) Data. Results of intercomparisons of long-term atmospheric temperature and humidity profile retrievals were published in *Remote Sensing*.

Background

The goal of this task is to derive temperature at 12 different altitudes/pressures (surface, 2m, 1000mb, 850mb, 700mb, 600mb, 500mb, 400mb, 300mb, 200mb, 100mb, and 50mb) and humidity at 8 different altitudes/pressures (2m, 1000mb, 850mb, 700mb, 600mb, 500mb, 400mb, 300mb) using HIRS data.

In previous dataset versions, HIRS Channels 2–12 were used for the temperature profiles, while HIRS Channels 4–8 and 10–12 were used as inputs for the humidity profiles. These selections were based on the known relations of the channel information to the different physical variables. The HIRS data coupled with CO_2 data were used as inputs to a neural network. The neural networks were calibrated according to surface pressure bins. There are two different neural nets, one each for surface pressures less than 850 mb and surface pressures greater than 850 mb. Radiative Transfer for Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) (RTTOV) data based on more than 62,000 ECMWF profiles were used as inputs for neural network training purposes.

The resultant neural networks were applied to produce global temperature and humidity profiles using a series of 13 satellites for 1978–2017. When processing the data, USGS topography information on a 1° grid was used to define topography (and thus surface pressure) to select which of the three neural nets to apply. Additionally, monthly CO_2 inputs (assumed to be global) were obtained from the Scripps CO_2 program.

Key updates in the latest v2018 dataset version include

- Removal of the HIRS Channel 10 dependencies from the neural networks based on the detection of long-term instability
- Removal of unreliable MetOp-02 data from May 2011 through March 2013
- Simplifying from three neural networks to two
- Using 3 years of RS92 and COSMIC2013 data for bias correction (2008–2010)
- A statistical methodology to remove extreme outliers
- Additional quality control flags

Accomplishments

To validate this long-term dataset, evaluation of the stability of the intersatellite time series is coupled with intercomparisons with independent observation platforms as available in more recent years. Twelve polar orbiting satellites with the HIRS instrument were used to produce the retrievals: N-6, N-7, N-8, N-9, N-10, N-11, N-12, N-14, N-15, N-16, N-17, and MetOp-2. Eleven pairs of satellites carrying the HIRS instrument with time periods that overlap are examined. Correlation coefficients were calculated for the retrieval of each atmospheric pressure level and for each satellite pair. Figure 1 illustrates the correlation coefficients, which may be interpreted as a measure of the agreement between the two sets of observations. When evaluating all cases for both temperature and humidity (11 satellite pairs × [8 humidity levels + 12 temperature levels] = 220 cases), a correlation coefficient greater than 0.7 is achieved more than 90% of the time. Very high correlation is demonstrated at the surface and 2-meter levels for both temperature (>0.99) and specific humidity (>0.93).

For 2006–2017, intercomparisons are performed with four independent observations platforms: radiosonde (RS92); Constellation Oserving System for Meteorology, Ionosphere, and Climate (COSMIC); Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN); and Infrared Atmospheric Sounding Interferometer (IASI). Figure 1 shows comparisons between HIRS and GRUAN, while Figure 2 illustrates comparisons with a Level 2 product derived from a hyperspectral instrument also onboard the MetOp IASI series. Good agreement is seen at all profile levels, but, notably, very close matching of surface and 2-meter temperatures over a wide domain of values is depicted in all presented intercomparisons.

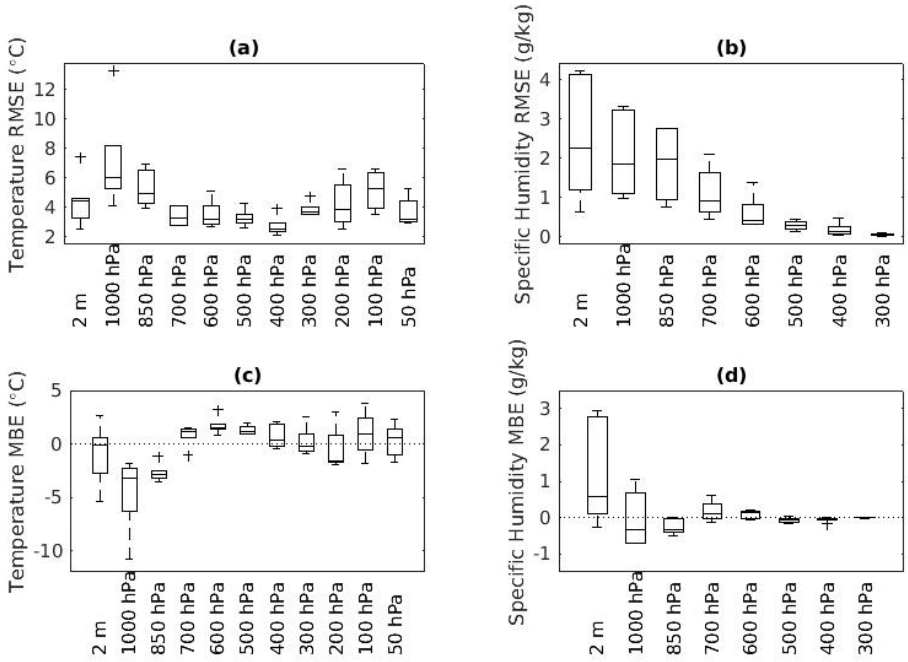


Figure 1: *Boxplots of comparisons between HIRS and GRUAN stations for temperature and specific humidity, root mean square error (RMSE), and mean bias errors (MBEs). The horizontal axis delineates the profile height from 2 meters to 50 hPa. The central mark in each box indicates the median value amongst all GRUAN stations. The edges of the box are the 25th (Q1) and 75th (Q3) percentiles, while the whiskers extend to values within Q3+W*(Q3–Q1) and Q1-W*(Q3–Q1) (roughly 99.3 coverage of normally distributed values) where W = 1.5. The plus signs indicate outlier values. (**a**) Temperature RMSE (°C); (**b**) specific humidity RMSE (g/kg); (**c**) temperature MBE (°C); (**d**) specific humidity MBE (g/kg).*

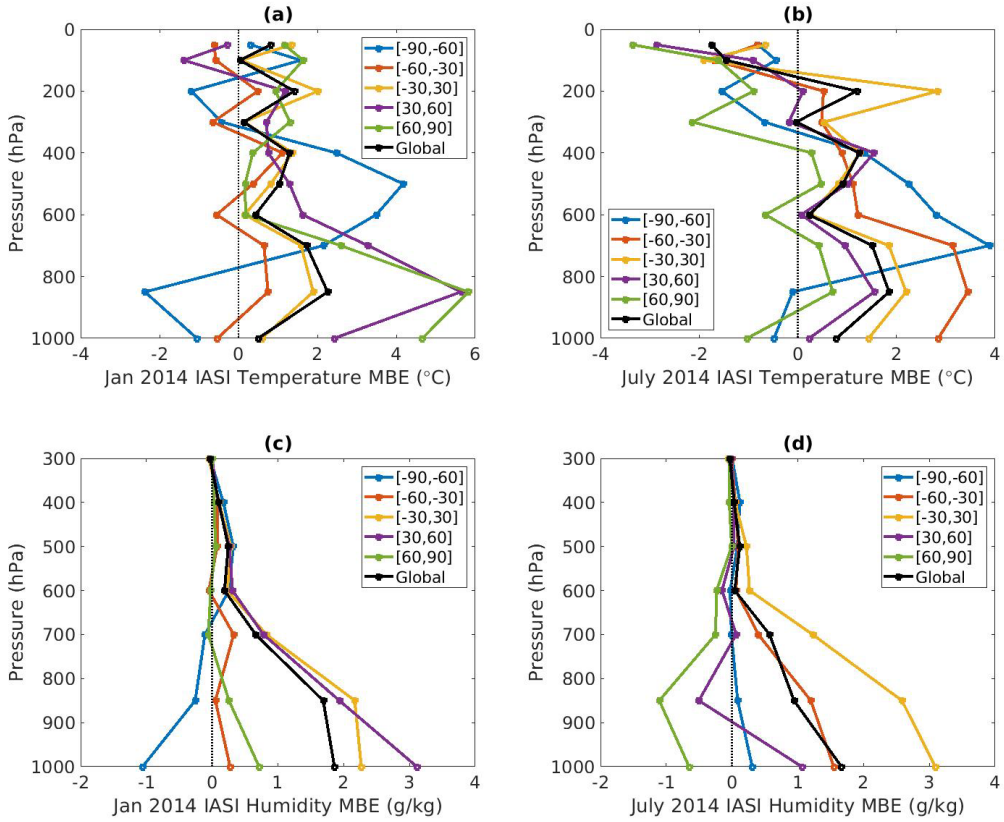


*Figure 2: MBE between HIRS and IASI retrievals (HIRS-IASI) at standard atmospheric pressure levels, subdivided by latitude ranges. Temperature MBE (°C) in (**a**) January 2014 and (**b**) July 2014. Humidity MBE (g/kg) in (**c**) January 2014 and (**d**) July 2014.*

Publication

Matthews, J. L., and L. Shi, 2019: Intercomparisons of long-term atmospheric temperature and humidity profile retrievals. *Remote Sensing*, **11**, 853, https://doi.org/10.3390/rs11070853.

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

Regional Variability of Sea Ice Coverage	
Task Leader	Ge Peng
Task Code	NC-CDR/SDS-06-NCICS-GP
NOAA Sponsor	Jeff Privette / Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Arctic

Highlight: This effort focuses on examining and characterizing temporal and spatial variability of Arctic sea ice coverage, sensitivity of trends, and statistical projections. Climate normals for sea ice concentration, area, and extent for the Arctic and sub-Arctic were evaluated and transitioned to NOAA.

Background

Since the late 1970s, reductions of about 49% in sea ice and 80% in sea ice volume were observed as of year 2012. With rapid and accelerated Arctic sea ice coverage depletion, it is critical to examine historical changes and continue monitoring the current state of sea ice to understand vulnerability and to provide reliable projections for climate adaptation and risk mitigation. To help put the changes into historical perspective, it is useful to baseline long-term sea ice states using a consistent, inter-calibrated, long-term time series of sea ice.

Not all sea ice changes are uniform in both space and time. Spatial sea ice variability may lead to a large spread in climate model sea ice projections which induces high uncertainty on regional scales. Thus, baselining the long-term mean ice state on both regional and local scales is important for monitoring how the current regional and local states depart from their normal and to understand vulnerability. In combination with up-to-date observations and reliable projections, these long-term data are essential to business strategic planning, climate adaptation, and risk mitigation.

The focus for this fiscal year has been on evaluating and transitioning to NOAA the climate normals; i.e., the average over the last three decades of sea ice concentration, area, and extent for the Arctic and sub-Arctic regions. One of the unique aspects of these sea ice climate normal products is that they represent data uncertainty estimates by using the spread (represented by the difference between the maximum and minimum), standard deviation, 10th and 90th percentiles, and the first, second, and third quartile distribution of all monthly values. This additional uncertainty information can help improve climate projections and better inform strategic planning on climate adaptation and risk mitigation.

Accomplishments

The CDR sea ice extent monthly climate normal values were compared with other products, including those from the National Snow and Ice Data Center (NSIDC) and Copernicus data derived from the ERA-Interim and v5 sea ice concentration data. Spatial modes of variability and how the corresponding principal component time series change over time are examined using the empirical orthogonal function (EOF) analysis. For September Arctic sea ice concentrations, the first three EOF modes account for 45% of the total variance. The first EOF mode of sea ice concentration shows a distinct spatial pattern with a solid downward trend of 9% per decade, which is significant at the 95% confidence level (Figure 1a,d) and suggests that Mode 1 largely represents a climate change signal.

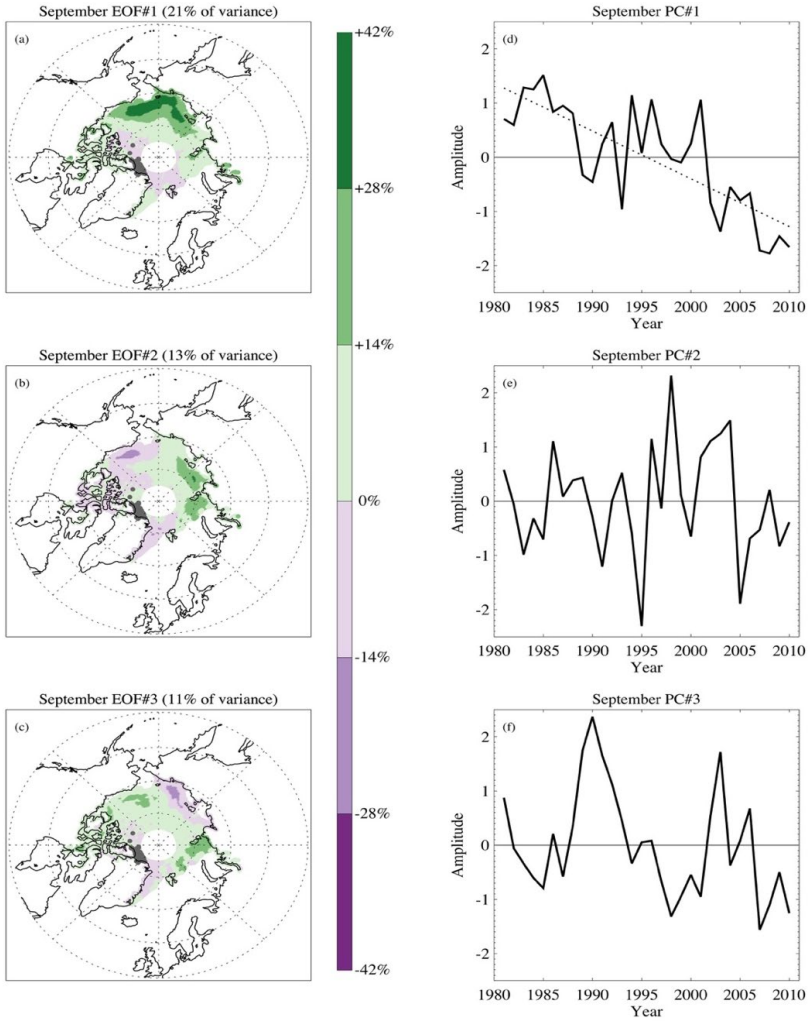


Figure 1. *(a–c) The spatial patterns of the first three leading empirical orthogonal functions (EOFs) for September sea ice concentration and (d–f) their corresponding principal component time series. The dashed line in (d) is the linear regression trend line. Green (purple) areas project positively (negatively) onto the associated time series, with the EOF magnitude modulating the intensity of the effect of the same (opposite) sign of the time series values. (From Peng et al. 2019a.)*

A data description paper has been published by a peer-review journal (Peng et al. 2019a), and the dataset is publicly available (Peng et al. 2019b). The product has been integrated into NCEI regional sea ice monitoring. The formal NCEI archive of this product has been delayed by NCEI in order for it to address other higher priority products that may result in permanent data loss if not archived.

Additional research, in collaboration with another NCICS scientist, Jessica Matthews, was carried out to examine when Arctic summers will be largely ice free based on global climate model projections (Peng et al. 2020) and the potential impact of sea ice concentration thresholds to computing Arctic sea ice extent trends (Matthews et al. 2020).

Product

Peng, G., A. Arguez, J. Crouch, and P. Jones, 2019b: Sea Ice Climate Normals (1981–2010) of Arctic and Sub-Regions, Version 1. NOAA National Centers for Environmental Information. https://doi.org/10.25921/TRXE-M983

Publications

Bliss, A. C., M. Steele, **G. Peng**, W. N. Meier, and S. Dickinson, 2019: Regional variability of Arctic sea ice seasonal change climate indicators from a passive microwave climate data record. *Environmental Research Letters*, **14**, 45003, https://doi.org/10.1088/1748-9326/aafb84.

Peng, G., A. Arguez, N. W. Meier, F. Vamborg, J. Crouch, and P. Jones, 2019: Sea Ice Climate Normals for Seasonal Ice Monitoring of Arctic and Sub-Regions. *Data*, **4**, https://doi.org/10.3390/data4030122.

Peng, G., **J. L. Matthews**, M. Wang, R. Vose, and **L. Sun**, 2020: What Do Global Climate Models Tell Us About Future Arctic Sea Ice Coverage Changes? *Climate*, *8*, https://doi.org/10.3390/cli8010015.

Matthews, J. L., **G. Peng**, W. N. Meier, and **O. Brown**, 2020: Sensitivity of Arctic Sea Ice Extent to Sea Ice Concentration Threshold Choice and Its Implication to Ice Coverage Decadal Trends and Statistical Projections. *Remote Sensing*, **12**, 807, https://doi.org/10.3390/rs12050807.

Presentations

Bliss, A.C., M. Steele, **G. Peng**, and W.N. Meier, 2019: Indicators of Arctic change from passive microwave dates of sea ice seasonal evolution. Poster. *International Glaciological Society Sea Ice Symposium*, Winnipeg, Canada, August 20, 2019.

Peng, G., M. Steele, A. Bliss, W. Meier, **J. Matthews**, M. Wang, and S. Dickinson, 2019: Characterizing Arctic Sea Ice Coverage Variability. *Barcelona Supercomputing Center and Copernicus Data Store*, Barcelona, Spain. September 23, 2019.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**4**
# of NOAA technical reports	**0**
# of presentations	**2**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Sea ice climate normal dataset

Toward the Development of Reference Environmental Data Records (REDRs) for Precipitation: Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs)	
Task Leader	Olivier Prat
Task Code	NC-CDR/SDS-07-NCICS-OP
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI/CWC
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research Applications 50%
	Theme 2: Climate and Satellite Observations and Monitoring 50%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50%
	Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: The project team conducted a long-term assessment of the different satellite-based precipitation products from four Climate 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. A book chapter incorporating project results was finalized.

Background

Four satellite-based precipitation Climate Data Records (CDRs) were evaluated (PERSIANN-CDR; GPCP; CMORPH; AMSU/MHS Hydro-bundle). PERSIANN-CDR is a 30-year record of daily-adjusted global precipitation. GPCP is an approximately 30-year record of monthly and pentad-adjusted global precipitation and a 17-year record of daily-adjusted global precipitation. CMORPH is a 17-year record of daily and sub-daily adjusted global precipitation. AMSU/MHS Hydro-bundle is a 15-year record of rain rate over land and ocean, snow cover and surface temperature over land, and sea ice concentration, cloud liquid water, and total precipitable water over ocean, among others. The different satellite-based quantitative precipitation estimations (QPEs) are evaluated over the concurrent period. Product intercomparisons are performed at various temporal (annual, seasonal, daily, or sub-daily, when possible) and spatial scales (global, over land and over ocean, tropics or higher latitudes, high elevation). The evaluation of the different products includes trend analysis and comparison with in situ datasets from the Global Historical Climatology Network (GHCN-Daily), the Global Precipitation Climatology Centre (GPCC) gridded full data daily product, and the U.S. Climate Reference Network (USCRN).

Accomplishments

Following the evaluation of the satellite precipitation products (SPP) CDRs reported previously, this year's work focused on finalizing associated publications. A chapter in the book *Satellite Precipitation Measurement* entitled "Satellite precipitation measurement and extreme rainfall" is currently available as an ebook (hardcover to follow). A paper was submitted using ancillary information from radar-based observations from the high spatial and temporal NOAA NEXRAD Reanalysis (NRR) and information from the USCRN to identify errors and biases between gauges and radars.

Planned work

Work will continue under the successor cooperative institute, CISESS.

Publication

Prat, O. P., and B. R. Nelson, 2020: Satellite precipitation measurements and extreme rainfall. In *Satellite Precipitation Measurement*, V. Levizzani, C. Kidd, D. B. Kirshbaum, C. D. Kummerow, K. Nakamura, and F. J. Turk, Eds., Springer, 761-790. https://www.springer.com/it/book/9783030357979

Presentation

Prat, O., 2019: Using Remotely Sensed Precipitation Information and Vegetation Observation from the NOAA/Climate Data Record (CDR) Program for Early Drought Detection and Near-Real Time Monitoring on a Global Scale. *AMS 2019 Joint Satellite Conference*, Boston, MA, October 3, 2019.

Performance Metrics	
# of new or improved products developed that became operational	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**1**
# of NOAA technical reports	**0**
# of presentations	**1**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Developing blended in situ and satellite global temperature dataset	
Task Leader	Yuhan (Douglas) Rao
Task Code	NC-CDR/SDS-08-NCICS-YR
NOAA Sponsor	Jeff Privette
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50%
	Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: This project explores using machine learning to integrate in situ measurements and satellite-derived surface temperature from HIRS to create a sub-daily gridded temperature dataset since 1978. During data preprocessing, a data availability issue was identified in the earlier version of HIRS-derived temperature data that resulted from conservative cloud screening. The team completed most of the HIRS temperature reprocessing.

Background

Current temperature data for global climate studies at NCEI (NOAAGlobalTemp v5) are primarily based on in situ temperature measurements taken from stations, buoys, and ships. Without statistical interpolation, the current dataset is only available with a coarse grid (5°×5°) and has notable data gaps in the polar regions. Although the dataset shows consistent analysis results with those of other institutions produced at global scales, this coarse resolution could miss important spatial details of climate change, while the data gap has increased the uncertainty for climate studies. These two limitations are mainly caused by the uneven distribution of in situ temperature measurements, where most measurements are clustered over well-developed and populated regions.

Conversely, satellite thermal remote sensing has been providing pole-to-pole coverage daily since the 1970s. The High Resolution Infrared Sounder (HIRS), onboard NOAA Polar Orbiting Environmental Satellite (POES) series and EUMETSAT Polar System (EPS) satellites, has provided a nearly 40-year Climate Data Record (CDR) of atmospheric temperature and moisture daily. This long-term temperature record has demonstrated its stability and accuracy when compared to in situ measurements. Thus, it may provide unique information that can be used to fill the data gap of regions with limited in situ temperature measurements.

The project team will use advanced machine learning tools to create a blended global gridded surface temperature dataset by leveraging the high-quality in situ measurements and global HIRS temperature data. The expected final blended dataset will be a global, sub-daily surface temperature dataset with a grid size of 0.5°×0.5° or higher since 1978. This dataset should reduce the uncertainty for climate studies especially over the polar regions.

Accomplishments

Major accomplishments to date include completion of a research framework design and data preparation for the model training.

Research Framework Design. The project is designed to be implemented in three stages: data preparation, model training and implementation, and dataset evaluation. The first stage focuses on preparing both in situ temperature measurements and satellite data that are needed for model training

and implementation. In situ temperature measurements will use near surface air temperature measurements from Global Summary of the Day (GSOD) over land and International Comprehensive Ocean–Atmosphere Data Set (ICOADS) over ocean. Temperature profiles derived from HIRS CDR for the satellite temperature data. Current HIRS temperature profile data is provided in ASCII format, which must be transformed into a gridded format to ensure the model implementation. Additionally, match-up data pairs must be extracted between in situ measurements and satellite data to enable model development. The match-up data pairs are extracted based on a nearest-neighbor rule to find the closest satellite pixel which matches the individual in situ measurement.

The model development stage will start after completing the match-up extraction. The extracted match-up data pairs will be randomly separated into two subsets for model training and evaluation, respectively. Considering the difference between land and ocean surface, model development will be separated for land and ocean surfaces. For each surface, the machine learning model will be trained using leave-one-station-out strategy to ensure the robustness of the final model. The model will then be evaluated using validation match-up data pairs held out form the training. Once the model has been evaluated, it will be applied to the historical satellite data to produce the global blended temperature dataset.

The final surface temperature product will be evaluated using multiple independent data sources, such as atmospheric reanalysis datasets, independent in situ measurements from field campaigns and nontraditional networks, and existing global gridded temperature datasets. The evaluation results will be summarized into a validation report accompanying the final product, together with a product users' guide.

Data preparation for model development. The team has been preparing both in situ and satellite data for model development. To transform HIRS temperature profile data into gridded format from the current ASCII version, the team analyzed the availability of HIRS temperature retrievals at different grid sizes (i.e., 0.25°×0.25°, 0.5°×0.5°, and 1°×1°). The analysis shows that the current version of HIRS temperature data has very limited availability over ocean (Figure 1). The lack of data over ocean is caused by the conservative cloud screening procedure based on a spatiotemporal homogeneity test, which will affect the blended temperature dataset development.

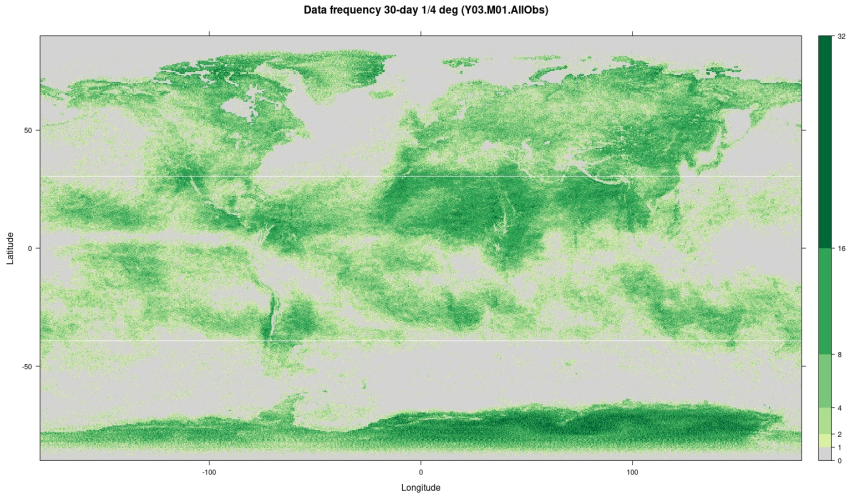


Figure 1. *The example of data availability analysis for the current version of HIRS temperature data for January 2003 at the grid of 0.25°×0.25°. The grey color means no HIRS data available, and the darker the green indicates the more data available for the grid.*

To resolve the data availability issue, the team reprocessed HIRS temperature profile retrievals using raw all-sky HIRS data. During the reprocess, PATMOS-X CDR cloud products were used to create cloud masks for the new version of the HIRS temperature profile data. Where PATMOS-X cloud data are not available, the team will use the previously developed spatiotemporal homogeneity test for cloud screening. The reprocessed HIRS data will be transformed into a gridded file using NetCDF4 format.

Meanwhile, the team completed the extraction of match-up data pairs between HIRS and GSOD, since the data availability issue is mostly only severe over oceans. The large footprint of HIRS data (nearly 30 km for each pixel) can result in a large spatial mismatch with in situ measurements (i.e., point measurement). To reduce the effect of these spatial mismatches, the team converted the temperature values to temperature anomalies for both in situ and satellite data in the extracted match-up data pairs between HIRS and GSOD. These match-up data pairs will be used for land model development in the next stage.

Planned work

- Generate a daily HIRS temperature climatology and diurnal cycle model for surface temperature
- Create gridded HIRS temperature data in NetCDF4 format
- Complete first version of model development for land and provide beta version of global land blended temperature dataset
- Extract match-up data pairs between HIRS and ICOADS data over ocean and start model development for ocean surfaces

Publications

Rao, Y., S. Liang, D. Wang, Y. Yu, Z. Song, Y. Zhou, M. Shen, and B. Xu, 2019: Estimating daily average surface air temperature using satellite land surface temperature and top-of-atmosphere radiation products over the Tibetan Plateau. *Remote Sensing of Environment*, **234**, 111462, https://doi.org/10.1016/j.rse.2019.111462.

Zhang, C., L. Ma, J. Chen, **Y. Rao**, Y. Zhou, and X. Chen, 2019: Assessing the impact of endmember variability on linear Spectral Mixture Analysis (LSMA): A theoretical and simulation analysis. *Remote Sensing of Environment*, **235**, 111471, https://doi.org/10.1016/j.rse.2019.111471.

Presentations

Rao, Y., 2019: Integrating long term satellite data and in situ observations to study snow-albedo-temperature feedback over the Tibetan Plateau. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 12, 2019.

Rao, Y., 2019: Improving surface temperature data quality by leveraging daily satellite observations and machine learning techniques. Poster. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

Rao, Y., 2020: Building Machine Learning Tutorials for Earth Science Applications. Poster. *ESIP 2020 Winter Meeting*, January 9, 2020.

Rao, Y., 2020: Improving surface temperature data quality by leveraging daily satellite observations and machine learning techniques. *ESIP 2020 Winter Meeting*, January 9, 2020.

Other

2020 ESIP Catalyst Award (received during the ESIP 2020 Winter Meeting, January 9, 2020)

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

Identifying Tropical Variability with CDRs	
Task Leader:	Carl Schreck
Task Code	NC-CDR/SDS-09-NCICS-CS
NOAA Sponsor	Jeff Privette/Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 50% Theme 3: Climate Research and Modelling 50%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 2: Weather-Ready Nation 100%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: This project resulted in several publications on monitoring and prediction of tropical cyclones using the OLR-Daily CDR and the International Best Track Archive for Climate Stewardship (IBTrACS). The new IBTrACS version 4 is being utilized to produce the "Hurricanes and Tropical Storms" report for NCEI's monthly State of the Climate report.

Background

The Madden–Julian Oscillation (MJO), equatorial Rossby waves, and Kelvin waves are the dominant sources of synoptic-to-subseasonal variability in the tropics. The divergent circulations from their convection can influence tropical cyclones and other weather patterns around the globe. Forecasters in the energy industry pay particular attention to these modes, harnessing their long time scales and global impacts to anticipate energy demand in the United States. Climate Data Records (CDRs) play a key role in the identification and forecasting of these modes. This project endeavors to develop new diagnostics for tracking tropical modes using CDRs.

Accomplishments

This project produced several published papers on monitoring and prediction of tropical cyclones using NCEI's OLR-Daily CDR and the International Best Track Archive for Climate Stewardship (IBTrACS). Saunders et al. (2020) examined the active 2018 Atlantic Hurricane season. They found that the activity was driven largely by storms in the subtropics that are more difficult to predict on seasonal scales. Similarly, Wood et al. (2019) compared the record-setting 2018 eastern Pacific hurricane season with other active years in the basin. Similar to the Atlantic, conditions in the eastern Pacific were favorable but certainly would not have indicated a record year. The lack of an El Niño in 2018 made the record activity particularly noteworthy.

On shorter scales, Schreck began leveraging the new IBTrACSv4 to produce the Hurricanes and Tropical Storms report for NCEI's monthly State of the Climate (e.g., https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201905). Using code from ncics.org/mjo, IBTrACSv4 is now updated twice-weekly with the operational positions and intensities of storms from the NOAA's National Hurricane Center (NHC) and the U.S. military's Joint Typhoon Warning Center (JTWC).

Two undergraduate interns worked on this project during summer 2020. They focused on leveraging NCEI's physical records of tropical cyclones from the western North Pacific in the 1950s–1970s. They verified that the most useful data had already been digitized. However, they also uncovered the history of wind–pressure relationships used by JTWC. Wind is notoriously difficult to measure in tropical cyclones, and it was particularly challenging before the advent of GPS dropsondes. Meanwhile, pressure is fairly

easy to measure, so JTWC typically derived the winds from the pressures, but only the winds are recorded in the JTWC best track data. Those data are heterogeneous and have large uncertainties. The interns worked with historical pressure data from NCEI to develop a new wind record that would be more temporally homogeneous (Figure 1).

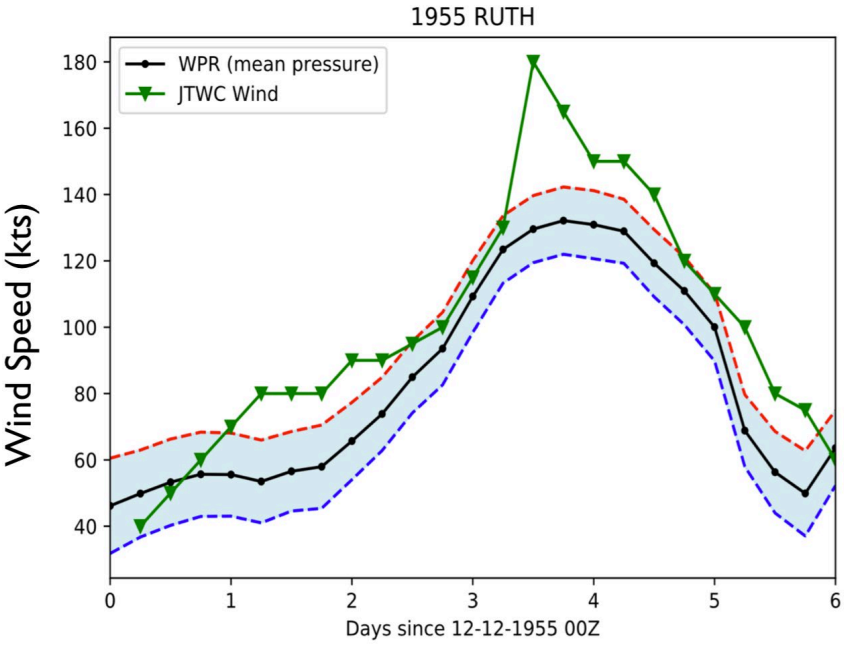


Figure 1. *Comparing best track winds from JTWC (green) with those derived from pressures (black) for Typhoon Ruth (1955).*

Planned work

The project was completed in August 2019.

Products

- Synoptic Discussions for NCEI's State of the Climate May–July 2019: e.g., https://www.ncdc.noaa.gov/sotc/synoptic/201905
- Hurricanes and Tropical Storms reports for NCEI's State of the Climate May–July 2019: e.g., https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201905

Publications

Camargo, S. J., J. Camp, R. L. Elsberry, P. A. Gregory, P. J. Klotzbach, **C. J. Schreck III**, A. H. Sobel, M. J. Ventrice, F. Vitart, Z. Wang, M. C. Wheeler, M. Yamaguchi, and R. Zhan, 2019: Tropical Cyclone Prediction on Subseasonal Time-Scales. *Tropical Cyclone Research and Review*, **8**, 150–165, https://doi.org/10.6057/2019tcrr03.04.

Diamond, H. J., and **C. J. Schreck**, eds., 2019: The tropics [in "State of the Climate in 2018"]. *Bulletin of the American Meteorological Society*, **100**, S101–S140, https://doi.org/10.1175/2019BAMSStateoftheClimate.1.

Saunders, M. A., P. J. Klotzbach, A. S. R. Lea, **C. J. Schreck**, and M. M. Bell, 2020: Quantifying the Probability and Causes of the Surprisingly Active 2018 North Atlantic Hurricane Season. *Earth and Space Science*, **7**, https://doi.org/10.1029/2019EA000852.

Klotzbach, P. J., M. M. Bell, S. G. Bowen, E. J. Gibney, K. R. Knapp, and **C. J. Schreck**, 2020: Surface pressure a more skillful predictor of normalized hurricane damage than maximum sustained wind. *Bulletin of the American Meteorological Society*, **In press**, https://doi.org/10.1175/BAMS-D-19-0062.1.

Huang, B., and Coauthors [including **J. J. Rennie** and **C. J. Schreck**], 2020: Uncertainty Estimates for Sea Surface Temperature and Land Surface Air Temperature in NOAAGlobalTemp Version 5. *Journal of Climate*, **33**, 1351–1379. https://doi.org/10.1175/JCLI-D-19-0395.1.

Wood, K. M., P. J. Klotzbach, J. M. Collins, and **C. J. Schreck**, 2019: The Record-Setting 2018 Eastern North Pacific Hurricane Season. *Geophysical Research Letters*, **46**, https://doi.org/10.1029/2019GL083657.

Camargo, S. J., and Coauthors [including **C. J. Schreck**], 2019: Tropical Cyclone Prediction on Subseasonal Time-Scales. *Tropical Cyclone Research and Review*, **8**, 16, https://doi.org/10.6057/2019TCRR03.04.

Presentation

Schreck, C., 2019: Speaking of Climate: Are hurricanes stronger, larger, and wetter? *The Collider,* Asheville, NC, September 24, 2019, case.simpletix.com/e/47619.

Other

- NOAA Hollings Scholar J. Seth Goodnight
- NCICS Undergraduate Intern Ryan Jenkins

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**2**
# f products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**7**
# of NOAA technical reports	**0**
# of presentations	**1**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**2**

Synoptic Discussions for NCEI's State of the Climate May–July 2019, and Hurricanes and Tropical Storms reports for NCEI's State of the Climate May–July 2019

El Niño–Southern Oscillation (ENSO) Normals	
Task Leader	Carl Schreck, Anand Inamdar
Task Code	NC-CDR/SDS-10-NCICS-CS/AI
NOAA Sponsor	Jeff Privette/Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 50%
	Theme 3: Climate Research and Modelling 50%
Main CICS Research Topic	Climate Data and Information Records
Contribution to NOAA goals	Goal 2: Weather-Ready Nation 100%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: A paper documenting the project's unique methodology for developing U.S. Normals from nClimGrid–Monthly conditioned on both climate change and the phase of ENSO was published.

Background

Climate normals have traditionally been calculated every decade or so as the average values over a long period of time, typically 30 years. Such an approach assumes a stationary climate, so several so-called alternative normals have recently been introduced. These alternative normals attempt to account for trends associated with global climate change by using a shorter averaging period, updating more frequently, and/or extrapolating the linear trend. While such approaches account for monotonic climate change, they fail to harness known interannual climate variability such as that associated with the El Niño–Southern Oscillation (ENSO). Similar to climate change, ENSO systematically alters the background state of the climate. These effects and their uncertainties are relatively well established, but they are not reflected in any readily available climate normals datasets. This project used nClimGrid-Monthly conditioned on both climate change and the phase of ENSO to develop normals for temperature and precipitation for the contiguous United States.

Accomplishments

This year's final project activity focused on finalizing the publication which described the development of the unique normals calculation methodology. The project results were published in May 2019.

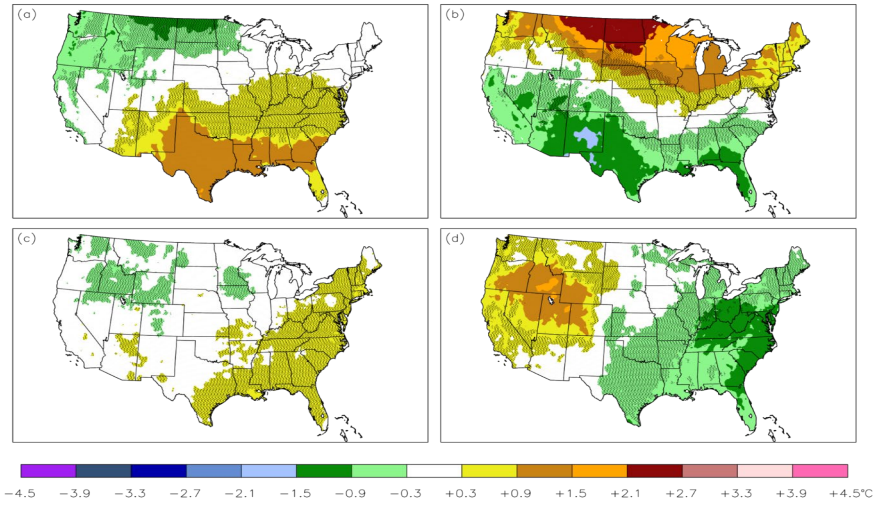


Figure 1. *ENSO composites of DJF mean monthly maximum temperature for (a) Strong La Niña, (b) Strong El Niño, (c) Weak La Niña, and (d) Weak El Niño. Hatching indicates values outside of the near-zero interval (white) that are not significantly different from zero at 90% confidence.*

Planned work
This project ended in June 2019.

Publications
Arguez, A., **A. Inamdar**, M. A. Palecki, **C. J. Schreck**, and A. H. Young, 2019: ENSO Normals: A new U.S. climate normals product conditioned by ENSO phase and intensity and accounting for secular trends. *Journal of Applied Meteorology and Climatology*, **58**, 1381–1397, https://doi.org/10.1175/JAMC-D-18-0252.1.

Arguez, A., S. Hurley, **A. Inamdar**, L. Mahoney, A. Sanchez-Lugo, and L. Yang, 2020: Should we expect each year in the next decade (2019–2028) to be ranked among the top 10 warmest years globally? *Bulletin of the American Meteorological Society*, https://doi.org/10.1175/bams-d-19-0215.1.

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

Calibration of High-resolution Infrared Radiation Sounder (HIRS) Brightness Temperatures	
Task Leader	Emma Scott
Task Code	NC-CDR/SDS-11-NCICS-ES
NOAA Sponsor	Jeff Privette/Lei Shi
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Calibration and Validation
Contribution to NOAA goals	Climate Adaptation and Mitigation
NOAA Strategic Research Priorities	Integrated Earth System Process and Predictions

Highlight: High-resolution Infrared Radiation Sounder (HIRS) measurements of brightness temperature must be calibrated in order to provide a consistent dataset for use as a Climate Data Record (CDR). Preliminary work identified a subset of the data that can be used for calibration of HIRS brightness temperature between satellites.

Background

The HIRS instrument has provided measurements of brightness temperature for over 30 years, qualifying it to serve as an important climate record. However, these measurements have been taken from different satellites and with different versions of the HIRS instrument. Different rates of instrument degradation can introduce biases between satellites, while the instrument degradation itself introduces bias over time within the measurements from a single satellite launch. These biases can be accounted for by implementing intersatellite calibration. HIRS measurements taken from onboard the NOAA and METOP satellite series were compared to find the magnitude of the bias between pairs of consecutive satellites. Because different satellites were launched with different versions of the HIRS instrument, this comparison also allows for determination of the bias between different versions of the sensor. Changes to the central wavelength measured by each channel between different versions of the instrument could cause inconsistencies in the height within the atmosphere that corresponds to the measured brightness temperature. Additional calibration can be performed to account for inconsistencies near the edges of the temperature range for each channel.

Accomplishments

Preliminary work resulted in a dataset that can be used for inter-satellite calibration of HIRS brightness temperature. These data are a subset of the current clear-sky, limb-corrected HIRS data. Points were located where pairs of satellites performed an overpass of locations within 0.2° latitude and longitude of each other within a 15-minute window of time in order to create a set of observations that could be used for direct comparison between satellites. The time window was chosen to allow for the maximum possibility of simultaneous nadir overpasses (SNOs) while minimizing the possibility of changes in cloud cover. Many satellite pairs only have SNOs located within polar regions due to the geometry and timing of their orbits, but some pairs have SNOs located across the full range of latitudes, which allows for testing of changes in intersatellite bias over the full range of brightness temperatures measured by each channel of the instrument. While some calibration had been performed previously, preliminary comparison of intersatellite brightness temperatures has shown that some channels may still have large intersatellite biases (over 1 K), especially toward the edges of the temperature range (Figure 1).

For each channel of HIRS measurements on the NOAA-17 and METOP-02 satellites, brightness temperature measurements that correspond to SNOs have been sorted by latitude and filtered to create a dataset on which the calibration can be based without undue influence from outliers. Future work will focus on calibration using this dataset.

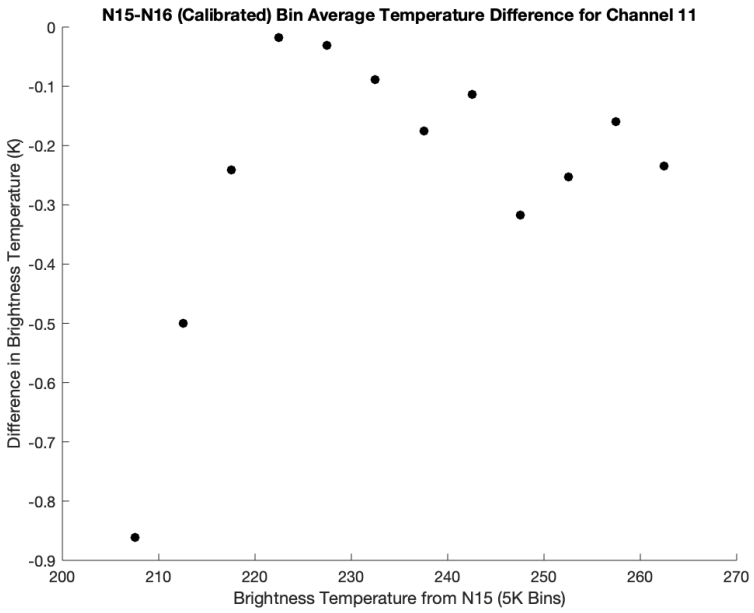


Figure 1. *Differences between brightness temperatures for Channel 11 between the NOAA-15 and NOAA-16 satellites over the range of temperatures measured. These data are based on the old calibration.*

Planned work

- Through the calibration process, intersatellite bias should be reduced to ±0.2 K for each channel of each satellite pair.
- Calibration will also be performed within each channel to account for changes near the edges of the temperature range.
- The resulting calibrated data will be released for use as a new CDR, and the calibration process will be published for reproducibility.

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

Climate Literacy, Outreach, Engagement, and Communications

CICS-NC climate literacy, outreach, engagement, and communication efforts are focused on improving the public's knowledge and understanding of climate change, its impacts, and options for adaptation and mitigation.

Over the last two decades, the understanding of climate change and its impacts has emerged as one of the most important areas of scientific endeavor. There is rapidly increasing realization that profound changes in the Earth climate system are already occurring and will impact nearly everyone either directly or indirectly. The need to mitigate the effects of climate change by reducing greenhouse emissions is well recognized globally, and society will need to adapt to the changes that have already occurred and those that will occur in the future.

CICS-NC supports NOAA's commitment to promote a society that is environmentally responsible, climate resilient, and adaptive and that utilizes effective science-based problem-solving skills (e.g., STEM-based learning) in education. The CICS-NC team participates in various climate education programs to advance the development of strong and comprehensive education and outreach activities about the Earth system and human impacts.

CICS-NC participates in a number of activities that educate a variety of stakeholders about the large volumes of Earth system data that NOAA collects. Working collaboratively with other academic and public partners, stakeholders, and the private sector, CICS-NC supports and engages in various educational, engagement, and outreach-related activities, including

- Climate literacy for academic communities, including those in the K–12, undergraduate, and graduate levels, as well as other organizations
- Climate literacy for private-sector partnerships through interdisciplinary activities, including executive roundtable sessions and outreach to the energy, insurance, and agriculture sectors
- Outreach to local and national television meteorologists and other media interested in climate information
- Operational support for NOAA outreach activities
- Outreach and engagement activities to public policy groups and economic development groups

Climate Literacy, Outreach, Engagement, and Communications	
Task Leader	Jenny Dissen
Task Code	NC-CLOEC-01-NCICS-JD
NOAA Sponsor	Jeff Privette/Michael Brewer
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Climate Literacy, Outreach, Engagement and Communications
Contribution to NOAA goals	Goal 1: 40%; Goal 2: 40%; Goal 4: 20%
NOAA Strategic Research Priorities	Scientific Outreach and Education

Highlight: CICS-NC provided operational customer engagement support to NCEI's Center for Weather and Climate (CWC), helped plan and host the 2019 NCEI Users' Conference, increased the number of targeted sector- and topic-specific engagement discussions, and participated in regional outreach activities promoting STEM and environmental information. https://ncics.org/events/

Background

Stakeholders across public and private sectors continue to seek robust, reliable, and authoritative environmental information to inform their decision-making. They are also exploring innovative ways to incorporate this information into their adaptation, resilience, and sustainability activities. Connecting stakeholders with scientists and data providers is a more holistic approach to climate services. An improved understanding of user requirements and applications will enable science and data producers to improve access to and utility of existing environmental information as well as develop innovative products. Facilitating this exchange between users and solution providers requires strategic engagement and collaboration.

To that end, CICS-NC engages in targeted and interdisciplinary literacy, engagement, and outreach activities for business and industry, academia, other scientists, organizations, and the general public. Activities include framing and analyzing the exchange of information, developing case studies, organizing sector-based engagement discussions, and building networks and partnerships to build capacity. In addition, CICS-NC promotes innovative uses of climate data and information to support NOAA and NCEI mission goals.

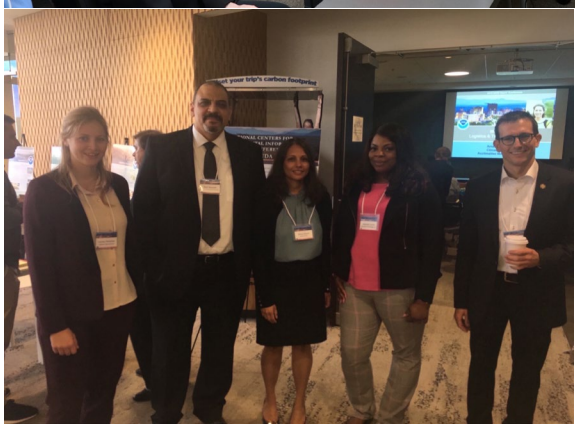
Accomplishments

The past year's highlights include

- Operational customer engagement support to CWC
- Targeted, sector- or topic-specific engagement discussions
- A robust regional outreach program promoting STEM and environmental education

Center for Weather and Climate (CWC) customer engagement support. CICS-NC supports and advises CWC's Climatic Information Services and Customer Engagement branches on strategic and operational sectoral engagement activities. CICS-NC also provides support for NCEI activities that document, analyze, and report on the experiences of NCEI data users. Task Leader Jenny Dissen serves as the Product Lead for NCEI CWC sectoral engagement.

Highlights included planning and hosting the 2019 NCEI Users' Conference in May 2019 in Asheville as part of NCEI's efforts to better understand user needs (web link). The 70+ conference participants represented multiple sectors, including weather service providers, logistics and transportation, agriculture, climate normals, finance, and insurance. Attendees discussed how NCEI serves NOAA, the Nation's economy, and society. Participants shared case studies on uses, applications, and requirements of environmental information. Participants also provided feedback and best practices to improve products and identify opportunities for innovation. This information was documented in *SalesForce*, NCEI's customer relationship management platform, which serves as the repository for customer information.



Education and General Public Outreach Activities.
CICS-NC staff engage in an interdisciplinary outreach program, which includes leading and participating in activities that reach K–12 and higher education and the general public. In this role, CICS-NC staff advance NOAA mission goals in promoting STEM and disseminating environmental information for capacity building and education.

NCICS has many local outreach partnerships, including with the Asheville Museum of Science, the North Carolina Science Festival, The Collider, and Western North Carolina STEM Leaders. Institute staff also support and respond to a variety of other outreach requests throughout the region.

In the spring of 2019, CICS-NC staff participated in several outreach activities and presented to a wide range of audiences and at a variety of educational events:

- 4/5: Isothermal Community College Annual Science and Technology Expo, Spindale, NC. Scott Stevens presented information on data collection and analysis to ~300 sixth-grade students.
- 4/27: North Carolina Arboretum Mountain Science Expo, Asheville, NC. Stevens and Erika Wagner hosted an interactive information/activity table at this STEM event with ~2,700 people in attendance.
- 5/1: Enka Intermediate School, Candler, NC. Stevens gave a Career Day presentation to ~100 fifth-grade students.
- 5/4: Buncombe County Schools 2019 STEM Day, Asheville, NC. Carl Schreck and Wagner hosted an interactive outreach table with ~700 in attendance.
- 5/9: National Weather Service Hurricane Awareness Tour, Charlotte, NC. Schreck and Jared Rennie hosted an interactive outreach table.
- 6/7: American Meteorological Society (AMS) Early Career Leadership Academy (ECLA) webinar. Jared Rennie remotely presentation on communicating science information.
- 8/10: Warren Wilson College Get off the Grid Fest, Swannanoa, NC. Tom Maycock presented information on climate change in North Carolina to ~30 attendees during the "Climate Change and Justice" panel discussion.

Presentations

Dissen, J., Easterling, D.R., **Kunkel, K.E.**, **Ballinger, A.**, Hayhoe, K., Akhtar, F., 2019: Development and Applications of Climate Projections in India. *17th Annual Climate Prediction Applications Science Workshop*, Charleston, SC, June 11, 2019.

Other

- Dissen serves on the External Engagement Steering Team for the North Carolina School of Science and Mathematics Morganton Campus (http://ncssm.edu/).

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**4***
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate (high school) students mentored during the year	**0**

**1 engagement presentation, 3 outreach presentations*

CICS-NC Communications	
Task Team	Tom Maycock and Jessicca Griffin
Task Code	NC-CLOEC-02-NCICS-TM/JG/AL
NOAA Sponsor	David Easterling / Katy Matthews
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: 33%; Theme 2: 33%; Theme 3: 33%
Main CICS Research Topic	Climate Literacy and Outreach
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Scientific Outreach and Education

Highlight: CICS-NC communication efforts promote the Institute and its research activities to its stakeholders and advance the external and internal communications efforts of NCEI. Key accomplishments included communications related to the new cooperative institute announcement, a blog post on cloud computing published by *Amazon*, and graphic design and visual communication support for NCEI's annual State of the Climate Report.

Background

CICS-NC communication activities serve to raise awareness and highlight the accomplishments of the Institute and its staff. A primary focus is sharing research findings of Institute scientists and their NOAA NCEI colleagues through web stories, press releases, social media, the Institute's newsletter *Trends*, and outreach events. Other activities include working to improve the science communication capabilities of Institute staff, including editorial and graphic design support for papers and presentations. CICS-NC also provides science writing, editing, and graphic design support to NCEI's Communications and Outreach Branch. The Science Public Information Officer (PIO) works to coordinate communication efforts between NCEI and CICS-NC.

Accomplishments

Major communication efforts centered around NOAA's May 2019 announcement that it had selected the University of Maryland and North Carolina State University as the hosts for a new cooperative institute to succeed CICS-NC. Science PIO Tom Maycock worked with leadership and communications staff from NCICS, North Carolina State University, the University of Maryland, and NOAA to develop and release coordinated press releases announcing the award and the formation of the new Cooperative Institute for Satellite Earth System Studies (CISESS). The announcement was supported with social media plans.

Selected press releases announcing the new CISESS award:

- https://ncics.org/cics-news/nc-state-climate-research-institute-to-host-noaa-cooperative-institute/
- https://sciences.ncsu.edu/news/ncics-to-host-noaa-cooperative-institute/
- https://www.nesdis.noaa.gov/content/noaa-names-university-maryland-host-cooperative-institute-satellite-earth-system-studies
- https://cisess.umd.edu/cics-is-now-the-cooperative-institute-for-satellite-earth-system-studies-cisess/

NCICS to Host NOAA Cooperative Institute

NCICS will host the Asheville location of the new Cooperative Institute for Satellite Earth System Studies, which will be dedicated to expanding our understanding of the full Earth system and its interactions with human activities

May 31, 2019: For Immediate Release

Asheville, NC — NOAA announced today that North Carolina State University's North Carolina Institute for Climate Studies (NCICS) will host an anchor location of the Cooperative Institute for Satellite Earth System Studies (CISESS). The $175-million, five-year agreement will fund a multi-institution consortium led by the University of Maryland (UMD) and NC State University (NCSU). CISESS will begin operations on July 1, 2019, and will expand on the success of the Cooperative Institute for Climate and Satellites, founded in 2009 under a similar partnership between NC State and the University of Maryland.

The grand scientific challenge of CISESS will be to enhance our understanding of how the natural components of the Earth system—atmosphere, ocean, land, and biosphere—interact with human activities as a coupled system. The Institute's multidisciplinary team of scientists and experts will engage in collaborative and transformative research activities to enhance NOAA's ability to use observations and models to meet that challenge, advance NOAA's science mission, and identify emerging science needs.

CISESS will also educate and train students and scientists in relevant fields, provide early-career scientists with opportunities to do important research at a world-class environmental data facility, and actively engage with the scientific community, decision makers, and the public.

The North Carolina site will be co-located with NOAA's National Centers for Environmental Information (NCEI) in Asheville, North Carolina, while the Maryland site will be hosted at the University of Maryland's M Square Research Park in College Park, which is also home to NOAA's Center for Weather and Climate Prediction.

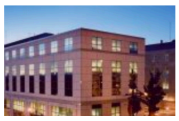


Figure 1. *Press release announcing that NCICS would host one of the two anchor locations of NOAA's new Cooperative Institute for Satellite Earth System Studies. From https://ncics.org/cics-news/nc-state-climate-research-institute-to-host-noaa-cooperative-institute/.*

The PIO coordinated media coverage related to various Institute research outcomes. A paper published in the *Bulletin of the American Meteorology Society* that used high-resolution radar to quantify how precipitation elevates the risk of a fatal car crash generated a significant amount of media interest, including stories by the *Washington Post* and the Associated Press and a live interview on the Weather Channel (https://ncics.org/cicsnews/precipitation-and-fatal-motor-vehicle-crashes/). Later in 2019, Assessment Lead Scientist Kenneth Kunkel was interviewed for a WLOS TV (Asheville, NC) story on climate change and extreme weather in Western North Carolina (https://wlos.com/news/local/drought-deluge-extreme-weather-events-increasing-across-wnc).

Following an invitation from *Amazon* as part of its Sustainability Data Initiative, the PIO worked with Jessica Matthews and Jared Rennie to develop a blog post highlighting their two pilot studies exploring the suitability and cost effectiveness of cloud computing options.
https://aws.amazon.com/blogs/publicsector/embracing-the-cloud-for-climate-research/

CICS-NC staff support the NOAA NCEI Communications and Outreach Branch with communications coordination and planning as well as graphic design and visual communications support for a variety of NCEI activities. CICS-NC staff provided graphics and layout support for NCEI's annual State of the Climate Report published in the *Bulletin of the American Meteorological Society*.

Figure 2. *CICS-NC provided graphics and layout support for NCEI's annual State of the Climate report. https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/*

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

Surface Observing Networks

Surface observing network activities address the sustainment and quality improvement of in situ climate observations and observing networks.

NCEI, along with NOAA partner institutions, leads two national climate-observing programs: the U.S. Climate Reference Network (USCRN) and the U.S. Historical Climatology Network-Modernized (USHCN-M). USCRN consists of 114 stations across the continental United States, 22 stations in Alaska, 2 stations in Hawai'i, and 1 station in Canada. These stations are collecting sustainable climate data observations to provide a 50-year picture of climate change. Deployment of additional stations in Alaska to enhance the detection of regional climate change signals is ongoing under the management of NCEI, in partnership with NOAA's Air Resources Laboratory Atmospheric Turbulence and Diffusion Division.

NCEI also manages a number of other climate network initiatives, including the Global Historical Climatology Network (GHCN) and the Hourly Precipitation Data (HPD) network. NCEI archives and maintains observational data for systems such as the Hydrometeorological Automated Data System and the Automated Surface Observing System (ASOS). Primary activities associated with these programs and systems include 1) collection and analysis of observations of soil moisture and soil temperature; 2) studies and analyses involving climate change and variation, climate monitoring, and visualization; and 3) development of quality control processes to ensure the fidelity of the climate record.

To support these activities, CICS-NC assembled a group of research scientists supporting various climate observing network initiatives and providing relevant scientific, technical, and software engineering expertise in the following areas:

- Integration of surface, model, and satellite fields focusing on surface temperature
- Quality assurance in the USCRN program through comparison of USCRN observations with those from other surface-observing networks (e.g., Cooperative Observer Program, ASOS, etc.)
- Drought data monitoring and the creation of new drought monitoring products for the USCRN network
- Maintenance and streamlining of the GHCN-M and HPD datasets
- Global Temperature Portfolio targeting specific activities in ocean (sea surface) and land temperature fields and products

Drought-related health impacts: advancing the science for public health applications	
Task Leader:	Jesse E. Bell
Task Code	NC-SON-01-UNMC
NOAA Sponsor	Veva Deheza
NOAA Office	OAR/CPO/NIDIS
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50%
	Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: The University of Nebraska Medical Center (UNMC) and the National Integrated Drought Information System (NIDIS) convened a National Drought and Public Health Summit in June 2019. The Summit provided a forum for stakeholders to discuss drought and its impacts on human health and highlight current drought research and preparedness activities.

Background

Drought, as characterized by the United Nations, is the "most far-reaching" of all natural disasters and internationally has caused more deaths compared to any other weather-related extreme events (flood, hurricane, etc.). However, due to lack of understanding of the adverse health linkages, droughts are not considered a public health threat in the United States. Drought's slow-evolving nature and delayed impacts make health studies more challenging, as the health outcomes are mainly indirect. The impact of drought on human health is a matter of growing concern as drought frequency and duration are projected to increase in the context of climate change. Many studies have investigated the secondary exposure pathways in which drought can affect human health, such as exposure to wildfire smoke and vector-borne habitat change, but little is known about extreme exposures that can lead to death. A few studies have found connections between drought and suicide among Australian rural communities, as well as increased cardiovascular and respiratory-related deaths in the United States. The existing literature still faces a gap as those studies are geographically limited and only target specific population subgroups such as older adults and do not embrace the whole Nation. This broader analysis is especially important because drought manifests differently across the United States, and health outcomes are regionally specific. Some of this regional variability is the result of population demographics, socioeconomic status, and occupational and environmental exposures. By advancing our understanding of the impacts of drought on human health, NIDIS and its partners in the drought community will be able to more effectively communicate drought forecasts, drought conditions, and drought impacts to public health officials and health care professionals. Improved communication will foster the development of plans and preparedness efforts in the health community to respond to drought events.

Accomplishments

Valley Fever /soil moisture study. Coccidioidomycosis, also called Valley fever, is caused by the fungus Coccidioides spp., which is found in the soils of the southwestern United States and in regions of South America, Central America, and Mexico. People contract coccidioidomycosis by breathing in fungal spores that are carried in the air. In 2017, a large outbreak of coccidioidomycosis occurred in the southwestern United States. While previous outbreaks reflected similar patterns across the Southwest, the 2017 outbreak showed unique differences between California and Arizona. Recent drought in California, and subsequent changes in the environment, likely caused the differences in the way the outbreak manifested. Coopersmith et al. (2017) were the first to study the incidence of coccidioidomycosis as related to actual

changes in soil moisture conditions, and the UNMC research team will be applying the Coopersmith approach to investigate the role soil moisture had on the 2017 Valley Fever outbreak. Analysis of NOAA soil moisture data and Centers for Disease Control and Prevention (CDC) coccidioidomycosis incidence records continued.

Drought-related mortality study. For this retrospective study, the UNMC team is utilizing CDC annual counts of all-cause mortality on a county level from 1980–2014 for all age groups in the contiguous United States (CONUS) and several drought indices to investigate drought event impact on regional and national mortality rates. Work continued on applying the refined drought-related mortality methodology developed last year to the greater CONUS. A paper on the epidemiological methodology developed last year was submitted to *Environmental Health Perspectives*.

Interaction opportunities between the drought and public health communities. NIDIS and UNMC convened a National Drought and Public Health Summit in Atlanta, Georgia, in June 2019. Local, state, federal, tribal, nonprofit, and academic stakeholders convened for a discussion around the linkages between drought and human health. The goal of this summit was to discuss ways to properly prepare our public health agencies and organizations for the health hazards associated with drought in order to reduce negative outcomes and save lives. https://www.drought.gov/drought/news/nidis-summit-connects-drought-and-public-health

Fifty participants engaged in active discussions regarding drought, its impact on human health, and the populations most affected by drought. Speakers from a broad range of organizations provided a look into the current state of knowledge for drought research and preparedness activities. The summit concluded with a facilitated discussion, during which participants brainstormed next steps and action items to address drought and human health in their own work.

Figure 1*. Dr. Jesse Bell leads a discussion at the National Drought and Public Health Summit, which brought together experts across disciplines and expertise to understand the impacts of drought on human health.*

Planned work

UNMC subcontract project work will continue under the new NOAA cooperative institute, the Cooperative Institute for Satellite Earth System Studies.

Product

- National Drought and Public Health Summit

Publications

Johansson, M. A., and Coauthors (including **J.E. Bell**), 2019: An open challenge to advance probabilistic forecasting for dengue epidemics. *Proceedings of the National Academy of Sciences of the United States of America*, **116**, 24268–24274, https://doi.org/10.1073/pnas.1909865116.

Rennie, J., **J. E. Bell**, K. E. Kunkel, S. Herring, H. Cullen, and A. M. Abadi, 2019: Development of a submonthly temperature product to monitor near-real-time climate conditions and assess long-term heat events in the United States. *Journal of Applied Meteorology and Climatology*, **58**, 2653–2674, https://doi.org/10.1175/JAMC-D-19-0076.1.

Presentations

Bell, J., 2019: Role of public health in dealing with drought. *2019 Water for Food Global Conference*. Lincoln, NE, April 30, 2019.

Bell, J., 2019: Health hazards associated with drought. *Western Regional Agriculture Safety and Health Conference*, Seattle, WA, August 8, 2019.

Bell, J., 2019: Why drought matters to human health. *Western Region Agriculture Safety and Health Conference*, Seattle, WA, August 8, 2019.

Other

- Postdoctoral researcher mentored: Dr. Azar Abadi and Dr. Babak Fard
- PhD students mentored: Qianqian Li, Hunter Jones, and Jagadeesh Puvvula
- MPH student mentored: Zackery Rodriguez
- Undergraduate Student: Riley Tenopir

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

Convened a National Drought and Public Health Summit in June 2019.

Software Development of a Cloud-Based Data Processing Prototype for GHCN-D	
Task Leader	Bjorn Brooks
Task Code	NC-SON-02-NCICS-BB
NOAA Sponsor	Jeff Privette / Scott Hausman
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation
NOAA Strategic Research Priorities	Environmental Obervations

Highlight: This project reexamines the Global Historical Climatology Network-Daily (GHCN-D) data pipeline to deliver a functional prototype that can operate on any cloud computing platform. Automation, scalability, and efficiency will be demonstrated and compared against 1) the existing in-house process and 2) the existing process if ported over to the commercial cloud.

Background

The Global Historical Climatology Network-Daily (GHCN-D) is a historical weather data observation product. Many services obtain their data from the GHCN-D database, which is maintained by NCEI in coordination with the Community Collaborative Rain, Hail and Snow Network.

GHCN-D includes daily weather summaries from across a network of more than 100,000 surface weather stations. Each individual observation has been subjected to a common quality assurance methodology that vets the data to ensure that it is accurate and can be used as a climactically representative summary observation.

The present GHCN-D dataflow process consists of a custom research code base that is run in-house on high-performance computing machines. Over time, the abundance of global network data and the complexity of parsing and analysis are growing, which leads to an ever-increasing demand for software code-base maintenance to ensure processing is 1) efficient and 2) backward-compatible with changing technology. This periodic process of maintaining legacy code will become impractical and far removed from the current state of data archival and dissemination. This project will reexamine the GHCN-D data ingest code base and present a modernized prototype that can achieve bit-for-bit identical results in a fraction of the time on any computer hardware system, including the commercial cloud. This alternative dataflow process will be capable of operating in the cloud, will require far less code maintenance, and will be more scalable across distributed networks.

Planned work

- Set up GHCN-D processing framework as a graph database
- Demonstrate automated data ingest capability of the graph database for a routine data source
- Demonstrate quality assurance/quality control compatibility of the graph database process versus existing process
- Produce benchmark stats for the graph database performance and scalability
- Demonstrate the efficiency and effectiveness of cloud-native approaches to GHCN-D algorithm
- Quantify the temporal and financial costs of processing GHCN-D in the cloud

This project will result in both a NoSQL database and a live API. The API will be attached to the GHCN-D database and will have the capacity to control and track access to GHCN-D by community users.

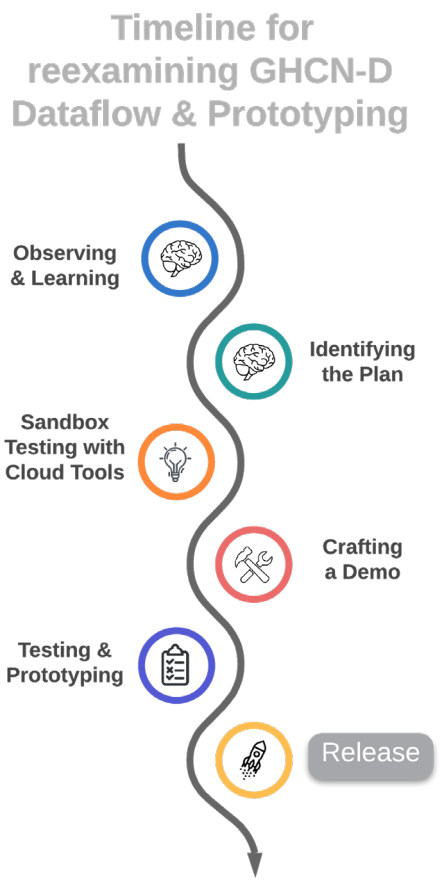


Figure 1. *This timeline of the proposed work broadly illustrates the steps involved. To date, the Observing and Learning through Sandbox Testing steps have been completed, and currently, a live demo is being created. This demo includes both a functioning database that regularly ingests new weather measurements from around the globe and an API (application programming interface) that controls access and distribution of the data.*

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

Optimum Interpolation Sea Surface Temperature (OISST) Algorithm Upgrades	
Task Leader	**Garrett Graham**
Task Code	NC-SON-03-NCICS-GG
NOAA Sponsor	Rost Parsons/Huai-min Zhang
NOAA Office	NESDIS/NCEI
Contribution to Research Themes	Climate and Satellite Observations and Monitoring
Main Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation
NOAA Strategic Research Priorities	Environmental Observations

Highlight: The task team successfully aided in upgrading the OISST dataset. This upgrade addressed a loss of buoy data due to data-transmission formatting changes, corrected bias errors with ship-derived temperature data, and streamlined the overall processing pipeline. The team will next study options for incorporating data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instruments on the NOAA-20 and Suomi-NPP satellites for a subsequent version of the OISST product.
https://www.ncdc.noaa.gov/oisst

Background

The Optimum Interpolation Sea Surface Temperature (OISST) dataset is one of NOAA's oldest continuously offered satellite-based products. Beginning in 1981 and running until the present, the OISST has undergone numerous upgrades to address emerging challenges and to incorporate new and/or improved technologies. OISST Version 2.0 came online in 2002 and has undergone significant upgrades since then, without undergoing a significant enough improvement to warrant a versioning change. Since the last major improvement in 2014, the quality of the OISST product has slowly degraded for two reasons. The first and most significant reason is a slow and steady loss of buoy spatial coverage as a result of a slow conversion of buoys from the Traditional Alphanumeric Code (TAC) data transmission protocol to the newer Binary Universal Form for the Representation of meteorological data (BUFR) (OISST v2.0's source for buoy and ship observations only accepted TAC data). The second reason for the degradation in OISST v2.0's quality was from improvements in the quality of ship observations. As ships' engine intake thermometers improved in their accuracy and precision, OISST v2.0 gradually began to over-adjust the ship observations by applying what has become too large of a bias correction. Thus, improvements were required in the OISST implementation in order for the product to remain relevant.

Accomplishments

The project team switched to a new NCEI database to source ship, buoy, and Argo float observations, and this has massively increased spatial in situ coverage. In addition, the team reduced the magnitude of the bias correction for ship observations to more appropriate values. All of these improvements have been demonstrated empirically via a series of computational experiments. Together, these experiments show that the quality of OISST v2.1 is much greater than that of OISST v2.0's more recent datasets OISST version 2.1 became operational in March 2020.

Planned work

- Incorporate VIIRS observations from the NOAA-20 and Suomi-NPP satellites to further improve the accuracy and reduce the variability of the OISST product
- Potentially implement algorithmic improvements in the core OI algorithm itself or within its pre-processing steps
- Refactor the code where appropriate

Product
Optimum Interpolation Sea Surface Temperature v2.1

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

Version 2.1 of OISST is now operational.

U.S. Climate Reference Network (USCRN) Applications and Quality Assurance	
Task Leader	Ronald D. Leeper
Task Code	NC-SON-04-NCICS-RL
NOAA Sponsor	Jeff Privette / Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 20%
	Theme 2: Climate and Satellite Observations and Monitoring 80%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: CICS-NC assisted in the evaluation and initial transition from the *HydraProbe* to *Acclima* soil sensor, which also involved streamlining the manual quality control (QC) process. Validation and verification of the reconstructed hourly land surface temperature dataset at USCRN and Surface Radiation Budget Network (SURFRAD) stations was also completed.

Background

The U.S. Climate Reference Network (USCRN) is a systematic and sustained network of climate monitoring stations deployed across the contiguous United States, Hawai'i, and Alaska. These stations use high-quality calibrated instrumentation to measure temperature, precipitation, wind speed, soil (temperature and moisture) conditions, humidity, land surface (infrared) temperature, and solar radiation. In addition to monitoring weather and climate, the network can be leveraged as a reference to other in situ and remotely sensed datasets and to support the development of products that are both internal and external to USCRN. Recently, a decision was made to evaluate a new soil sensor (*Acclima*) to improve the network's capacity to monitor soil moisture conditions in high-clay-content soils, mostly in the U.S. Southeast. This transition is expected occur over several years as the new *Acclima* sensor slowly replaces the original *HydraProbe*.

Accomplishments

Soil. The USCRN evaluated a new soil sensor, the *Acclima* probe, by comparing it against the current *HydraProbe* in both a homogeneous test bed and at 43 USCRN stations. Results from these comparisons revealed that the *Acclima* probe had similar observations of volumetric and temperature conditions in the homogenous test bed and provided more realistic soil moisture conditions (lower volumetric conditions) compared to the *HydraProbe* at stations with high-clay-content soils (Figure 1). As the transition to the new sensor continues across the network, soil moisture and temperature quality control methods, which were mostly manual, are being revised, exploring opportunities to make this process more automated using machine-learning techniques. To this end, a manual review of the 217 *Acclima* sensors currently in the ground was completed to curate a training dataset for machine-learning-based approaches.

All-Sky Land Surface Temperature. Remotely sensed surface solar absorption was combined with daily temperature extremes (daily maximum and minimum) to estimate hourly land surface temperatures (LSTs). USCRN's hourly LST and solar radiation observations were used as a training dataset to estimate and constrain the relationship between surface solar absorbtion and LST. This technque was sucessfully applied to several stations from both USCRN and the Surface Radiation Budget Network (SURFRAD) (Figure 2).

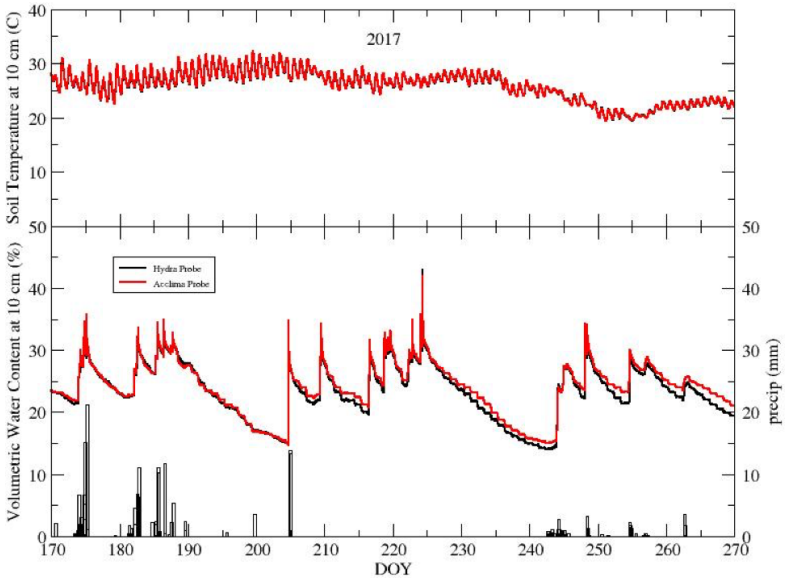


Figure 1. *Hourly time series of the soil temperature and volumetric water content measured by the Acclima probe and HydraProbe in the soil test bed from DOY 170 to 270, 2017.*

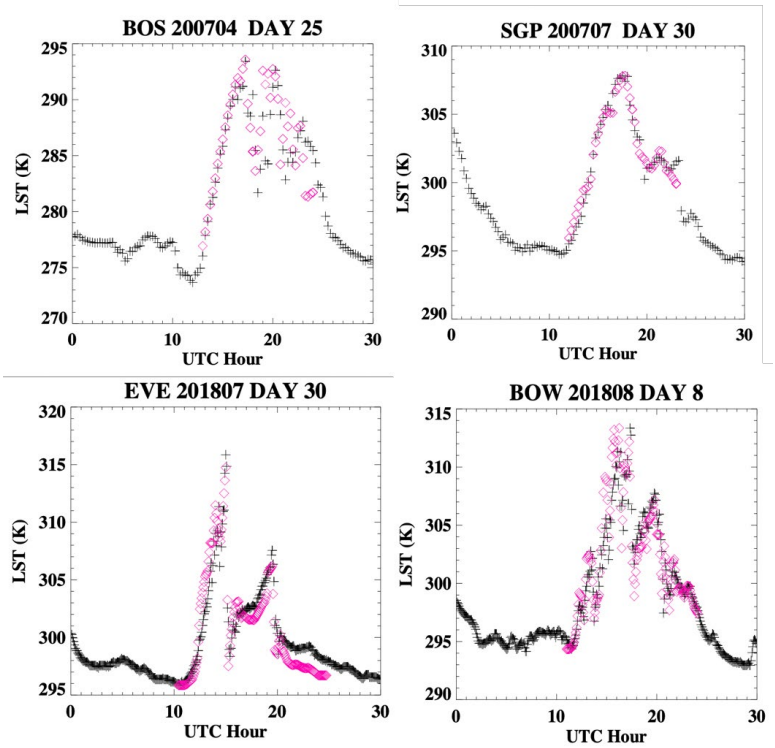


Figure 2. *In situ (black) and reconstructed (purple) hourly LST for SURFRAD site Table Mountain, CO (top-left), and Southern Great Plains, OK (top-right), and USCRN Everglades City, FL (bottom-left), and Bowling Green, KY (bottom-right), for dates shown on top.*

Planned work
USCRN support activities will continue under the successor cooperative institute, CISESS.

Publication
Leeper, R. D., J. Kochendorfer, T. Henderson, M. A. Palecki, 2019: Impacts of small-scale urban encroachment on air temperature observations. *Journal Applied Meteorology and Climatology*, **58**, 1369–1380, http://doi.org/ 10.1175/JAMC-D-19-0002.1.

Presentation
Leeper, R. D. and M. A. Palecki, 2019: U.S. Climate Reference Network Soil Moisture Collection and Processing. *National Soil Moisture Network Soil Moisture Working Group*, Asheville, NC, June 12, 2019.

Other
- Proposed a technique to improve the efficiency of manual quality control that would fundamentally change how redundant soil moisture observations are integrated
- Developed an outline for an automated QC approach that captures the majority of the necessary flags

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

Standardization of U.S. Climate Reference Network (USCRN) Soil Moisture Observations	
Task Leader	Ronald D. Leeper
Task Code	NC-SON-05-NCICS-RL
NOAA Sponsor	Jeff Privette / Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: The operational standardized soil moisture product was compared with other hydrological indicators, including the standardized precipitation index (SPI), standardized precipitation–evapotranspiration index (SPEI), and the U.S. Drought Monitor. These comparisons revealed that combining standardized soil moisture conditions with other indicators can provide insight on drought onset and amelioration.

Background

Soil moisture observations are challenging to interpret and use. Interoperability issues stem from the sensitivity of observations to localized factors such as soil characteristics, vegetation cover, topography, and climate (e.g., precipitation patterns). As such, the same soil moisture observation can have very different meanings depending on where and at what time of year the measurement was taken. These challenges have been overcome by placing measurements into historical context, a technique referred to as standardization. The short-term (less than 10 years) standardization method has been applied to all soil-moisture-observing USCRN stations and available depths (5, 10, 20, 50, and 100 cm), resulting in soil moisture climatologies, anomalies, and percentiles that augment station observations.

Accomplishments

USCRN standardized soil moisture anomalies and percentiles were compared against other commonly used drought indicators, including the standardized precipitation index (SPI) and the standardized precipitation–evapotranspiration index (SPEI). To evaluate these separate indicators, U.S. Drought Monitor (USDM) data were used to define unique drought events at each USCRN station (Figure 1). From these events, it was found that measures of precipitation and soil moisture were more closely aligned in the months before and following drought than during or outside of drought events (Figure 2). These results suggest that combining soil moisture with SPI and SPEI can provide a leading indicator of drought onset. Additionally, a series of weekly drought monitoring metrics were derived from the standardized soil moisture datasets and evaluated over each of these drought events. The percent of weekly hours below the 20th percentile and weekly anomaly averages were well correlated with USDM-based drought evolution, demonstrating that these datasets show some promise as monitoring tools.

In a separate analysis, comparisons between the Kentucky Mesonet soil moisture observations and the Evaporative Demand Drought Index (EDDI) and Landscape Evaporative Response Index (LERI) suggest that soil moisture change may prove useful in identifying when drought events evolve from energy-limited to moisture-limited states. This can have important implications for agricultural land management and drought monitoring/response. Efforts to apply the standardization methodology against remotely sensed soil moisture observations is underway using the European Copernicus blended satellite dataset, which provides near-global soil moisture observations back to 1979.

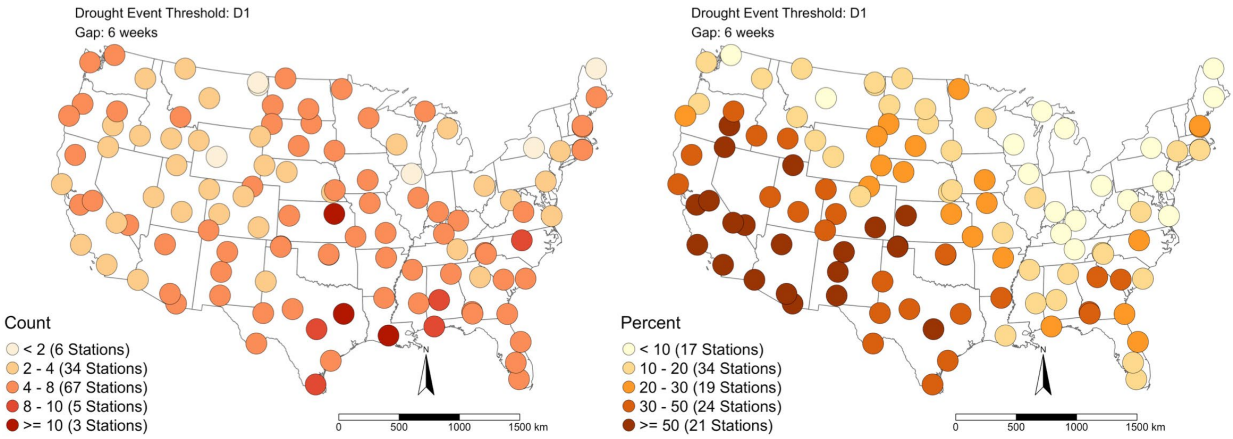


Figure 1. *USCRN station (left) counts of unique drought events and (right) percent of time in drought from 2010 through 2018.*

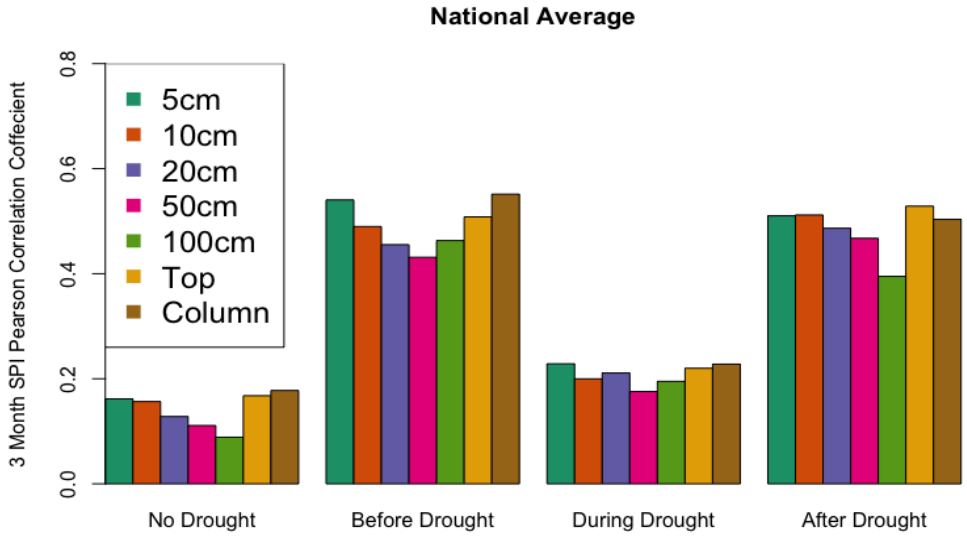


Figure 2. *Pearson correlation coefficients between USCRN standardized soil moisture anomalies and the SPI for months in the categories No Drought, Before Drought (3-month period prior to onset of a drought event), During Drought, and After Drought (3-month period following drought events) and for all monitored depths and aggregated levels—Top (combined 5 and 10 cm level) and Column (all depths combined).*

Planned work

USCRN support activities will continue under the successor cooperative institute, CISESS.

Products

- USCRN soil moisture climatologies
- USCRN standardized soil moisture anomalies and percentiles

Presentations

Leeper, R. D., 2019: Evaluating the Linkages between Soil Moisture and Drought. *2019 National Soil Moisture Network Workshop: Expanding the Frontiers of Soil Moisture Measurements and Applications*, Manhattan, KS, May 22, 2019.

Leeper, R. D., M. A. Palecki, and B. Petersen, 2019: Efficacy of Drought Indices Derived from In Situ Soil Moisture Observations. *U.S. Drought Monitor Forum*, September 18, 2019.

Other

- Two technical reports (Product Description and Verification and Validation) were generated for NCEI's Science Council beta readiness review.
- Hollings Scholar Bryan Petersen of Lincoln, NE, helped evaluate drought metrics over the summer of 2019

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

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	
Task Leader:	Douglas Miller
Task Code	NC-SON-06-UNCA
NOAA Sponsor	Dan Lindsey
NOAA Office	NESDIS/GOESPO
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications
	Theme 2: Climate and Satellite Observations and Modeling
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50%
	Goal 2: Weather-Ready nation 50%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: Completed the Spring 2019 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).

Background

The Duke University Great Smoky Mountains National Park Rain Gauge Network (Duke GSMRGN), originally funded by NASA to measure rainfall accumulation at 32 mid- (~3,400 feet) and high- (~6,600 feet) elevation locations in the Pigeon River basin (Figure 1 and Table 1 of Miller et al. 2018), has collected observations since June 2007. One of the overarching goals of the NASA-funded study (Barros et al. 2014) was to advance the understanding of physical processes responsible for precipitation production in a temperate mountain range and to incorporate knowledge of these processes in NASA-derived rain-rate retrieval algorithms. Although analysis of the 10-year (July 2007–June 2017) record of precipitation observations continues, significant findings have emerged and been published (e.g., Wilson and Barros 2014, Duan et al. 2015, Miller et al. 2018, Miller et al. 2019).

NASA funding for the Duke GSMRGN ended with calendar year 2014, and other internal ad hoc Duke University grant support ended in calendar year 2015. This project represents a collaborative research effort to extend the period of observations of the Duke GSMRGN for three years beyond 1 July 2016, with funding provided by UNC Asheville, the Scripps Institution of Oceanography Center for Western Weather and Water Extremes, and NOAA NESDIS.

Accomplishments

Gauge visitation in support of the Duke GSMRGN occurred over 10–14 days spanning a 10-week period for the spring 2019 cycle (12 March–18 May). Volunteers accompanied technicians to assist with personal safety (should someone become injured during a particular series of gauge visits) but were not directly involved in gauge visit tasks. The primary purpose of each gauge visit is to 1) perform downloads of gauge tip observations since the previous gauge visits, 2) complete maintenance tasks (general gauge maintenance and data logger condition monitoring), 3) clear vegetation and tree limbs within a 5-foot radius of the rain gauge, and, 4) where necessary, calibrate the rain gauges (three calibration trials using the 50, 100, and 300 mm nozzles) and/or replace lithium batteries that have drained to a low voltage. Tasks may vary slightly depending on the season and/or issues identified in previous gauge visits.

Spring 2019: 12 March–18 May 2019
Ten technicians and volunteers made the visits and performed the required work.

All of the field rain gauges were calibrated when the last calibration was completed in spring 2018.

Regular maintenance and datalogger condition monitoring tasks resulted in the following:

- *Preventative lithium battery replacements* at gauges #010 [ML1-420], #108 [ML1-420], #311 [ML1], and #300 [ML1-420] to ensure record continuity between spring and summer 2019. Significant problems have been observed with ML1-420 loggers draining the lithium batteries down in a very short period of time.
- The g103 ML1-420 logger lithium battery voltage (replaced during the autumn 2018 visit) was found to have dropped below 3.00V. Comparing the g103 rain record to that of nearby g102 and g101, the low-voltage logger was able to detect all precipitation events through 15 March 2019. Another data logger will have to be installed at g103 if the logger battery voltage shows a significant drop between spring and autumn 2019.
- g#310 (near the Mt. Sterling fire tower) reflected error message "3.6V Lithium Battery Needs Replacing." No data record was retrievable from this logger during the 9 May 2019 visit.
- g110 ML1 logger continued to show a poor response using the TA command and may require replacement during the summer 2019 visit if improvement isn't noted after trying the TA "clear" command ("TA=<cr>").
- g105 ML1 logger bucket tip testing reflected no registration of three test bucket tips. Logger wires were changed from switch #1 to switch #2 (similar to problems found at g #109 in 2016 and at g #106 in 2018). It is unknown when, during the winter season, this switching problem became significant such that g105 failed to register bucket tips forced by rainfall.

Liquid wrench was needed at g101, g103, and g108 in the summer 2019 visit to remove rusty bolt port nuts, and rusty nuts will need to be replaced with new stainless steel nuts.

One location (g311) will need tree limbs cleared using an extension saw, and one location (g308) will need a rope saw to clean limbs from almost overhead during the summer 2019 visit.

Challenges encountered during some of the gauge visits in the spring 2019 were 1) muddy and rainy conditions early in the campaign (resulting in gauge visit postponements and scheduling challenges), and 2) surprisingly large voltage drops in the loggers at several rain gauge locations (see description above). Otherwise, the gauge network was functioning as smoothly as possible. A new *Davis Pro* weather station has been installed near the Mount Sterling fire tower, next to g310. The owner of the weather station (and data) at Duke Power has yet to respond to repeated inquiries about the sharing of weather data helpful in discerning the source of bucket tips (falling rain or melting ice/snow).

Details of each gauge visit with quality-controlled precipitation CSV format files can be accessed at:
http://blizzard.atms.unca.edu/dmiller/GSMRGN_report_20may2019.pdf,
https://drive.google.com/file/d/1KNVHkB-G2hxCaRSsvKcvyRxtQnY8mraH/view?usp=sharing

Planned work

- The Spring 2019 gauge visitation was the last scheduled maintenance and data collection cycle under this CICS-NC project. Additional gauge visits are scheduled under the new CISESS NC project.

The technician roster during the 2018–2019 academic year consisted of Meredith Avison, Marlee Burgess, Lyn Comer, Alex Flynt, Andrew Hill, Alice Monroe, Jacob Thome, and Zachary Tuggle.

Products

- Ralph Ferraro's group, including one University of Maryland undergraduate intern (J. Hill), used collocated 24-hr Duke GSMRGN precipitation observations for examining GOES-16 Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR, Kuligowksi et al. 2002) over a study period in 2017.

- Bob Kuligowski's group is using observations of the Duke GSMRGN as part of validation efforts in their research (Kuligowski 2002).

Other

Ten undergraduate students of the University of North Carolina Asheville received field research credit based on assisting Principal Investigator Miller with the activities described in the Accomplishments section.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**11**

References

Barros, A. P., Petersen, W., Schwaller, M., Cifelli, R., Mahoney, K., Peters-Liddard, C., Shepherd, M., Nesbitt, S., Wolff, D., Heymsfield, G., Starr, D., Anognostou, E., Gourley, J. J., Kim, E., Krajewski, W., Lackman, G., Lang, T., Miller, D., Mace, G., Petters, M., Smith, J., Tao, W.-K., Tsay, S.-C., and Zipser, E.: NASA GPM-Ground Validation: Integrated Precipitation and Hydrology Experiment 2014 Science Plan, Duke University, Durham, NC, 64 pp., doi:10.7924/G8CC0XMR, 2014.

Duan, Y., Wilson, A. M., Barros, A. P.: Scoping a field experiment: error diagnostics of TRMM precipita-tion radar estimates in complex terrain as a basis for IPHEx2014, Hydrology and Earth System Sciences, 19, 1501- 1520, doi:10.5194/hess-19-1501-2015, 2015.

Kuligowski, R. J.: A self-calibrating real-time GOES rainfall algorithm for short-term rainfall estimates.this link opens in a new window J. Hydrometeor., 3, 112-130, 2002.

Miller, D.K., Hotz, D., Winton, J., Stewart, L.: Investigation of atmospheric rivers impacting the Pigeon River Basin of the southern Appalachian Mountains. Wea. Forecasting, 33, 283 - 299 https://journals.ametsoc.org/doi/pdf/10.1175/WAF-D-17-0060.1, 2018

Wilson, A. M. and Barros, A. P.: An investigation of warm rainfall microphysics in the southern Appala-chians: Orographic enhancement via low-level seeder–feeder interactions, J. Atmos. Sci., 71, 1783–1805, doi:10.1175/jas-d-13-0228.1, 2014.

Development of the United States Climate Reference Network (USCRN) National Precipitation Index	
Task Leader	Jared Rennie
TaskCode	NC-SON-07-NCICS-JR
NOAA Sponsor	Michael Palecki, Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 50% Theme 2: Climate and Satellite Observations and Monitoring 50%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50% Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: An algorithm to build a national precipitation index (NPI) using 100+ stations from the United States Climate Reference Network has been in development and updated to 2019. A white paper has been completed, and the team is working to make the NPI operational at NCEI.

Background

NCEI produces a monthly National Temperature Index (NTI), a set of calculations of air temperature for the contiguous United States at the monthly, seasonal, and annual time scales. Two versions of NTI are displayed: one is derived using only the stations from the United States Climate Reference Network (USCRN), and the other is a compilation from thousands of stations across the United States interpolated onto a 5-kilometer-resolution gridded temperature product called nClimGrid. USCRN was developed to provide long-term homogeneous observations for the detection and attribution of present and future climate change and is used as a reference to evaluate how well the historical stations measure U.S. climate.

To date, no National Precipitation Index (NPI) set analogous to the NTI set has been operational, although NCEI's Climate at a Glance (CAG) tool does provide national estimates of precipitation at the monthly, seasonal, and annual scale based on the nClimGrid 5 km gridded product. To facilitate precipitation comparisons like those available for NTI, the USCRN team has developed its own version of NPI.

Accomplishments

An algorithm was developed and finalized. One hundred and seven stations from the 114 USCRN sites encompassing the contiguous United States were used in this analysis. For the 7 sites with paired stations, one was chosen from each pair based on data availability and quality. Monthly measurements of precipitation (in millimeters) were extracted for each station from the monthly product on the USCRN website. For continuous and ubiquitous coverage of precipitation, data from 2006–2018 were used, with updates including data through the end of 2019. These precipitation values were calculated with the assistance of a wetness sensor beginning in 2007.

A white paper describing the methodology was drafted and approved by members of the NCEI dataset section. Data has been updated to 2019 and is being closely monitored during 2020. The CRN team will meet with the NCEI monitoring team to discuss next steps in making this product operational on their website. This includes porting over the code base to NCEI monitoring systems, as well as updating figures when new data become available. Finally, an operational readiness review (ORR) needs to be initiated and approved by NCEI before the product becomes operational.

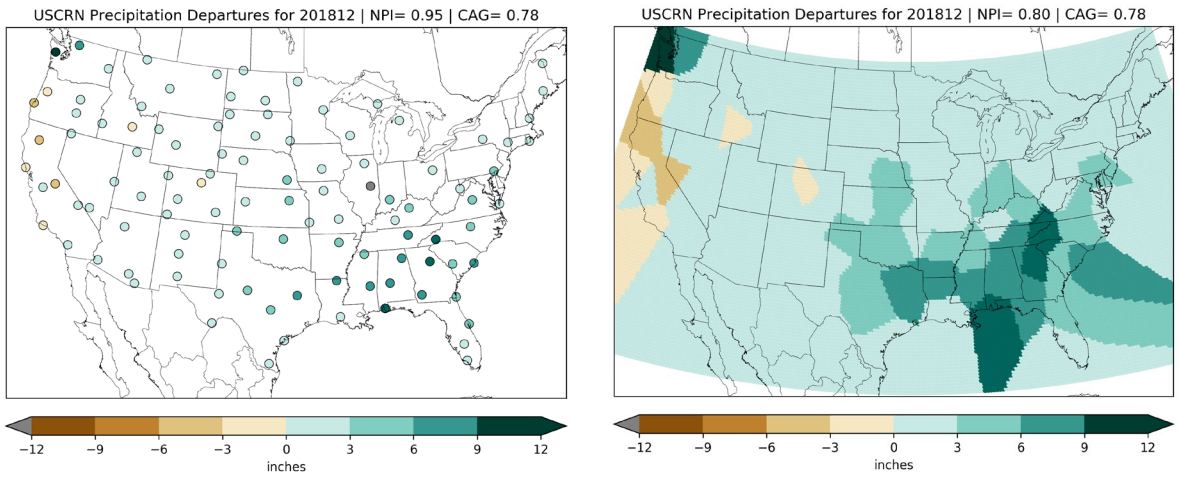


Figure 1. *Prototype of the monthly USCRN National Precipitation Index for December 2018. (left) Values of NPI at individual USCRN stations. (right) Gridded values after interpolation scheme applied.*

Planned work

Support will continue under the successor cooperative institute CISESS.

Products

- The National Precipitation Index dataset has been updated.

Other

- NCEI's National Temperature Index: https://www.ncdc.noaa.gov/temp-and-precip/national-temperature-index/
- NCEI's Climate at a Glance: https://www.ncdc.noaa.gov/cag

Performance Metrics	
# of new or improved products developed that became operational	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**1**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

The product is being considered to supplement the NTI on the NCEI webpage, pending ORR and coordination with the NCEI monitoring team.

Maintenance and Streamlining of the Global Historical Climatology Network-Monthly (GHCNm) Dataset	
Task Leader	Jared Rennie
Task Code	NC-SON-08-NCICS-JR
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: The next iteration of NOAA's global temperature product has been developed and is operational. Updates are ongoing and provided as necessary. www.ncdc.noaa.gov/ghcnm/

Background

Since the early 1990s, the Global Historical Climatology Network-Monthly (GHCNm) dataset has been an internationally recognized source of information for the study of observed variability and change in land surface temperature. The fourth version of this product has undergone many updates since its initial release in 2018. Updates include incorporating monthly maximum and minimum temperature, improving processing run time, and providing user-driven products. Currently the product is at version 4.0.1 and includes over 25,000 stations globally.

The success of GHCNm version 4 stems from a need to address gaps in data coverage and improve documentation of data provenance. The International Surface Temperature Initiative (ISTI), developed in 2010, has addressed these issues by developing a state-of-the-art databank of global surface temperature observations. Released in 2014, the first version of the databank contains data from more than 30,000 surface temperature stations, has an open and transparent design, and documents observations back to the original source data. Many international organizations have heralded this development and provided feedback that has gone into subsequent updates. All versions are available online, and the current operational version, version 1.1.1, was released in late 2017.

Because of the increase in the number of stations, along with its transparency, this databank serves as the starting point for version 4 of GHCNm. A new end-to-end processing system was established with updates, ingest, and quality control procedures. In addition, the algorithm to remove non-climatic influences in the observations was updated to incorporate the addition of stations and to adhere to NCEI coding standards.

Accomplishments

The current ISTI databank is version 1.1.1. Much work has been done to GHCNm version 4 since its operational release in October 2018. In May 2019, it was upgraded to version 4.0.1, which includes minor changes to the dataset. These include updating the World Record Extremes Check to incorporate the record warmest month occurring at Death Valley, California, in July 2018 (monthly average value of 108.1°F). Station metadata was also upgraded using NCEI's Historical Observing Metadata Repository (HOMR). This information helps train the Pairwise Homogeneity Adjustment algorithm to detect breakpoints. This version of GHCNm was also used to develop the latest version of NOAAGlobalTemp version 5 (NGTv5), which incorporates both land (GHCNm) and sea surface (ERSST) temperature data. A paper has been drafted and accepted, and NGTv5 is now being used in monthly monitoring reports by NCEI.

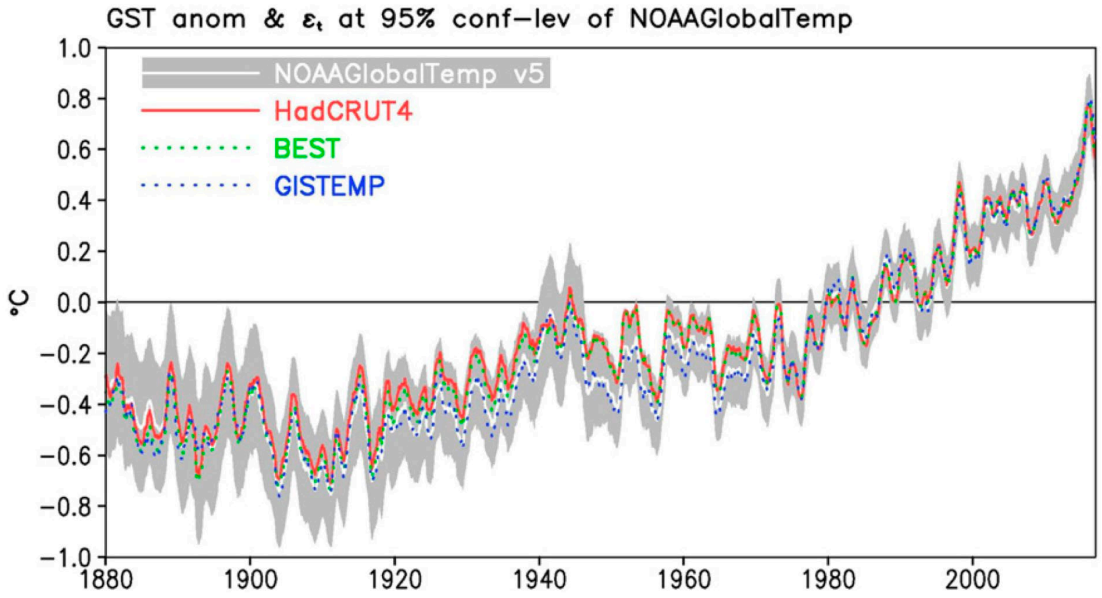


Figure 1. *Globally averaged surface temperature anomaly and 95% confidence interval in NOAAGlobalTemp version 5, which incorporates GHCNm version 4.0.1. Data is compared against HadCRUT4 (Met Office), BEST (Berkeley Group), and GISTEMP (NASA).*

Updates are developed on an NCEI-provided three-tiered system, including development, test, and production environments. Nightly runs are performed internally and checked by the ISTI and GHCN teams to ensure adequate data quality. In early 2020, all three systems were upgraded to new NCEI servers running on *Red Hat* version 7. Data integrity tests were performed to ensure no issues existed on the new operating system. Finally, an installation script was developed and pushed to NCEI's git repository to ensure version control and portability. Once the code base has been set up and run by a NOAA employee, the work performed by CICS will be completed.

Planned work

Assist NOAA employees with version control and executing the GHCNm version 4 code base

Products

- Public, operational version of GHCNm version 4.0.1
- NOAAGlobalTemp version 5, with journal article published describing methods

Publications

Huang, B., M. J. Menne, T. Boyer, E. Freeman, B. E. Gleason, J. H. Lawrimore, C. Liu, **J. J. Rennie**, **C. J. Schreck III**, F. Sun, R. Vose, C. N. Williams, X. Yin, and H.-M. Zhang, 2020: Uncertainty estimates for sea surface temperature and land surface air temperature in NOAAGlobalTemp version 5. *Journal of Climate.* https://doi.org/10.1175/JCLI-D-19-0395.1.

Presentations

Rennie, J., 2019: Climate in Your Neck of the Woods: A Real Time, Interactive GIS Product to Assess Historical and Current Trends in Temperature and Precipitation. *National Weather Association (NWA) Annual Meeting*, Huntsville, AL, September 10, 2019.

Other

- The International Surface Temperature Initiative: www.surfacetemperatures.org
- FTP site of GHCNm version 4: ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/v4/

Performance Metrics	
# of new or improved products developed that became operational	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**1**
# of NOAA technical reports	**0**
# of presentations	**1**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

GHCNm version 4.0.1 and NOAAGlobalTemp version 5 are now operational.

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool	
Task Leader/Task Team	Jared Rennie, Kenneth Kunkel
Task Code	NC-SON-09-NCICS-JR/KK
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 50% Theme 2: Climate and Satellite Observations and Monitoring 50%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50% Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Environmental Observations

Highlight: A sub-monthly tool for monitoring impacts of temperature extremes in the United States has been created and described in an article in an American Meteorological Society journal. The resulting dataset can be used to assess heat extreme events in the United States from 1895–2018 and can be compared against other relevant data. https://ncics.org/portfolio/monitor/sub-monthly-temperatures/

Background

Land surface air temperature products have been essential for monitoring the evolution of the climate system. Most temperature datasets require homogenization schemes to remove or change non-climatic influences that occur over time so the dataset is considered homogenous. Inhomogeneities include changes in station location, instrumentation, and observing practices. While many homogenized products exist on the monthly time scale, few daily products exist due to the complication of removing break points that are truly inhomogeneous rather than effects due to natural variability (for example, sharp temperature changes due to synoptic conditions such as cold fronts). However, there is a demand for sub-monthly monitoring tools and thus a need to address these issues.

The Global Historical Climatology Network-Daily (GHCN-D) dataset provides a strong foundation for monitoring the Earth's climate on the daily scale and is the official archive of daily data in the United States. While the dataset adheres to a strict set of quality assurance practices, no daily adjustments are applied. However, this dataset lays the groundwork for other NCEI products, including the climate divisional dataset (nClimDiv), the North American monthly homogenized product (Northam), and the 1981–2010 Normals. Since these downstream products provide homogenization and base period schemes, it makes sense to combine these datasets to provide a sub-monthly monitoring tool for the United States.

Accomplishments

An automated system has been established to extract the latest version of the following datasets each day: GHCN-D, Northam, the 1981–2010 Normals, and nClimDiv. Using these datasets, monthly adjustments are applied to daily data, and then anomalies are created using a base climatology defined by the 1981–2010 Normals. Station data are aggregated to the state level and then region level (as defined by the National Climate Assessment; NCA). Daily plots are made to analyze U.S. temperature values and anomalies. Once daily averages for each state and NCA region are computed, probability distribution functions are generated to provide ranks on different time scales. These are important for understanding recent extremes in a changing climate. Figure 1 provides an example of the operational product, which is similar to ones produced by NCEI, but at a temporal scale shorter than 1 month.

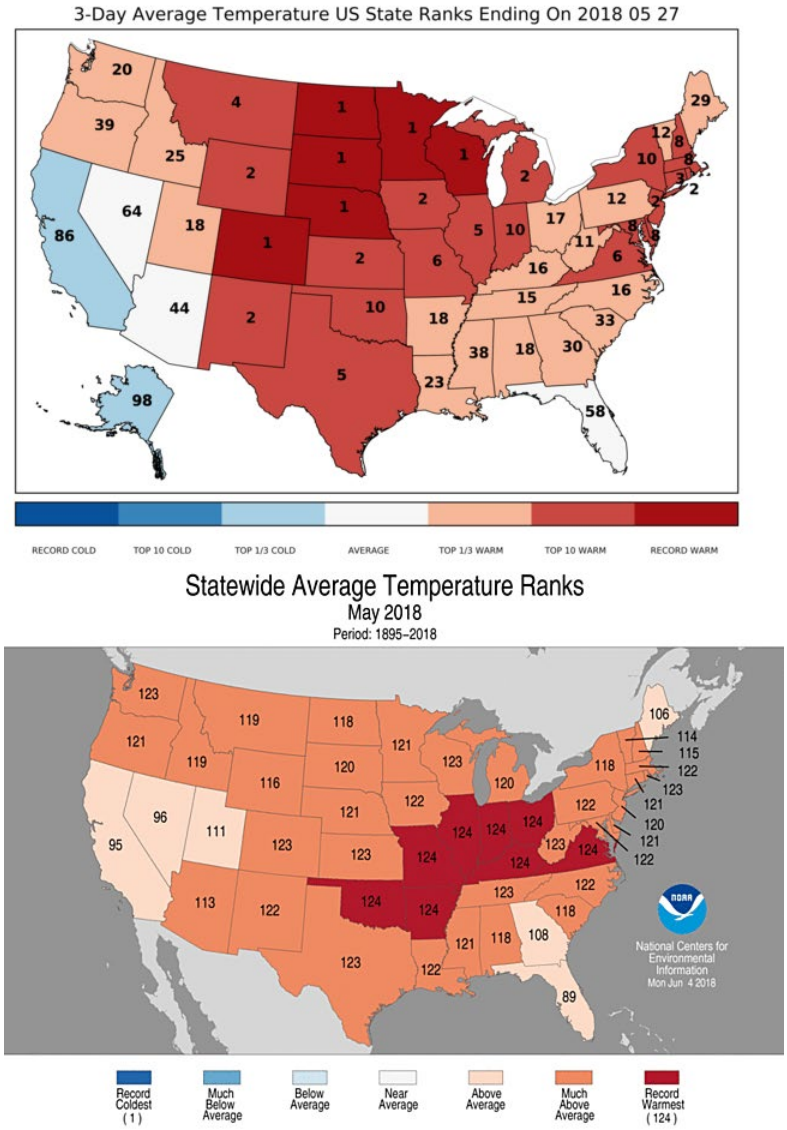


Figure 1. *(Top) Temperature ranks for CONUS and Alaska using 3 days of average temperature readings from 24 to 27 May 2018. Ranks are compared with all 3-day periods of record ending on 27 May and are colorized by severity. (Bottom) The NCEI monthly report for May 2018 (https://www.ncdc.noaa.gov/sotc/national/201805).*

The dataset has been updated through 2018, and heat events are identified using this quasi-homogenized data. To identify an event, the distribution of temperature for a particular area is taken for the period of record, and the 98th percentile of the distribution is taken as the threshold for a much warmer-than-normal heat event. Using this temperature threshold, data are analyzed to search for a consecutive period of three or more days where the value exceeds this threshold. Once an event is found, information including the onset, length, and severity is extracted. Statistics are calculated, including departure from normal, extreme daily maximum and minimum temperatures, and ranks against the period of record. Probability density functions are used to determine how severe the event is against its period of record. Trends are calculated using the Mann–Kendall method, which assesses the significance of a monotonic upward or downward trend over time. Results show the climatology encompasses nearly 3,000 extreme maximum and minimum temperature events across the United States since 1901. A sizeable number of events occurred during the Dust Bowl period of the 1930s; however, trend analysis shows an increase in

heat event number and length since 1951. Overnight extreme minimum temperature events are increasing more than daytime maximum temperatures, and regional analysis shows that events are becoming much more prevalent in the western and southeastern parts of the United States.

A manuscript was published in the *Journal of Applied Meteorology and Climatology* in December 2019. Since publication, the sub-monthly temperature product has been considered operational and can be found here: https://ncics.org/portfolio/monitor/sub-monthly-temperatures/. The heat event database will be updated on an annual basis and will be used as the baseline to match heat event data with available health data provided by the University of Nebraska Medical Center (UNMC), the University of Pittsburgh, and the North Carolina Detect (NC DETECT) organizations. Future work also includes comparison with available data from the United States Climate Reference Network (USCRN), including soil moisture.

Planned work

- Continue to engage with users of the monitoring product
- Work with the University of Nebraska Medical Center and other health-related organizations to identify heat events with available health and socioeconomic data
- Compare dataset with other climate metrics, such as soil moisture

Products

- Updated monitoring tool for sub-monthly data for the United States
- Updated database of heat events through 2018

Publication

Rennie, J., **J. E. Bell**, **K. E. Kunkel**, S. Herring, H. Cullen, and A. M. Abadi, 2019: Development of a submonthly temperature product to monitor near-real-time climate conditions and assess long-term heat events in the United States. *Journal of Applied Meteorology and Climatology*, **58**, 2653–2674, https://doi.org/10.1175/JAMC-D-19-0076.1.

Performance Metrics	
# of new or improved products developed that became operational	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**2**
# of peer-reviewed papers	**1**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

A state-of-the-art monitoring tool for sub-monthly data for the United States is now operational. A heat event database was updated through 2018.

International Comprehensive Ocean–Atmosphere Data Set (ICOADS)	
Task Leader	Scott Stevens
Task Code	NC-SON-10-NCICS-SS
NOAA Sponsor	Rost Parsons/Huai-min Zhang
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Decision Science, Risk Assessment and Risk Communication

Highlight: The International Comprehensive Ocean–Atmosphere Data Set (ICOADS) is the most complete and heterogeneous collection of surface marine data in existence. The high-impact scripts and workflow used to retrieve and process this data were migrated to a new, more robust computation environment.

Background

The International Comprehensive Ocean–Atmosphere Data Set (ICOADS) offers surface marine data spanning the past three centuries, and simple gridded monthly summary products for 2° latitude x 2° longitude boxes back to 1800 (and 1° x 1° boxes since 1960)—these data and products are freely distributed worldwide. As it contains observations from many different observing systems encompassing the evolution of measurement technology over hundreds of years, ICOADS is the most complete and heterogeneous collection of surface marine data in existence. The most recent version, ICOADS Release 3.0 (R3.0; Freeman et al. 2017) released in June 2016, contains over 455 million individual marine reports from 1662–2014, with Near-Real-Time (NRT) extensions from 2015–present.

Accomplishments

This process was successfully migrated to an operational platform in November 2019, having been significantly improved and streamlined. The data flow has been greatly simplified and no longer relies on compiled software, but uses native applications that will run on any *Linux* platform with robustness. Several problems with data timestamps have also been resolved, resulting in much more accurate data.

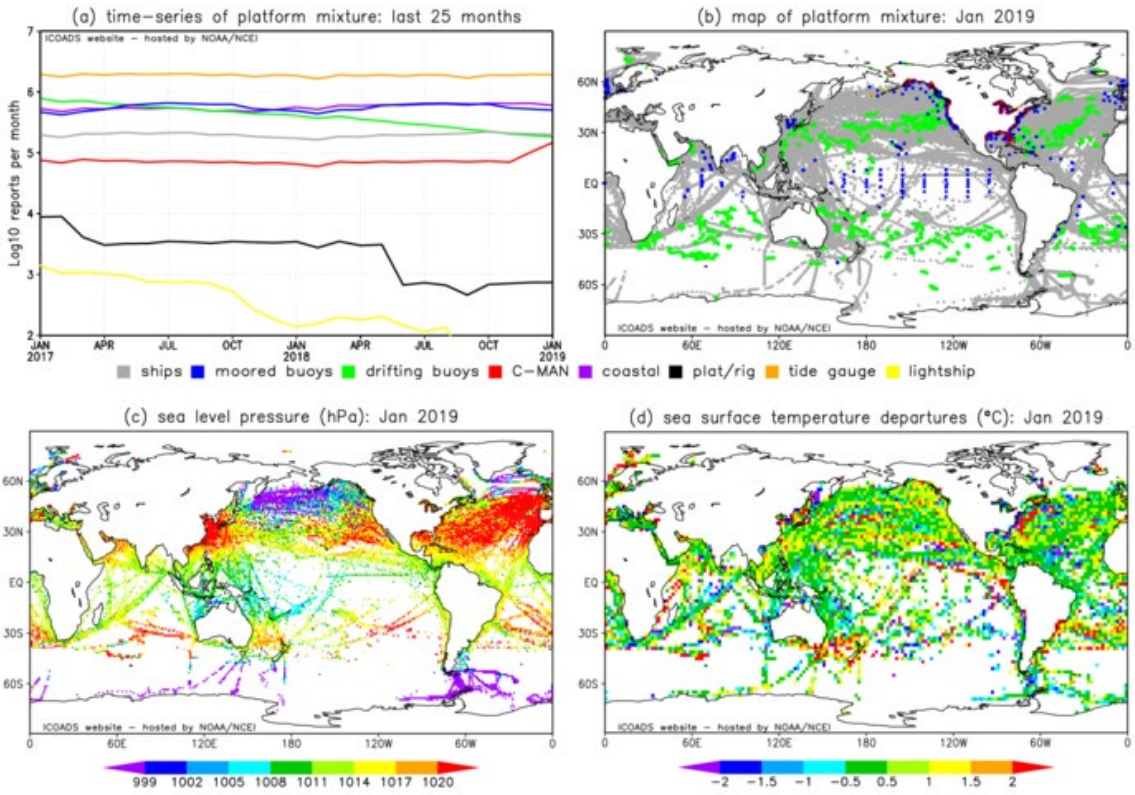


Figure 1. *Example of several variables available through ICOADS.*

Product

- Significantly improved data retrieval and processing system

Planned work

- Continue periodically monitoring output to ensure that data are being produced as expected

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

Improved ICOADS data retrieval and processing system is now operational

Workforce Development

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

Research faculty. Senior CICS-NC scientists hold research faculty positions in the Department of Marine, Earth, and Atmospheric Sciences (MEAS) in the College of Sciences (COS) at North Carolina State University (NCSU) and provide mentorship to junior scientists and students both in CICS-NC and MEAS. Several junior scientists have also secured adjunct appointments in pertinent NCSU departments and at other universities to gain experience and exposure with their academic peers and to mentor graduate students. CICS-NC scientists also mentor students formally and informally (NCICS student internships, NOAA Hollings Scholars, NASA DEVELOP team members, etc.) and engage in various outreach activities to promote awareness and increase interest in K–12 climate science studies.

- Otis Brown and Kenneth Kunkel hold Research Professor appointments in NCSU's MEAS/COS. Kunkel serves as PhD committee chair for CICS-NC research staff members Brooke Stewart and Sarah Champion.
- Carl Schreck holds adjunct Research Assistant Professor appointments with NCSU MEAS and with NC A&T University.
- Jessica Matthews holds an adjunct Research Assistant Professor appointment with NCSU's Mathematics Department.
- Jennifer Runkle holds an adjunct Research Assistant Professor appointment with Appalachian State University.

Post-doctoral scholars. CICS-NC initiated its workforce development program by hiring an initial group of post-doctoral research scholars working on applied research topics in Climate Data Records and Surface Observing Networks. CICS-NC continues to hire post-docs for 2- to 3-year commitments to support identified project needs. Senior scientists from CICS-NC and NCEI provide mentoring for these post-docs. In the past year, CICS-NC personnel included two post-doctoral scholars:

- Andrew Ballinger (PhD, Atmospheric and Ocean Sciences, Princeton University) finished 3 years at NCICS. This year, Ballinger worked with Kunkel and Jenny Dissen in support of the U.S.–India Partnership for Climate Resilience efforts. (See project reports under Assessment and Engagement.)
- Douglas Rao (PhD, Geographical Sciences, University of Maryland) post-doctoral Research Scholar, began his first year at CICS-NC working with Jessica Matthews on developing global blended temperature data using in situ and satellite data. (See project report under Surface Observing Networks.)

Students (graduate/undergraduate/high school). CICS-NC continues to be successful in recruiting and involving area undergraduate and graduate students in temporary student internships, providing an opportunity for the students to explore their interest in science and/or apply their ongoing education to current projects within the institute under the oversight of CICS-NC and NCEI mentors. CICS-NC scientists also serve as mentors and advisors for the NOAA Hollings Scholars and NASA DEVELOP team members who complete their 10-week internship projects at NCEI.

Summer 2019:

- *Margaret Lawrimore*, NCSU undergraduate, worked with Jennifer Runkle to complete a project looking at climate change impacts on reproductive health.
- *Bryan Peterson*, Hollings Scholar and University of Nebraska–Lincoln undergraduate, completed an internship with Ronald Leeper, studying connections between USCRN standardized soil moisture and drought.
- *Mahima Kumara*, Hollings Scholar and Yale University undergraduate, worked with Jared Rennie on building a heat vulnerability index using available climate and socioeconomic data.
- *Charlie Wallin*, Asheville–Buncombe Technical College faculty, collaborated with Linda Copley and Jonathan Brannock on cloud operationalization using Docker and GitLab CI/CD.

Summer and Fall 2019:

- *Ryan Jenkins*, University of North Carolina Asheville undergraduate, worked with Carl Schreck on a typhoon reanalysis project, analyzing historical tropical cyclone pressure data from NCEI to develop a new, more temporally homogeneous wind record.
- *James Goodnight*, Hollings Scholar and NCSU undergraduate, worked with Carl Schreck on the same typhoon reanalysis project.
- *Caitlin Turbyfill*, University of North Carolina at Chapel Hill Master of Public Health student, worked with Jennifer Runkle to develop, test, administer, and analyze a survey examining coastal climate readiness at the Medical University of South Carolina.

Fall 2019:

- The NASA DEVELOP team composed of *Darcy Gray* (Tulane University graduate), *Amiya Kalra* (University of Pittsburgh graduate), and *Amy Kennedy* (Ohio State University graduate) completed their science project, "Using NASA Earth Observations to Quantify the Impact of Urban Tree Canopy Cover on Urban Heat and Identify Community Vulnerability in Asheville, North Carolina," under science advisor Scott Stevens. The project focused on the correlation between tree cover and land surface temperature in Asheville and identified vulnerable communities to support the Urban Forestry Commission's decisions about tree planting and preservation. https://develop.larc.nasa.gov/2019/fall/AshevilleUrban.html
- The NASA DEVELOP team composed of *Adelaide Schmidt* (Delta State University), *Jared Kelly* (University of California, Berkeley), and *Cade Justad-Sandberg* (University of North Carolina Asheville) completed their science project, "Assessing Vegetation Response to Remote Sensing Drought Indices within the Dry Corridor of Central America Using NASA Earth Observations," under science advisor Olivier Prat. The project focused on examining the area of severe and extreme drought during El Niño events in the Central American dry corridor and provided time series maps that visually demonstrated the progression of drought in the region. https://develop.larc.nasa.gov/2019/fall/CentralAmericaDryFoodAg.html

- *Qing Dong*, Hohai University (Nanjing, China) PhD student, completed her year as a Visiting Research Scholar working with Kenneth Kunkel on her graduate research studies involving trends in extreme rainfall and flooding using historical change analyses and future climate model simulations.
- *Lakemarium Worku*, North Carolina A&T PhD student, completed his work with Carl Schreck on his NASA Maritime Continent grant—examining the strong diurnal cycle of convection over the Maritime Continent and demonstrating how it impacts subseasonal to seasonal forecasts—and successfully defended his dissertation.

Other CICS PI Projects

The North Carolina Institute for Climate Studies (NCICS) vision is to *inspire* cutting-edge research and collaboration; *advance* understanding of the current and future state of the climate; and *engage* with business, academia, government, and the public to enhance decision-making. The Institute's main objectives are to promote discovery of new knowledge about global, regional, and local climate variability and its impacts and to provide information that is critical for determining trends and validating climate forecasts at all these spatial scales.

CICS's scientific vision centers on observations (via satellite and surface network instruments) and predictions (using realistic mathematical models) of present and future Earth system behaviors. In this context, observations include the development of new ways to use existing observations, the invention of new methods of observation, and the creation and application of ways to synthesize observations from many sources into a complete and coherent depiction of the full system. Prediction requires the development and application of coupled models of the complete climate system, including atmosphere, oceans, land surface, cryosphere, and ecosystems. Underpinning all Institute projects and activities is the fundamental goal of enhancing our collective interdisciplinary understanding of the state and evolution of the full Earth system.

While CICS-NC projects and activities under the CICS cooperative agreement are the primary NCICS focus, NCICS scientists also participate in and receive partial support through other sponsored research programs awarded through competitive proposal solicitations. Individual and collaborative climate science proposals are submitted through NCSU to relevant federal solicitations.

Climate indicators to Track the Seasonal Evolution of the Arctic Sea Ice Cover to Support Stakeholders	
Task Leader	Ge Peng
Task Code	NC-OTH-01-NCICS-GP
Other Sponsor	NASA
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 75%; Goal 4: 25%
NOAA Strategic Research Priorities	Arctic

Highlight: This project examined the long-term average and temporal variability of the new sea ice climate indicators, including snow melt onset and sea ice retreat, advance, and freeze-up dates. A dataset was released by the National Snow and Ice Data Center.

Background

Since 1979, satellite sea ice concentration data have been used to track climate change and variability. Sea ice extent (the area within the 15% concentration contour) and area (the area-integrated concentration) have long been considered key sea ice coverage climate indicators. However, these two parameters provide only limited information about the character of the sea ice; in addition, they have limited skill as indicators of future sea ice conditions, both seasonal and interannual. This three-year project utilized the NOAA National Snow and Ice Data Center (NSIDC) Sea Ice Concentration Climate Data Record to develop a consistent, high-quality suite of sea ice climate indicators that track the seasonal evolution (sea ice melt onset, opening, retreat, freeze-up, and advance) of the Arctic sea ice cover from spring through fall, in addition to commonly used sea ice coverage indicators (area and extent).

Accomplishments

A dataset has been released by NSIDC.

Presentation

Peng, G., M. Steele, A. Bliss, W. Meier, and S. Dickinson, 2019: Integrated Climate Indicators for Monitoring Seasonal Arctic and sub-Arctic Sea Ice Coverage Using a Satellite Climate Data Record. Poster. *EGU General Assembly 2019*. Vienna, Austria, April 10, 2019.

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

Synthesis of Observed and Simulated Rain Microphysics to Inform a New Bayesian Statistical Framework for Microphysical Parameterization in Climate Models	
Task Leader	Olivier Prat
Task Code	NC-OTH-02-NCICS-OP
Other Sponsor	Columbia University/US Department of Energy (DOE)
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 50% Theme 3: Climate Research and Modeling 50%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 50% Goal 2: Weather-Ready Nation 50%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: This multi-institutional research project comprehensively investigated the representation and associated uncertainties of rain microphysical processes in weather and climate models. The team developed an innovative Bayesian statistical framework that combines the extensive radar and ground-based data from the Department of Energy Atmospheric Radiation Measurement (ARM) field campaigns, bin microphysical modeling, and a new bulk parameterization.

Background

Rain microphysical processes exert a critical control on the evolution and impact of weather systems, including deep convection. In particular, the microphysical characteristics of rain determine evaporation and hydrometeor loading, which in turn controls downdraft characteristics and subsequent cold-pool formation and convective structure and organization. It has never been more important to accurately represent these effects, as the increasingly fine resolution of regional and global climate models can now explicitly simulate these processes and quantify their impacts. Recent advances in observational capabilities, such as available Atmospheric Radiation Measurement (ARM) polarimetric and zenith-pointing radars, allow for unprecedented information on rain microphysical processes. However, the current state of microphysical parameterization schemes complicates the assimilation of observational insights into models.

Microphysics schemes contain numerous assumptions, ad-hoc parameter choices, and structural uncertainties. In this work, we are investigating the uncertainties in the representation of microphysical processes in climate models. The goal is to develop a novel warm-rain microphysics scheme that uses Bayesian inference to estimate parameter uncertainties and reduce unnecessary assumptions. The Bayesian Observationally constrained Statistical-physical Scheme can use any combination of prognostic drop size distribution (DSD) moments without assuming a prior DSD. Dual-polarization radar observations provide a probabilistic constraint on scheme structure and microphysical sensitivities to environmental conditions. Because the same value of a given prognostic moment can correspond to an infinite number of DSDs, the development of a moment-based polarimetric-radar forward operator is required to determine the optimal combination of prognostic moments (2- or 3-moment scheme) that minimizes uncertainties. This Bayesian statistical approach combines real rainfall dual-polarization radar data from ARM field campaigns, bin microphysical modeling, and a new bulk parameterization. This work is conducted in collaboration with our partners, Dr. Marcus van Lier-Walqui (Columbia University), Dr. Matthew Kumjian (Pennsylvania State University), and Dr. Hughbert Morrison (National Center for Atmospheric Research).

Accomplishments

The NCSU team's contribution to the project involved providing one-dimensional (1-D) bin-model simulations covering the totality of realistic DSDs encountered in nature (i.e., approximately 10,000 initial conditions imposed at the top of the 1-D model that resulted in about 199 million DSDs). Last year, the team refined the bin-model evaporation module and ran an ensemble of simulations that included a subset of all possible initial DSDs combined with a range of atmospheric conditions (relative humidity [RH], temperature [T]) derived from U.S. Surface Climate Reference Network (USCRN) stations (rainy and non-rainy cases). The model results were used as input for an electromagnetic scattering model that emulates the evolution of the polarimetric-radar variables (Z_H, Z_{DR}, K_{DP}).

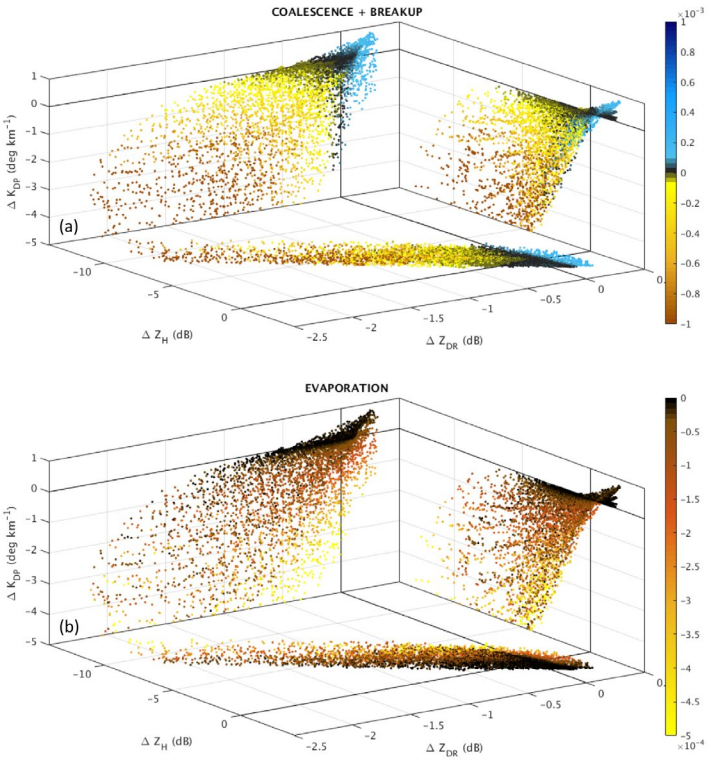


Figure 1. *Changes in Z_{DR} as a function of changes in Z_H and K_{DP} over the 3-km rain shaft in the presence of coalescence, breakup, and evaporation for all the initial DSDs and atmospheric conditions (RH, T) derived from USCRN stations over the contiguous United States. The markers are colored by process rate contribution to the sixth moment of the DSD. Process rate contributions to M_6 are presented for (a, top) coalescence and breakup, and (b, bottom) evaporation.*

Figure 1a, displays the combined influence of coalescence and breakup on the sixth moment of the distribution (M_6). The changes in the polarimetric variables (ΔZ_H, ΔZ_{DR}, ΔK_{DP}) within the 3-km rain shaft indicate areas where coalescence and breakup are dominant. When both Z_H and Z_{DR} (or K_{DP}) decrease toward the ground, drop breakup is dominant. Conversely, an increase in both Z_H and Z_{DR} (or K_{DP}) indicates that drop coalescence is dominant. The limited range where ΔZ_H and ΔZ_{DR} (ΔK_{DP}) reverse signs indicates the signature of a balance between coalescence and breakup. Markers with various shades of blue indicate that coalescence dominates (positive contribution of the process rate to M_6), while markers with various shades of yellow/orange indicate that breakup dominates (negative contribution of the process rate to M_6). Figure 1b displays the evaporation contribution to M_6, with the brighter colors (orange/yellow) indicating a greater impact of evaporation. The work represents a generalization of the

results presented in Kumjian and Prat (2014) to a large number of initial DSDs and an extension to evaporation processes.

The second aspect of the work involved comparing results obtained using the 1-D microphysical model with a three-moment bulk microphysics scheme. The comparison of process rates calculated from bin and bulk microphysical schemes indicated more aggressive breakup parameterizations for the bin scheme, in particular at the top of the column (not shown). This work showed the uncertainties in microphysical parameterization. An example of the influence of different collision–coalescence–breakup parameterizations on vertical profiles of the DSD properties is provided in Figure 2. Depending on the collision–coalescence–breakup parameterizations considered, the integral properties of the DSD exhibit large differences using the different parameterizations at the transient stage (Figure 2a) and especially after steady state is achieved (Figure 2b). Those results illustrate the challenge in quantifying the outcome of drop–drop collisions for developing physically based parameterizations of collision, coalescence, and breakup.

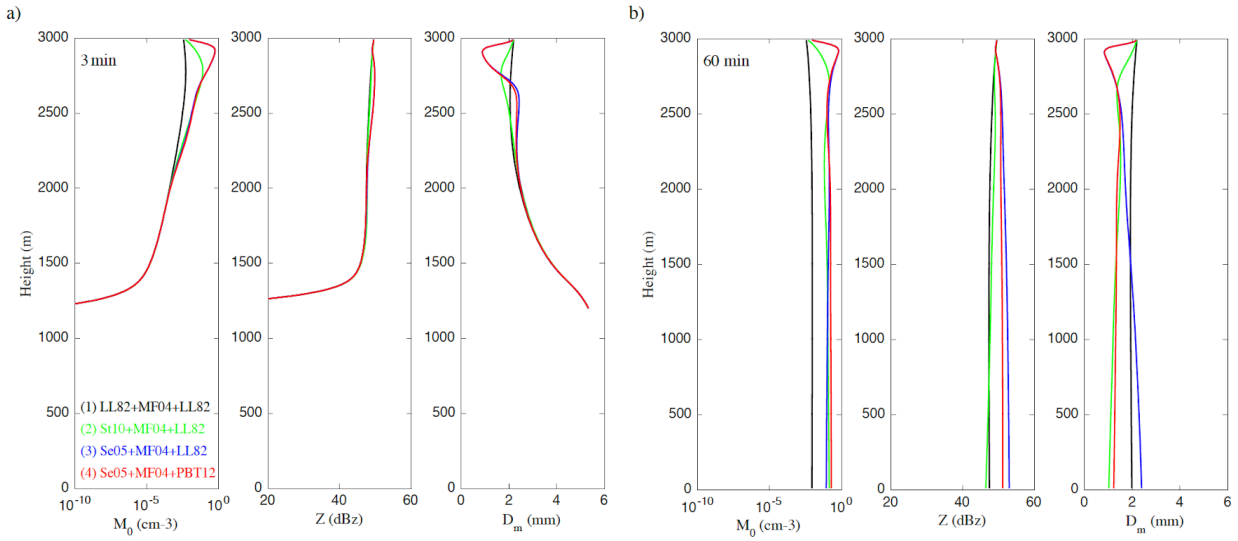


Figure 2. *Comparison of vertical profiles of the drop number concentration (M_0 in cm^{-3}), radar reflectivity (Z in dBz), and mass-weighted mean drop diameter (D_m in mm) for a 1-D rain shaft simulated using a bin scheme with various combinations of coalescence and breakup kernel formulations. The formulations include 1) LL82, MF04, LL82 (black), 2) St10, MF04, LL82 (green), 3) Se05, MF04, LL82 (blue), and 4) Se05, MF04, PBT12 (red), with LL82, MF04 [McFarquhar 2004], St10 [Straub et al. 2010], Se05 [Seifert et al. 2005], and PBT12 [Prat et al. 2012]. Results are presented for a total simulated time of a) 3-minute (i.e., transient situation) and b) 1-hour (i.e., steady-state situation). The simulations use an exponential DSD with a nominal rain rate of 50 mm/h imposed at the top of the column.*

Additional refinements of the model and simulations were conducted to complete the publication in progress on the bin-microphysical component of the project and the dual-polarization signature of microphysical processes (coalescence, breakup, and evaporation).

Planned work

- Complete project manuscripts

Publications

Morrison, H., M. Van Lier-Walqui, M. Kumjian, and **O.P. Prat**, 2020: A Bayesian approach for statistical-physical bulk parameterization of rain microphysics, Part I: Scheme description. *Journal of the Atmospheric Sciences*, **77**, 1019-1041, https://doi.org/10.1175/JAS-D-19-0070.1.

Van Lier-Walqui, M, H. Morrison, M. Kumjian, K. J. Reimel, **O.P. Prat**, S. Lunderman, and M. Morzfeld, 2020. A Bayesian approach for statistical-physical bulk parameterization of rain microphysics, Part II: Idealized Markov chain Monte Carlo experiments. *Journal of the Atmospheric Sciences*, **77**, 1043–1064, https://doi.org/10.1175/JAS-D-19-0071.1.

Presentations

van Lier-Walqui, M., H. Morrison, M. Kumjian, M., C. Martinkus, **O.P. Prat**, and K.J. Reimel, 2019: Probabilistic observational constraint of a microphysics scheme with flexible structural complexity. *2019 ARM/ASR Joint User Facility and PI Meeting*, Rockville, MD, June 11, 2019.

Riemel, K.J., M. Van Lier-Walqui, M.R. Kumjian, **O.P. Prat**, and H.C. Morrison, 2019: How much can we learn about rain microphysics from polarimetric radar observations? An investigation of information content and parameter estimation using the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS). *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco CA, December 12, 2019.

Prat, O.P., M.R. Kumjian, K.J. Riemel, H.C. Morrison, and M. Van Lier-Walqui, 2019: A comparison of bulk- and bin-microphysical schemes for warm rain processes and their polarimetric radar fingerprints: sensitivity analysis and implications for microphysical parameterizations. Poster. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

van Lier-Walqui, M., H. Morrison, M.R. Kumjian, K.J. Reimel, **O.P.** Prat, S. Lunderman, and M. Morzfeld, 2020: Statistical-physical microphysics parameterization schemes: A proposed framework for physically based microphysics schemes that learn from observations. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.

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

Climate Change Impacts on Human Health	
Task Leader	Jennifer Runkle
Task Code	NC-OTH-03-NCICS-JR
Other Sponsor	Mountain Area Health Education Center (MAHEC), Medical University of South Carolina (MUSC)**;** in-kind partnerships
Contribution to CICS Research Themes	
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Decision Science, Risk Assessment and Risk Communication

Highlight: Exploratory research and pilot studies were conducted to examine the impact of climate change—a known environmental determinant—on health risks for vulnerable persons (e.g., pregnant women, persons with a mental health condition).

Background

Surveillance of the impacts of climate change on human health is an urgent and understudied research priority. Climate change serves as a threat multiplier by which existing health disparities, as well as other vulnerabilities related to social and environmental determinants are amplified, accelerated, or worsened. The goal of this exploratory work was to examine the impact of climate change—a known environmental determinant—on health risks for two vulnerable populations (e.g., pregnant women, persons with a mental health condition). Results will address a significant research gap in understanding climate and health and inform the development of a scalable population-based indicator to be used in climate-health surveillance efforts at the local, state, and national levels.

Accomplishments

- Completed a digital health intervention study at MAHEC that investigated the feasibility of blood pressure self-monitoring with pregnant women in their third trimester
- Completed reconstruction of birth cohort comprising over 20 years of maternal and child health delivery and readmission data
- Partnered with the Medical University of South Carolina, a coastal health system, to develop, test, and administer a climate readiness survey to all staff and provided data to inform their resilience plan
- Completed analysis examining crisis text patterns in youth before, during, and after Hurricane Florence; conduced a sensitivity analysis using 2018 emergency department visits for North Carolina

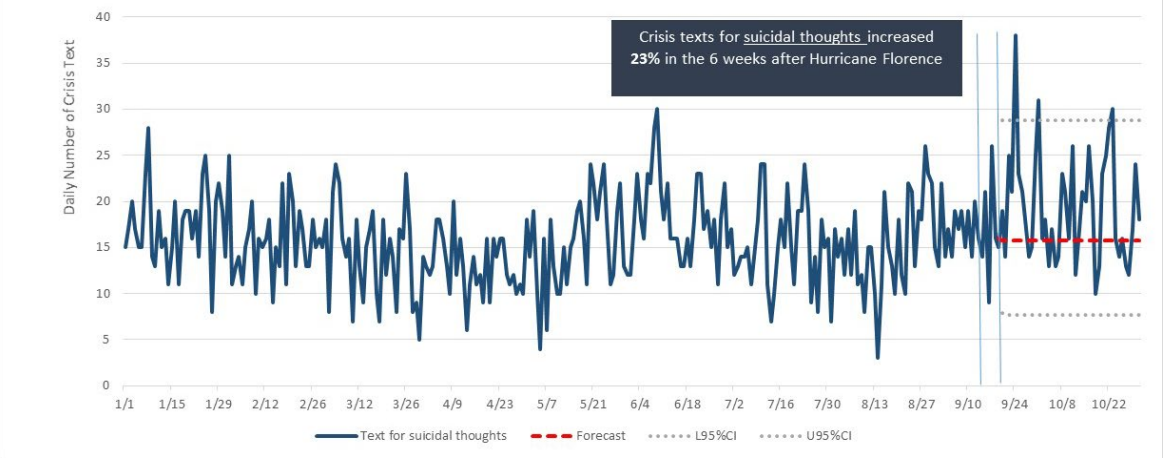


Figure 1. *Crisis text volume for "suicidal thoughts" over time in youth for North and South Carolina following Hurricane Florence. Data source. Crisis Text Line data, 2018.*

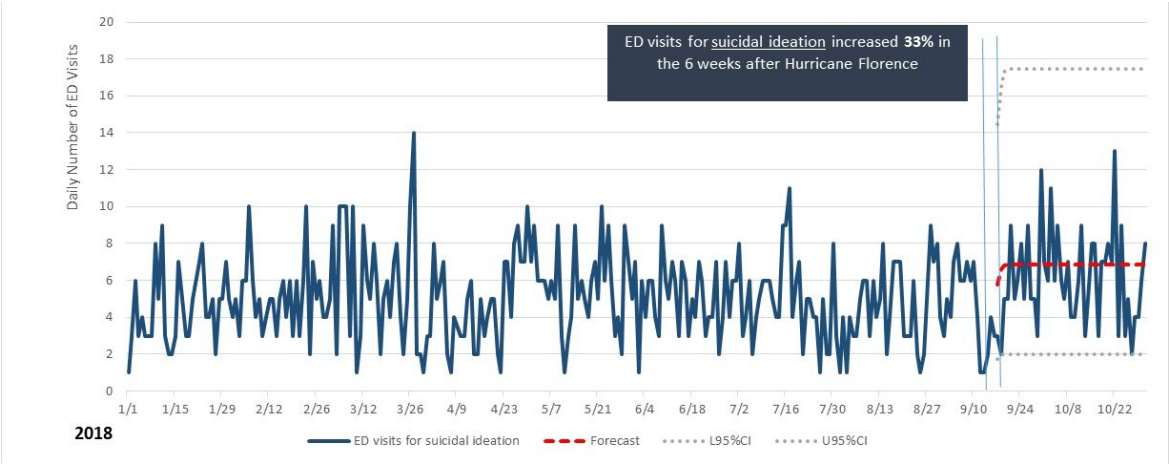


Figure 2. *Emergency department volume for "suicidal ideation" over time in youth for North and South Carolina following Hurricane Florence Data source. North Carolina Disease Event Tracking and Epidemiologic Collection Tool emergency department data, 2018.*

Publications

Sugg, M. M., C. M. Fuhrmann, and **J. D. Runkle**, 2020: Perceptions and experiences of outdoor occupational workers using digital devices for geospatial biometeorological monitoring. *International Journal of Biometeorology*, https://doi.org/10.1007/s00484-019-01833-8.

Sugg, M. M., K. D. Michael, **S. E. Stevens**, R. Filbin, J. Weiser, and **J. D. Runkle**, 2019: Crisis Text Patterns in Youth following the Release of 13 Reasons Why Season 2 and Celebrity Suicides: A Case Study of Summer 2018. *Preventive Medicine Reports*, 100999, https://doi.org/10.1016/j.pmedr.2019.100999.

Sugg, M. M., **S. Stevens**, and **J. D. Runkle**, 2019: Estimating personal ambient temperature in moderately cold environments for occupationally exposed populations. *Environmental Research*, 173, 497–507, https://doi.org/10.1016/j.envres.2019.03.066.

Bailey, E., M. M. Sugg, C. Fuhrmann, **J. Runkle**, **S. E. Stevens**, and M. Brown, 2019: Wearable Sensors for Personal Temperature Exposure Assessments: A Comparative Study. *Environmental Research*, **180**, 108858, https://doi.org/10.1016/j.envres.2019.108858.

Runkle, J. D., **C. Cui**, **S. Stevens**, C. Fuhrmann, and M. Sugg, 2019: Evaluation of Wearable Sensors for Physiologic Monitoring of Personal Heat Exposure in Outdoor Workers in Southeastern U.S. *Environment International*, **129**, 229–238, https://doi.org/10.1016/j.envint.2019.05.026.

Presentations

Michael, M., M. M. Sugg, **J. D. Runkle**, and **S. Stevens**, 2019: Celebrity Deaths and Media Portrayals of Suicide are Temporally Related to Spikes in Crisis Text Line Conversations Nationwide. *AAS Annual Conference*, Portland, OR, April 22, 2019.

Thompson, L. K., M. Michael, **J. D. Runkle**, and M. M. Sugg, 2019: Crisis Text Line Use Following the Release of Netflix Series 13 Reasons Why Season 1: Time Series Analysis of Help-Seeking Behavior in Youth. *52nd American Association of Suicidology*, Denver, CO, April 25, 2019.

Bailey, E., M. M. Sugg, C. M. Fuhrmann, and **J. D. Runkle**, 2019: Personal Sensors for Temperature Exposure Assessments: A Validation Study. Celebration of Student Research and Creative Endeavors, *Appalachian State University*, Boone, NC, April 18, 2019.

Bailey, E., M. M. Sugg, C. M. Fuhrmann, and **J. D. Runkle**, 2019: Personal Sensors for Temperature Exposure Assessments: A Validation Study. *Annual Meeting of the Association of American Geographers*, Washington, D.C. April 4, 2019.

Other

- Convened workshop (sponsored by Oak Ridge Associated Universities) with seven Southeast climate, health, and geography scientists to develop collaborative climate change research proposal
- Mentored six undergraduate/graduate students (Appalachian State University, University of North Carolina at Chapel Hill Gillings School of Public Health, North Carolina State University)

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer-reviewed papers	**5**
# of NOAA technical reports	**0**
# of presentations	**4**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**5**
# of undergraduate students mentored during the year	**1**

Multiscale Convection and the Maritime Continent	
Task Leader	Carl Schreck
Task Code	NC-OTH-04-NCICS-CS
Other Sponsor	National Aeronautics and Space Administration (NASA)
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 50%**.** Theme 3: Climate Research and Modeling 50%
Main CICS Research Topic	Climate Data and Information Records
Contribution to NOAA goals	Goal 2: Weather-Ready Nation 100%
NOAA Strategic Research Priorities	Integrated Earth System Processes and Predictions

Highlight: Project results show that the Madden–Julian Oscillation (MJO) modulates rainfall over the Maritime Continent during the afternoon peak of the diurnal cycle but has little impact on the morning minimum. Results exploring the skill of a novel Fourier filtering of combined observations and model hindcasts in the region were published and presented at two seminars. ncics.org/mjo

Background

The Madden–Julian Oscillation (MJO) is the largest source of tropical intraseasonal variability, with impacts spanning the globe. Unfortunately, numerical models fail to adequately simulate its convection, limiting their opportunity to harness its long-range predictability. Nowhere is this shortcoming more apparent than over the Maritime Continent (MC). Many MJO events terminate before crossing the MC, a tendency that is exaggerated in most numerical models. The MC poses complex topography that may reduce the MJO's moisture source from surface fluxes and impede the MJO's low-level circulation. The exceptional diurnal cycles in the vicinity of the large islands in the MC can also drain the MJO's energy. Most models fail to capture this diurnal cycle properly and result in large biases in rainfall over the MC.

Many studies have examined the interactions between the MJO and convection over the MC. Far fewer have looked at the role of convectively coupled equatorial waves, even though models that faithfully represent these waves also tend to produce more representative MJO signals. This study identified avenues for model improvement by investigating the interactions between the MJO, equatorial waves, and the diurnal cycle over the MC.

Accomplishments

The project was split into two main components. One was led by Co-Investigator (Co-I) Ademe Mekonnen (North Carolina A&T State University), who investigated the diurnal cycle of convection over the Maritime Continent (MC) using a variety of Tropical Rainfall Measuring Mission (TRMM) and International Satellite Cloud Climatology Project (ISCCP) datasets. The other was led by Primary Investigator Schreck and Co-I Anantha Aiyyer (NCSU), who explored the skill of a novel Fourier filtering of combined observations and Climate Forecast System Version 2 (CFSv2) hindcasts in the region.

Figure 1 highlights some of the results from the first branch of the project. Notably, the rainfall in the afternoon (1800 local standard time, LST) peak of the diurnal cycle is strongly modulated by the MJO, but morning (0900 LST) values are not affected. Interestingly, the convection identified by the ISCCP Infrared-Weather States (IR-WS) are more consistent between both times of day. These results were part of advisee Lakemarium Worku's PhD dissertation research.

Results from the second branch of this project were published in Schreck et al. (2020). They were also shared through a seminar the University of Maryland attended by forecasters from NOAA's Climate

Prediction Center. Another seminar presented the results at the Millennium Change Corporation to explore possible applications within developing countries.

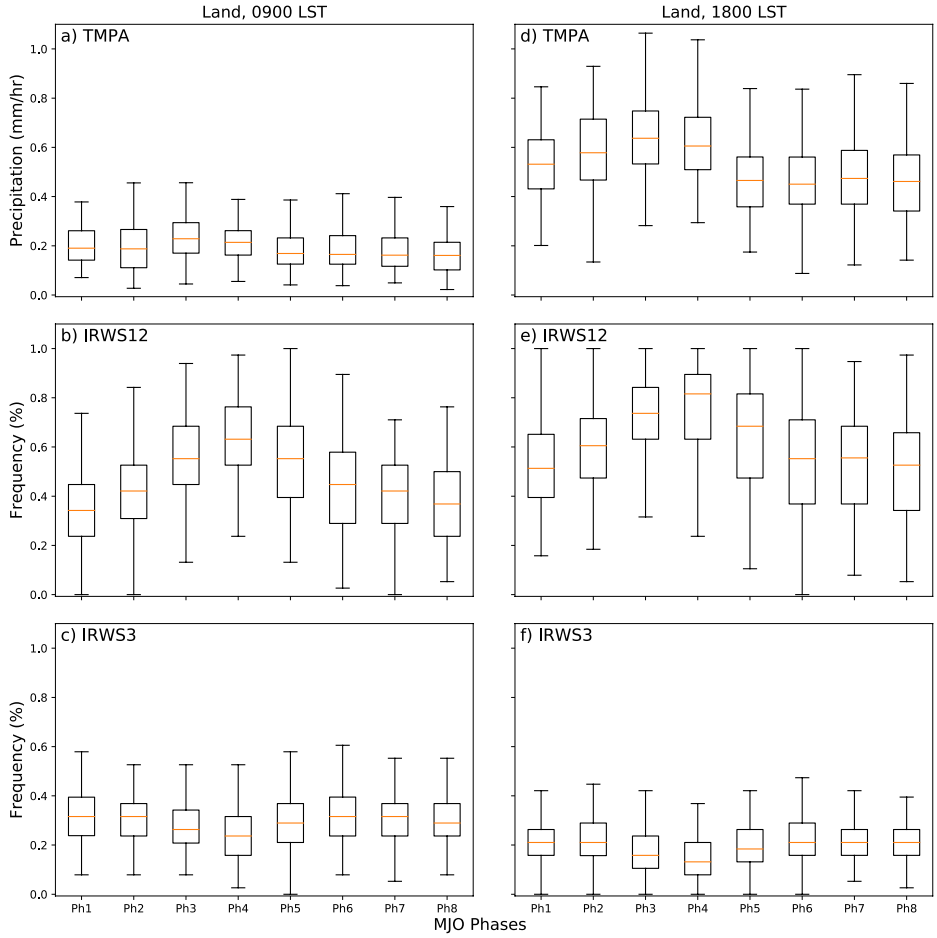


Figure 1. *Variation of rainfall and different types of deep convection at 0900 and 1800 LST over land with respect to MJO phase.*

Planned work

This project ended in February 2020.

Publications

Schreck, C. J., M. A. Janiga, and S. Baxter, 2020: Sources of Tropical Subseasonal Skill in the CFSv2. *Monthly Weather Review*, **148**, 1553–1565, https://doi.org/10.1175/MWR-D-19-0289.1.

Worku, L. Y., A. Mekonnen, and **C. J. Schreck**, 2019: Diurnal cycle of rainfall and convection over the Maritime Continent using TRMM and ISCCP. *International Journal of* Climatology, **39**, 5191–5200, https://doi.org/10.1002/joc.6121.

Presentations

Schreck, C., 2019: The MJO and Equatorial waves in the CFSv2. *University of Maryland – College Park*, College Park, MD, July 24, 2019.

Schreck, C., 2019: Climate and Weather Applications for Developing Countries. *Millennium Challenge Corporation*, Washington, DC, November 5, 2019.

Worku, L., 2019: Multi-scale interactions between the diurnal cycle, MJO, and convectively coupled equatorial waves over the Maritime Continent. Ph.D. Defense, Energy & Environmental Systems (EES) Ph.D. Program, *North Carolina A&T State University*, Greensboro, NC, December 4, 2019.

Schreck, C., 2020: Subseasonal Rainfall Forecasting. *Water Collaborative Mini-Symposium, NC State University,* Raleigh, NC, January 16, 2020.

Other

Advisor for PhD students Lakemarium Worku (NC A&T University) and Sridhar Mantripragada (NCSU)

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

Appendix 1: CICS-NC Personnel and Performance Metrics

CICS-NC Personnel	Numbers*		CICS-NC Subcontractors	Numbers**
Scientists working ≥ 50% time	**25**		Scientists working ≥ 50% time	**0**
Scientists working < 50% time	**3**		Scientists working < 50% time	**14**
Scientists working at no cost	**3**		Scientists working at no cost	**1**
Total Scientists	**31**		**Total Scientists**	**15**
Administrative/technical staff	**10**		**Administrative/technical staff**	**3**
Graduate Students	**2**		Graduate Students	**1**
Undergraduate Students	**3**		Undergraduate Students	**3**
High School Students	**0**		High School Students	**0**
Total Students	**0**		**Total Students**	**4**
Total Personnel	**36**		**Total Personnel**	**22**

**Excludes institute personnel supported solely by non-NOAA sponsors and unpaid student interns.*

***Based on NOAA/CICS-NC budgeted support effort for this year's current subcontractor projects*

Performance Metrics	
# of new or improved products developed that became operational	**64**
# of products or techniques submitted to NOAA for consideration in operations use	**24**
# of peer reviewed papers	**35**
# of NOAA technical reports	**6**
# of presentations	**72*** **
# of graduate students supported by your CICS task	**4**
# of graduate students formally advised	**14**
# of undergraduate students mentored during the year	**17**

****Presentations: 68 science presentations; 4 outreach and engagement presentations.*

Appendix 2: CICS-NC Publications 2019–2020

Arguez, A., **A. Inamdar**, M. A. Palecki, **C. J. Schreck**, and A. H. Young, 2019: ENSO Normals: A new U.S. climate normals product conditioned by ENSO phase and intensity and accounting for secular trends. *Journal of Applied Meteorology and Climatology*, **58**, 1381–1397, https://doi.org/10.1175/JAMC-D-18-0252.1.

Arguez, A., S. Hurley, **A. Inamdar**, L. Mahoney, A. Sanchez-Lugo, and L. Yang, 2020: Should we expect each year in the next decade (2019-2028) to be ranked among the top 10 warmest years globally? *Bulletin of the American Meteorological Society*, https://doi.org/10.1175/bams-d-19-0215.1.

Bailey, E., M. M. Sugg, C. Fuhrmann, **J. Runkle**, **S. E. Stevens**, and M. Brown, 2019: Wearable Sensors for Personal Temperature Exposure Assessments: A Comparative Study. *Environmental Research*, **180**, 108858, https://doi.org/10.1016/j.envres.2019.108858.

Bliss, A. C., M. Steele, **G. Peng**, W. N. Meier, and S. Dickinson, 2019: Regional variability of Arctic sea ice seasonal change climate indicators from a passive microwave climate data record. *Environmental Research Letters*, **14**, 45003, https://doi.org/10.1088/1748-9326/aafb84.

Camargo, S. J., J. Camp, R. L. Elsberry, P. A. Gregory, P. J. Klotzbach, **C. J. Schreck III**, A. H. Sobel, M. J. Ventrice, F. Vitart, Z. Wang, M. C. Wheeler, M. Yamaguchi, and R. Zhan, 2019: Tropical Cyclone Prediction on Subseasonal Time-Scales. *Tropical Cyclone Research and Review*, **8**, 150–165, https://doi.org/10.6057/2019tcrr03.04.

Diamond, H. J., and **C. J. Schreck**, eds., 2019: The tropics [in "State of the Climate in 2018"]. *Bulletin of the American Meteorological Society*, **100**, S101–S140, https://doi.org/10.1175/2019BAMSStateoftheClimate.1.

Frankson, R., K. Kunkel, and **S. Champion**, 2017: Louisiana State Climate Summary. *NOAA Technical Report NESDIS 149-LA,* March 2019 Revision, 4 pp. http://statesummaries.ncics.org/la/

Frankson, R., K. Kunkel, L. Stevens and D. Easterling, 2017: Utah State Climate Summary. *NOAA Technical Report NESDIS 149-UT,* September 2019 Revision, 4 pp. http://statesummaries.ncics.org/ut/

Frankson, R., K. Kunkel, L. Stevens, and D. Easterling, 2017: New Mexico State Climate Summary. *NOAA Technical Report NESDIS 149-NM*, May 2019 Revision, 4 pp. http://statesummaries.ncics.org/nm/

Frankson, R., **K. Kunkel, L. Stevens**, D. Easterling, W. Sweet, A. Wootten, and R. Boyles, 2017: North Carolina State Climate Summary. *NOAA Technical Report NESDIS 149-NC*, May 2019 Revision, 4 pp. http://statesummaries.ncics.org/nc/

Frankson, R., **K. Kunkel, S. Champion** and D. Easterling, 2017: Ohio State Climate Summary. *NOAA Technical Report NESDIS 149-OH,* September 2019 Revision, 4 pp. http://statesummaries.ncics.org/oh/

Huang, B., M. J. Menne, T. Boyer, E. Freeman, B. E. Gleason, J. H. Lawrimore, C. Liu, **J. J. Rennie**, **C. J. Schreck III**, F. Sun, R. Vose, C. N. Williams, X. Yin, and H.-M. Zhang, 2020: Uncertainty estimates for sea surface temperature and land surface air temperature in NOAAGlobalTemp version 5. *Journal of Climate*, https://doi.org/10.1175/JCLI-D-19-0395.1.

Klotzbach, P. J., M. M. Bell, S. G. Bowen, E. J. Gibney, K. R. Knapp, and **C. J. Schreck**, 2020: Surface pressure a more skillful predictor of normalized hurricane damage than maximum sustained wind. *Bulletin of the American Meteorological Society*, **In press**, https://doi.org/10.1175/BAMS-D-19-0062.1.

Kunkel, K. E., and **S. M. Champion**, 2019: An assessment of rainfall from Hurricanes Harvey and Florence relative to other extremely wet storms in the United States. *Geophysical Research Letters*, **46**, 13500–13506, https://doi.org/10.1029/2019GL085034.

Kunkel, K. E., T. R. Karl, M. F. Squires, X. Yin, **S. T. Stegall**, and D. R. Easterling, 2020: Precipitation Extremes: Trends and Relationships with Average Precipitation and Precipitable Water in the Contiguous United States. *Journal of Applied Meteorology and Climatology*, **59**, 125–142, https://doi.org/10.1175/JAMC-D-19-0185.1.

Lee, J., D. Waliser, H. Lee, P. Loikith, and **K. E. Kunkel**, 2019: Evaluation of CMIP5 ability to reproduce twentieth century regional trends in surface air temperature and precipitation over CONUS. *Climate Dynamics*, **53**, 5459–5480, https://doi.org/10.1007/s00382-019-04875-1.

Leeper, R. D., J. Kochendorfer, T. Henderson, and **M. A. Palecki**, 2019: Impacts of small-scale urban encroachment on air temperature observations. *Journal of Applied Meteorology and Climatology*, **58**, 1369–1380, https://doi.org/10.1175/JAMC-D-19-0002.1.

Matthews, J. L., and L. Shi, 2019: Intercomparisons of long-term atmospheric temperature and humidity profile retrievals. *Remote Sensing*, **11**, 853, https://doi.org/10.3390/rs11070853.

Matthews, J. L., **G. Peng**, W. N. Meier, and **O. Brown**, 2020: Sensitivity of Arctic Sea Ice Extent to Sea Ice Concentration Threshold Choice and Its Implication to Ice Coverage Decadal Trends and Statistical Projections. *Remote Sensing*, **12**, 807, https://doi.org/10.3390/rs12050807.

*Moroni, D. F., H. Ramapriyan, **G. Peng**, J. Hobbs, J.Goldstein, R. Downs, R. Wolfe. C.-L. Shie, C. J. Merchant, M. Bourassa **J. L. Matthews**, P. Cornillon, L. Bastin, K. Kehoe, B. Smith, J. L. Privette, A. C. Subramanian, **O. Brown**, and I. Ivanova, 2019: Understanding the Various Perspectives of Earth Science Observational Data Uncertainty, https://esip.figshare.com/articles/Understanding_the_Various_Perspectives_of_Earth_Science_Observational_Data_Uncertainty/10271450.

Morrison, H., M. van Lier-Walqui, M. R. Kumjian, and **O. P. Prat**, 2020: A Bayesian approach for statistical-physical bulk parameterization of rain microphysics, Part I: Scheme description. *Journal of the Atmospheric Sciences*, **77**, 1019–1041, https://doi.org/10.1175/JAS-D-19-0070.1.

Moss, R.H., S. Avery, K. Baja, M. Burkett, A.M. Chischilly, J. Dell, P.A. Fleming, K. Geil, K. Jacobs, A. Jones, K. Knowlton, J. Koh, M.C. Lemos, J. Melillo, R. Pandya, T.C. Richmond, L. Scarlett, J. Snyder, M. Stults, A. Waple, J. Whitehead, D. Zarrilli, **J. Fox**, A. Ganguly, L. Joppa, S. Julius, P. Kirshen, R. Kreutter, A. McGovern, R. Meyer, J. Neumann, W. Solecki, J. Smith, P. Tissot, G. Yohe, and R. Zimmerman, 2019: "A Framework for Sustained Climate Assessment in the United States." *Bulletin of the American Meteorological Society*, **100**, 897–907, https://doi.org/10.1175/BAMS-D-19-0130.1.

Moss, R.H., S. Avery, K. Baja, M. Burkett, A.M. Chischilly, J. Dell, P.A. Fleming, K. Geil, K. Jacobs, A. Jones, K. Knowlton, J. Koh, M.C. Lemos, J. Melillo, R. Pandya, T.C. Richmond, L. Scarlett, J. Snyder, M. Stults, A.M. Waple, J. Whitehead, D. Zarrilli, B.M. Ayyub, **J. Fox**, A. Ganguly, L. Joppa, S. Julius, P. Kirshen, R. Kreutter, A. McGovern, R. Meyer, J. Neumann, W. Solecki, J. Smith, P. Tissot, G. Yohe, and R. Zimmerman, 2019: "Evaluating Knowledge to Support Climate Action: A Framework for Sustained Assessment. Report of an Independent Advisory Committee on Applied Climate Assessment." *Weather, Climate, and Society*, **11**, 465–487, https://doi.org/10.1175/WCAS-D-18-0134.1.

Peng, G., A. Arguez, N. W. Meier, F. Vamborg, J. Crouch, and P. Jones, 2019: Sea Ice Climate Normals for Seasonal Ice Monitoring of Arctic and Sub-Regions. *Data*, **4**, https://doi.org/10.3390/data4030122.

Peng, G., A. Milan, N. A. Ritchey, R. P. Partee II, S. Zinn, E. McQuinn, K. S. Casey, P. Lemieux III, R. Ionin, P. Jones, A.Jakositz, and D. Collins, 2019: Practical Application of a Data Stewardship Maturity Matrix for the NOAA OneStop Project. *Data Science Journal*, **18**, 41, https://doi.org/10.5334/dsj-2019-041.

Peng, G., **J. L. Matthews**, M. Wang, R. Vose, and **L. Sun**, 2020: What Do Global Climate Models Tell Us about Future Arctic Sea Ice Coverage Changes? *Climate*, **8**, https://doi.org/10.3390/cli8010015.

Prat, O.P., and B.R. Nelson, 2019. Satellite precipitation measurements and extreme rainfall. In: *Satellite Precipitation Measurement*, V. Levizzani, C. Kidd, D. B. Kirshbaum, C.D. Kummerow, K. Nakamura, and F.J. Turk, Eds., Springer, 761-790, https://www.springer.com/it/book/9783030357979.

Rao, Y., S. Liang, D. Wang, Y. Yu, Z. Song, Y. Zhou, M. Shen, and B. Xu, 2019: Estimating daily average surface air temperature using satellite land surface temperature and top-of-atmosphere radiation products over the Tibetan Plateau. *Remote Sensing of Environment*, **234**, 111462, https://doi.org/10.1016/j.rse.2019.111462.

Rennie, J., **J. E. Bell**, **K. E. Kunkel**, S. Herring, H. Cullen, and A. M. Abadi, 2019: Development of a submonthly temperature product to monitor near-real-time climate conditions and assess long-term heat events in the United States. *Journal of Applied* Meteorology *and Climatology*, **58**, 2653–2674, https://doi.org/10.1175/JAMC-D-19-0076.1.

Runkle, J. D., **C. Cui**, **S. Stevens**, C. Fuhrmann, and M. Sugg, 2019: Evaluation of Wearable Sensors for Physiologic Monitoring of Personal Heat Exposure in Outdoor Workers in Southeastern U.S. *Environment International*, **129**, 229–238, https://doi.org/10.1016/j.envint.2019.05.026.

Runkle, J., K. Kunkel, L. Stevens, and **R. Frankson**, 2017: Alabama State Climate Summary. *NOAA Technical Report NESDIS 149-AL*, March 2019 Revision, 4 pp. http://statesummaries.ncics.org/al/

Runkle, J., K. Kunkel, S. Champion, R. Frankson, and **B. Stewart**, 2017: Mississippi State Climate Summary. *NOAA Technical Report NESDIS 149-MS,* March 2019 Revision, 4 pp. http://statesummaries.ncics.org/ms/.

Russell, B. T., M. D. Risser, R. L. Smith, and **K. E. Kunkel**, 2019: Investigating the association between late spring Gulf of Mexico sea surface temperatures and U.S. Gulf Coast precipitation extremes with focus on Hurricane Harvey. *Environmetrics*, **In press**, e2595, https://doi.org/10.1002/env.2595.

Saunders, M. A., P. J. Klotzbach, A. S. R. Lea, **C. J. Schreck**, and M. M. Bell, 2020: Quantifying the Probability and Causes of the Surprisingly Active 2018 North Atlantic Hurricane Season. *Earth and Space Science*, **7**, https://doi.org/10.1029/2019EA000852.

Schreck, C. J., III, M. A. Janiga, and S. Baxter, 2020: Sources of Tropical Subseasonal Skill in the CFSv2. *Monthly Weather Review*, **148**, 1553–1565, https://doi.org/10.1175/mwr-d-19-0289.1.

Sugg, M. M., C. M. Fuhrmann, and **J. D. Runkle**, 2020: Perceptions and experiences of outdoor occupational workers using digital devices for geospatial biometeorological monitoring. *International Journal of Biometeorology*, https://doi.org/10.1007/s00484-019-01833-8.

Sugg, M. M., K. D. Michael, **S. E. Stevens**, R. Filbin, J. Weiser, and **J. D. Runkle**, 2019: Crisis Text Patterns in Youth following the Release of 13 Reasons Why Season 2 and Celebrity Suicides: A Case Study of Summer 2018. *Preventive Medicine Reports*, 100999, https://doi.org/10.1016/j.pmedr.2019.100999.

Sugg, M. M., **S. Stevens**, and **J. Runkle**, 2019: Estimating personal ambient temperature in moderately cold environments for occupationally exposed populations. *Environmental Research*, **173**, 497–507, https://doi.org/10.1016/j.envres.2019.03.066.

van Lier-Walqui, M., H. Morrison, M. R. Kumjian, K. J. Reimel, **O. P. Prat**, S. Lunderman, and M. Morzfeld, 2020: A Bayesian approach for statistical-physical bulk parameterization of rain microphysics, Part II: Idealized Markov chain Monte Carlo experiments. *Journal of the Atmospheric Sciences*, 77, 1043–1064, https://doi.org/10.1175/JAS-D-19-0071.1.

Wood, K. M., P. J. Klotzbach, J. M. Collins, and **C. J. Schreck**, 2019: The Record-Setting 2018 Eastern North Pacific Hurricane Season. *Geophysical Research Letters*, **46**, 10072–10081, https://doi.org/10.1029/2019GL083657.

Worku, L. Y., A. Mekonnen, and **C. J. Schreck**, 2019: Diurnal cycle of rainfall and convection over the Maritime Continent using TRMM and ISCCP. *International Journal of Climatology*, **39**, 5191–5200, https://doi.org/10.1002/joc.6121.

Zhang, C., L. Ma, J. Chen, **Y. Rao**, Y. Zhou, and X. Chen, 2019: Assessing the impact of endmember variability on linear Spectral Mixture Analysis (LSMA): A theoretical and simulation analysis. *Remote Sensing of Environment*, **235**, 111471, https://doi.org/10.1016/j.rse.2019.111471.

**Non-peer-reviewed*

Appendix 3: CICS-NC Presentations 2019–2020

Science / Project Presentations

- Anderson, E., **J. Fox**, M. Roderick, and A. Weaver, 2019: Community and Regional Resilience Planning in Action. *2019 APA North Carolina Planning Conference*, Wilmington, NC, October 9, 2019.
- Bailey, E., M. M. Sugg, C. M. Fuhrmann, and **J. D. Runkle**, 2019: Personal Sensors for Temperature Exposure Assessments: A Validation Study. *Annual Meeting of the Association of American Geographers*, Washington, D.C. April 4, 2019.
- Bailey, E., M. M. Sugg, C. M. Fuhrmann, and **J. D. Runkle**, 2019: Personal Sensors for Temperature Exposure Assessments: A Validation Study. *Celebration of Student Research and Creative Endeavors*, *Appalachian State University*, Boone, NC, April 18, 2019.
- **Bell, J.**, 2019: Health hazards associated with drought. *Western Regional Agriculture Safety and Health Conference*, Seattle, WA, August 8, 2019.
- **Bell, J.**, 2019: Role of public health in dealing with drought. *2019 Water for Food Global Conference*. Lincoln, NE, April 30, 2019.
- **Bell, J.**, 2019: Why drought matters to human health. *Western Region Agriculture Safety and Health Conference*, Seattle, WA, August 8, 2019.
- Bliss, A. C., M. Steele, **G. Peng**, and W. N. Meier, 2019: Indicators of Arctic change from passive microwave dates of sea ice seasonal evolution. Poster. *International Glaciological Society Sea Ice Symposium*, Winnipeg, Canada, August 20, 2019.
- **Brown, O.**, and **J. Brannock**, 2019: BDP Data Broker Update. *ESIP 2019 Summer Meeting*, Tacoma, WA, July 16, 2019.
- **Dissen, J.**, Easterling, D. R., **Kunkel, K. E.**, **Ballinger, A.**, Hayhoe, K., Akhtar, F., 2019: Development and Applications of Climate Projections in India. *17th Annual Climate Prediction Applications Science Workshop*, Charleston, SC, June 11, 2019.
- **Fox, J.**, 2019: Building Resilience Through Risk Management of Climate-Related Coastal Hazards. *Climate Prediction Applications Science Workshop*, Charleston, SC, June 13, 2019.
- **Fox, J.**, 2019: Climate Resilience: Moving From Data to Decisions. *NCEI 2019 Users' Conference*, The Collider, Asheville, NC, May 14, 2019.
- Hutchins, M., **J. Fox**, J. Hicks, K. Rogers, and N. Hall, 2019: After the assessment: Informing and prioritizing projects and strategies to build resilience, *National Adaptation Forum 2019*, Madison, WI, April 23, 2019.
- **Inamdar, A.**, 2019: Status of ISCCP H-Series Data; 35 Years and Counting. *AMS 2019 Joint Satellite Conference,* Boston, MA, October 1, 2019.
- **Inamdar, A.**, and **R. Leeper**, 2019: Extracting Surface Absorbed Solar Radiation in Near Real-time from GOES-R. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.
- **Kunkel K. E.**, D. E. Easterling, **S. M. Champion, J. P Dissen**, and **O. B. Brown**, 2019: North Carolina Climate Science Report Activities and Updates. *NC Interagency Council Meeting*, Winston-Salem, NC, July 16, 2019.
- **Kunkel K. E.**, D. E. Easterling, **S. M. Champion, J. P Dissen**, and **O. B. Brown**, 2019: North Carolina Climate Science Report Update. *Regional Resiliency Workshops*, Sylva, NC, October 15, 2019.

- **Kunkel K. E.**, D. E. Easterling, **S. M. Champion, J. P Dissen**, and **O. B. Brown**, 2019: North Carolina Climate Science Report Update. *Regional Resiliency Workshops*, Hickory, NC, October 16, 2019.
- **Kunkel, K. E.**, 2019: Hydroclimatic Extremes Trends and Projections: A View from the Fourth National Climate Assessment. *4th Annual NRC Probabilistic Flood Hazard Assessment Workshop*, Rockville, MD. May 2, 2019.
- **Kunkel, K. E.**, 2019: Overview of the Climate Science in the National Climate Assessment and Support for the NC Assessment. *NC DEQ Climate Council Meeting on EO80*, Raleigh, NC, April 8, 2019.
- **Kunkel, K. E.**, D. E. Easterling, **J. P Dissen**, and **O. B. Brown**, 2019**:** Initial Perspective on the NC Climate Science Activities. *NC DEQ Climate Change Interagency Council Meeting*, Raleigh, NC, April 26, 2019.
- **Kunkel, K.**, 2019: Climate Science in the National Climate Assessment. *Osher Lifelong Learning Institute*, Raleigh, NC, April 9, 2019.
- **Kunkel, K.**, 2019: Overview of the Climate Science in the National Climate Assessment and Support for the NC Assessment. *NC DEQ Climate Council Meeting on EO80*, Raleigh, NC, April 8, 2019.
- **Kunkel, K.**, 2019: Probabilities of Extreme Climate Events. *NCSU MEA 593 "Quantitative Analysis of Climate Change" class*, Raleigh, NC, September 3, 2019.
- **Leeper, R. D**. and M. A. Palecki, 2019: U.S. Climate Reference Network Soil Moisture Collection and Processing. *National Soil Moisture Network Soil Moisture Working Group,* Asheville, NC, June 12, 2019.
- **Leeper, R. D.**, 2019: Evaluating the Linkages between Soil Moisture and Drought. *2019 National Soil Moisture Network Workshop: Expanding the Frontiers of Soil Moisture Measurements and Applications*, Manhattan, KS, May 22, 2019.
- **Leeper, R. D**., M. A. Palecki, and **B. Petersen**, 2019: Efficacy of Drought Indices Derived from In Situ Soil Moisture Observations. *U.S. Drought Monitor Forum*, September 18, 2019.
- Lief, C., **G. Peng**, O. Baddour, W. Wright, V. Aich, and P. Siegmund, 2019: WMO Stewardship Maturity Matrix for Climate Data (SMM-CD) Developed under the High-Quality Global Data Management Framework for Climate. Poster. *EGU General Assembly 2019*, Vienna, Austria, April 9, 2019.
- **Mantripragada, S.**, A. Aiyyer, and **C. J. Schreck**, 2019: Surface variability and tropical waves over the Atlantic. *CYGNSS Science Team Meeting*, Ann Arbor, MI, June 7, 2019.
- Michael, M., M. M. Sugg, **J. D. Runkle**, and **S. Stevens, 2019**: Celebrity Deaths and Media Portrayals of Suicide are Temporally Related to Spikes in Crisis Text Line Conversations Nationwide. *AAS Annual Conference*, Portland, OR, April 22, 2019.
- Moroni, D., H. Ramapriyan, and **G. Peng**, 2019: Community Whitepaper on Uncertainty Quantification. *2019 US CLIVAR Summit,* Long Beach, CA, August 6, 2019.
- **Peng, G.**, 2019: A Brief Update on the Activity of the RDA FAIR Data Maturity Model Working Group. *47th Committee on Earth Observation Satellites (CEOS) Meeting of the Working Group on Information Systems & Services,* Silver Spring, MD, May 1, 2019.
- **Peng, G.**, 2019: A Framework for Curating Rich and Structured Data Quality Descriptive Information. *DataONE Community Meeting*, Tacoma, WA, July 15, 2019.
- **Peng, G.**, 2019: A Holistic Framework for Supporting Evidence-Based Institutional Research Data Management. *CODATA 2019 Conference*, Beijing, China, September 19, 2019.
- **Peng, G.**, 2019: An Introduction to Stewardship Maturity Matrix for Climate Data. *WMO Catalogue on Assessed Climate Datasets Expert Meeting*, Geneva, Switzerland, April 12, 2019.

- **Peng, G.**, 2019: An overview of maturity models for consistent dataset quality ratings. *Barcelona Supercomputing Center and Copernicus Data Store*, Barcelona, Spain. September 26, 2019.
- **Peng, G.**, 2019: Introducing ESIP Information Quality Cluster. *Barcelona Supercomputing Center and Copernicus Data Store*, Barcelona, Spain. September 23, 2019.
- **Peng, G.**, 2019: Providing Rich and Structured Dataset Quality Information -Practical Application of a Data Stewardship Maturity Matrix. *Research Data Alliance's 13th Plenary Meeting*, Philadelphia, PA, April 2, 2019.
- **Peng, G.**, 2019: Update on Maturity Matrix Related Activities. Session: Conveying Information Quality – Recent Progress. *ESIP 2019 Summer Meeting,* Tacoma, WA, July 16, 2019.
- **Peng, G.**, 2019: What is the WMO Stewardship Maturity Matrix for Climate Data? Why need one? Why now? *WMO Catalogue on Assessed Climate Datasets Expert Meeting*, Geneva, Switzerland, April 12, 2019.
- **Peng, G.**, 2019: WMO Stewardship Maturity Matrix for Climate Data (SMM-CD) – An Update and Possible Collaboration. *47th Committee on Earth Observation Satellites (CEOS) Meeting of the Working Group on Information Systems & Services,* Silver Spring, MD, May 1, 2019.
- **Peng, G.**, A. Milan, N. Ritchey, et al, 2019: Providing Rich and Structured Dataset Quality Information – Practical Application of a Data Stewardship Maturity Matrix. Poster. *DataONE Community Meeting*, Tacoma, WA, July 15, 2019.
- **Peng, G.**, J. L. Privette, and **T. Maycock**, 2019: An Integrated Framework for Managing Scientific Data Stewardship Activities. Poster. *ESIP 2019 Summer Meeting*, Tacoma, WA, July 17, 2019.
- **Peng, G.**, M. Steele, A. Bliss, W. Meier, and S. Dickinson, 2019: Integrated Climate Indicators for Monitoring Seasonal Arctic and sub-Arctic Sea Ice Coverage Using a Satellite Climate Data Record. Poster. *EGU General Assembly 2019*. Vienna, Austria, April 10, 2019.
- **Peng, G.,** M. Steele, A. Bliss, W. Meier, **J. Matthews**, M. Wang, and S. Dickinson, 2019: Characterizing Arctic Sea Ice Coverage Variability. *Barcelona Supercomputing Center and Copernicus Data Store*, Barcelona, Spain. September 23, 2019.
- **Peng, G**., N. Ritchey, and I. Maggio, 2019: Establishing Trustworthiness and Suitability of Data Products and Services with Content-Rich, Interoperable and Findable Quality Descriptive Information. Session. *EGU General Assembly 2019*, Vienna, Austria, April 9, 2019.
- **Prat, O. P.**, M. R. Kumjian, K. J. Riemel, H. C. Morrison, and M. Van Lier-Walqui, 2019: A comparison of bulk- and bin-microphysical schemes for warm rain processes and their polarimetric radar fingerprints: sensitivity analysis and implications for microphysical parameterizations. Poster. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.
- **Prat, O.**, 2019: Using Remotely Sensed Precipitation Information and Vegetation Observation from the NOAA/Climate Data Record (CDR) Program for Early Drought Detection and Near-Real Time Monitoring on a Global Scale. *AMS 2019 Joint Satellite Conference*, Boston, MA, October 3, 2019.
- **Rao, Y.**, 2019: Improving surface temperature data quality by leveraging daily satellite observations and machine learning techniques. Poster. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.
- **Rao, Y.**, 2019: Integrating long term satellite data and in situ observations to study snow-albedo-temperature feedback over the Tibetan Plateau. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 12, 2019.
- **Rao, Y.**, 2020: Building Machine Learning Tutorials for Earth Science Applications. Poster. *ESIP 2020 Winter Meeting*, January 9, 2020.

- **Rao, Y.**, 2020: Improving surface temperature data quality by leveraging daily satellite observations and machine learning techniques. *ESIP 2020 Winter Meeting*, January 9, 2020.
- **Rennie, J.**, 2019: Science Communication. *American Meteorological Society (AMS) Early Career Leadership Academy (ECLA)* webinar, June 7, 2019.
- **Rennie, J.**, 2019: Climate in Your Neck of the Woods: A Real Time, Interactive GIS Product to Assess Historical and Current Trends in Temperature and Precipitation. *National Weather Association (NWA) Annual Meeting*, Huntsville, AL, September 9, 2019.
- **Rennie, J.**, 2020: From NCL to Python: The Triumphs (and Struggles) of Upgrading a Tropical Monitoring Page for Air Force Operations. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.
- Riemel, K. J., M. Van Lier-Walqui, M. R. Kumjian, **O. P. Prat**, and H. C. Morrison, 2019: How much can we learn about rain microphysics from polarimetric radar observations? An investigation of information content and parameter estimation using the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS). *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 12, 2019.
- **Rogers, K.**, 2019: Scaling Technology with a Lens on Equity. *Climate City Expo*, The Collider, Asheville, NC, April 3, 2019.
- **Rogers, K.,** and N. Hall, 2019: Focusing the Frame: Engaging and Connecting with Your Resilience Audience, *National Adaptation Forum 2019*, Madison, WI, April 23, 2019.
- **Schreck, C.**, 2019: Climate and Weather Applications for Developing Countries. *Millennium Challenge Corporation*, Washington, DC, November 5, 2019.
- **Schreck, C.**, 2019: Speaking of Climate: Are hurricanes stronger, larger, and wetter? *The Collider.* September 24, 2019. case.simpletix.com/e/47619
- **Schreck, C.**, 2020: Subseasonal Rainfall Forecasting. *Water Collaborative Mini-Symposium, NC State University,* Raleigh, NC, January 16, 2020.
- **Stevens, L. E.**, J. Blunden, and D. S. Arndt, 2019: Curating a multi-agency set of Federal climate indicators, *2019 National Adaptation Forum*, Madison, WI, April 23, 2019.
- **Stevens, L. E.**, J. Blunden, and D. S. Arndt, 2019: Curating a multi-agency set of Federal climate indicators, *ESRL 47th Global Monitoring Annual Conference*, Boulder, CO, May 21, 2019.
- **Stevens, L.**, 2019: Highlights from the Fourth National Climate Assessment Volume II: Impacts, Risks, and Adaptation in the United States. *Association of Environmental and Engineering Geologists 62nd Annual Meeting*, Asheville, NC, September 18, 2019.
- Thompson, L. K., M. Michael, J. D. Runkle, and M. M. Sugg, 2019: Crisis Text Line Use Following the Release of Netflix Series 13 Reasons Why Season 1: Time Series Analysis of Help-Seeking Behavior in Youth. *52nd Annual Conference of the American Association of Suicidology*, Denver, CO, April 25, 2019.
- van Lier-Walqui, H. Morrison, M. Kumjian, M., C. Martinkus, **O. P. Prat**, and K. J. Reimel, 2019: Probabilistic observational constraint of a microphysics scheme with flexible structural complexity. *2019 ARM/ASR Joint User Facility and PI Meeting*, Rockville, MD, June 11, 2019.
- van Lier-Walqui, M., H. Morrison, M. R. Kumjian, K.J. Reimel, **O. P.** Prat, S. Lunderman, and M. Morzfeld, 2020: Statistical-physical microphysics parameterization schemes: A proposed framework for physically based microphysics schemes that learn from observations. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.
- Whitehead, J., and **J. P. Dissen**, 2019: Bringing Academic and Scientific Assessment to Decisions. *NC DEQ Climate Change Interagency Council Meeting*, Raleigh, NC, April 26, 2019.
- **Worku, L.**, 2019: Multi-scale interactions between the diurnal cycle, MJO, and convectively coupled equatorial waves over the Maritime Continent. Ph.D. Defense, Energy & Environmental

Systems (EES) Ph.D. Program, *North Carolina A&T State University*, Greensboro, NC, December 4, 2019.

Outreach and Engagement Presentations

- **Maycock, T.**, 2019: Climate Change in North Carolina (panel discussion). Get off the Grid Fest, *Warren Wilson College,* Swannanoa, NC, August 10, 2019.
- **Rennie, J.**, 2019: Science Communication. *American Meteorological Society (AMS) Early Career Leadership Academy (ECLA)* webinar, June 7, 2019.
- **Steven, S.**, 2019: Careers in Data Analysis. *Enka Intermediate School*, Candler, NC, May 1, 2019.
- **Steven, S**., 2019: Data Analysis. Isothermal Science and Technology Expo, *Isothermal Community College,* Spindale, NC, April 5, 2019.

Appendix 4: CICS-NC Products 2019–2020

- Common Ingest Agile Development Team
    - Common Ingest v2. 17.0 Complete chooseTar algorithm processing; operationalize object-storer
    - Common Ingest v2.16.1 Persist *RabbitMQ* message in all engines
    - Common Ingest v2.16.0 Tar-creator create tarball in new working directory
    - Common Ingest v2.15.8 Partition tar-creator
    - Common Ingest v2.15.7 Add ingest report scraper
    - Common Ingest v2.15.5 Fixed missing variable declaration in Ftpser
    - Common Ingest v2.15.4 Include *RabbitMQ* thread option for engines
    - Common Ingest v2.15.2 Close temporary manifest files
    - Common Ingest v2.15.1 Allow checksums to begin with zero
    - Common Ingest v2.15.0 Allow aggregation stream name change
    - Common Ingest v2.14.0 Create fetch-processor light engine
    - Common Ingest v2.13.0 Retry on tar and untar failures
    - Common Ingest v2.12.0 Remote-io retry with queues
    - Common Ingest v2.11.1 Fix tar-creator message too large
    - Common Ingest v2.11.0 Cleanup for chooseTar processing algorithm

- Programming and Applications Development for Climate Portal
    - Data snapshots on Climate.gov (https://www.climate.gov/maps-data/data-snapshots/start)
    - U.S. Climate Resilience Toolkit (https://toolkit.climate.gov)
    - Climate Explorer 1 (http://climate-explorer.nemac.org)
    - Climate Explorer 2 (CE2.5) (https://crt-climate-explorer.nemac.org/)
    - USGCRP Indicator graphics (http://www.globalchange.gov/browse/indicators)

- NCEI Infrastructure Architecture Planning and Implementation
    - CDS system architecture design

- National Climate Assessment Scientific and Data Support Activities
    - Improved interactive, web-based metadata viewer, providing additional downloadable content, most notably including direct access to TSU derived datasets
    - NOAA State Climate Summaries for Alabama, Louisiana, Mississippi, Utah, New Mexico, Ohio, and North Carolina

- National Climate Assessment Technical Support Activities
    - **Fourth National Climate Assessment, Volume II** – accessibility and errata updates https://nca2018.globalchange.gov
    - **The Scientific Assessment of Ozone Depletion: 2018** – https://www.esrl.noaa.gov/csd/assessments/ozone/2018/
    - **State of the Carbon Cycle Report 2018** – version 2.0 – https://carbon2018.globalchange.gov/
    - **PDF Alternative Text Tool** – new software tool for automatically applying alternative text to figures in PDFs

- Climate Change Indicators
    - Updated 15 of the 16 USGCRP Indicators: Annual Greenhouse Gas Index, Arctic Glacier Mass Balance, Arctic Sea Ice Extent, Atmospheric Carbon Dioxide, Billion Dollar Disasters, Frost-Free Season, Global Surface Temperatures, Heat Waves, Heating and Cooling Degree Days, Ocean Chlorophyll Concentrations, Sea Level Rise, Sea Surface Temperatures, Start of Spring, Terrestrial Carbon Storage, U.S. Surface Temperatures

- Scientific Subject Matter Expertise Support
    - AVHRR Surface Reflectance CDR, Normalized Difference Vegetation Index CDR, and Leaf Area Index and FAPAR CDR all underwent a version change to version 5.0.
    - Precipitation – CMORPH transitioned to operations

- Spatial–Temporal Reconstruction of Land Surface Temperature (LST) from Daily Max/Min Temperatures
    - Updated algorithm to reconstruct LST from daily max/min temperatures and Surface Solar Absorption retrieved in near real time from GOES-R data

- Transitioning of the International Satellite Cloud Climatology Project (ISCCP) Process to NCEI-NC
    - H-series cloud product for the extended period (2015–2017), including the new NOAA-19 sensor from 2013
    - H-series cloud product (ICDR) for 2017 July–2018 December using the nnHIRS climatology
    - HBT Calibration (counts to radiance) tables for the period 2017 July–2018 December, including for the new sensors NOAA-19, HIMAWARI-8, and GOES-16 and for MSG-1 (INS segment), MSG-2, and MSG-3

- Regional Variability of Sea Ice Coverage
    - **Peng, G.,** A. Arguez, J. Crouch, and P. Jones, 2019b: Sea Ice Climate Normals (1981–2010) of Arctic and Sub-Regions, Version 1. NOAA National Centers for Environmental Information. https://doi.org/10.25921/TRXE-M983

- Identifying Tropical Variability with CDRs
    - Synoptic Discussions for NCEI's State of the Climate May–July 2019: e.g., https://www.ncdc.noaa.gov/sotc/synoptic/201905
    - Hurricanes and Tropical Storms reports for NCEI's State of the Climate May–July 2019: e.g., https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201905

- Drought-related health impacts: advancing the science for public health applications
    - Convened a National Drought and Public Health Summit in June 2019

- Optimum Interpolation Sea Surface Temperature (OISST) algorithm upgrades
    - Optimum Interpolation Sea Surface Temperature v2.1

- Standardization of U.S. Climate Reference Network (USCRN) Soil Moisture Observations
    - USCRN soil moisture climatologies
    - USCRN standardized soil moisture anomalies and percentiles

- Development of the United States Climate Reference Network (USCRN) National Precipitation Index
    - The National Precipitation Index dataset has been updated

- Maintenance and Streamlining of the Global Historical Climatology Network-Monthly (GHCNm) Dataset
    - Public, operational version of GHCNm version 4.0.1
    - NOAAGlobalTemp version 5, with journal article published describing methods

- Development of a Homogenized Sub-Monthly Temperature Monitoring Tool
    - Updated monitoring tool for sub-monthly data for the United States
    - Updated database of heat events through 2018

- International Comprehensive Ocean–Atmosphere Data Set (ICOADS)
    - Improved ICOADS data retrieval and processing system is now operational