COOPERATIVE INSTITUTE FOR SATELLITE EARTH SYSTEM STUDIES (CISESS)

Annual Scientific Report

CISESS NC TASK REPORTS

For the period:

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CISESS NC Overview

The operation of the Cooperative Institute for Satellite Earth System Studies in North Carolina (CISESS 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/CISESS 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. CISESS NC is collocated with the NOAA/NESDIS National Centers for Environmental Information (NCEI) and NOAA's Chief Information Officer in Asheville, NC, and focuses on enhancing the understanding of how the natural atmosphere–ocean–land–biosphere components of Earth interact with human activities as a coupled system. CISESS NC engages in collaborative research and other related activities with NCEI and the National Environmental Satellite, Data, and Information Service (NESDIS) as well as 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 Office of the Chief Information Officer (OCIO). CISESS NC also supports other federal agency collaborators with NOAA/NCEI, including the United States Global Climate Research Program (USGCRP), the U.S. Department of State, and the Centers for Disease Control and Prevention (CDC).

CISESS NC is led by the Director of the IRC and includes numerous academic and community partners with specific expertise in the challenges of utilizing remotely sensed and in situ observations in Earth system research and applications as well as the broader expertise needed to support Earth system/societal impact/societal response studies. Current community partners include The Collider, the North Carolina Arboretum, NCSU's The Science House, the State Climate Office of North Carolina, and the Asheville Museum of Science. NCSU provides CISESS with access to strong graduate programs in Earth, engineering, data analytics, and life sciences, and many of the CISESS consortium partners offer complementary programs.

The CISESS 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 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 CISESS scientists work on projects that advance NOAA objectives. CISESS conducts collaborative research with NOAA scientists in three principal, interrelated Research Themes: Satellite Services, Earth System Observations and Services, and Earth System Research.

The CISESS NC mission focuses on collaborative research into the use of in situ and remotely sensed observations, the Earth system, and climate products and applications; innovation of new products and 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 applications development; engagement with corporate leaders and the public to develop climate-literate citizens and a climate-adaptive society; and the facilitation of regional economic development through its engagement activities.

CISESS NC activities primarily support NCEI program activities and enterprise services. Main collaborative and other research activities are currently organized by the following task streams:

1) Administration (Task I)
2) Access and Services Development
3) Assessments
4) Information Technology Services
5) Science and Services
6) Workforce Development
7) Consortium and/or Other Projects

These streams are currently supported by the different divisions in NCEI; NOAA Line Offices including the NESDIS, OAR, and NWS; and North Carolina State University. Other Projects led by CISESS principal investigators (PIs) are generally funded by other federal or private (non-NOAA) sponsors but reflect broader Institute research efforts that complement CISESS mission goals.

Highlights

CISESS NC

CISESS 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 CISESS NC activities remain primary, NCICS scientists are also engaged in research projects (Other Projects) supported by other federal or private sponsors that currently include: The National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy (DOE), and the U.S. Department of Defense (DoD).

Administration [NCSU/NOAA]

***Institute Information Technology Support Services*:** Institute IT staff provide modern, scalable approaches to keep sustain CISESS NC at the competitive edge of technology advances and maintain core technologies as a stable base for staff operations. This year's accomplishments included security and monitoring improvements, network upgrades, and transitioning data storage to the *Ceph* file system.

***Institute Communications*:** Institute communication efforts promote the Institute and its research activities to its stakeholders and advance the external and internal communications efforts of NCEI. Communications support was provided for the transition from the predecessor cooperative institute to CISESS, and a new partnership was established with Blue Ridge Public Radio, resulting in three audio/web stories on climate and climate change.

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 and backfilled GOES data from archive sources. Testing of ingest and product development directly in the cloud is underway, and *Elasticsearch* is being used to provide near-real-time monitoring and metrics. https://ncics.org/data/noaa-big-data-project/

***Development and Support of NOAA Climate Products and Services*:** In support of the overall advancement of NOAA's Climate Products and Services program, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with managing the U.S. Climate Resilience Toolkit, launching Climate Explorer 3, prototyping an author "Sandbox", updating USGCRP Indicators website graphics design and data, and redesigning NIDIS drought.gov.

***Scientific Data Stewardship for Digital Environmental Data Products*:** The NCEI/CICS-NC-developed Data Stewardship Maturity Matrix (DSMM) has been adapted by several international groups, including the Working Group on Information System and Services of the Committee on Earth Observation Satellites and the International Expert Group on Climate Data Modernisation (IEG-CDM) of the World Meteorological Organization (WMO) Commission for Climatology.

Assessment Activities [NCEI/CPO/DOS]

***Assessment Scientific and Data Support Activities*:** The Assessment science/data team began preliminary planning for the Fifth National Climate Assessment and led the development of the North Carolina Climate Science Report through overall project management, authorship contributions to several chapters, and development of numerous specialized scientific analyses and graphs**.** https://ncics.org/programs/nccsr

***Assessment Technical Support Activities*:** The Assessment technical support team began preparation and planning for the Fifth National Climate Assessment (NCA5), including the development of a new assessment collaboration website. The team also supported the development and production of the North Carolina Climate Science Report (NCCSR), a comprehensive assessment of past and future climate change in North Carolina. https://ncics.org/nccsr

***North Carolina Climate Science Report*:** CISESS staff led the development and release of the North Carolina Climate Science Report (NCCSR), an independent scientific assessment of observed and projected climate change in North Carolina intended to inform North Carolina citizens about important climate trends and potential future changes. https://ncics.org/programs/nccsr/

***Climate Change Indicators*:** Assessment Technical Support Unit (TSU) staff provide scientific and technical expertise in support of USGCRP efforts to maintain a comprehensive suite of climate change indicators. Work included a comprehensive update of the full indicator suite including new graphics as well as planning for the development of several new indicators. http://www.globalchange.gov/indicators

***U.S.–India Partnership for Climate Resilience Activities Support*:** CISESS NC initiated U.S.–India Partnership for Climate Resilience Phase II capacity-building activities. In collaboration with the U.S. Department of State and NCEI, the project team worked with India-based partner The Energy and Resources Institute (TERI) to co-convene a forestry-related session at TERI's 2020 World Sustainable Development Summit and coordinated a technical and policy roundtable discussion with India forestry sector stakeholders.

***The Energy and Resources Institute Supporting the U.S.–India Partnership for Climate Resilience*:** As part of the U.S.–India Partnership for Climate Resilience (PCR) Phase II activities, The Energy and Resources Institute (TERI), NCEI, and CISESS co-convened 1) a 2020 World Sustainable Development Summit session targeting key India forestry management stakeholders focused on relevant climate change impacts and using climate projections for adaptation planning and 2) a roundtable discussion with various forestry sector stakeholders.

Information Technology Services [NCEI]

***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 worked on completing enhancements to improve the system for operational use.

NCEI Infrastructure Architecture Planning and Implementation: This project team and its collaborators drive NCEI and NCICS IT infrastructure and architecture that will support a modern, flexible, distributed approach to data science, archive, and access capabilities. A high-performance workflow data processing system, *NiFi*, was prototyped and presented to NCEI.

Science and Services [NCEI]

***Scientific Subject Matter Expertise Support*:** CISESS scientists served as subject matter experts on 3 Climate Data Record Integrated Product Teams, as Product Leads for 25 products, and as Product Area Leads for 3 product areas. https://www.ncdc.noaa.gov/cdr

***Drought-related health impacts: advancing the science for public health applications*:** CISESS Consortium partner University of Nebraska Medical Center and the National Integrated Drought Information System (NIDIS) conducted two state-level workshops on drought and health following the 2019 National Drought

and Public Health Summit. The project team is evaluating the impact of historical drought events on mortality and morbidity with preliminary results reflecting a greater impact on minority subpopulations.

***Strategic Engagement and Outreach*:** Key accomplishments this year included continuing improvements to NCEI's use of a customer relationship management (CRM) tool, multiple engagement activities at the American Meteorological Society Annual Meeting, new collaboration efforts with the State Climate Office of North Carolina, and a variety of educational and outreach events in Western North Carolina. https://ncics.org/events/**;** https://ncics.org/expertise/engagement/

Understanding Future Changes in Cold/Shoulder-Season Precipitation: International environmental change studies focused on the northern extratropics were conducted to better inform vulnerable societies and prepare them for potential future developments.

***GOES-R-Based Products*:** The project team is employing NASA's Clouds and Earth's Radiant Energy System (CERES) instrument observations as an anchor for calibration/validation of the GOES visible channel sensor. An algorithm was developed to evaluate surface solar absorption in near real time from GOES-R data.

***HIRS-Like Data from New-Generation Sensors*:** This new project is exploring the generation of High-resolution Infrared Sounder (HIRS)-like data from the next generation of sensors in anticipation of HIRS instrument retirement. Atmosphere and surface data, including temperature and water vapor profiles, were obtained from HIRS observations using a neural network algorithm. https://www.ncdc.noaa.gov/isccp

***U.S. Climate Reference Network (USCRN) Applications and Quality Assurance*:** USCRN precipitation observations were applied to evaluate the quality of gauges used to correct radar estimates of precipitation and to verify NOAA's satellite-based precipitation climate data records. Precipitation extremes and frequency of NOAA Atlas 14 threshold exceedances were updated through 2019 at USCRN stations. This analysis was also extended to the Cooperative Observer Program's hourly precipitation dataset (HPD).

***Standardization of U.S. Climate Reference Network Soil (USCRN) Moisture Observations*:** USCRN's hourly standardized soil moisture observations were aggregated to provide metrics of soil moisture variability over weekly time scales. Two metrics—the percent of hours below the 30th percentile and anomalous averages—were found to correlate best with U.S. Drought Monitor–based drought evolution, demonstrating that these datasets show some promise as monitoring tools.

***Exploring the Impacts of Drought Events on Society*:** U.S. Drought Monitor data were intersected with U.S. county data to define unique drought events. Characteristics of these events revealed stark contrasts between the western and eastern United States. In addition, county-level economic losses did not always align with measures of drought severity, suggesting that other factors, such as the timing of the drought event, may influence agricultural losses.

***Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES Data*:** The GSA algorithm was implemented as the U.S. contribution in an international collaboration between Europe, Japan, South Korea, and the United States to produce a joint climate data record. The cloud mask developed by MeteoSwiss has been was installed, configured, compiled, and successfully executed with test METEOSAT data on CISESS computing servers. 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 1978–present. The data are produced by applying neural networks to High-Resolution Infrared Radiation Sounder (HIRS) data.

***Evaluation and Elucidation of SCaMPR Performance in Complex Terrain Leveraging GOES-R Observations and Ground-based Precipitation Measurements (Duke)*:** Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) precipitation estimates were evaluated against rain-gauge measurements from the Southern Appalachian Mountains Duke network. SCaMPR quantitative precipitation estimation (QPE) errors exhibit a strong diurnal cycle and spatial structure that can be tied to orographic precipitation regimes. This is a promising outcome toward developing improved QPE.

***Evaluation and Elucidation of SCaMPR Performance in Complex Terrain Leveraging GOES-R Observations and Ground-based Precipitation Measurements (UNC Asheville)*:** Completed summer and fall 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).

***Gridded In Situ USCON Temperature and Precipitation Normals*:** Thirty-year averages of daily, monthly, and annual gridded USCON temperature and precipitation data are being computed using NCEI's gridded dataset (nClimGrid). The team examined day-to-day variability in daily average temperatures, produced maps of extreme event days and a comparison with PRISM data, and incorporated results in NCEI's monthly State of the Climate reports.

***Development of Satellite Alternate Precipitation Normals*:** Prior evaluation of the satellite precipitation CDRs (CMORPH-CDR, PERSIANN-CDR, GPCP) and of their strengths and weaknesses is being used to develop alternate precipitation normals.

***Toward Earlier Drought Detection Using Remotely Sensed Precipitation Data from the Reference Environmental Data Record CMORPH*:** Monthly and daily Standardized Precipitation Indices (SPIs) were implemented using precipitation satellite data from the CMORPH and PERSIANN climate data records to investigate their suitability for detecting and monitoring drought.

***Developing and Validating Heat Exposure Products Using the U.S. Climate Reference Network*:** Using hourly and sub-hourly data from the United States Climate Reference Network (USCRN), heat exposure indices such as including heat index, apparent temperature, and wet-bulb globe temperature (WBGT) are being developed and validated against nearby sites. These derived products will be used to address heat health, combining climate data with available socioeconomic and hospital data.

***Development of the United States Climate Reference Network (USCRN) National Precipitation Index*:** The CISESS project team is working to transition the previously developed National Precipitation Index (NPI) developed under the previous NOAA cooperative institute into NCEI operations.

***NCEI Innovates: Developing 1991–2020 Normals along the Northeast and Mid-Atlantic Coasts*:** Coastal normals for 1991–2020 were developed for areas around the Northeast and Mid-Atlantic regions, and an *ArcGIS Online* tool was developed to allow users to interact with the data.

***Collaborative Climate and Human Health Activities*:** In support of NOAA and Centers for Disease Control and Prevention (CDC) mutual interests and objectives, initial project efforts focused on conducting a needs assessment with two CDC programs, Climate and Health and the Environmental Public Health Tracking Network, to identify their environmental data product needs.

***Climate Monitoring*:** nClimGrid-Daily and IBTrACSv4 are being incorporated into NCEI's monthly State of the Climate reports to improve tracking of sub-monthly weather patterns and tropical cyclones.

***Global Historical Climatology Network–Hourly (GHCN-H)*:** The project team is working to add global, standardized hourly data to the Global Historical Climatology Network dataset for use in climate applications. Networks are being added to the data flow, processes are being developed to standardize their format, and an initial survey of existing hourly quality control checks is taking place.

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 CISESS PI Projects

***Changes in the Frequency of Freezing Precipitation*:** Several international environmental change studies focused on the northern extratropics were conducted to better inform vulnerable societies and prepare them for potential future environmental change.

***The Urban Resilience to Extremes Sustainability Research Network (UREx SRN)*:** The NCSU team on this collaborative multi-institution National Science Foundation (NSF) project conducted studies using the Weather Research and Forecasting (WRF) model to successfully simulate extreme precipitation amounts. A new method was also developed to create the pseudo-global warming scenarios.

***Incorporation of Climate Change into Intensity–Duration–Frequency Design Values*:** The Strategic Environmental Research and Development Program (SERDP) project team is working to develop a framework for incorporating the potential impact of future climate change into estimates of heavy precipitation Intensity–Duration–Frequency (IDF) design values. Analysis of historical climate data shows that water vapor is the primary determinant of the amount of precipitation falling in extreme events. Future changes in IDF values will be mainly dependent on changes in water vapor.

***Operational Transition of Novel Statistical-Dynamical Forecasts for Tropical Subseasonal to Seasonal Drivers*:** Metrics developed for the Madden–Julian Oscillation (MJO) monitoring page highlight the most predictable signals for NOAA's Climate Prediction Center (CPC). ncics.org/mjo

***Kelvin Waves and Easterly Waves in CYGNSS*:** Atmospheric Kelvin waves enhance the strength of easterly waves through barotropic energy conversion related to an increased the meridional gradient of zonal winds.

Administration

Administrative, or Task I, activities provide a central shared resource for CISESS 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 CISESS NC–initiated consortium projects, and coordination with 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, CISESS NC serves as one of two CISESS sites and is collocated with NCEI in the Veach-Baley Federal Complex in Asheville, NC. The operation of CISESS 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/CISESS 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/CISESS NC Director reports to the NCSU Vice Chancellor for ORI. CISESS personnel are hired as NCSU employees and serve under NCSU policies and administrative guidelines. CISESS NC administrative staff implement, execute, and coordinate administrative activities with pertinent CISESS, UNC, NCSU, ORI, NOAA, and NCEI administrative offices.

The CISESS NC Director, in coordination with the Business Manager and University Program Specialist, is responsible for the operations of CISESS 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 (two 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 facilitating research 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.

CISESS 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 System Administrator II
Steven Marcus, IT Network Administrator II
Scott Wilkins, IT System Administrator II

Institute Information Technology Support Services	
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)

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

Background

CISESS 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.

Distributed *Ceph* file systems are provided 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 CISESS and other building partners with strong-signal, fast wireless coverage. This allows CISESS 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.

CISESS 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.

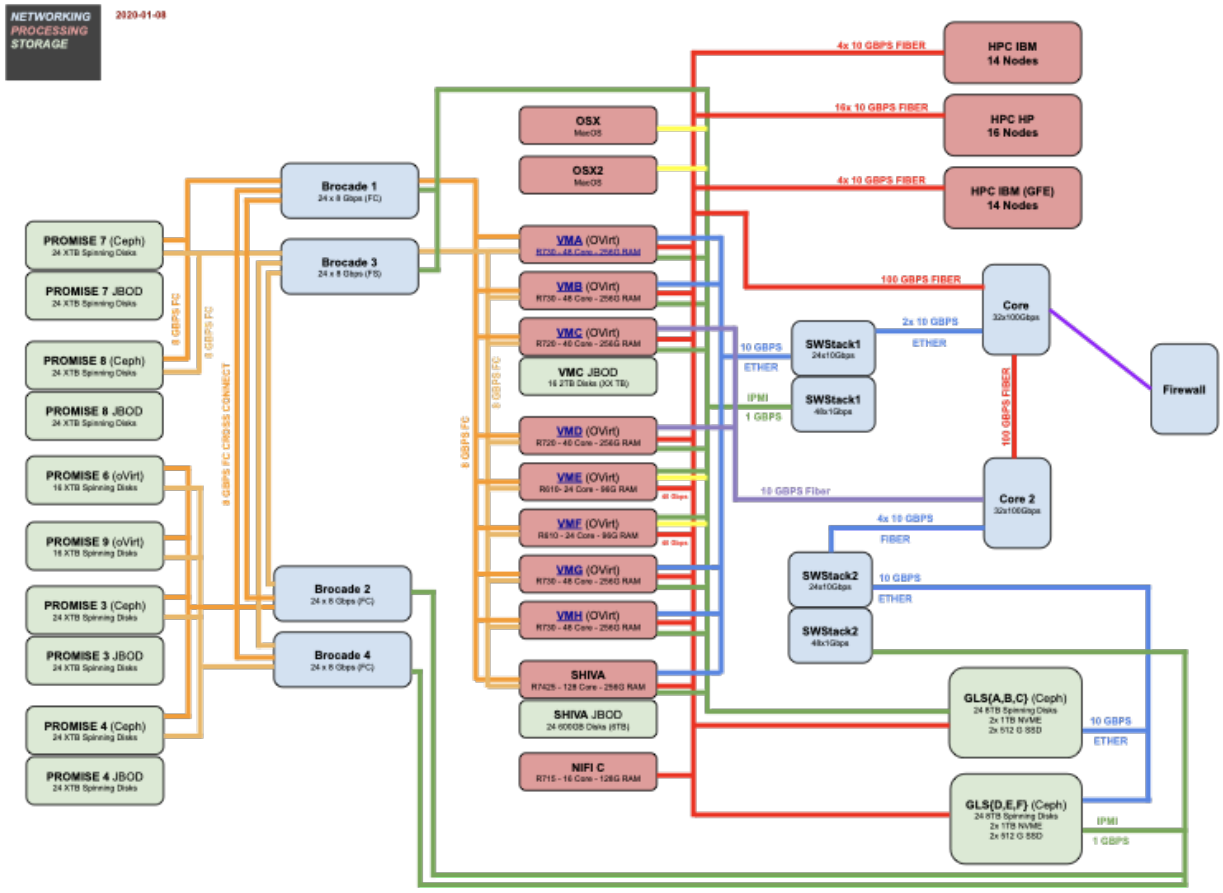


***Figure 1**. Network and System Diagram.*

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 to perform both 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 Institute endpoints. Approved security exceptions were obtained to allow 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) in high traffic areas. 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 adapt to the loss of switches, network interface cards and loss of network links.

Ceph file systems. The *Gluster* file systems were replaced with *Ceph Reliable Autonomic Distributed Object Store (RADOS) Block Device (RBD)* file systems. The existing *Gluster* hardware was reconfigured to host Ceph after encountering data corruption issues with the *Gluster* infrastructure. The *Ceph RBD* file systems

have been very stable and much more performant. Input datasets were placed on the older *Promise Storage Area Network (SAN)* systems to maximize performance. These slower drives are still very responsive in read-intensive operations. The *Ceph* infrastructure allows CISESS researchers to transition their code from file systems to object stores on-premises in preparation for cloud deployment.

Kubernetes transition. CISESS IT staff are transitioning the batch-only compute cluster to *Kubernetes*. At present, four of the 44 available compute nodes are running a *Kubernetes* cluster while support and update procedures are under further development. Development has proceeded on several fronts: a pod that will run the current *Openlava* batch environment to provide a seamless transition off the current cluster is deployed, while exploration of *Argo Workflow Engine* as a platform for converting scientific code, and direct conversion of user jobs to pods is in the queue. Once completely operational, the 44-node cluster will provide the CISESS scientists with an on-premise location to test running their code using cloud-based technologies.

NOAA and other building tenant support. The Institute provides its partners in the Federal building with IT support, including regular Wi-Fi, audiovisual, and video conferencing support for 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 the NOAA Hollings Scholar 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

- Ongoing monitoring and maintenance tasks
- Plan for upcoming equipment end of life and associated replacements
- Improve security scanning regularity and address issues
- Continue support for our federal partners and internship programs
- *Kubernetes* cluster development
- Assist users with leveraging cloud-based technologies

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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Institute Communications	
Task Team	Tom Maycock, Jessicca Griffin, Angel Li
Task Code	NC-ADM-02-NCICS-TM/JG/AL
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI

Highlight: Institute communication efforts promote the Institute and its research activities to its stakeholders and advance the external and internal communications efforts of NCEI. Communications support was provided for the transition from the predecessor cooperative institute to CISESS, and a new partnership was established with Blue Ridge Public Radio, resulting in three audio/web stories on climate and climate change.

Background

Institute 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. CISESS staff also provide science writing, editing, and graphic design support to NCEI's Communications and Outreach Branch. The Science Public Information Officer works to coordinate communication efforts between the Institute and its various stakeholders, including NCEI and NCSU.

Accomplishments

Cooperative institute transition. With the transition from CICS to CISESS, a number of updates were needed, including social media account identities, website content, and other communications materials, and a new section of the website devoted to CISESS was developed.

Media. The Institute is now working with Blue Ridge Public Radio (BPR) in Asheville, NC, on a series of climate-related radio and website features involving Institute staff and colleagues from around Western North Carolina. To date, BPR has produced segments on how climate change affects hurricanes, featuring Carl Schreck; public perceptions of a key finding from the Intergovernmental Panel on Climate Change report on 1.5°C of global warming, featuring Tom Maycock and NCEI archive specialist Jason Cooper; and the connections between climate change and human health, featuring Jennifer Runkle and Appalachian State University's Maggie Sugg. Links to these stories and other media coverage are available at https://ncics.org/in-the-media.

The North Carolina Climate Science Report was officially released on March 11, 2020. The Institute coordinated a video media conference featuring lead authors Kenneth Kunkel of CISESS and David Easterling of NCEI, members of the report advisory panel from around the state, and approximately a dozen reporters. The conference and a follow-up onsite interview by WLOS TV generated several stories on the report. Plans are underway for an extended social media engagement campaign to share key findings and regional highlights.

The Institute's social media accounts continued to see modest growth, with Twitter followers expanding from 445 to 578 and the Facebook audience growing from 659 to 743.

The latest issue of the Institute's *Trends* newsletter, published in October 2019, included articles on CISESS, support for the North Carolina Climate Science Report, new peer-reviewed research, a range of outreach and engagement activities, and more.

NCEI communications support. CISESS communications staff support the NOAA NCEI Communications and Outreach Branch with extensive graphic design and visual communications support for a variety of NCEI activities and communications coordination and planning. Design and layout support were provided for two reports currently being produced at NCEI: the Extended Continental Shelf report and an engineering study on the reallocation of the 1675–1680 MHz spectrum. Other graphic design work included new branding for NOAA's Collection Metadata Editing Tool (CoMET), photography services, and graphics design for various scientific and media projects and presentations.

Planned work

- Produce two issues of *Trends* newsletter
- Continuing outreach related to the North Carolina Climate Science Report
- Expand production of news stories and press releases highlighting research papers

Presentations

Maycock, T., Veasey, S., and G. Hammer, 2019: Poster Production Creation- A whole new approach. *NCEI Seminar Series*, Asheville, NC, October 1, 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**

Access and Services Development

Access and Services Development activities support improvements to access mechanisms to the expansive data and product holdings of NOAA NCEI. NOAA daily generates terabytes of data from satellites, radars, ships, weather models, and other sources, and NCEI currently archives more than 30 petabytes of data. Current petascale data holdings are forecasted to continue to grow, and NOAA's computational needs are projected to push exascale boundaries by 2023. The continued growth of the archive necessitates forward-thinking design and scalable algorithms and architectures. It is becoming increasingly important not only to manage the amount of data but also to harness these data in ways that result in products that are of use by, and accessible to, decision-makers and the general public. Scientific data stewardship efforts focus on improving measures of stewardship, accessibility, and curation for NOAA's data holdings. This requires the input and guidance of scientific data management expertise, applicable user-interface enhancement design and implementation, and the integration of end-user needs into data products with the goal of providing useful tools and information to improve societal resilience to climate change.

The NOAA Big Data Project (BDP) was created to explore 1) sustainable models to increase access to NOAA open data and 2) the potential benefits of storing copies of key observations and model outputs in the cloud in order to allow computing directly on the data without need of further distribution. CISESS NC's predecessor, the North Carolina campus of the Cooperative Institute for Climate and Satellites (CICS-NC), developed and implemented a data hub to facilitate data transfers to the cloud and served as a broker between NOAA and the public cloud providers, transferring and certifying multiple NOAA datasets to multiple cloud platforms. CISESS NC continues in the data broker role as NOAA transitioned to a contract model with the cloud service providers for continued provision of BDP Cloud datasets.

CICS-NC was also instrumental in the design, development, and implementation of the U.S. Climate Resilience Toolkit (toolkit.climate.gov) and other associated navigational and visualization tools and data for NOAA's online climate services portal, climate.gov. Capitalizing on that initial tool and application development, CICS-NC expanded its work to identify synergies and integrate products and tools across various programs, including the Climate Services Portal, the National Climate Assessment, the National Climate Indicators, and the National Integrated Drought Information System drought-monitoring portal. CISESS NC will continue to support these efforts to develop, enhance, and provide more useful tools and information for decision-makers and society.

Data stewardship encompasses all activities that preserve and improve the information content, accessibility, and usability of data and metadata. CISESS NC will support continuing data maturity stewardship assessment, an ongoing effort initiated by CICS-NC to provide dataset users with a common set of indices for understanding various aspects of the stewardship for a specific dataset.

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

Highlight: Utilizing the CICS-NC-designed data hub/broker architecture, the project team moved multiple NCEI and other NOAA datasets to the cloud and backfilled GOES data from archive sources. Testing of ingest and product development directly in the cloud is underway, and *Elasticsearch* is being used to provide near-real-time monitoring and metrics. 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 larger 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.

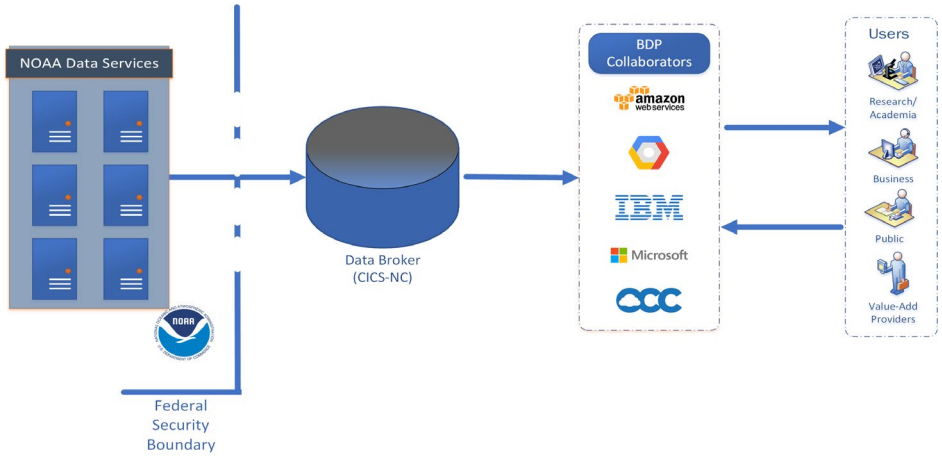


***Figure 1**. Data Hub/Broker Overview.*

CISESS NC is a partner in the BDP and currently acts as a broker between NOAA and the public cloud providers. Institute 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*, and *Microsoft Azure.*

The CISESS high-performance computing cluster has served 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. These services are being migrated to cloud service provider resident operations to improve their resiliency.

Accomplishments

This year's BDP efforts focused on broadening the availability of NOAA datasets while maintaining performance and using cloud-based agents to mediate transfers. Datasets were added from various data holdings, including the Automated Surface Observing System, the Integrated Surface Database, and Global

Surface Hourly data (NCEI); Global Hydro-Estimator and 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 requires working with various NOAA partners to gain access and/or obtain data missing from the existing BDP datasets and exploring options to maintain and/or enhance data transfer workflows.

GOES data backfill. Since BDP did not receive all GOES data products as soon as they were available, gaps occurred in the BDP cloud service provider historical data records. The project team is working with NOAA's Comprehensive Large Array-Data Stewardship System to backfill this data.

Ingest and product generation in the cloud. In support of NESDIS Center for Satellite Applications and Research trial testing of secure ingest and product generation in the cloud, Himawari-8 data is being utilized for testing. System tests are complete and the Himawari-8 data is publicly available.

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 available. NEXRAD Level 2 and Level 3 were configured, as well as a selection of NOAA Port data products.

Metrics and monitoring. *AWS* usage information and application metrics have been collected since project inception. With the growth of BDP datasets, this function has become increasingly challenging. *Elasticsearch* is currently being leveraged to provide insights, monitoring, and dashboarding of these metrics and usage in near real time.

Planned work

- Continue prototype operation of the BDP broker function and manage its transition for NOAA.
- Add NOAA datasets as requested by the collaborators.
- Move broker activities into NOAA operations.

Products

- *Cloud Run* serverless functions

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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Development and Support of NOAA Climate Products and Services	
Task Leader:	James Fox / Karin Rogers
Task Code	NC-ASD-02-UNCA
NOAA Sponsor	David Herring / David Easterling
NOAA Office	OAR/CPO

Highlight: In support of the overall advancement of NOAA's Climate Products and Services program, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with managing the U.S. Climate Resilience Toolkit, launching Climate Explorer 3, prototyping an author "Sandbox", updating USGCRP Indicators website graphics design and data, and redesigning NIDIS drought.gov.

Background

NOAA has identified an increasing need for greater collaboration to incorporate climate services across NOAA line offices and divisions and to enhance its web presence to best deliver climate data and information to meet customer requirements. The NOAA Climate Portal provides climate data and information to help build a resilient nation and a climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions. NOAA has an immediate need for expertise and resources to support programming work for applications development, data visualization, content development, and content management system (CMS) development and management in support of the Climate Portal, which includes climate.gov, the U.S. Climate Resilience Toolkit (CRT), and the Climate Explorer (CE); the National Integrated Drought Information System (NIDIS); and support of NOAA's participation in the sustained National Climate Assessment (NCA) and climate Indicators through the U.S. Global Change Research Program (USGCRP).

The University of North Carolina Asheville (UNCA)—a CISESS Consortium member—and its National Environmental Modeling and Analysis Center (NEMAC) have the requisite expertise in visualization, geographic information systems, programming, multimedia, marketing, community engagement, outreach, meeting facilitation, and environmental science to address NOAA's current needs. NEMAC facilitates the interaction between science producers and users, specializing in science communication and the development of decision support tools for local, regional, and national decision-makers, planners, and the public.

Accomplishments

The project team supported four programs: the NOAA Climate Program Office (CPO) Climate Portal, the NCA, the USGCRP Indicators Working Group, and NIDIS.

Climate Portal/U.S. Climate Resilience Toolkit (CRT): Project staff worked with CPO staff in the continuing CRT and CE development and/or enhancement and editorial/content management. Tasks included

- Planning, design, and implementation of interface changes and the successful launch of Climate Explorer v3.0
- Development planning for a new CRT website training content type; management and provision of video transcriptions for content development assessment
- Editorial initiative implementation to review, identify, and develop Fourth National Climate Assessment case studies for the CRT to solidify ties between the two products
- Author team coordination, development, and publication of new CRT website Midwest regional section; coordination with potential team leads for development of new Southeast, Northern Great Plains, and U.S. Caribbean regions
- CRT glossary terms review and edit

- CRT site content update including five new case studies (total of 154)
- White paper development assessing the economic impact of NOAA's investment in the CRT
- Editorial team meetings and management of public inquiries via the CRT email address
- Stakeholder engagement, including
    - Development and facilitation of a Train the Trainer workshop (The Collider, Asheville, NC, September 25, 2019)
    - Collaborative work on the Interoperability Project with Georgetown Climate Center and EcoAdapt
    - Participation on review panels for the 2020 NOAA CPO CEE federal funding opportunity
    - Presentation on the Steps to Resilience at the NC Planning Conference in October 2019
    - Participation on planning committees for the 2021 National Adaptation Forum
    - General Resilience Ecosystem work

National Climate Assessment (NCA): The project team worked with CISESS NC and the Assessment Technical Support Unit to develop an NCA Sandbox prototype and contributed to state agency efforts in support of a North Carolina state climate assessment summary report.

The project team provided guidance on using NCA products within the State Climate Assessment, created an all-hazard and resilience database, and co-facilitated six sectoral workshops with NOAA CPO staff using these products:

- 09/27/2019: Overview and Introduction
- 10/11/2019: Explore Hazards
- 10/15/2019: Mountain Region Workshop in Sylva
- 10/16/2019: Mountain Region Workshop in Hickory
- 12/05/2019: Assess Vulnerability and Risk
- 02/07/2020: Identify Options and Compile Resilience Plan

NCA Sandbox efforts included

- Understanding pain points, work flows
- Developing customer journey map
- Researching out-of-the box options (e.g., *Tableau* and *Google Data Studio*)
- Creating and sorting NCA4 figures and graphics inventory
- Creating interactive mock-ups in *Adobe XD* for prototype (Figure 1)
- Versioning prototype with project team

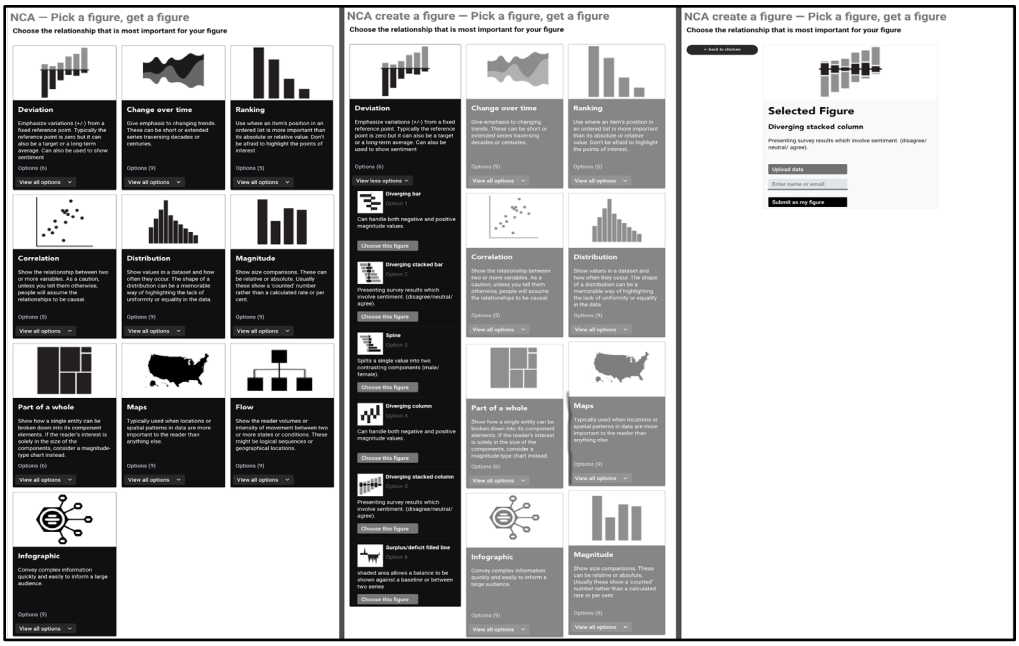


Figure 1. *National Climate Assessment (NCA) Sandbox mock-up.*

USGCRP Indicators: Indicators work focused on USGCRP Indicators website static indicator graphics design and data updates in collaboration with the CISESS NC/NCEI Indicators team. Graphics were updated for the following Indicators:

- Heavy Precipitation
- Billion Dollar Disasters
- Heating and Cooling Degree Days (static and interactive/animated)
- Sea Level Rise
- Arctic Glacier Mass Balance (Figure 2)

Additional work included updating 2019 metadata for the Indicators Metadata Viewer.

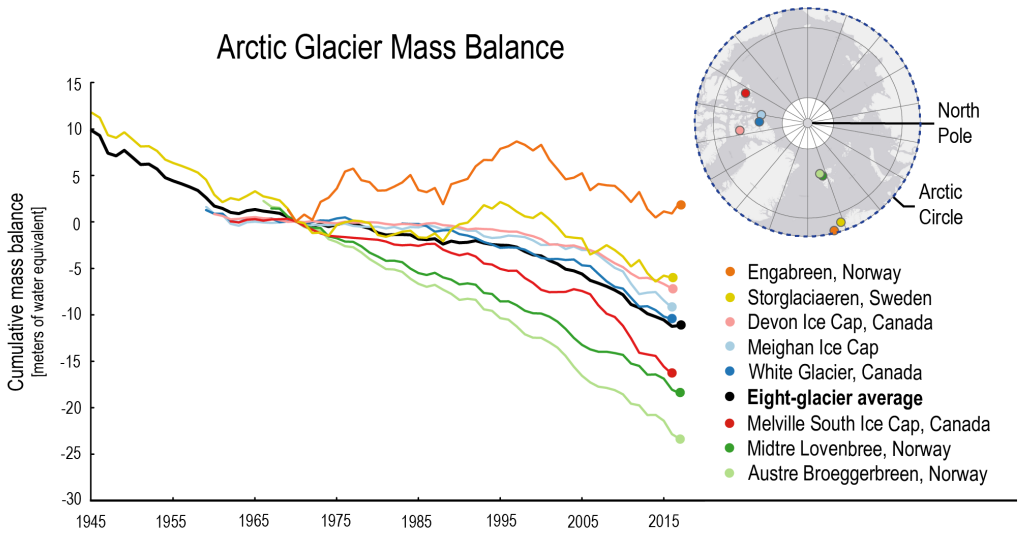


Figure 2. *Figure for the Arctic Glacier Mass Balance Indicator.*

National Integrated Drought Information System (NIDIS): The NEMAC team supported the NIDIS team with the redesign of the drought.gov website, including leading user research and usability efforts and content development.

- User research and usability:
    - Performed user research and usability studies on "By Sector" pages
    - Developed, reviewed, and edited the UX/feedback plan
    - Created a survey for unmoderated usability
    - Designed and implemented AGU meeting prototype testing
    - Summarized results (NPS and SUS scores) from mock-up
    - Worked with undergraduate intern on usability results
- Content generation:
    - Reviewed, developed, and edited new website content for "Data and Maps," "About," "Research & Learn," "By Sector," "Drought Interactions," and "Drought Impacts" sections
    - Ingested and edited content from existing site (News Articles, Events) into new stage CMS site
    - Ingested available Drought Early Warning System regional activities content
    - Worked with development team to improve CMS editorial interface

Planned work

- Maintenance and content development/management for the CRT
- Updates and improvements to Climate Explorer v3.0
- Climate Portal and CRT stakeholder engagement
- NCA Sandbox prototype development and testing
- Usability studies on NCA Sandbox and figure generation
- Creation of NCA Sandbox maintenance plan with CISESS NC
- Update and creation of new Indicator graphics (static and interactive)
- NIDIS website content development as needed (case studies, regional themes, etc.)
- NIDIS website usability studies after official launch

Products

- U.S. Climate Resilience Toolkit (https://toolkit.climate.gov)
- Climate Explorer v3.0 (https://crt-climate-explorer.nemac.org/)
- USGCRP Indicator graphics (http://www.globalchange.gov/browse/indicators)

Presentations

Gardiner, N., J. Fox, and K. Rogers, 2019: The Steps to Resilience. *The Steps to Resilience: Learn to Develop Workable Solutions to Climate-Related Risks, a One-Day Workshop*, The Collider, Asheville, NC, September 25, 2019.

Gardiner, N., J. Fox, and K. Rogers, 2019: Explore Hazards. *The Steps to Resilience: Learn to Develop Workable Solutions to Climate-Related Risks, a One-Day Workshop*, The Collider, Asheville, NC, September 25, 2019.

Gardiner, N. and J. Fox, 2019: The Path Forward. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop*, Raleigh, NC, September 27, 2019.

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.

Gardiner, N. and J. Fox, 2019: Workshop One: Explore Hazards. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop*, Raleigh, NC, October 11, 2019.

Fox, J., 2019: Mountain Workshops. *North Carolina Climate Risk Assessment and Resiliency Plan Workshops*, Sylva, NC, October 15, 2019.

Fox, J., 2019: Mountain Workshops. *North Carolina Climate Risk Assessment and Resiliency Plan Workshops*, Hickory, NC, October 16, 2019.

Gardiner, N., J. Fox, and A. Patel, 2019: Developing a Shared Understanding of Vulnerability and Risk. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop,* Cary, NC, December 5, 2019.

Gardiner, N., J. Fox, and A. Patel, 2020: Chapter 5 Review and Discussion. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop*, Raleigh, NC, February 7, 2020.

Other

Four UNC Asheville undergraduate students were mentored in writing/editing internships for the CRT and NIDIS (Benji Chappelow, Maddy Sherer, Kelsey Hall, and Katie Caruso), and one undergraduate student was mentored in usability (Natalie Melech).

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	**2**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**9**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**5**

Products improved and/or redesigned that became operational: the U.S. Climate Resilience Toolkit, Climate Explorer v3.0, and multiple graphics products (static and interactive) for the USGCRP Indicators website.

Scientific Data Stewardship for Digital Environmental Data Products	
Task Leader	Ge Peng
Task Code	NC-ASD-03-NCICS-GP
NOAA Sponsor	Monica Youngman/Kenneth Casey
NOAA Office	NESDIS/NCEI

Highlight: The NCEI/CICS-NC-developed Data Stewardship Maturity Matrix (DSMM) has been adapted by several international groups, including the Working Group on Information System and Services of the Committee on Earth Observation Satellites and the International Expert Group on Climate Data Modernisation (IEG-CDM) of the World Meteorological Organization (WMO) Commission for Climatology.

Background

U.S. governmental directives (e.g., the Information Quality Act of 2001 and 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 has garnered international attention: the Committee on Earth Observation Satellites' Working Group on Information System and Services Data Stewardship Interest Group has adapted the DSMM for global use in 2017.

Accomplishments

The DSMM was adapted for use by the International Expert Group on Climate Data Modernisation (IEG-CDM) of the World Meteorological Organization (WMO) Commission for Climatology. The WMO Stewardship Maturity Matrix for Climate Data (SMM-CD) is one of the three building blocks of WMO High Quality Global Data Management Framework for Climate (HQ-GDMFC). The manual on HQ-GDMFC was adopted by the Eighteenth World Meteorological Congress and formally published. The use and reuse of DSMM was also highlighted in a poster presented at the 2020 International Digital Curation Conference (IDCC 2020; Figure 1).

CISESS NC supported several other data stewardship maturity assessment activities, including

- Ongoing development of the manual on WMO HQ-GDMFC
- Review of the SMM-CD assessment of 18 WMO global climate datasets

- Evaluation of the FAIRness of NCEI *OneStop*-Ready datasets, utilizing the FAIR (Findable, Accessible, Interoperable, and Reusable) data maturity indicators developed by the Research Data Alliance (RDA) FAIR Data Maturity Model Working Group

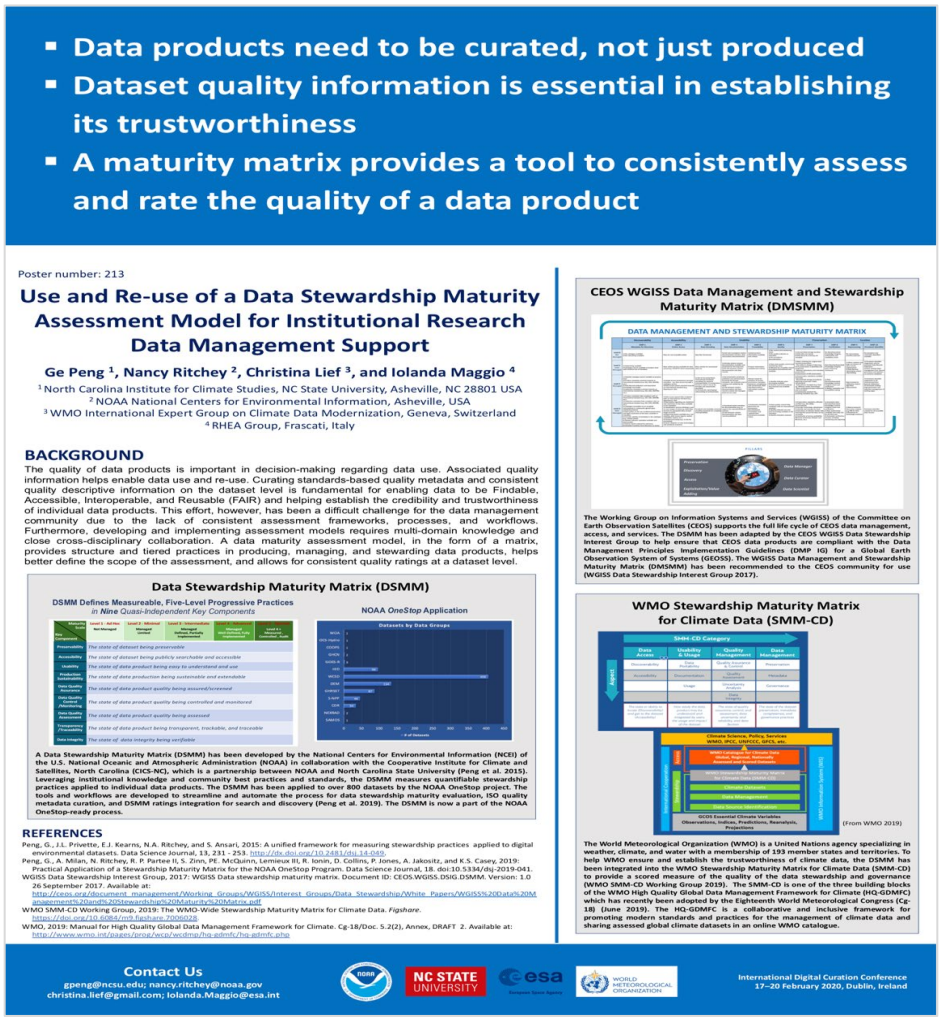


***Figure 1**. The poster presented at the 2020 IDCC. It is available at https://zenodo.org/record/3666260.*

Planned work

- Support the WMO HQ-GDMFC effort as a member of the WMO IEG-CDM
- Participate in the RDA FAIR Data Maturity Model Working Group to develop a maturity assessment model of FAIR datasets
- Engage stakeholders and the Earth science community by participating in NOAA, national, and international data stewardship working groups and attending relevant conferences

Presentations

Peng, G., 2020: NOAA's Data Stewardship Maturity Matrix – Stewardship Maturity Scores and Quality Information. *ESIP 2020 Winter Meeting*, Bethesda, MD, January 8, 2020.

Peng, G., N. Ritchey, C. Lief, and I. Maggio, 2020: Use and Re-use of a Data Stewardship Maturity Assessment Model for Institutional Research Data Management Support. *15th International Digital Curation Conference*, Dublin, Ireland, February 19, 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	**0**
# of NOAA technical reports	**0**
# of presentations	**2**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

References

CEOS WGISS Data Stewardship Interest Group, 2017: WGISS Data Management and Stewardship Maturity Matrix. Version 1.0. Available at: http://ceos.org/document_management/Working_Groups/WGISS/Interest_Groups/Data_Stewardship/White_Papers/WGISS%20Data%20Management%20and%20Stewardship%20Maturity%20Matrix.pdf

Peng, G., 2018: The state of assessing data stewardship maturity – An overview. *Data Science Journal*. **17**, doi: 10.5334/dsj-2018-007.

Peng, G., J.L. Privette, E.J. Kearns, N.A. Ritchey, and S. Ansari, 2015: A unified framework for measuring stewardship practices applied to digital environmental datasets. *Data Science Journal,* **13**, 231 - 253. http://dx.doi.org/10.2481/dsj.14-049.

WMO SMM-CD Working Group, 2019: The WMO-Wide Stewardship Maturity Matrix for Climate Data. *Figshare*. https://doi.org/10.6084/m9.figshare.7006028.

WMO, 2019: Manual on the High-quality Global Data Management Framework for Climate. 2019 edition. Available at: https://library.wmo.int/doc_num.php?explnum_id=10197.

Assessment Activities

Assessment efforts support interagency activities for global, national, and regional assessments of climate change. NOAA conducts a number of global, national, regional, and sectoral-level climate assessment activities, including participation in the high-level, visible, and 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). The USGCRP is an organization of 13 federal agencies (including NOAA) that conduct research and develop and maintain capabilities supporting the Nation's response to global change. Climate assessments and associated special reports synthesize the state of scientific knowledge about climate change, including observed changes and potential future states. The goal of these assessments is to provide integrated analyses of impacts and vulnerabilities and to advance climate science understanding in the larger social, ecological, and policy systems.

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.

In 2010, under the previous Cooperative Institute project, the Cooperative Institute for Climate and Satellites-North Carolina formed the Assessment Technical Support Unit (TSU) to provide an array of NCA scientific and report development and production support to NOAA and the USGCRP. The TSU's contribution was integral for the Third NCA, the Climate and Health Assessment, and Volumes I and II of the Fourth NCA (NCA4). The team also built and continues to update a suite of online tools used for the report development, review, and delivery processes, including a collaborative metadata collection and management tool that provides readers with the full provenance of all figures in NCA4. Thanks to these efforts, the recent NCA reports have set a new standard for readability, accessibility, and transparency. The TSU, under CISESS NC, will continue to provide and enhance scientific and technical support for these national interagency efforts.

The USGCRP Climate Indicator Platform was designed as a system of physical, natural, and societal Indicators that communicate and inform decisions about key aspects of the physical climate, climate and social impacts, vulnerabilities, and preparedness. Its primary purpose is to support the sustained NCA process. The TSU will continue to provide support for the USGCRP Indicator Platform through updates of the current Indicators and the development of new Indicators.

Assessment Scientific and Data Support Activities	
Task Leader	Kenneth Kunkel (lead), James Biard, Sarah Champion, Linda Copley, Katharine Johnson, Laura Stevens, Liqiang Sun
Task Code	NC-AA-01-NCICS-KK/et al
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI and OAR/CPO

Highlight: The Assessment science/data team began preliminary planning for the Fifth National Climate Assessment and led the development of the North Carolina Climate Science Report through overall project management, authorship contributions to several chapters, and development of numerous specialized scientific analyses and graphs**.** https://ncics.org/programs/nccsr

Background

NOAA is participating in a number of global, national, regional, and sectoral-level climate assessment activities, including the high-level, visible, and legally mandated National Climate Assessment (NCA) process, which 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.

The Assessment Technical Support Unit (TSU), initially established under the Cooperative Institute for Climate and Satellites-North Carolina, continues to support these local to global assessment activities. Within the TSU, a group focused on scientific and data support consists of a Lead Senior Scientist (Kenneth Kunkel), Deputy Scientist (Liqiang Sun), Support Scientist (Laura Stevens), Data Lead (Sarah Champion), Web Developer/GIS Specialist (Katharine Johnson), and two Software Engineers (James Biard and Linda Copley). 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 federal Foundations for Evidence-Based Policymaking Act (EBPA) and Information Quality Act (IQA) compliance efforts. Report information is disseminated through websites providing access to reports, figure metadata, and figure data.

Accomplishments

North Carolina Climate Science Report (NCCSR): Expanding on the North Carolina State Climate Summary, the science team led the development and release of the NCCSR, an independent scientific assessment of climate change in North Carolina to inform citizens of the state about important climate trends and potential future changes. This effort supported the North Carolina Governor's Executive Order 80 (EO80; "North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy"). The report includes an overview of the physical science of climate change, 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.

Fifth National Climate Assessment (NCA5): The science and data team began preliminary NCA5 planning, including several collaborative meetings with the USGCRP National Coordination Office staff. The TSU data and web teams successfully migrated the existing content management system from a dual-software platform to a single-software platform. The result is a much more technically sound interface and underlying architecture that will facilitate a greatly improved data collection and tracking system for the forthcoming NCA5.

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 the 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. Work will continue on the redesign and update of the TSU collaborative system, currently branded as the Global Data Acquisition System, to improve the metadata collection survey and the associated user interface and to implement a streamlined collection of new details now required to comply with the EBPA and updates to the IQA.

Planned work

- Initiation of analysis of CMIP6 climate model data, in anticipation of NCA5
- NOAA State Climate Summaries updates
- Redesign and update of the TSU collaborative system
- Improvement of capabilities to provide access to NCA data, including GIS formats
- Assembly of NCCSR figure metadata and other data to meet federal Information Quality standards and creation of a website for dissemination and an improved metadata viewer

Presentations

Kunkel, K., 2019: Fourth National Climate Assessment: Southeast U.S. *East Carolina University Ocean Global Change Biology class*, Greenville, NC, November 26, 2019.

Kunkel, K., 2019: Observed Climatological Relationships between Precipitable Water and Extreme Precipitation in the Contiguous United States*. 2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

Kunkel, K., 2019: Extreme Precipitation Trends and Weather System Influences. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

Champion, S., 2020: Metadata Quality and The National Climate Assessment. *ESIP 2020 Winter Meeting*, Bethesda, MD, January 7, 2020.

Kunkel, K., 2020: Extreme precipitation trends and weather system influences. Poster. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.

Kunkel, K., 2020: Observed climatological relationships between precipitable water and extreme precipitation in the contiguous United States. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.

Kunkel, K., 2020: NCICS Journey in Developing a N.C. Climate Science Report. *100th AMS Annual Meeting*, Boston, MA, January 16, 2020.

Kunkel, K., 2020: Analysis of Heavy Multi-day Precipitation Events in CMIP6 Model Simulations in Support of the Fifth National Climate Assessment. *U.S. Nuclear Regulatory Commission 5th Annual Probabilistic Flood Hazard Assessment Workshop*, Rockville, MD, February 19, 2020.

Kunkel, K., 2020: Extreme Precipitation and Climate Change: Observations and Projections. *FEMA National Dam Safety Program Technical Seminar (ND SPTS) No. 27: Dam and Levee Resiliency in the Era of Intensifying Natural Hazards and Climate Conditions*, Emmitsburg, MD, February 19, 2020.

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)
- Myleigh Neill, NCSU/MEAS (MS advisor)
- Mike Madden, NCSU/MEAS (PhD committee)
- Alyssa Stanfield, Stony Brook University (PhD committee)

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)	**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	**9**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**6**
# of undergraduate students mentored during the year	**0**

Assessment Technical Support Activities	
Task Team	Jim Biard, Linda Copley, Jessicca Griffin, Katharine Johnson, Angel Li, Tom Maycock, Andrea McCarrick, Brooke Stewart-Garrod
Task Code	NC-AA-02-NCICS-JB/LC/JG/KJ/AL/TM/AM/BS
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI and OAR/CPO

Highlight: The Assessment technical support team began preparation and planning for the Fifth National Climate Assessment (NCA5), including the development of a new assessment collaboration website. The team also supported the development and production of the North Carolina Climate Science Report (NCCSR), a comprehensive assessment of past and future climate change in North Carolina. https://ncics.org/nccsr

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 Assessment 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 Assessment science/data team and in coordination with NCA authors, NCEI, and USGCRP.

The TSU editorial team—Brooke Stewart-Garrod, Tom Maycock, and Andrea McCarrick—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 CISESS 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 that serve as foundational guidelines for NCA authors.

Jessicca Griffin serves as the CISESS 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 and Linda Copley—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

North Carolina Climate Science Report (NCCSR)

The TSU editorial team supported the management and production of NCCSR throughout the development process. Members of the team served as authors, science writers, science editors, and technical editors for the report, providing substantive editing at each stage of review and revision. The editorial team also coordinated with in-house graphic designers, reference managers, and project managers to finalize the report for public release.

Jessicca Griffin provided graphic design support services throughout the development of NCCSR. She made ongoing updates, revisions, and stylistic adjustments to more than 120 report figures in response to author and reviewer requests. Additionally, Griffin designed the cover and title page that appear in the full report, the Report Findings and Executive Summary, and the Plain Language Summary.

The TSU's web team designed and implemented a web page (https://ncics.org/nccsr) that provides background information and access to the full report and summary products.

Figure 1. *The North Carolina Climate Science Report, released on March 11, 2020 provides detailed information on observed and projected climate change for North Carolina, both at the state and regional levels. The report is intended to serve as a key input for risk assessment and resilience planning activities in North Carolina.*

The Fifth National Climate Assessment (NCA5)

The TSU is working with USGCRP on preliminary NCA5 planning. A major effort was made to provide a draft timeline and to work with USGCRP management to complete a detailed timeline defining the entire report development and production process. Additionally, TSU members have advised on the structure of the report, assisted with initial framing of author guidance, and attended in-person meetings focused on the planning of all aspects of NCA5.

Assessment Collaboration Environment (ACE) Website Development

The web team implemented requirements from the science/data team and USGCRP that integrated and updated aspects of the current *Drupal 7* Resources site (resources.cicsnc.org) into the *Meteor/Mongo* framework used for the existing graphics and metadata management system (resources-metadata.cicsnc.org). The new site was renamed the Assessment Collaboration Environment (ACE). This work facilitates the retirement of the *Drupal 7* portion of the platform. The site supports major aspects of report development, including collaboration on report text, figure development and management, and collecting metadata for figures.

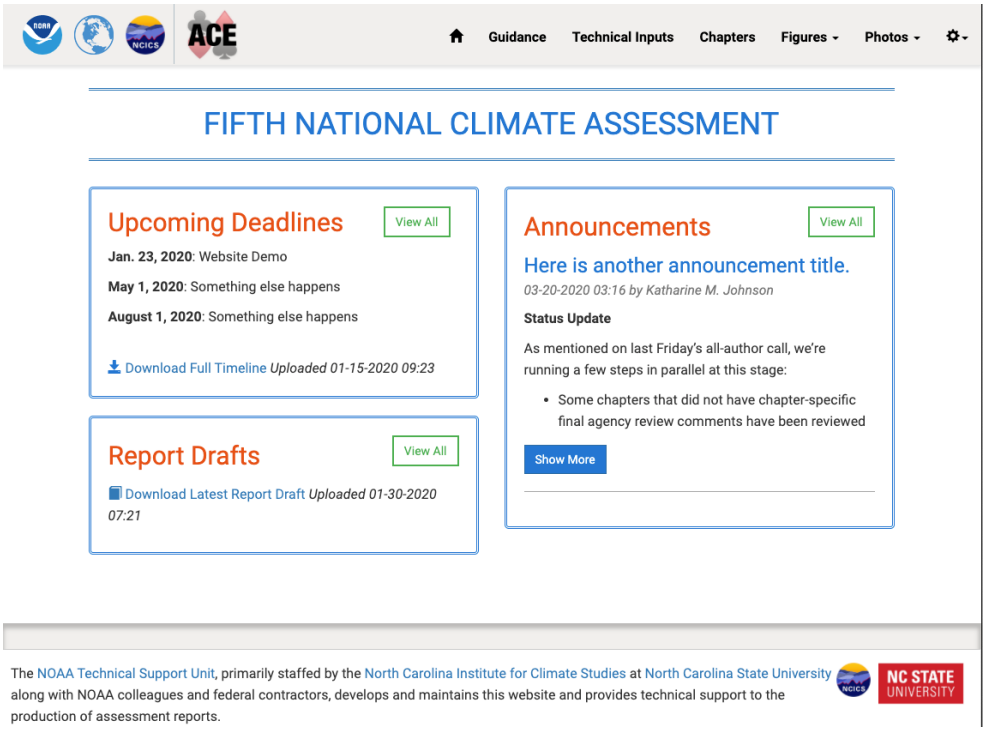


Figure 2. *The new ACE website supports a broad range of collaborative activities related to producing climate assessment reports. Development of the new site is ongoing, with initial release expected later this year to coincide with the initiation of NCA5 activities.*

Scientific Assessment of Ozone Depletion: 2018 Content Updates

The web team updated the Ozone report website to include text, figures, and tables for the "20 Questions and Answers" section developed after the initial release of the report.

Fourth National Climate Assessment (NCA4) Website Maintenance

Links to the Climate Resilience Toolkit were added to, and updated in, relevant sections of the NCA4 website, an an errata item was updated. Updated PDFs were added to the website, and updates were successfully deployed to the USGCRP *AWS* hosting environment.

Planned work

- Provide NCA5 project management, development of author guidance, science communication, editorial support, and graphics development support
- Complete ACE website development and release it to production
- Provide user and technical support for NCA5 activities
- Retire the *Drupal 7* Resources site and perform an assessment of all *Drupal 7* websites and tools used in Assessment activities to create a migration or rebuild strategy prior to November 2021

Products

- Updated Ozone Assessment website
- NCA4 website updates
- New Assessments Collaboration Environment website

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	**0**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Released a new assessment collaboration website, updates to the NCA4 site, and a new section of the Ozone Assessment site.

North Carolina Climate Science Report	
Task Leader	Kenneth Kunkel and Jenny Dissen
Task Code	NC-CAA-03-NCICS-KK/JD
NOAA Sponsor	David R. Easterling
NOAA Office	NESDIS/NCEI

Highlight: CISESS staff led the development and release of the North Carolina Climate Science Report (NCCSR), an independent scientific assessment of observed and projected climate change in North Carolina intended to inform North Carolina citizens about important climate trends and potential future changes. https://ncics.org/programs/nccsr/

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 resiliency 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. NCICS/CICS-NC staff began engagement with DEQ in April 2019, supported regional resiliency planning workshops, established a Climate Science Advisory Panel (CSAP) to provide scientific oversight, and began initial development of the North Carolina Climate Science Report (NCCSR). Project oversight and effort transitioned to CISESS in December 2019.

Accomplishments

Following multiple reviews by the CSAP and an anonymous peer review organized by NCEI, the NCCSR was publicly released in March 2020.

Kenneth Kunkel, NCICS Lead Assessment Scientist and NCSU Research Professor, and the CISESS project management team (Jenny Dissen, Sarah Champion, and Brooke Stewart-Garrod) participated in presentations, updates, and weekly meetings with the DEQ staff as well as CCIC meetings throughout the project. CISESS staff members (Laura Stevens, Jessicca Griffin, Thomas Maycock, James Biard, Ronnie Leeper, Andrea McCarrick, Katharine Johnson, and Liqiang Sun) provided science and technical support for the report development and production, as well as media outreach.

CISESS received initial input from Department Cabinet Designee members to determine the most relevant climatological information for the state agency needs. The report and its findings, however, were developed independently from government input by North Carolina–based climate experts. While some authors (including those from CISESS) are employed by state universities and although state agency needs informed the selection of report topics, the NCCSR 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 North Carolina State Climate Summary.

The advisory panel consisted of North Carolina academic and federal research scientists with national and international reputations in their specialty areas of climate science. The author team comprised NCICS scientists and several members of the advisory panel. The author and advisory panel members also developed supporting documents, which included the NCCSR Report Findings and Executive Summary and the Plain Language Summary, led by Dr. Kathie Dello of the State Climate Office of North Carolina. A full list of author team and advisory panel members is available at ncics.org/nccsr.

Planned work

- Edit and/or revise report as needed
- Continue DEQ engagement to understand the use and application of the report findings
- Seek report-user feedback to improve science assessments processes

Publication

Kunkel, K. E., D. R. Easterling, A. Ballinger, S. Bililign, **S. M. Champion**, D. R. Corbett, K. D. Dello, **J. P. Dissen**, G. M. Lackmann, R. A. Luettich, Jr., L. B. Perry, W. A. Robinson, **L. E. Stevens**, **B. C. Stewart**, and A. J. Terando, 2020: North Carolina Climate Science Report. North Carolina Institute for Climate Studies, 233 pp. https://ncics.org/nccsr

Presentations

Kunkel, K. E., and D. R. Easterling, 2020: North Carolina Climate Science Report. *NCICS Media Release*, Asheville, NC, March 11, 2020.

Kunkel, K. E., and D. R. Easterling, 2020: North Carolina Climate Science Report. *North Carolina Interagency Council Meeting*, Raleigh, NC, January 22, 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	**1**
# of NOAA technical reports	**0**
# of presentations	**2**
# 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

Highlight: Assessment Technical Support Unit (TSU) staff provide scientific and technical expertise in support of USGCRP efforts to maintain a comprehensive suite of climate change indicators. Work included a comprehensive update of the full indicator suite including new graphics as well as planning for the development of several new indicators. http://www.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), including NCA5.

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, including NOAA. The current suite of 16 indicators is maintained within the USGCRP Indicator Platform, which serves as an authoritative resource highlighting data, research, and indicators-related activities. Building on USGCRP cross-agency efforts, 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) provides an interagency forum to support and facilitate the development of the USGCRP Indicators effort.

CISESS and NCEI are working with the IndIWG to better broker and administer the Indicator set, based on the synergy with, and similarity to, the work of the Technical Support Unit (TSU). Laura Stevens (CISESS) and Jessica Blunden (NCEI) are supporting the overall USGCRP effort with scientific and technical expertise. Other CISESS 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, as well as an annual in-person meeting. Recent efforts focused on a comprehensive update of the full indicator suite and development of a communications plan. As part of the indicators update process, the TSU also works with CISESS consortium partner UNC Asheville's National Environmental Modeling and Analysis Center in the creation of indicator graphics. The IndIWG plans to add 3–5 new indicators to the USGCRP Indicator Platform (Figure 1) in the coming year.

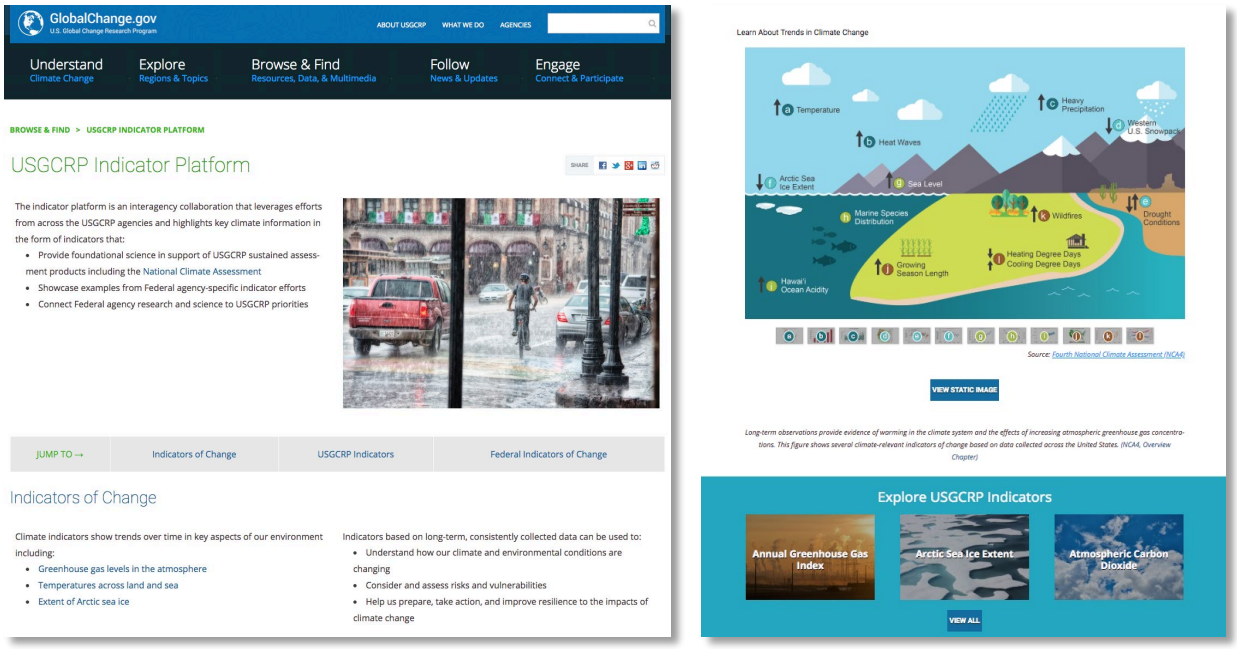


Figure 1. *The USGCRP Indicator Platform at* globalchange.gov/indicators.

The TSU worked with NCEI communications staff to produce an indicators web story (https://www.ncei.noaa.gov/news/ongoing-study-global-change). The web story was published concurrently with a series of social media posts featuring the Heat Waves Indicator. Indicators postcards were developed as an additional communications tool (Figure 2). These 5 x 7-inch full-color cards highlight the Indicator Platform (side one) and a specific indicator (side two) and are intended for distribution at meetings, events, and other engagement fora. Postcards were produced for six different indicators, with plans to complete the full set in 2020.

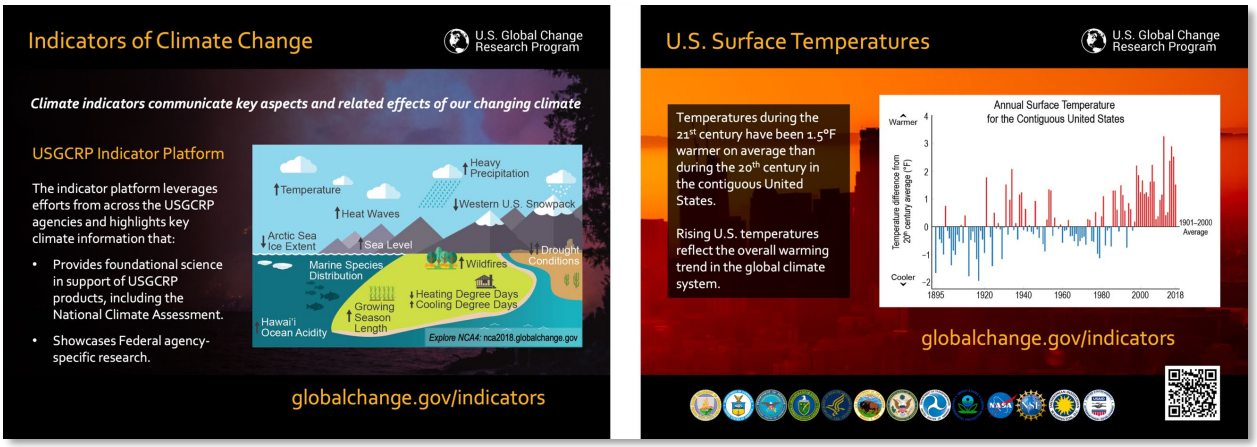


Figure 2. *Postcard for the U.S. Surface Temperatures Indicator, highlighting the Indicators Platform (side one) and information specific to the featured Indicator (side two).*

To foster the advancement of indicators research, a small-group indicators science meeting is planned in 2020. The major meeting goals are to encourage, inspire, identify, advance, and prioritize work on climate-relevant indicators (particularly non-physical-climate indicators) among the IndIWG's agencies and their affiliated communities in support of the USGCRP Indicator Platform.

As Indicators are integral to the sustained NCA process, including NCA5, discussions are underway to determine how the IndIWG and the USGCRP Indicator suite can be of the most value to NCA5 authors. Initial efforts include composing a matrix that matches indicators from recent USGCRP reports with NCA5 draft chapters.

Planned work

- Update current indicators annually
- Develop 3–5 new indicators
- Produce postcards for the full set of indicators
- Participate in a small-group indicators science meeting
- Work with USGCRP to determine the IndIWG's role in preparing indicators for NCA5

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**

U.S.–India Partnership for Climate Resilience Activities Support	
Task Leaders	Kenneth Kunkel, Jenny Dissen
Task Code	NC-CAA-05-NCICS-KK/JD
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI (U.S. Department of State)

Highlight: CISESS NC initiated U.S.–India Partnership for Climate Resilience Phase II capacity-building activities. In collaboration with the U.S. Department of State and NCEI, the project team worked with India-based partner The Energy and Resources Institute (TERI) to co-convene a forestry-related session at TERI's 2020 World Sustainable Development Summit and coordinated a technical and policy roundtable discussion with India forestry sector stakeholders.

Background

In September 2014, former U.S. President Obama and Indian Prime Minister Modi agreed to a new strategic partnership on energy security, clean energy, and climate change. The U.S.–India Partnership for Climate Resilience (PCR) aims to advance climate adaptation planning by supporting the development of climate resilience tools. Joint activities include downscaling global climate models for the Indian subcontinent, assessing climate risks at the subnational level, working with local technical institutes on capacity building, and engaging local decision-makers on climate information needs and planning for climate-resilient sustainable development, including India's State Action Plans on Climate Change.

With their National Climate Assessment scientific and technical expertise and experience, NCEI and the Cooperative Institute for Climate and Satellites-North Carolina (CICS-NC, predecessor to CISESS) led the initial U.S. team PCR efforts. NCEI and CICS-NC scientists first met with India government officials and other relevant institutions in India to discuss their current status, specific needs, and priorities in addressing climate change. NCEI and CICS-NC successfully established collaborative partnerships with several key technical institutes in India, coordinated three downscaling workshops, and facilitated a number of other PCR Phase I bilateral activities in collaboration with the U.S. Department of State. CISESS NC is planning and executing expanded Phase II PCR activities, which extend the collaboration between NCEI, CISESS NC, the Indian Institute of Tropical Meteorology (IITM), and other partners in India, such as The Energy and Resources Institute (TERI), to build the capacity of Indian scientists and policy makers in the areas of forest management, agriculture, and water resource planning.

Accomplishments

CISESS NC PCR engagement efforts include sharing climate model techniques, applications, and uses of climate projections, as well as best practices on climate resilience frameworks and methodologies. The CISESS NC team continued collaboration with TERI in Delhi and initiated engagement with the International Centre for Integrated Mountain Development (ICIMOD) in the Hindu Kush Himalaya region to discuss PCR Phase II objectives and collaborative opportunities.

TERI collaboration. In January 2020, CISESS collaborated with TERI on two PCR activities:

1) A co-convened session, "Forest – A Tool for Adaptation and Mitigation of Climate Change," at TERI's 2020 World Sustainable Development Summit focused on major challenges faced by the forestry sector, effects of climate variability and change on forest ecosystems, and the strengths, gaps, and opportunities of climate change adaptation and mitigation. In addition to session planning and coordination, CISESS NC provided an expert science panelist who gave a presentation on historical and projected climate trends to aid the discussion of custom modeling tool development.

2) A technical and policy roundtable discussion, "Capacity Building, Technology, and Finances for Achieving Forestry Sector Nationally Determined Contributions in India," was held at TERI. Participants included stakeholders, policy makers, government representatives, and individuals from international and development organizations. Given India's varied climate conditions, its successful use of the emerging climate modeling techniques could inform and impact global environmental techniques.

Figure 1. *David Easterling (NCEI, front row, center), Kenneth Kunkel (CISESS, front row, third from right), and Jenny Dissen (CISESS, front row at right) participated in a scoping meeting hosted by ICIMOD in Katmandu, Nepal. Participants discussed climate projection needs and applications for the Himalayan region.*

ICIMOD engagement. ICIMOD is an intergovernmental learning center based in Katmandu, Nepal, that serves the eight member countries (including India) of the Hindu Kush Himalaya region. They provide a regional platform for knowledge exchange for sustainable mountain development. CISESS NC and NCEI participated in an initial scoping meeting with ICIMOD, focused on understanding climate projection needs and applications for the ICIMOD Himalayan region and on collaborative opportunities.

Planned work

- Conduct needs assessment with key India-based partners for workshop specific goals and topics
- Collaborate with ICIMOD on a Hindu Kush Himalaya region technical workshop
- Facilitate technical and scientific collaboration on extreme precipitation analysis
- Continue collaboration with India-based partners on the development of the web-based climate projection tool

Presentations

Easterling, D., **K. Kunkel**, and **J. Dissen**, 2020: ICIMOD Scoping Discussion. *The International Centre for Integrated Mountain Development (ICIMOD) Meeting*, Kathmandu, Nepal, January 28, 2020.

Easterling, D., **K. Kunkel**, **J. Dissen**, and **E. Scott**, 2020: Climate Projections for Considerations in Land Use Planning. *2020 World Sustainable Development Summit*, New Delhi, India, January 29, 2020.

Easterling, D., **K. Kunkel**, and **J. Dissen**, 2020: Capacity Building, Technology and Finances for Achieving Forestry Sector NDCs in India. *TERI – NOAA/NCICS Roundtable*, The Energy Resources Institute, New Delhi, India, January 31, 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	**0**
# of NOAA technical reports	**0**
# of presentations	**3**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

The Energy and Resources Institute Supporting the U.S.–India Partnership for Climate Resilience	
Task Leader:	Dr. Yogesh Gokhale
Task Code	NC-AA-06-TERI
NOAA Sponsor	David R. Easterling
NOAA Office	NESDIS/NCEI

Highlight: As part of the U.S.–India Partnership for Climate Resilience (PCR) Phase II activities, The Energy and Resources Institute (TERI), NCEI, and CISESS co-convened 1) a 2020 World Sustainable Development Summit session targeting key India forestry management stakeholders focused on relevant climate change impacts and using climate projections for adaptation planning and 2) a roundtable discussion with various forestry sector stakeholders.

Background

The U.S.–India Partnership for Climate Resilience (PCR), launched in 2014 by former U.S. President Obama and India Prime Minister Modi, aims to advance capacity for climate adaptation planning. Under a previous interagency agreement between the U.S. Department of State (U.S. DOS) and NOAA, scientists and staff from NCEI and CICS-NC established initial U.S.–India collaborations and conducted several downscaling and capacity-building workshops for decision-makers. With the successful completion of initial PCR goals, the U.S. DOS and NCEI executed a new agreement to continue PCR engagement and capacity-building activities in conjunction with CISESS. PCR Phase II goals focus on training Indian and other regional institutions, scientists, and policy makers on the technical aspects of high-resolution climate models and their applications in the areas of sustainable landscapes, natural resource management, and reforestation.

The Energy and Resources Institute (TERI) is a nonprofit, policy research organization based in India working in the fields of energy, environment, sustainable agriculture, forestry management, water resource planning, and climate resilience. As an organization with a vast network of professionals with expertise in climate change adaptation, mitigation, and science-based policies, TERI has the regional resources to support PCR training and other capacity-building activities.

Accomplishments

During this reporting period, TERI worked with NCEI and CISESS to develop and coordinate activities to convene forestry leaders, conservators, and planners to discuss and understand climate change impacts. TERI and the U.S. team completed two workshop meetings/discussions on current climate change impacts and technical training needs for other foresters in the northern region of India.

2020 World Sustainable Development Summit (WSDS) session (January 29, 2020). TERI and CISESS co-convened "Forest – A Tool for Adaptation and Mitigation of Climate Change at WSDS 2020," a thematic session focused on the major challenges faced by the forestry sector, including deforestation, degradation, overgrazing, conversion to other land uses, fires, excessive fuel wood collection, unsustainable harvests of non-timber forest products, weak institutions, poor governance, policy and market failures, land fragmentation and uncertain tenure, demographic and socioeconomic factors, and the impacts of globalization. Discussions were also held on the strengths, gaps, and opportunities of climate change adaptation and mitigation in the forestry sector and the effects of climate change and climate variability on forest ecosystems around the world.

Session panelists discussed several priorities to achieve India's forestry sector Nationally Determined Contributions (NDCs), including financial resources, institutional frameworks, agroforestry, policy interventions, and sustainable forest management. Panelists provided an overview of the sector, a case study reflecting energy requirements and their dependency on forests, the importance of forest-based adaptation in tackling climate change, and the importance of using various climate model projections as a tool for regional studies in determining climate scenarios. Graphs depicting historical and projected climate trends for 20 variables (e.g., surface temperature, precipitation, and heating, cooling, and growing degree days) aided the discussion of custom climate modeling tool development.

Figure 1. *Panelists and participants at the World Sustainable Development Summit session "*Forest – A Tool for Adaptation and *Mitigation of Climate Change at WSDS 2020."*

Roundtable Discussion (January 31, 2020). The roundtable meeting "Capacity building, technology and finances for achieving forestry sector NDCs in India" focused on the need for the government to build the capacities of frontline staff and associated community-based institutions, provide technological inputs for procuring quality planting material, and provide adequate and assured finances to achieve forestry NDC targets by 2030. The roundtable attendees included representatives from the Ministry of Environment, Forests, and Climate Change; policy makers; officials from State Forest Departments; TERI; CISESS and North Carolina State University; and other international and development organizations, including GIZ, The Nature Conservancy Department for International Development, the U.S. Embassy, and the U.S. Agency for international Development.

Workshop discussions elicited the following conclusions:

- Low productivity and degrading quality of forests are major concerns for Indian forestry.
- Forest degradation in India stems from factors such as overgrazing, demand for fuel wood, excessive logging, forest fires, and shifting cultivation.
- Current modeling techniques don't include land-use and land-cover changes, which are a major challenge. Panelists and roundtable participants highlighted the importance of incorporating local demographic effects in the climate modeling data and incorporating climate modeling into field planning.
- The emerging climate modeling techniques will help frame the foundation of a climate-smart forestry sector. Much can be learned from India's varied climatic conditions, and India's successful use of these modeling techniques could inform and impact global environment techniques.
- Government policies and targets should consider climate change models as important components of planning. Forestry is a tool for mitigating climate change, but the impact on the future climate should be a consideration in the choice of species to promote forestation.

Figure 2. *Roundtable discussion on India forestry sector trends, challenges, and opportunities.*

Planned work

- Develop a survey to determine forestry needs from other Indian states
- Plan a technical workshop in Dehradun, Uttarakhand, focused on climate projections training
- Identify a collaborative downscaling research project analyzing specific case study for Dehradun, Uttarakhand

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**

Information Technology Services

Information Technology Services efforts focus on improving the underlying infrastructure support components required for NCEI to provide end-to-end services, from acquisition of environmental information to its delivery to users in a cost-effective and timely manner. The goal is to develop systems that provide acquisition, curation, archiving, analysis, and data access for the Federal Government's billion-dollar investment in high-quality environmental data.

Data are organizational assets. The quality of datasets and associated information is fundamental for achieving quality data services, ensuring the trustworthiness of the data holdings, and managing organizational risk. Requirements on research data continue to mount from scientific societies, scholarly publishers, and federal policies and laws. NCEI is the Nation’s leading authority for environmental information and is responsible for shepherding that data throughout the dataset life cycle.

Effective movement of information through its life cycle requires a robust information technology infrastructure with an architecture designed to optimally address the needs of each step in the dataset life cycle. Existing NCEI architecture supporting data science, archiving, and access does not scale efficiently, redirect quickly, or shift to readily available solutions or services without redesign. The predecessor Cooperative Institute (Cooperative Institute for Climate and Satellites-North Carolina [CICS-NC]) provided input and a prototyping environment to facilitate architecture development and optimize hardware and software environments to support the NCEI workflows and their migration to NOAA’s Mission Science Network. CISESS NC will continue these interactions and support.

The expanding ability of modern science to produce data presents a significant challenge to the traditional process of analyzing and interpreting that data. As NOAA positions itself to make data available via commercial cloud partners through initiatives like the NOAA Big Data Project and the NESDIS Cloud Pilot, the opportunity exists to collocate computation with the data. Researchers gain the ability to do computation on data located within these cloud providers, eliminating many of the data transfer requirements that currently influence attempts to leverage cloud capabilities. Additionally, the availability of resources offered by cloud providers yields a nearly limitless opportunity to scale elastically on-demand. CISESS NC will support NCEI’s information technology services efforts to deploy new technologies and move towards more efficient approaches and systems that minimize support needs and advance capability for the environmental information life cycle.

Common Ingest Agile Development Team	
Task Leader	Linda Copley
Task Code	NC-ITS-01-NCICS-LC
NOAA Sponsor	Scott Hausman
NOAA Office	NESDIS/NCEI

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 worked on completing enhancements to improve the system for operational use.

Background

Common Ingest (CI) is the solution delivered by the Common Ingest Agile Development Team for the ingest and archive of environmental information at NCEI. CI was deployed at NCEI-NC to ingest 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.

CI 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, CISESS 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 with enhancements to better support the operational CI system. As the operations matured 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.

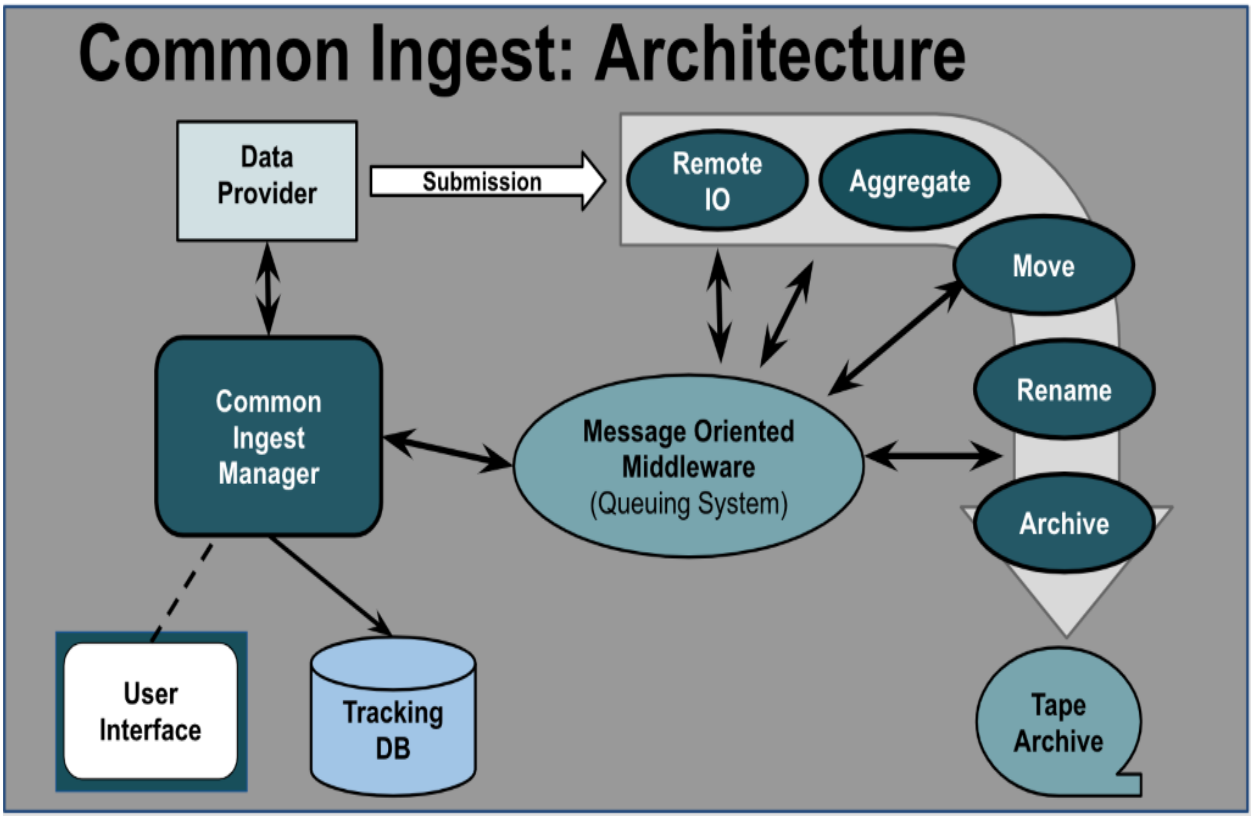


Figure 2. *CI architecture.*

The *Quartz* cron scheduler that controls when data are picked up for ingest into the CI systems was not always initiating new jobs. Some jobs missed the scheduled time, while other jobs never executed. After adjusting several setup parameters and analyzing scheduler logs, the team determined that excess load on the CI servers was backing up the scheduler to the extent that jobs were being lost. To overcome the busy-server limitation, CI was modified to immediately process all scheduler jobs and simply place the work request on a *RabbitMQ* persistent queue to await processing. This adjustment meant that all jobs were guaranteed to be processed, even if they were not processed at the correct time because of server overload.

Some tar (aggregation) files created by CI were not usable by downstream systems trying to open the tar file for distribution of individual constituent files. The issue was caused by file system hard links with a file size of zero bytes being included in the tar file. These files never actually existed and they were remnants of the underlying file system in use by CI in the production environment. CI was modified to detect these zero-size files in the tar file and remove them prior to writing the tar file to the NCEI archive. This resolved the issue for the downstream data delivery system.

The team implemented a batch cleanup functionality. In the past, files that have been sent to the archive were removed from the network file system. New functionality allows CI to send files to the archive multiple times as new files come in and need to be included in the aggregation. For this reason, we want to keep the original aggregation on the file system. The batch cleanup functionality allows files to be registered for deletion at some time in the future. As new files are added, the retention time is automatically adjusted to a date further out. When the expiration date is reached, the files are deleted without operator intervention.

Products

Common Ingest components deployed in NCEI production:

- Common Ingest v2.15.8a Batch cleanup to tarByDir algorithm
- Common Ingest v2.15.8b Deploy cronTrigger queue for *Quartz* cron jobs
- Common Ingest v2.15.6 Add logging for *Quartz* cron
- Common Ingest v2.15.3 Disallow hard-linked zero-size files in tar files

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	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Delivered 4 Common Ingest components (see 'Products') that are deployed in the NCEI production environment.

NCEI Infrastructure Architecture Planning and Implementation	
Task Leader	Lou Vasquez
Task Code	NC-ITS-02-NCICS-LV
NOAA Sponsor	Scott Hausman/Drew Saunders
NOAA Office	NESDIS/NCEI

Highlight: This project team and its collaborators drive NCEI and NCICS IT infrastructure and architecture that will support a modern, flexible, distributed approach to data science, archive, and access capabilities. A high-performance workflow data processing system, *NiFi*, was prototyped and presented to 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 efficiently or reconfigure quickly and cannot be shifted to readily available, robust alternatives without redesign. Existing projects such as Common Ingest (CI) are experiencing the limitations of current NCEI infrastructure and processing approaches. In addition to the general need to stay current and have effective infrastructure, specific new projects such as Common Data Services (CDS) and NESDIS Cloud Framework make new approaches a requirement. 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 stores for data, scalable workflow automation for data and metadata processing, and architecture that ties them together in a flexible, effective way for NCEI.

Because linking these pieces together requires an understanding of NCEI processes, from science to hardware, this project's collaborators include people 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 people involved in data ingest, archive, management, preservation, and access. This cross-disciplinary approach has been absent in several prior attempts to drive NCEI architectural solutions.

Collaborators at NCEI have begun deploying new equipment, data and metadata workflow systems, and object storage. Work is underway at NCEI and separately in coordination with CISESS to deploy IaaS and container approaches that will support a variety of systems and the transition of NCEI to cloud-based services.

Accomplishments

NiFi deployment. A high-performance workflow data processing system, *NiFi*, was prototyped and presented to NCEI. *NiFi* is an open source Apache project, and its deployment at NCEI was the result of much work performed in concert with NCEI IT and other projects. Its configuration demonstrated ingest capability similar to that currently existing at NCEI (Figure 1) but with added platform benefits of scalability, rapid reconfigurability, and directed acyclic graph workflow. It was paired with elastic monitoring, object store, and drop-in external components displaying loose coupling.

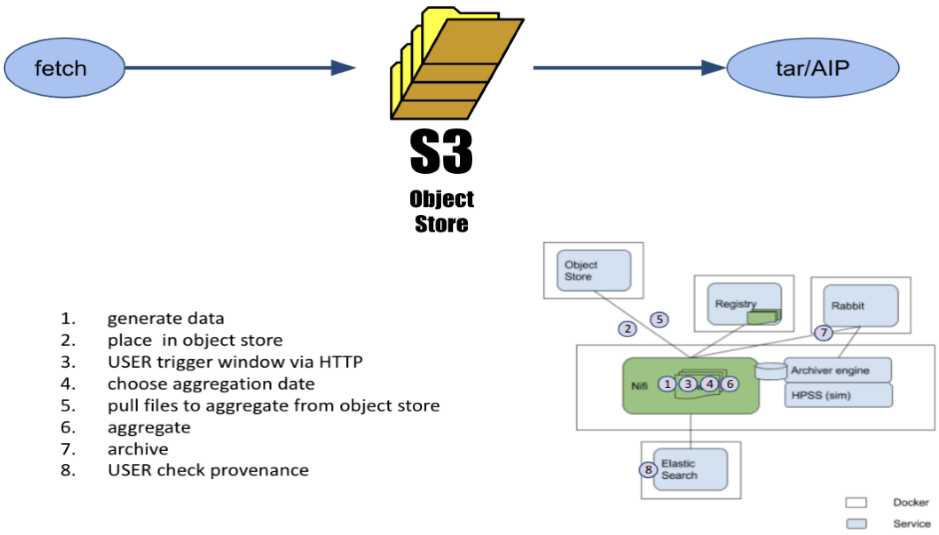


Figure 1. NiFi *demonstration of ingest capability.*

NiFi is currently in test tier, processing multiple preparatory ingest streams, and is awaiting NCEI resources for its transition to production tier. *NiFi* retrieves specific problematic subsets of Unrestricted Mesoscale Analysis as well as other unique data from the National Center for Environmental Prediction. The capability to support Service Records Retention System data retrieval was also developed within *NiFi*'s pluggable component framework. Training was provided to NCEI's ingest development team on these *NiFi* capabilities.

Common Ingest (CI) modification. A split-stream aggregation approach—where data in rest awaiting aggregation can be held in a file store—was designed and deployed in the CI system (choose-tar aggregation). This was implemented in support of the more modern object store, splitting incoming data from the aggregation (top of Figure 1) and archiving it in a reliable, scalable location. This also supports the planned upgrade to *NiFi* and other cloud-oriented solutions.

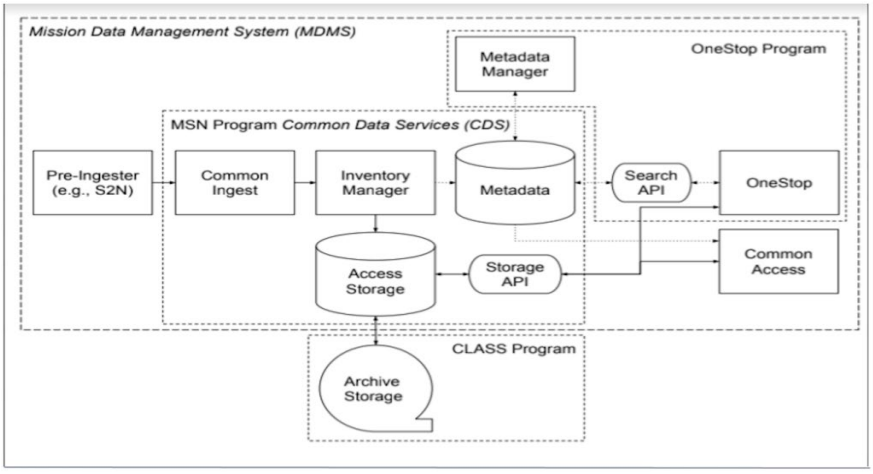


Figure 2. *Common Data Services and Mission Data Management System architecture.*

Common Data Services (CDS) deployment. The CDS system at NCEI (Figure 2) brings together tools that exhibit desired infrastructure qualities. *Kafka*—another open source Apache tool at the center of CDS—is

scalable, containerize-able, workflow driven, and widely deployed in the cloud. This project supported the test-tier deployment of CDS, integration with Common Ingest, and the demonstration of its ability to support metadata at NCEI. It is awaiting NCEI resources for its transition to production tier.

Argo Workflows. Scalable cluster processing management via *Argo Workflows* (an open source container-native workflow engine for orchestrating parallel jobs on *Kubernetes*) was tested as part of the transition from a legacy compute cluster to one that is containerized. *Argo Workflows* is cloud ready and uses *Kubernetes*, a de facto standard for scalable cloud processing. Basic capability was demonstrated for parallelization of a simple compute workflow.

Training and other support. Various training and assistance-oriented tasks were performed to promote NCEI developer and operator use of modern tools. These included the migration of numerous *Apache Subversion* versioning system projects to open source *Git version control* repositories and the conversion of Continuously Operating Reference Stations to FTPS transfer. Continuing support of the NCEI CI system included support for the transition from non-scalable shared file systems to on-premises object store, resolving issues beyond the scope of typical planned features, and implementing monitoring for the redundant CI site.

Planned work

- Transition NCEI *NiFi* to production use
- Assist deployment of CDS system architecturally
- Develop CISESS container compute capability
- Promote cloud-oriented solutions at NCEI
- Investigate, document, and prototype archive in cloud capability
- Support NCEI ingest utilization of split-stream aggregation product

Products

- Common Data Services deployed to NCEI test tier, with completed operational readiness review
- Continuous *NiFi* retrieval streams of live datasets within NCEI tiered infrastructure
- Common Ingest split-stream aggregation functionality

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	**2**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Common Ingest (CI) split-stream aggregation became operational in the CI system.

Science and Services

Science and Services efforts support societal decision-making through the acquisition, monitoring, analysis, synthesis, and delivery of in situ and satellite observations; derived products; and associated information and engagement and outreach services.

CISESS NC science centers on 1) observations from instruments on Earth-orbiting satellites and surface networks and 2) predictions using realistic mathematical models of the present and future behavior of the Earth system. 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 these activities is the fundamental goal of understanding the state and evolution of the full Earth system and its interactions with human activities to promote a more environmentally responsible, resilient, and adaptive society. Collecting and processing the fundamental data on Earth system conditions, developing the models and algorithms to simulate natural cycles, assessing the possible projections, and communicating the information are critical activities in building resilience. As NCEI's collocated Cooperative Institute partner, CISESS NC provides collaborative science and services that directly support the NESDIS mission of providing "*secure and timely access to global environmental data and information from satellites and other sources to promote and protect the Nation's security, environment, economy, and quality of life.*"

CISESS NC scientists and technicians work with NCEI scientists in the development and production of new datasets, development of calibration and validation approaches for high-quality baseline climate datasets from satellite and in situ observations, reprocessing and/or reanalysis of environmental data in existing datasets, and transition of these climate-quality satellite and in situ observing datasets from research to operations. CISESS scientists also support NOAA's various climate-observing programs including the U.S. Climate Reference Network and the U.S. Historical Climatology Network.

The public's awareness and understanding of Earth system variability, change, prediction, and projection continues to grow, and CISESS NC scientists utilize remotely sensed and in situ observations in a variety of studies to further that understanding with research focused on the Earth system's interaction with human activities such as climate (e.g., extreme heat or cold, drought, and flooding) and human health impacts. As the private sector explores practical and cost-effective approaches for addressing risks and opportunities resulting from changes in the Earth system, it continues to seek robust, reliable, and authoritative environmental information that supports its decision-making. CISESS NC will continue and/or expand these studies to help inform societal decision-making to foster healthy, resilient, and prosperous communities and businesses.

Scientific Subject Matter Expertise Support	
Task Team	Jessica Matthews (Lead), Jenny Dissen, Anand Inamdar, Ronald Leeper, Ge Peng, Olivier Prat, Carl Schreck
Task Code	NC-SAS-01-NCICS-JM/JD/AI/RL/GP/OP/CS
NOAA Sponsor	Jeff Privette/Jay Lawrimore/Imke Durre
NOAA Office	NESDIS/NCEI

Highlight: CISESS scientists served as subject matter experts on 3 Climate Data Record Integrated Product Teams, as Product Leads for 25 products, and as Product Area Leads for 3 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, and execution and reporting of members' office/organization tasks required to transition the 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, CISESS staff have been enlisted as Product Leads for 25 of NCEI's 214 products and as Product Area Leads for 3 of 15 product areas.

Accomplishments

CISESS scientists participated in the IPTs of the following CDRs during this reporting period:

- Total Solar and Solar Spectral Irradiance (Inamdar)
- Sea Ice Concentration – Annual (Peng)
- Ocean Surface Bundle (Peng)

Subject Matter Expert IPT responsibilities include

- leading and scheduling IPT meetings needed for resolving technical issues on the products with the 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 O&M 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 (WA; Climate Algorithm Basis Document, Maturity Matrix, Data Flow Diagram, Implementation Plan) and providing feedback;
- reviewing PI-submitted documents delivered as part of the WA (quality assurance [QA] procedure, QA results, VDD, annual reports) for information only; and
- delivering presentations to the NCEI User Engagement Branch on the CDR.

CISESS 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)
- 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)
- 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)

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;
- sustaining operational products 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; and
- providing regular status reports and participating in technical meetings.

CISESS scientists acted as Product Area Lead 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, that are responsive to evolving user needs;
- maintaining a life cycle management plan for portfolio products, as well as a high-level schedule to accomplish plans;
- maintaining status and priority ranking of each product in the 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

- Continue participating on CDR IPTs as requested to transition CDRs to initial operating capability status
- Continue acting as Product Leads and Product Area Leads to support the NOAA NCEI product inventory

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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Drought-related health impacts: advancing the science for public health applications	
Task Leader	Jesse E. Bell
Task Code	NC-SAS-02-UNMC
NOAA Sponsor	Veva Deheza
NOAA Office	OAR/CPO/NIDIS

Highlight: CISESS Consortium partner University of Nebraska Medical Center and the National Integrated Drought Information System (NIDIS) conducted two state-level workshops on drought and health following the 2019 National Drought and Public Health Summit. The project team is evaluating the impact of historical drought events on mortality and morbidity with preliminary results reflecting a greater impact on minority subpopulations.

Background

Over the last century, droughts caused more deaths internationally than any other weather-related extreme event (floods, hurricanes, etc.). Droughts in the United States, however, are not generally thought of as public health threats, even though there are known associations between droughts and negative health outcomes. By better understanding the linkages between droughts and human health, we can better prepare public health agencies for drought-associated health impacts, and, in turn, help reduce health risks and save lives. By advancing our understanding of the impacts of drought on human health, the National Integrated Drought Information System (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. This work will inform and be incorporated into regional Drought Early Warning Systems and shared with key partners, such as state health departments, the National Drought Mitigation Center, and NOAA Regional Integrated Sciences and Assessments teams.

Three project tasks build on the previous activities completed in partnership with NIDIS and the Cooperative Institute for Climate and Satellites (CICS). These project tasks will help advance the understanding of the impacts of drought on human health and identify opportunities to forge an alliance between drought and public health communities. Thus they could collectively address drought and health-related issues, including 1) determining the role of soil moisture on the 2017 Valley Fever outbreak, 2) evaluating the impact of historical drought events on mortality and morbidity, and 3) identifying/scoping opportunities for future interaction/collaboration between drought and public health communities.

Accomplishments

Drought-related mortality study. In the drought-attributable mortality analysis for the U.S. West climate region, we estimated that 8,837 fewer deaths would have occurred at a drought index of 15.01 (most severe) compared to a drought index of 0 (no drought) in 1991 (Table 1). Excluding the wet county-years, the total estimated attributable deaths for the West climate region was −8,638. The attributable deaths ranged from −2,092 for 75- to 84-year-old white females to 121 for 65- to 74-year-old black males in the analysis including wet county-years, and from −2,061 for 75- to 84-year-old white females to 124 for 75- to 84-year-old black males for the analysis without wet county-years. Most of the increases in deaths were among minority subpopulations, and decreases in deaths were with white subpopulations.

After adjusting for the false discovery rate, the team found significant associations remained for some of the stratified analyses, which differed by subpopulation, suggesting possible health effects for certain

groups. Based on the estimated attributable deaths, the net effect of drought severity on mortality was a reduction in deaths in the same year. However, as shown in Table 1, a majority of increases in deaths occurred with minority populations. Thus, the reduction in deaths from non-minority populations counteracted the total death estimates.

Age	Race	Sex	Maximum Drought Severity	No Drought	Attributable Deaths
Total			212,746	221,582	-8,837
25-34	White	Male	3,752	3,748	4
25-34	White	Female	1,367	1,373	-6
25-34	Black	Male	303	334	-31
25-34	Black	Female	226	226	0
25-34	Other	Male	417	387	30
25-34	Other	Female	170	173	-3
35-44	White	Male	4,624	5,041	-417
35-44	White	Female	2,573	2,568	4
35-44	Black	Male	506	463	44
35-44	Black	Female	461	424	37
35-44	Other	Male	544	538	6
35-44	Other	Female	337	317	20
45-54	White	Male	8,777	9,055	-278
45-54	White	Female	5,184	5,471	-287
45-54	Black	Male	874	876	-2
45-54	Black	Female	700	723	-23
45-54	Other	Male	873	944	-71
45-54	Other	Female	568	583	-15
55-64	White	Male	15,377	15,403	-26
55-64	White	Female	9,241	9,661	-420
55-64	Black	Male	1,440	1,408	32
55-64	Black	Female	1,154	1,061	93
55-64	Other	Male	1,384	1,272	113
55-64	Other	Female	937	881	56
65-74	White	Male	21,343	22,427	-1,084
65-74	White	Female	14,485	16,525	-2,040
65-74	Black	Male	1,799	1,678	121
65-74	Black	Female	1,516	1,409	107
65-74	Other	Male	1,682	1,677	5
65-74	Other	Female	1,182	1,259	-77
75-84	White	Male	26,065	27,114	-1,049
75-84	White	Female	24,864	26,956	-2,092
75-84	Black	Male	1,533	1,415	119
75-84	Black	Female	1,563	1,639	-76
75-84	Other	Male	1,770	1,899	-129

75-84	Other	Female	1,634	1,666	-32
85+	White	Male	17,249	17,487	-238
85+	White	Female	29,979	30,958	-979
85+	Black	Male	590	629	-39
85+	Black	Female	1,181	1,306	-125
85+	Other	Male	1,109	1,182	-74
85+	Other	Female	1,410	1,427	-17

Table 1. *Expected same-year deaths in Nevada and California in 1991 for counterfactual scenarios of no drought or most severe drought (from years 1968–2014), and attributable deaths for each age–race–sex stratum. Abnormally wet county-years included in analysis.*

Interaction opportunities between the drought and public health communities. Following the success of the June 2019 National Drought and Public Health Summit convened in conjunction with NIDIS and CICS, two state-level drought and health workshops were held in Minnesota and Arizona. The workshops followed the same framework as the summit, bringing together climate and health stakeholders for discussions on drought and human health impacts, as reflected in Figure 1.

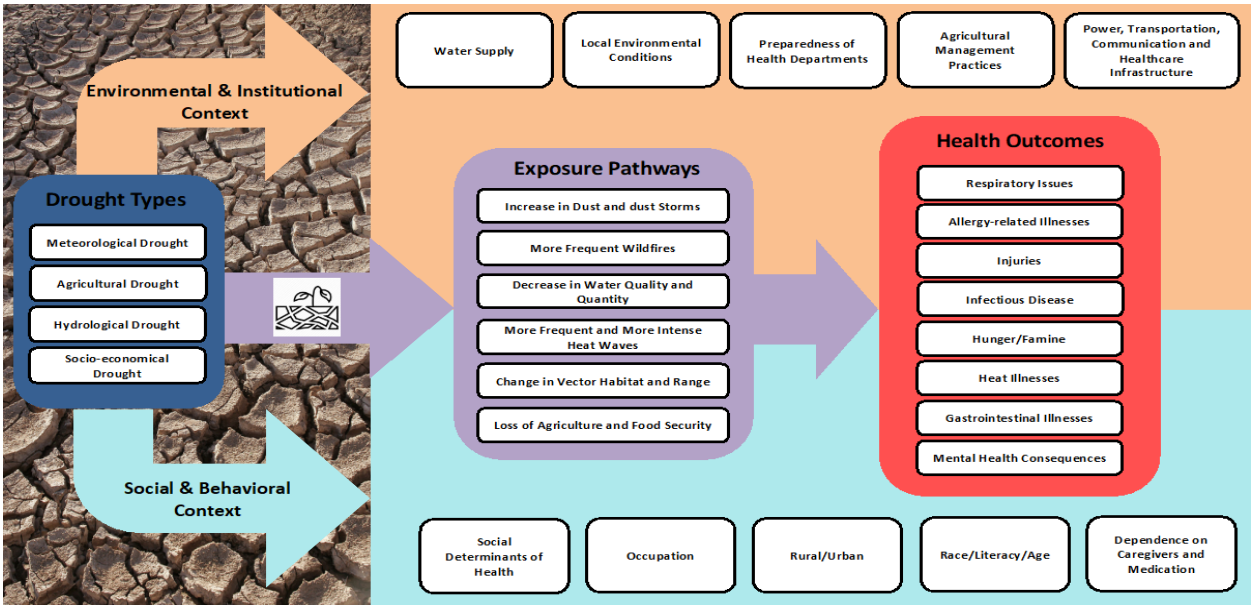


Figure 1. *The pathways from a drought event to health outcomes and the environmental, institutional, social, and behavioral contexts that influence these health outcomes.*

Planned work

- Continue state-level drought and health workshops
- Continue studying the health impacts associated with droughts
- Complete peer-reviewed journal articles on drought and health

Products

- Midwest Drought and Health Workshop
- Southwest Drought and Health Workshop

Presentations

Abadi, A.,and **J. Bell**, 2019: Drought Severity and All-cause Mortality Rates in Nebraska: Are Heat Waves to Blame Partially? *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 9, 2019.

Bell, J., 2020: Drought and human health in the United States: an evaluation of knowledge. *100th AMS Annual Meeting*, Boston, MA, January 15, 2020.

Abadi, A., 2020: Droughts and all-cause mortality in all age groups in Nebraska. *100th AMS Annual Meeting*, Boston, MA, January 15, 2020.

Other

- Postdoctoral researcher mentored: Dr. Azar Abadi
- PhD students mentored: Qianqian Li and Jagadeesh Puvvula
- MPH student mentored: Zackery Rodriguez

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	**0**
# of NOAA technical reports	**0**
# of presentations	**3**
# of graduate students supported by your task	**2**
# of graduate students formally advised	**3**
# of undergraduate students mentored during the year	**1**

Two regional drought and public health workshops were held.

Strategic Engagement and Outreach	
Task Leader	Jenny Dissen
Task Code	NC-SAS-03-NCICS-JD
NOAA Sponsor	Jeff Privette/Michael Brewer
NOAA Office	NESDIS/NCEI

Highlight: Key accomplishments this year included continuing improvements to NCEI's use of a customer relationship management (CRM) tool, multiple engagement activities at the American Meteorological Society Annual Meeting, new collaboration efforts with the State Climate Office of North Carolina, and a variety of educational and outreach events in Western North Carolina. https://ncics.org/events/; https://ncics.org/expertise/engagement/

Background

CISESS extends NOAA's mission goals by exploring new frontiers for public- and private-sector engagement with innovative Earth system science and environmental data. This information has international, regional, national, and personal significance across all aspects of society. Through interdisciplinary engagement, outreach, and literacy activities, CISESS connects with decision-makers, planners, practitioners, and other researchers to highlight the utility of NOAA and NCEI environmental data and to disseminate knowledge to end users. Both the public and private sectors continue to seek improved access to and understanding of environmental information to inform their planning and decisions, such as incorporating environmental information into business planning as well as adaptation, resilience, and sustainability programs. Improving the utility of environmental information also enables science and data producers to develop innovative science based on practical applications. Improved analytics on users' needs is essential. Connecting stakeholders with science and data providers advances NOAA mission goals and the development of a robust climate services sector.

CISESS applies both traditional and innovative engagement and outreach activities involving business and industry, academia, other scientists, organizations, and the general public. Activities include framing and analyzing the information exchange, developing case studies, organizing sector-based engagement discussions, and building networks and partnerships that support capacity building.

Accomplishments

The past year's activities focused on the following areas:

- Building the processes, methods, and platforms for NCEI's Center for Weather and Climate (CWC) to establish an integrated, center-wide information services program
- Broad and targeted sector interactions aimed at identifying user needs on regional, national, and international scales
- Exploring applications of high-resolution climate projection techniques to support policy making and other planning efforts
- Executing a robust outreach program that promotes STEM and environmental education

CISESS supports CWC's Climatic Information Services and Customer Engagement Branches on strategic and operational sectoral engagement activities, and Task Leader Jenny Dissen serves as the Product Lead for CWC sectoral engagement. CISESS supported continuing improvements to NCEI's use of a customer relationship management (CRM) tool, including modifications, visualizations, improved access, and analytics generation for center-wide use. The CRM solution is being extended across other parts of NESDIS and NOAA by developing frameworks, processes, and business, functional, and technical requirements.

As an extension of the NCEI Users' Conference activities, CISESS collaborated with NCEI and Riverside staff to plan and execute engagement activities at the 2020 American Meteorological Society Annual Meeting, which included

- An NCEI-hosted Town Hall Meeting, "2019 NCEI Users' Conference – Debrief and Path Forward"
- A presentation on "User Engagement and Service Delivery — Collecting Requirements at Regional Scales"
- A presentation on "Use-Inspired Science at NOAA's National Centers for Environmental Information: Incorporating User Feedback into Product Improvement"
- An NCEI engagement poster "A Model for Engagement: 2019 NCEI Users' Conference" (Figure 1)

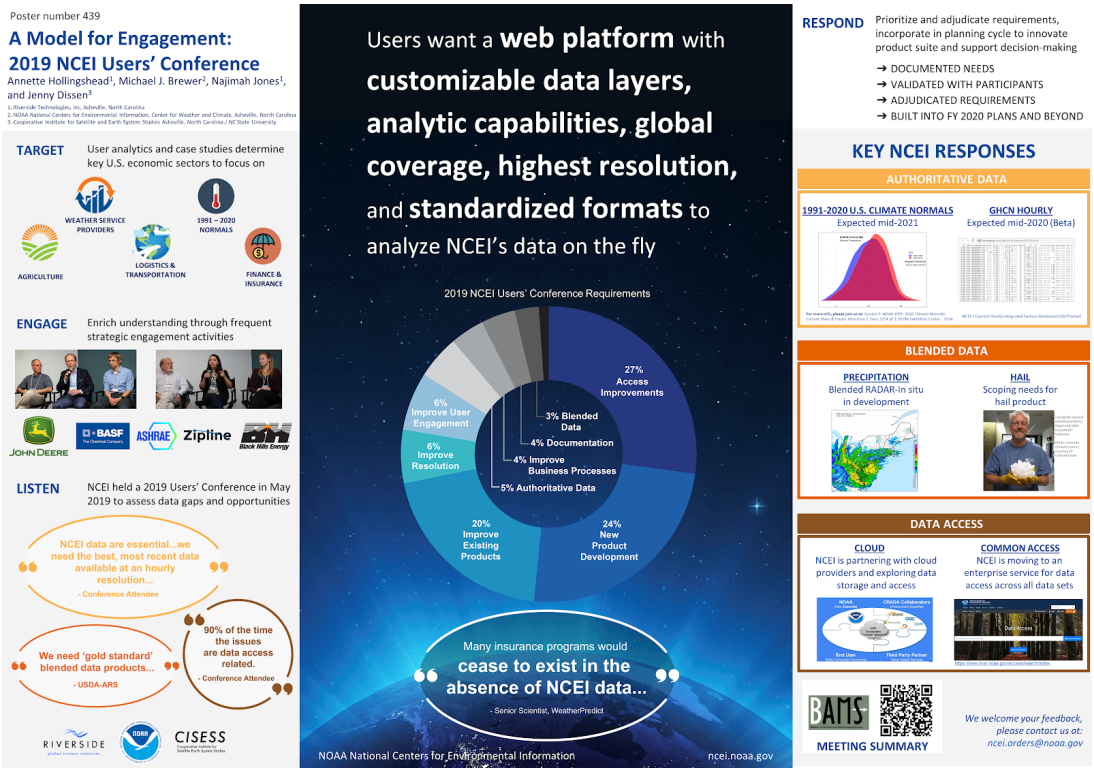


Figure 1. *This poster highlighting outcomes from the 2019 NCEI Users' Conference was presented at the 2020 Annual Meeting of the American Meteorological Society.*

Education and General Public Outreach Activities

CISESS staff engage in an interdisciplinary outreach program which includes activities that reach K-12, higher education, and the general public. NCICS has outreach partnerships with several regional organizations, including the Asheville Museum of Science, the NC Science Festival, The Collider, and Western North Carolina STEM Leaders. Institute staff support and respond to a variety of other outreach requests throughout the region and also provide remote presentations to schools across the United States.

CISESS outreach events included

- 9/24: The Collider, Asheville, NC. Carl Schreck gave a brown bag lunch presentation, “Are hurricanes stronger, larger, and wetter?” case.simpletix.com/e/47619
- 10/24: Monett Elementary School, Monett, MO. Jared Rennie gave a remote “Skype a Scientist” presentation on weather and climate to ~35 kindergarteners.
- 10/28: Buncombe County Schools Secondary Professional Development Day, Asheville, NC. Schreck presented information on climate change, hurricanes, and North Carolina with ~60 middle and high school teachers in attendance.
- 10/29: Shepherd Glen Elementary School, Hamden, CT. Rennie gave a remote “Skype a Scientist” presentation on weather and climate to ~40 kindergarteners.
- 11/6: Hall Fletcher Elementary School STEAM Night, Asheville, NC. Yuhan Rao and Erika Wagner hosted an interactive table with ~120 in attendance.
- 11/15: Isaac Dickson Elementary School, Asheville, NC. Jenny Dissen, Jessica Matthews, and NCEI’s Matthew Menne installed a climate station to facilitate discussions with students and teachers at the school (Figure 2).
- 11/15: NCEI, Asheville, NC. Dissen, Jennifer Runkle, and Laura Stevens participated in a professional development panel for NASA DEVELOP interns.
- 2/5: Ponderosa Elementary School, Post Falls, ID. Rao, gave a remote “Skype a Scientist” presentation on weather, climate change, and satellite data to ~15 third-grade students.
- 2/6: Christ School, Arden, NC. Rennie presented information on coding weather and climate data to ~15 AP Computer Science students.
- 2/11: University of North Carolina Asheville Applied Climatology class, Asheville, NC. Rennie presented information on NCEI use of weather station data in monthly climate reports.
- 2/13–2/14: Western Carolina University’s 2020 Region 8 Western Regional Science & Engineering Fair, Cullowhee, NC. Rennie, Linda Copley, Emma Scott, Laura Stevens, Scott Stevens, and Wagner hosted an interactive information/activity table at this STEM event.
- 3/11: Buncombe Community High School, Swannanoa, NC. Copley and Rao presented information on programming and professions in computer sciences to ~20 students.
- 3/11: The Collider Open House, Asheville, NC. Dissen, Rennie, Scott, Laura Stevens, and Sarah Champion hosted an interactive information/activity table with ~100 in attendance.

Figure 2. *Jenny Dissen (right) and Jessica Matthews (third from right) from CISESS join Matt Menne of NCEI (left) at the installation of a weather monitoring station at Isaac Dickson Elementary School in Asheville, North Carolina.*

Planned work

- Continue sectoral engagement activities for NCEI Information Services, including support for NCEI's Center for Coasts, Oceans, and Geophysics initiatives and collaboration with Acclimatise
- Develop a proposal and plan activities for the NOAA Satellite Conference
- Support activities for the Climate Informatics Conference
- Continue to engage with local and regional partners on uses and applications of climate information

Publication

Brewer, M. J., A. Hollingshead, **J. Dissen**, N. Jones, and L. F. Webster, 2019: User Needs for Weather and Climate Information: 2019 NCEI Users' Conference. *Bulletin of the American Meteorological Society*, **In press**, https://doi.org/10.1175/BAMS-D-19-0323.1.

Presentations

Brewer, M., A. Hollingshead, N. Jones, and **J. Dissen**, 2020: Use-Inspired Science at NOAA's National Centers for Environmental Information: Incorporating User Feedback into Product Improvement. *100th AMS Annual Conference*, Boston, MA, January 14, 2020. (Link)

Hollingshead, A., M. Brewer, **J. Dissen**, and N. Jones, 2020: Town Hall: 2019 NCEI Users' Conference – Debrief and Path Forward. *100th AMS Annual Conference*, Boston, MA, January 14, 2020. (Link)

Hollingshead, A., M. Brewer, N. Jones, and **J. Dissen**, 2020: Model for Engagement: 2019 NCEI Users' Conference. *100th AMS Annual Conference*, Boston, MA, January 13, 2020.

Other

- Initiated a collaboration with the Electric Power Research Institute to help understand the climate change information needs of the electric energy industry
- Hosted the newly appointed North Carolina State Climatologist Dr. Kathie Dello for meetings with NCEI and CISESS scientists to foster collaboration
- Dissen continues to serve on the External Engagement Steering Team for the North Carolina School of Science and Mathematics Morganton Campus (http://ncssm.edu/)
- Designed and conducted an Institute organizational health survey

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	**10***
# of graduate students supported by your CICS task	**1**
# of graduate students formally advised	**0**
# of undergraduate (high school) students mentored during the year	**0**

**3 engagement presentations, 7 outreach presentations*

Understanding Future Changes in Cold/Shoulder-Season Precipitation	
Task Leader	Pavel Groisman
Task Code	NC-SAS-04-NCICS-PG
NOAA Sponsor	Jeff Privette/Imke Durre
NOAA Office	NESDIS/NCEI

Highlight: International environmental change studies focused on the northern extratropics were conducted to better inform vulnerable societies and prepare them for potential future developments.

Background

Contemporary environmental changes are not restricted to changes in major climatic characteristics such as temperature and precipitation, but are multi-faceted, affect and are affected by human activities, and may manifest themselves differently in different regions of the world and feedback to other regions. These manifestations and feedbacks are not well understood and require thorough attention and integrated multidisciplinary approaches to assess, as they may affect the environment, including in regions many miles away from the areas of initial forcing, in unexpected ways.

The overarching goal of this project is to improve our understanding of future changes in hazardous cold/shoulder season precipitation, especially occurring near 0°C. Achieving this requires an understanding of past and present changes and a consideration of future conditions. To support these research studies, CISESS staff will identify and utilize best available datasets from in situ and satellite observations and reanalyses as well as CMIP6 climate model simulations to gain an understanding of the climatology of key variables and phenomena, simulate key driving processes, and assess projections and their potential shortcomings.

Accomplishments

The task leader contributed to several studies focused on hydrological cycle changes in high-latitude regions around the world. For example, one project developed an algorithm for weather conditions conducive to freezing rain (WCCFR) using a combination of in situ and collocated upper air observations and reanalyses from the National Centers for Environmental Prediction Climate Forecast System Reanalysis version 2. This algorithm was used to build a WCCFR climatology for North America and Northern Eurasia at the plain terrain at elevations below 1,200 m above sea level and estimate changes in WCCFR (Figure 1).

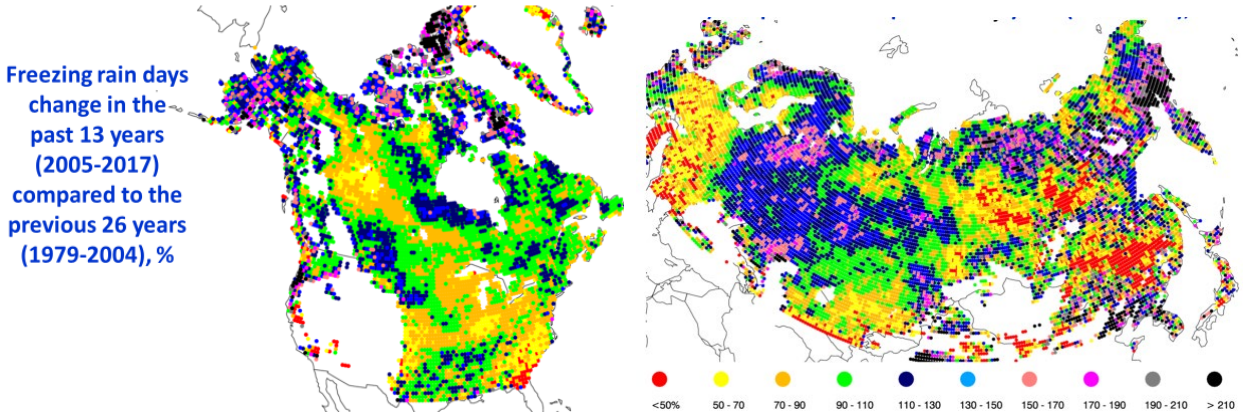


Figure 1. *Percent change in in the annual number of freezing rain days for 2005–2017, compared to 1979–2004.*

Presentations

Groisman P. Ya., 2019: Human-Associated Extreme Events. *III* International *Scientific Conference, IV All-Russian Scientific Youth Forum*, Sochi, Russia, May 15, 2019.

Groisman P. Ya., 2020: About the history of one of the ideas of Mikhail I. Budyko, to which I was slightly linked. *International Conference on Ecology and Climate*, St. Petersburg, Russia, February 25, 2020.

Product

- Algorithm of defining weather conditions conducive to freezing rain (WCCFR) was refined and applied to North America and Northern Eurasia reanalysis data

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/book chapters	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

WCCFR algorithm was refined and applied to reanalysis data

GOES-R-Based Products	
Task Leader	Anand Inamdar
Task Code	NC-SAS-05-NCICS-AI
NOAA Sponsor	Jeff Privette/Imke Durre
NOAA Office	NESDIS/NCEI

Highlight: The project team is employing NASA's Clouds and Earth's Radiant Energy System (CERES) instrument observations as an anchor for calibration/validation of the GOES visible channel sensor. An algorithm was developed to evaluate surface solar absorption in near real time from GOES-R data.

Background

The CERES instrument is one of the best-calibrated sensors of the NASA Earth Observing System (optical emission spectrometer) era. The broadband shortwave (SW) radiometers provide a great opportunity for calibrating geostationary visible channels when employed in conjunction with radiative transfer simulations. Calibrating the NOAA GOES narrowband visible channels using the CERES broadband SW measurements as a reference also provides opportunities to estimate broadband fluxes from GOES narrowband channels and to employ the CERES subsystem's extensively validated top-of-atmosphere to surface flux algorithms. An extension of this to the GOES visible channel has been successfully demonstrated in an earlier study using a narrowband-to-broadband conversion.

Accomplishments

Using CERES broadband SW measurements as reference, assessments of GOES-16 visible channel calibration were made 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 Science Data Center. A radiative transfer model (libRadtran, http://www.libradtran.org/doku.php?id=start) was installed, compiled, and employed for developing calibration for geostationary visible channels. The algorithm was also tested in producing near-real-time surface solar absorption (SSA) values from the GOES-16 sensor. Sample validation results are shown in Figure 1 for a recent time period.

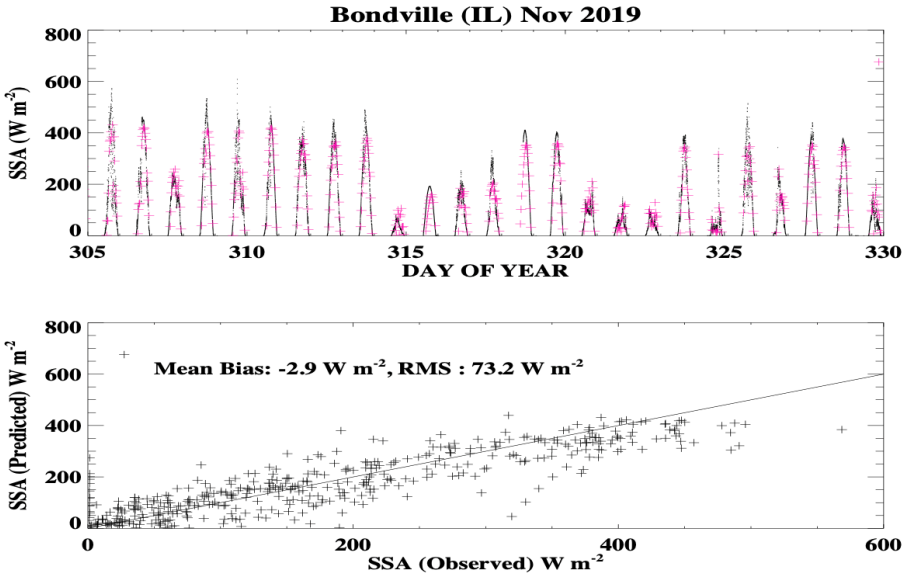


Figure 1. *(top) Time series of in situ measurements of net surface flux, or SSA (black symbols), at the Bondville (IL) site for November 2019 and evaluations of these measurements by the algorithm (magenta symbols). (bottom) Data points from the top panel plotted as a scatter plot with accompanying error statistics.*

Planned work

- Investigate using GOES-16-retrieved SSA in determining all-sky land surface temperature

Product

- Algorithm to evaluate near-real-time surface solar absorption from GOES-R data

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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Algorithm to evaluate near real time surface solar absorption from GOES-R data.

HIRS-Like Data from New-Generation Sensors	
Task Leader	Anand Inamdar
Task Code	NC-SAS-06-NCICS-AI
NOAA Sponsor	Jeff Privette/Lei Shi
NOAA Office	NESDIS/NCEI

Highlight: This new project is exploring the generation of High-resolution Infrared Sounder (HIRS)-like data from the next generation of sensors in anticipation of HIRS instrument retirement. Atmosphere and surface data, including temperature and water vapor profiles, were obtained from HIRS observations using a neural network algorithm. https://www.ncdc.noaa.gov/isccp

Background

Profiles of atmospheric temperature and humidity obtained from neural network analysis of HIRS (nnHIRS) at 16 vertical levels form an important ancillary input to the International Satellite Cloud Climatology Project (ISCCP) processing. The nnHIRS processing has recently been disrupted due to problems in channel 10 of the HIRS instrument, leading to the use of climatologically produced profiles for years 1995–2015 to produce ISCCP Interim CDRs. This HIRS instrument is experiencing increasing degradation will not be flown on future satellite missions. This will necessitate a change in ISCCP processing and/or the production of HIRS-like data from other sensors.

We are exploring the use of measurements from the Infrared Atmospheric Sounding Interferometer (IASI) on board the MetOp-series satellites to continue ISCCP processing with a HIRS-like product. This will entail a multi-step process including

1) developing the capability to process IASI and NOAA Cross-track Infrared Sounder (CriS) data to simulate HIRS,
2) performing limb correction of the resulting HIRS-like data,
3) developing schemes for cloud clearing, and
4) developing intersatellite calibration to produce the HIRS-like pixel data.

Accomplishments

Initial project work has generated a single month (August 2019) of IASI-simulated HIRS data which are being processed for limb correction. Figure 1 shows the effect of limb correction on the brightness temperature for HIRS all-sky data.

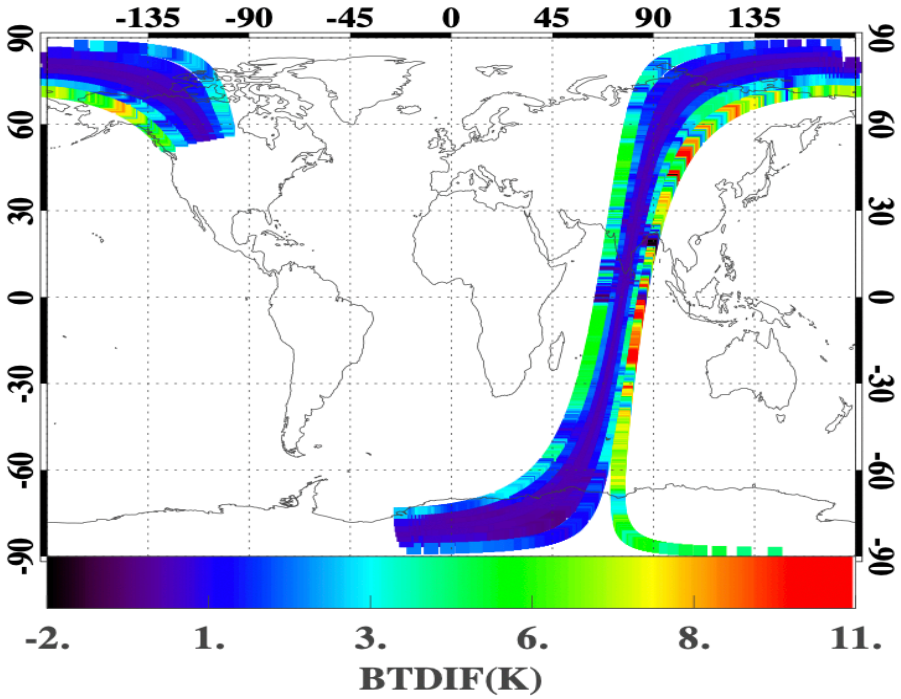


Figure 1. *Difference in brightness temperature (BT) after applying limb correction to HIRS all-sky data for August 26, 2019. Note the increase in limb-corrected BT towards the edge of the scan.*

Planned work

- Develop capability to process IASI and CrIS data to produce HIRS-like data
- Perform limb-correction of HIRS-like data from IASI and CrIS
- Develop schemes for cloud clearing of HIRS-like data from IASI and CrIS
- Develop inter-satellite calibration algorithms for the HIRS-like pixel 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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

U.S. Climate Reference Network (USCRN) Applications and Quality Assurance	
Task Leader	Ronald D. Leeper
Task Code	NC-SAS-07-NCICS-RL
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: USCRN precipitation observations were applied to evaluate the quality of gauges used to correct radar estimates of precipitation and to verify NOAA's satellite-based precipitation climate data records. Precipitation extremes and frequency of NOAA Atlas 14 threshold exceedances were updated through 2019 at USCRN stations. This analysis was also extended to the Cooperative Observer Program's hourly precipitation dataset (HPD).

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, NOAA decided 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

Precipitation. USCRN's high-quality precipitation observations were applied to evaluate the quality of gauges used to correct radar estimates of precipitation and to verify NOAA's satellite-based precipitation climate data records (CDR). In addition, USCRN's precipitation extreme analysis (maximum precipitation totals) and frequency of NOAA's Atlas-14 exceedance were updated through 2020 and expanded to include the recently released volume 11, which covers Texas. In addition, the scripts used to process USCRN precipitation data were modified to process stations from the Hourly Precipitation Dataset (HPD). This network provides a greater density of stations over a longer period of record as compared to the USCRN. Once HPD has been fully quality controlled, the two networks can provide an overview of the nature and evolution of precipitation extremes over differing time scales from sub-daily to sub-monthly.

Planned work

- Draft manuscript evaluating USCRN's precipitation extremes
- Explore opportunities to incorporate additional satellite products (GOES-R) to estimate global all-sky, sub-daily LSTs
- Evaluate the curated *Acclima* sensor error dataset and provide feedback to USCRN about the predominance of error type (i.e., data spike, noise, drop to zero, etc.) as compared to the *HydraProbe*
- Analyze any shift caused by the sensor transition on hourly soil temperature and moisture observations
- Develop and evaluate an automated method to QC soil moisture and temperature observations

Publication

Wilson, T. B., H. J. Diamond, J. Kochendorfer, T. P. Meyers, M. Hall, N. W. Casey, C. B. Baker, **R. Leeper**, and M. A. Palecki, 2020: Evaluating time domain reflectometry and coaxial impedance sensors for soil observations by the U.S. Climate Reference Network. *Vadose Zone Journal*, **19**, https://doi.org/10.1002/vzj2.20013.

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**

Standardization of U.S. Climate Reference Network (USCRN) Soil Moisture Observations	
Task Leader	Ronald D. Leeper
Task Code	NC-SAS-8-NCICS-RL
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: USCRN's hourly standardized soil moisture observations were aggregated to provide metrics of soil moisture variability over weekly time scales. Two metrics—the percent of hours below the 30th percentile and anomalous averages—were found to correlate best with U.S. Drought Monitor–based drought evolution, demonstrating that these datasets show some promise as monitoring tools.

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's hourly standardized soil moisture observations were aggregated to provide metrics of soil moisture variability over weekly time scales. These metrics include percent of hours below or above critical thresholds (<30th and >70th percentiles), standardized anomalous average, and trends in soil moisture anomalies. In addition, these metrics were evaluated over 1- to 8-week periods and compared against U.S. Drought Monitor (USDM) conditions. Overall, the percent of hours below the 30th percentile and anomalous averages were found to correlate best with USDM-based drought evolution, demonstrating that these datasets show some promise as monitoring tools. These comparison efforts will be expanded upon by incorporating other hydrological measures, such as standardized precipitation index, evaporative demand drought index, and others, to evaluate the added value of standardized soil moisture in drought monitoring. It is expected that soil moisture conditions may help to distinguish when droughts evolve from energy-limited to moisture-limited conditions.

Planned work

- Continue development of soil moisture-based drought index
- Further explore the relationship between soil moisture and other hydrological indicators (SPI, SPEI, EDDI, and LERI)

Presentations

Petersen, B., **R. D. Leeper**, and M. A. Palecki, 2020: Evaluating Flash Drought Detection Utilizing In Situ Soil Moisture Observations, *100th American Meteorological Society Annual Meeting*, Boston, MA, January 16, 2020.

Other

- A NASA Develop Team evaluated the evaporative drought demand index (EDDI) and landscape evapotranspiration response index (LERI) against in situ soil moisture conditions over the Ohio River Basin 2019 flash drought event. This group consisted of Adelaide Schmidt of Delta State University, Jessica Ganim of University of Delaware, Isabelle Runde of University of California, Santa Barbara, and Kayleigh DeBruyne of Pacific 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	**0**
# of NOAA technical reports	**0**
# of presentations	**1**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**4**

Exploring the Impacts of Drought Events on Society	
Task Leader	Ronald D. Leeper
Task Code	NC-SAS-9-NCICS-RL
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: U.S. Drought Monitor data were intersected with U.S. county data to define unique drought events. Characteristics of these events revealed stark contrasts between the western and eastern United States. In addition, county-level economic losses did not always align with measures of drought severity, suggesting that other factors, such as the timing of the drought event, may influence agricultural losses.

Background

Deficits in moisture due to drought can have profound societal and economic impacts and elevate risks of fire, landslides, adverse health outcomes, and other impacts. However, droughts are often defined based on a specific application: meteorological, agricultural, or hydrological. This approach can make it challenging to assess drought characteristics and link drought to adverse societal outcomes. This challenge is further complicated by the fact that droughts can evolve and intensify in many different ways due to regional and seasonal influences that lead to varying societal outcomes. A more unifying definition of drought would be based on all aspects of the hydrological cycle, with clearly defined start and end dates that are applicable over time. The U.S. Drought Monitor (USDM) provides a holistic view of drought across the hydrological cycle at weekly time scales since 2000. This dataset provides an opportunity to more broadly explore if and how drought events influence societal outcomes.

Accomplishments

Weekly data since 2000 from the USDM were intersected with U.S. county data to create 3,142 county-equivalent (parishes, boroughs, etc.) time series of USDM data. Each weekly time series was analyzed to identify unique, non-overlapping drought events, defined as starting the first week in which USDM conditions met or exceeded D1 status and ending the week in which USDM conditions met or exceeded D1 status followed by six or more consecutive weeks of D0 or lower status. An evaluation of U.S. county-level drought events revealed that the U.S. Southwest had fewer but longer-lasting drought events than in the eastern half of the country (Figure 1). In addition, the year with the worst drought event differed significantly across definitions based on drought intensity and economic loss (Figure 2).

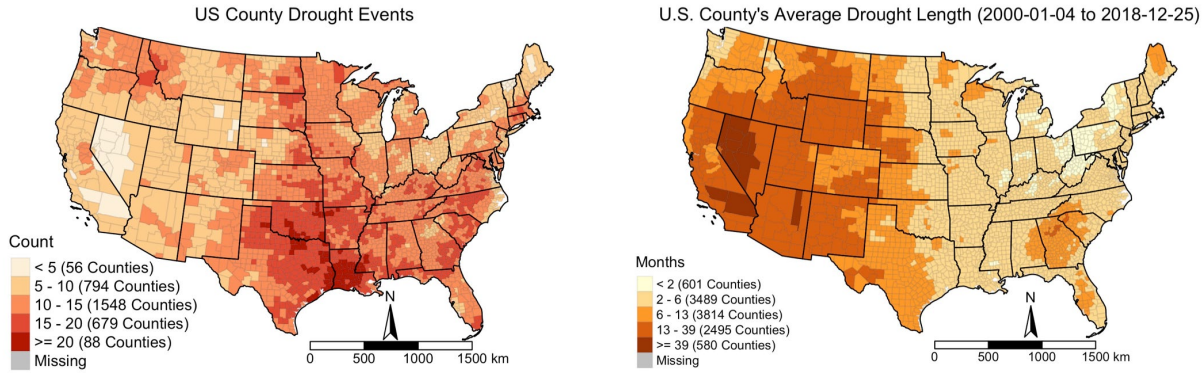


Figure 1. *(left) U.S. county drought event count and (right) average length from 2000 through 2018.*

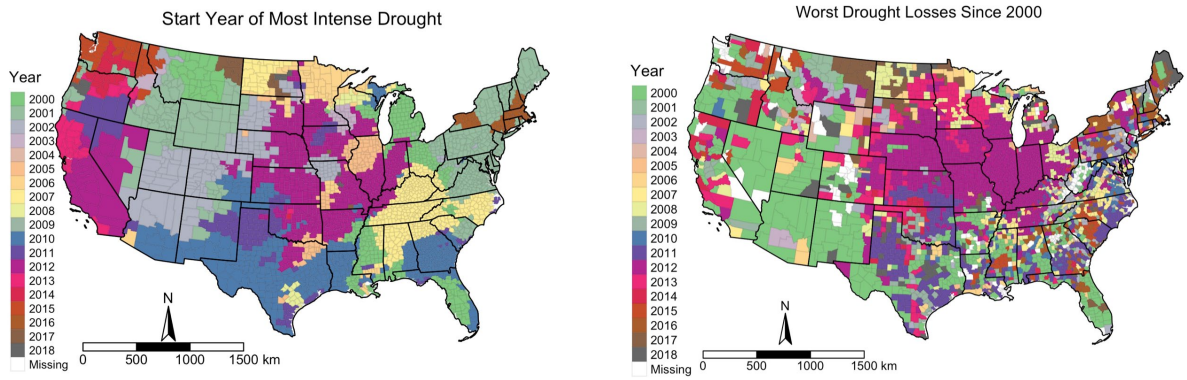


Figure 2. *(left) Start year of the worst drought event defined by drought intensity based on the number of weeks exceeding D2 status and (right) economic losses based on insurance payouts from the U.S. Department of Agriculture.*

Planned work

- Complete initial analysis of U.S. county-level drought events
- Further explore the linkages between U.S. county drought events and economic losses
- Evaluate correlations between drought events and adverse health outcomes

Presentation

Leeper, R. D., B. Petersen, and M. A. Palecki, 2020: Development and Characterization of U.S. Drought Monitor Based Drought Events, *100th American Meteorological Society Annual Meeting*, Boston, MA, January 13, 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	**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-SAS-10-NCICS-JM
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: The GSA algorithm was implemented as the U.S. contribution in an international collaboration between Europe, Japan, South Korea, and the United States to produce a joint climate data record. The cloud mask developed by MeteoSwiss was installed, configured, compiled, and successfully executed with test METEOSAT data on CISESS computing servers. http://www.scope-cm.org/projects/scm-03/

Background

Surface albedo is the fraction of incoming solar radiation reflected by the land surface and is therefore a sensitive indicator of environmental changes. Surface albedo is identified as an Essential Climate Variable 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 Geostationary Surface Albedo (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 gvar 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 Climate Data Records Program (CDRP), 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.

Project activities will include development of a common cloud-mask approach and a common intercalibration method, exploration of different temporal resolutions and formats of output, and validation of Level 2 products.

Accomplishments

MeteoSwiss developed a cloud mask for geostationary satellites that will be leveraged by all international partners for a unified approach in this project. To date, the cloud-mask code has been installed, configured, compiled, and successfully executed with test METEOSAT data on CISESS computing servers.

In the current phase, each agency is focused on producing Level 2 data from their own satellites. The long-term plan involves the fusion of the five Level 2 products to form a near-global product. In preparation for this activity, the CISESS team is collaborating with statisticians from University of California, Santa Cruz, to create a framework leveraging spatial statistics methods.

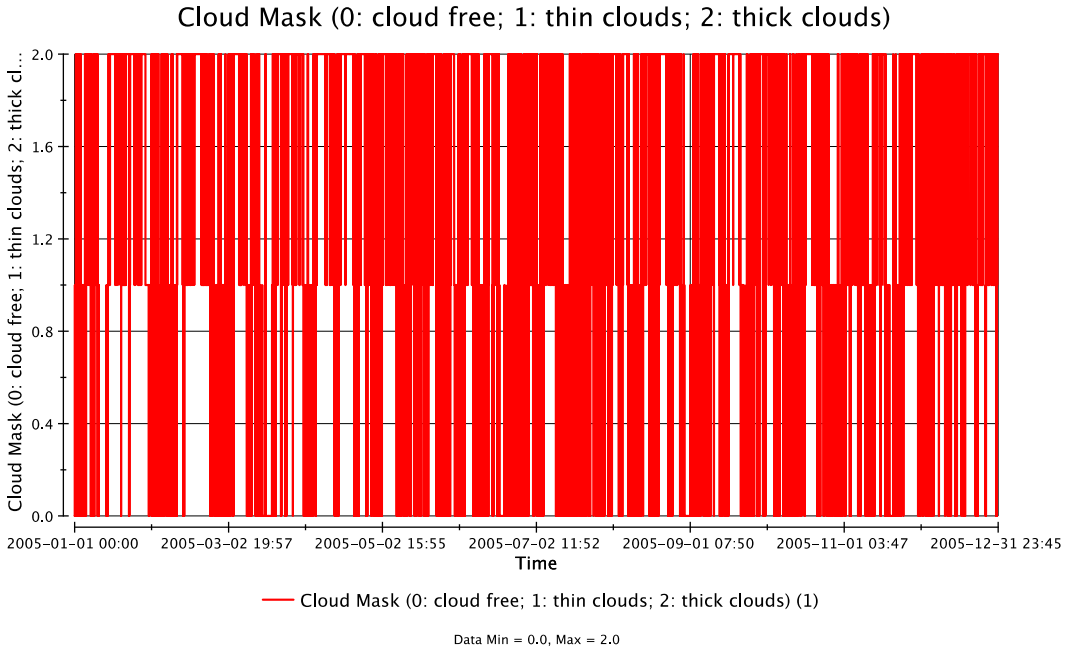


Figure 1. *Results from the cloud-mask installation on CISESS servers, processing test METEOSAT data.*

Planned work

- Implement and test cloud mask for GOES, as developed by the Satellite Application Facility on Climate Monitoring
- Reprocess GOES-E and GOES-W data for all of 1995–2018 with this cloud mask on *Amazon Web Services*
- Perform validation of GSA products with *MODIS* and in situ observational data
- Begin transition to Initial Operating Capability within NOAA's CDRP

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 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-SAS-11-NCICS-JM
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: The team is developing a global temperature and humidity profile dataset for 1978–present. The data are produced by applying neural networks to High-Resolution Infrared Radiation Sounder (HIRS) data.

Background

The goal of this task is to derive temperature at 12 different altitudes/pressures (surface, 2m, 1,000mb, 850mb, 700mb, 600mb, 500mb, 400mb, 300mb, 200mb, 100mb, and 50mb) and humidity at 8 different altitudes/pressures (2m, 1,000mb, 850mb, 700mb, 600mb, 500mb, 400mb, 300mb) using High-Resolution Infrared Radiation Sounder (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 CO2 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 lower than 850 mb and for surface pressures greater than 850 mb. RTTOV (Radiative Transfer for Television Infrared Observation Satellite Operational Vertical Sounder) data based on more than 62,000 profiles from the European Centre for Medium-Range Weather Forecasts were used as inputs for neural network training.

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, U.S. Geological Survey 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 well-mixed globally) were obtained from the Scripps CO_2 Program.

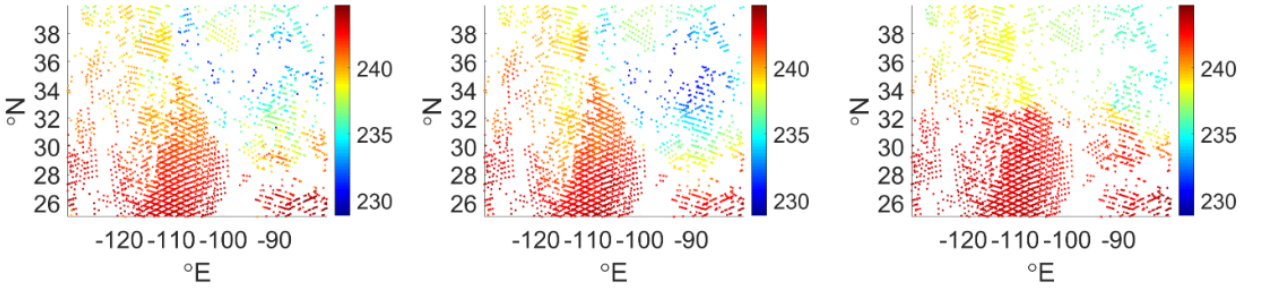
The latest version of the dataset, v2018, has been validated through evaluation of the stability of the intersatellite time series coupled with intercomparisons with independent observation platforms, as available in more recent years. Among the 11 pairs of satellites carrying the HIRS instrument with overlapping time periods, correlation coefficients greater than 0.7 are 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). Comparisons with independent datasets for 2006–2017 (e.g., RS92, COSMIC, COSMIC2013, IASI) show good agreement at all profile levels, but very close matching of surface and 2-meter temperatures over a wide domain of values is depicted in all presented intercomparisons.

Accomplishments

Current work is focused on 1) improving intersatellite calibration of raw HIRS brightness temperatures and 2) leveraging the surface and 2-meter temperatures to create a blended product along with in situ observations, where the HIRS-based data can be especially useful to improve spatial coverage in regions where in situ stations are sparse (e.g. Arctic, Africa)

Through a collaboration with University of Cincinnati's Statistics Department, hierarchical Bayesian nearest-neighbor co-kriging Gaussian process (NNCGP) models are applied to address the intersatellite

calibration problem in a novel way. These models have the capacity to account for cross-dependencies among overlapping satellite observations with varying fidelity levels. The proposed method reduces the computation complexity of the often-used auto-regressive co-kriging model to something tractable for datasets of massive scale, such as HIRS data. The method also enables gap-filling of the large, irregularly spaced datasets that occur due to the presence of clouds.



(a) NOAA-15 testing data-set (b) Prediction means by NNCGP model (c) Prediction means by single level NNGP model

Figure 1: (a) March 1, 2001, NOAA-15 Channel 5 brightness temperatures, compared to (b) using NOAA-14 data and the newly developed NNCGP model versus (c) the same NOAA-14 data with a traditional nearest-neighbor Gaussian process model.

Planned work

- Process and extend the time series of HIRS temperature and humidity profiles to present
- Develop code to convert from ASCII to *netCDF* format
- Assist in meeting operational readiness review requirements for the dataset transition to Climate Data Record Initial Operating Capability
- Explore implementing bootstrap methodology to provide associated uncertainty estimates
- Continue collaborations with user groups (including the International Satellite Cloud Climatology Project and NASA's Surface Radiation Budget Team)

Presentations

Matthews, J., 2019: Long-Term HIRS-Based Temperature and Humidity Profiles. Poster. *AMS 2019 Joint Satellite Conference*, Boston, MA, October 2, 2019.

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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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Evaluation and Elucidation of SCaMPR Performance in Complex Terrain Leveraging GOES-R Observations and Ground-based Precipitation Measurements (Duke)

Task Leader	Ana Barros
Task Code	NC-SAS-12-Duke
NOAA Sponsor	Dan Lindsay
NOAA Office	NESDIS/GOES

Highlight: Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) precipitation estimates were evaluated against rain-gauge measurements from the Southern Appalachian Mountains Duke network. SCaMPR quantitative precipitation estimation (QPE) errors exhibit a strong diurnal cycle and spatial structure that can be tied to orographic precipitation regimes. This is a promising outcome toward developing improved QPE.

Background

The Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) algorithm is an effort to combine the relative strengths of infrared-based and microwave-based estimates of precipitation. The objective of this project is to systematically characterize SCaMPR's performance at sub-daily and daily time scales and to elucidate the physical basis of errors toward improving its skill for near-real-time applications and for improving the quality of long-term QPE (quantitative precipitation estimation) in regions of complex terrain. The ultimate objective is to develop a physically based intelligent precipitation classification, detection, and correction (IPCDC) algorithm that builds on GOES-16/17 observations and current SCaMPR capabilities to meet short-term operational needs. The team will leverage the science-grade high-elevation rain gauge network in the Southern Appalachian Mountains (SAM) maintained in collaboration with the University of North Carolina Asheville over the last twelve years, which served as the core ground validation infrastructure for IPHEX (Integrated Precipitation and Hydrology Experiment).

The project is organized in four tasks: 1) ongoing calibration and maintenance of the rain gauge network, 2) error analysis and ongoing evaluation of SCaMPR QPE at seasonal and sub-daily time scales, 3) contextual forensic analysis of SCaMPR retrievals to identify error sources and error propagation, and 4) synthesis and integration of tasks 2 and 3 to develop and verify the IPCDC algorithm.

Accomplishments

Task 1. Two cycles of maintenance and calibration (UNCA) and estimation and quality control (Duke) were completed.

Task 2. SCaMPR precipitation from June to September 2018 was evaluated against rain gauge measurements from the SAM Duke network. Error analysis is provided below. The results show that SCaMPR generally underestimates warm rain, with a large number of missed detections (MDs) throughout the day except in the late afternoon, when the number of false alarms (FAs) is high. Because the errors exhibit a strong diurnal cycle, it is possible to isolate the precipitation regimes tied to specific types of errors, and exploratory research has been initiated to identify opportunities to improve the algorithm performance.

Task 3. Very preliminary results from forensic analysis suggest that GOES lightning mapper (GLM) data can be readily used to reduce the number of MDs. The team is currently exploring the possibility of using GLM to help constrain FAs as well.

SCaMPR Quantitative Precipitation Estimates (QPE) Climatology

The climatology of SCaMPR summer precipitation estimates for the year 2018 is shown in Figure 1. The number of precipitating events in the SAM as detected by SCaMPR shows higher frequency of precipitation at lower elevations away from the mountains, in contrast with ground-based observations from rain gauges, National Centers for Environmental Prediction Stage IV data, and High-Resolution Rapid Refresh (HRRR) analysis products (Figure 2). Note that although the statistics are not very robust due to the limited dataset, the inner region of the SAM has 50% less precipitation compared to the surrounding Ridge and Valley region to the west and Piedmont to the east, suggesting that missed detection is severe.

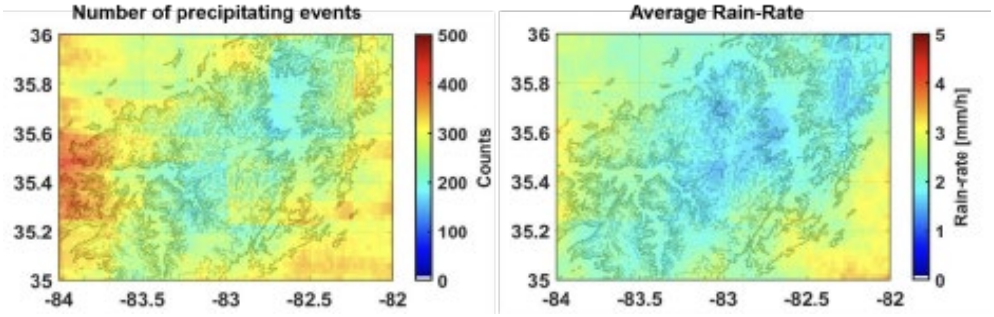

Figure 1. *Summer (JJAS) precipitation climatology of SCaMPR precipitation estimates: (left) number of precipitating events and (right) rain-rate.*

In the inner region, the average rainfall rate is ~ 1.5 mm/h, while the surrounding low-elevation region shows ~ 3.5 mm/h precipitation. This pattern is not consistent with the findings from previous studies, as the intensity of shallow warm rain can be as high in the inner region valleys as it is over the ridges due to interactions among layered low-level clouds and fog.

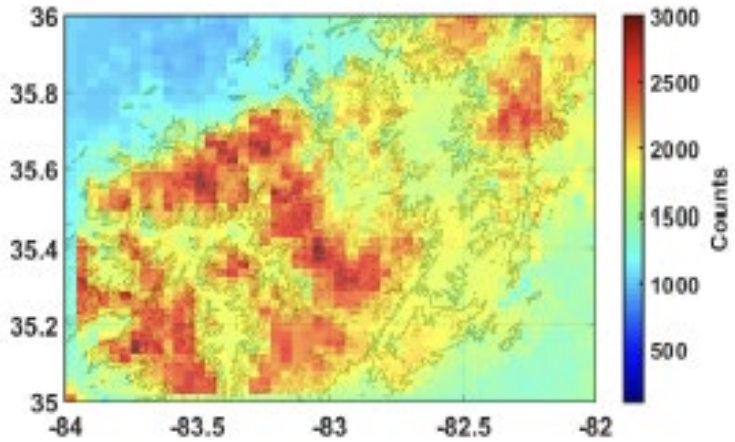

Figure 2. *Climatology of number of precipitating events according to the HRRR analysis product.*

Error Analysis

The measurements from the long-term, spatially dense rain gauges located in the Pigeon River basin are used to conduct error analysis on the SCaMPR precipitation estimates.

Detection Errors. The number of MDs and FAs in Table 1 exceed the correct detection cases in the Pigeon River basin. It is not raining most (~ 95%) of the time, and thus the agreement when it is not raining (bottom right) is very high. Missed detection is a severe handicap.

Rain-Gauges	**SCaMPR**	
	Rain	**No Rain**
Rain	3200 (17.6%)	***14959 (82.4%) Missed Detections (MDs)***
No-Rain	***4451 (24.5%) False Alarms (FAs)***	343059

Table 1. *Contingency table. (%) is ratio of MDs (top) or FAs (bottom left) over rain gauge detections. Although the MDs and FAs are very high, it is interesting to note that detection errors exhibit a strong diurnal cycle that mimics the diurnal cycle of observed rainfall (Figure 3). In particular, FAs tend to occur mostly in the late afternoon, whereas MDs occur throughout the day but are more severe in the early afternoon and in the evening when low-level clouds and fog contribute to significant low-level enhancement of precipitation via seeder–feeder interactions (valley fog and cap clouds play a role early in the day and radiation fog in the evening and at night).*

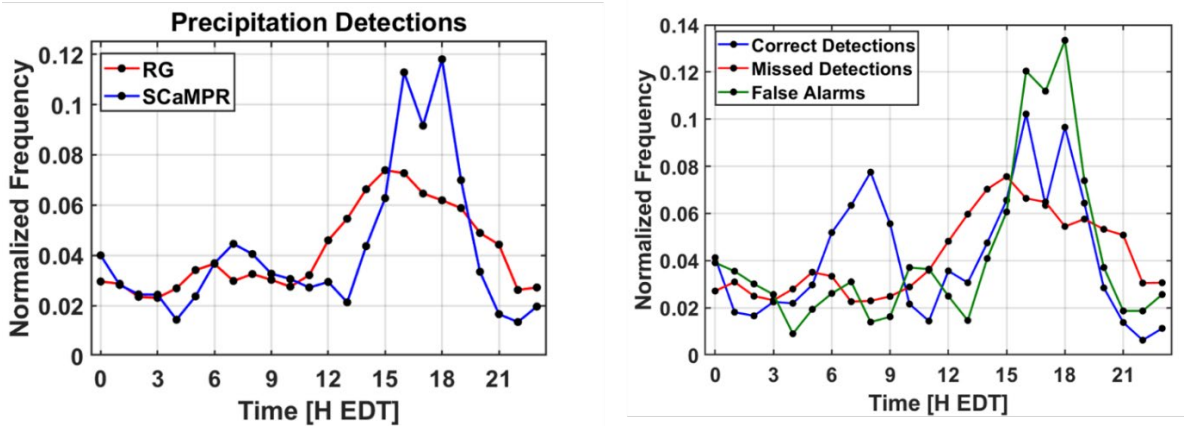

Figure 3. *Diurnal cycle of rainfall (left) and detection errors (right). The y-axis was normalized according to Table 1.*

Planned Work

- Analysis for warm season rainfall, cold season rainfall, and spring–summer transition season
- Characterization of season rainfall errors in the phase-space of ABI channels
- Development of algorithm to improve precipitation detection using Advanced Baseline Imager, Generalized Linear Model, and HRRR forecasts
- Development of algorithm for improving season SCaMPR orographic QPE
- Testing in distinct mountain geographies and climes

Presentation

Barros, A., 2020: Evaluation and Elucidation of SCaMPR Performance in Complex Terrain Leveraging GOES-R Observations and Ground-based Precipitation Measurements, JPSS Hydrology Initiative: Project Overview (remote). *Joint Polar Satellite System Hydrology Initiative*, Greenbelt, MD, February 4, 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	**0**
# of NOAA technical reports	**0**
# of presentations	**1**
# of graduate students supported by your CICS task	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Evaluation and Elucidation of SCaMPR Performance in Complex Terrain Leveraging GOES-R Observations and Ground-based Precipitation Measurements (UNC Asheville)	
Task Leader:	Douglas Miller
Task Code	NC-SAS-13-UNCA
NOAA Sponsor	Dan Lindsey
NOAA Office	NESDIS/GOESP

Highlight: Completed summer and fall 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, 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. Analysis of the 12-year (July 2007–June 2019) record of precipitation observations continues and significant findings have emerged and been published (e.g., Wilson and Barros 2014, Miller et al. 2018, Miller et al. 2019).

Since 2016, NOAA's National Environmental Satellite, Data and Information Service (NESDIS) has helped support the extension of the Duke GSMRGN period of observations. This is a collaborative effort to extend the period of observations beyond July 1, 2019, supported by UNC Asheville and NOAA NESDIS.

Accomplishments

Gauge visitation in support of the Duke GSMRGN occurred over 10–14 days spanning 5–6 weeks during each of the following cycles: summer 2019 (3 July–2 August) and fall 2019 (5 October–8 November). 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.

Summer 2019; 3 July – 2 August

Two technicians and volunteers made the visits and performed the required work.

Gauge maintenance and data logger condition monitoring included the following:

- *G #310 data logger* (near the fire tower on Mt. Sterling) *issues* continued during the summer visit with unsuccessful full recovery of 2018/2019 (10 November 2018 – 9 May 2019) winter observations using the "dur/+" command used to dump the entire contents of the data logger. The logger may need replacement during the Autumn 2019 visit.
- *"TA" resets for 3 data loggers.* The g #110 (Hawkins) data logger still ran fast compared to the GPS time. The WinComLog software had reset the g #307 (Balsam Mtn Trail) and g #112 data loggers

to '+1 sec every 56-h', which would put the logger time way behind the GPS time by the next visit in autumn 2019. "TA" was reset and should be reset again during the autumn 2019 visit.
- *Replacement of rusting nuts* with new stainless steel nuts at gauges #111, #103, and #101, where the original threads of the connector bolt openings in the rain gauge base had become stripped.
- *Future maintenance needs.* Locations g311 and g308 will need a rope saw and slingshot to clean limbs from almost overhead during the autumn 2019 visit, and location g008 will need the extension saw to clear limbs that are almost encroaching on the overhead field of view.

Specialized tasks completed:
- *g301 (Mt. Guyot) rain gauge calibration test* using the 100 mm nozzle was completed.
- *Data logger lithium battery replacement at six rain gauge locations* (#311, #310, #010, #301, #302, and #008). Significant problems continue to be noted with ML1-420 loggers draining the lithium batteries down in a very short period of time.

The primary challenges encountered during some of the gauge visits in the summer 2019 centered around the 'quirky' nature of the data loggers, particularly of the ML1-420 loggers. No data was lost between the spring and summer 2019 gauge visits at any of the locations. However, continuous coverage will continue to be a challenge between the autumn and spring visits at a handful of gauges with ML1-420 loggers. It is likely these will have to be gradually replaced over the next two years of the study. A new *Davis Pro* weather station has been installed near the Mount. Sterling fire tower, next to g 310. 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).

Fall 2019; 5 October – 8 November
Seven technicians and volunteers made the visits and performed the required work. In addition to the general tasks completed at every gauge visit, specialized tasks included replacement of all lithium data logger or HOBO batteries in anticipation of cold winter weather (when lithium batteries respond with a drop in operating voltage) and the replacement of four AA batteries of the T/RH sensor at the fire tower on Mount Sterling (near g310) to record air temperature during the cool season.

Gauge maintenance and data logger condition monitoring included the following:
- *Poor TA command response* from four ML1 loggers (g003, g107, g109, and g302), TA error "At least 12hrs must elapse!" Several data loggers (especially ML1-420 models) show signs of increasingly frequent problems and may need to be replaced to maintain continuity of the Duke GSMRGN observations record.
- *ML1 logger time adjust* was set to "off" at g011, g106, g107, g109, g304 in the hope the adjustment will self-correct during visits in the spring 2020, following the extended winter period.
- *Tree limb removal* was performed at two gauge sites (g010, g105) using an extension saw; six locations will need tree limbs cleared during the spring 2020 visit via the extension saw [g008, g301, g305, 306] or baseball/ rope/ rope saw method (g308, g311).
- *Tip bucket testing* reflected underreported rain accumulation (low tip count) at g111 (25 October 2019), similar to that found earlier in the study at g106 and g109. Oxidization on the logger cables may be preventing good contact with the switch terminal. Test tips registered as normal when the logger cables were placed on a different terminal on the switch. However, g106 (8 November 2019) showed a return of low tip count; test tips registered as normal when the switch was replaced. It is possible the magnet in the tipping bucket is bad at g106 and that the bucket will require replacing during the spring 2020 visit.

- The g010 rain gauge and base were found knocked over (presumably by a bear) on 15 October 2019. The tip observations indicated that this likely happened on 15 September 2019. The gauge was righted, and adjustments to the logger and gauge level were made.
- The rain gauge cover at g112 was found by the property owner to be off the rain gauge base for about four days (see field log report), likely during the drought of September 2019.

Challenges encountered during some of the gauge visits in the autumn 2019 were a result of diminishing daylight hours and of quickly approaching precipitation associated with T.S. Nestor (19 October 2019), which prevented the clearing of some tree limbs and replacement of "C" batteries in one of the two video cameras. We continue to contact Duke Power regarding the possibility of gaining access to weather station observations taken near the Mount Sterling fire tower, next to g310 (~5,800 feet ASL). The weather observations will help discern the source of tips in the cool season: rain or melting snow.

Details of each gauge visit with quality-controlled precipitation CSV format files can be accessed at:
Summer 2019:

http://blizzard.atms.unca.edu/dmiller/GSMRGN_report_5august2019.pdf
https://drive.google.com/file/d/1HJ9N5ETnMEL-S_s6rYpkS3SD94kkJD1h/view?usp=sharing

Fall 2019:

http://blizzard.atms.unca.edu/dmiller/GSMRGN_report_18november2019.pdf
https://drive.google.com/file/d/1qJE8FVDzqoponW0rDLo1VvChusAnuVGe/view?usp=sharing

Planned work

Spring 2020 (March – May) gauge visitation

In addition to the general visit tasks, all rain gauges will be calibrated (the last calibration was completed in spring 2019). Calibrations are scheduled at ALL rain gauge locations during the spring season due to the increased availability of daylight hours and to a seasonal (March, April, May) minimum in precipitation observed in the Pigeon River Basin (Miller et al. 2018).

Summer and fall 2020

The summer and fall gauge visitations will focus on normal collection of precipitation observations and maintenance tasks, and replacing data logger lithium batteries (fall 2020).

Details of every gauge visit along with each gauge precipitation record will be posted online with sub-folders for each gauge that include individual data files (often having at least two different formats), pictures taken at the gauge site during the visit, screenshots of the GPS (laptop) and ML1 logger time comparison, and an MS Word document that mirrors the notes made in the field journal during the visit.

The current 2019–2020 academic year technician roster includes Meredith Avison, Marlee Burgess, Lyn Comer, Andrew Hill, Alice Monroe, Samuel Peterson, and Samantha Wood. New students will be recruited in fall 2020, as one student will graduate from UNC Asheville in May 2020.

Products

Ralph Ferraro's group, including University of Maryland undergraduate intern (J. Hill), used collocated 24-hour precipitation observations of the Duke GSMRGN for examining GOES-16 Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR, Kuligowksi et al. 2002) over a study period in 2018.

Bob Kuligowski's group use Duke GSMRGN observations as part of research validation efforts.

Presentations

Hill, J., 2019: Gauge and satellite data comparison programming. *2019 NOAA/NESDIS/Cooperative Research Program (CoRP) Science Symposium*, College Park, MD, August 29, 2019.

Miller, D.K., 2019: Fellowship of the rain (gauge network). *NOAA STAR Seminar, Satellite Climate Studies Branch*, College Park, MD, September 12, 2019.

Miller, D.K., 2020: Influence of atmospheric rivers on long-duration freezing rain events in eastern North America. *100th AMS Annual Meeting*, Boston, MA, January 15, 2020.

Other

- Ten UNC Asheville undergraduate students received field research credit for project activities.
- PI Miller completed discrimination and harassment prevention training on February 12, 2020.
- PI Miller became certified in Wilderness First Aid (WFA) at UNC Asheville on February 8-9, 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	**0**
# of NOAA technical reports	**0**
# of presentations	**3**
# 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.

Miller, D.K., Miniat, C.F., Wooten, R.M., Barros, A.P.; An expanded investigation of atmospheric rivers in the southern Appalachian Mountains and their connection to landslides. Atmosphere, 10, 71-93, 2019.

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

Wilson, A. M. and Barros, A. P.: An investigation of warm rainfall microphysics in the southern Appalachians: Orographic enhancement via low-level seeder–feeder interactions, J. Atmos. Sci., 71, 1783–1805.

Gridded In Situ USCON Temperature and Precipitation Normals	
Task Team	Ge Peng, Carl Schreck
Task Code	NC-SAS-14-NCICS-GP/CS
NOAA Sponsor	Jeff Privette/Imke Durre
NOAA Office	NESDIS/NCEI

Highlight: Thirty-year averages of daily, monthly, and annual gridded USCON temperature and precipitation data are being computed using NCEI's gridded dataset (nClimGrid). The team examined day-to-day variability in daily average temperatures, produced maps of extreme event days and a comparison with PRISM data, and incorporated results in NCEI's monthly State of the Climate reports.

Background

The purpose of this project is to provide a historical perspective that can serve as a baseline for monitoring and planning by NCEI, the National Weather Service, other governmental agencies, climate scientists, the private sector, and the general public. Previous generations of NCEI's climate normals were calculated based on station data. This next generation will leverage NCEI's new nClimGrid-Daily data, which provides 4 km gridded data over the contiguous United States. That dataset is still in beta, pending archive and publication of its algorithm. A necessary prerequisite of this project is thus supporting the transition of nClimGrid-Daily into operations.

Accomplishments

- Reviewed daily and monthly gridded in situ USCON temperature (average, maximum, and minimum) and precipitation fields
- Examined preliminarily spatial and decadal variability using monthly data, including decadal temperature trends (Figure 1)
- Examined day-to-day variability of daily average temperatures of nClimGrid-Daily data (1895–2019)
- Produced maps of nClimGrid-Daily for extreme event days to highlight its utility
- Compared the nClimGrid-Daily and the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate datasets by calculating mean differences and mean absolute differences at each grid point
- Incorporated maps (Figure 2) based on nClimGrid-Daily into the Synoptic Discussion of NCEI's monthly State of the Climate reports (https://www.ncdc.noaa.gov/sotc/synoptic).

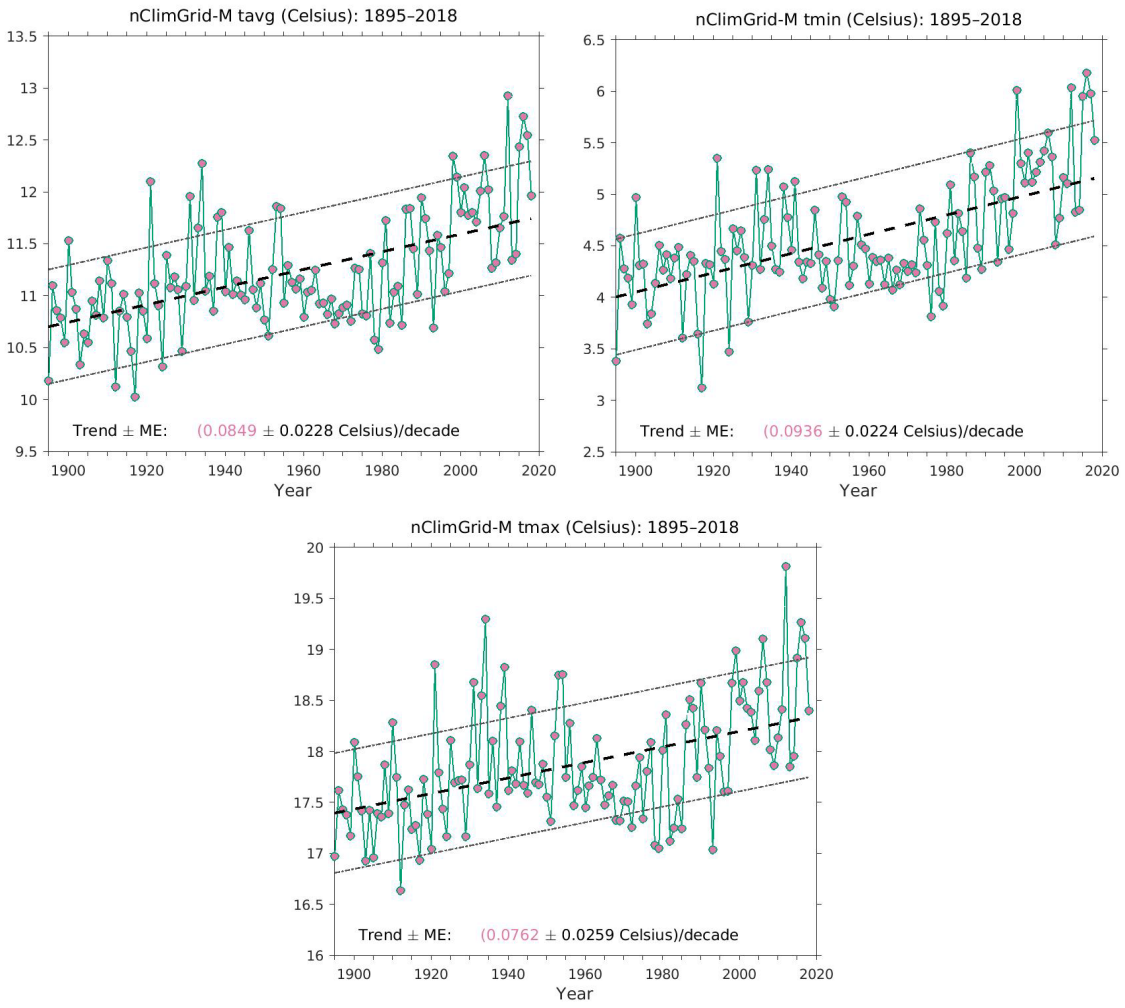

Figure 1. *Time series of monthly gridded average temperature (top left), minimum temperature (top right), and maximum temperature (bottom) for 1895–2018 from the monthly nClimGrid data files, downloaded from https://www.ncei.noaa.gov/thredds/catalog/data-in-development/nclimgrid/catalog.html. These figures show significant trends of 0.0849°C, 0.0936°C, and 0.0762°C per decade, respectively.*

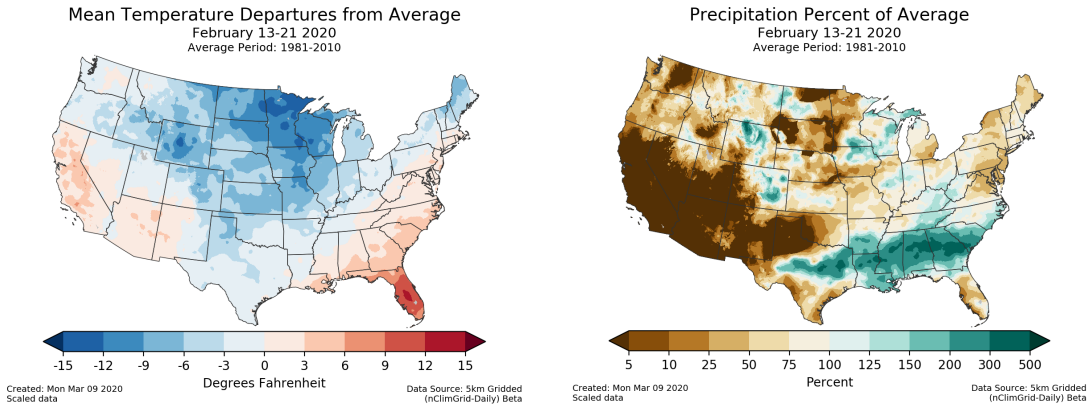

Figure 2. *Maps of (left) average daily temperature anomalies and (right) percent of normal precipitation. Both plots are for 2020 February 13–21 and are calculated relative to the daily climatologies for 1981–2010.*

Planned work

- Port the *Fortran* code for computing 1981–2010 station normals to the NCICS computing environment
- Implement code to compute 1990–2019 averages of daily and monthly nClimGrid data files and developing any additional *Fortran* code necessary
- If time permits, compute 1981–2010 gridded normals and compare them with station normals.
- Contribute figures and other content to a planned publication describing the nClimGrid-Daily dataset

Presentation

Gleason, K., D. Arndt, **C. Schreck**, and C. Fenimore, 2019: NCEI Daily Gridded Data and Selected Derived Products. *44th Annual Climate Diagnostics and Prediction Workshop*, Durham, NC, October 22, 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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Development of Satellite Alternate Precipitation Normals	
Task Leader	Olivier Prat
Task Code	NC-SAS-15-NCICS-OP
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: Prior evaluation of the satellite precipitation CDRs (CMORPH-CDR, PERSIANN-CDR, GPCP) and of their strengths and weaknesses is being used to develop alternate precipitation normals.

Background

Four satellite-based precipitation Climate Data Records (CDRs) were evaluated (PERSIANN-CDR; GPCP; CMORPH; AMSU/MHS Hydro-bundle) to improve understanding of their strengths and weaknesses for specific applications. 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) were evaluated over the concurrent period. Product intercomparisons were 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 included 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).

This evaluation work will be used as the basis for developing alternate precipitation normals.

Accomplishments

Alternative precipitation normals will be computed over a 30-year period (GPCP-Monthly available since 1979; PERSIANN-CDR available since 1983) or a shorter period of 20 years (GPCP-Daily available since 1997; CMORPH-CDR available since 1998), depending on each satellite QPE period of availability. Because of their homogeneous coverage and high spatial resolution, those satellite QPE can provide useful supplementary information and refinements in places where stations are sparse or lacking. In addition to monthly averages that routinely constitute climate precipitation normals, other quantities such as standard deviations, maximum precipitation, conditional means, percentiles, and percentage of rainy days are being computed. Those satellite precipitation normals are compared to in situ normals over CONUS, and the differences between each product are evaluated. Comparisons with other alternative precipitation normals, such as those derived from the WSR-88 NEXRAD, will also be conducted.

Planned work

- Continue development of the alternate precipitation normals
- Finalize the manuscript on the evaluation of the precipitation REDRs (CMORPH, PERSIANN, GPCP)
- Submit a revised version of the paper to *Journal of Hydrometeorology*

Presentation

Nelson, B.R., **O.P. Prat**, and A. Arguez, 2020: Alternative precipitation normals based on NEXRAD quantitative precipitation estimates. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.

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	**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**

Toward Earlier Drought Detection Using Remotely Sensed Precipitation Data from the Reference Environmental Data Record CMORPH	
Task Team	Olivier Prat, Ronald Leeper, Jessica Matthews
Task Code	NC-SAS-16-NCICS-OP/RL/JM
NOAA Sponsor	Steve Ansari
NOAA Office	NIDIS/NCEI

Highlight: Monthly and daily Standardized Precipitation Indices (SPIs) were implemented using precipitation satellite data from the CMORPH and PERSIANN climate data records to investigate their suitability for detecting and monitoring drought. Comparison of satellite SPI with an in situ drought index showed comparable patterns for droughts events around the globe but important differences over areas with limited precipitation.

Background

Satellite precipitation data from the CMORPH-CDR (Climate Prediction Center Morphing technique-climate data record) program are being utilized to detect and monitor drought on a global scale. Precipitation data are used to compute and evaluate the Standardized Precipitation Index (SPI) over the continental United States (CONUS). In order to evaluate the relevance of using satellite data for the purpose of early drought detection and drought monitoring, several scenarios have been tested using the rain-gauge-adjusted version of the satellite quantitative precipitation estimate (QPE), the near-real-time version of the satellite QPE, and a mixed combination of gauge-adjusted and near-real-time versions of the satellite QPE. The drought indices are evaluated over CONUS, for which numerous in situ data as well as drought products exist. In particular, the difference between indices obtained with the corrected (CMORPH-CDR) and interim near-real-time (CMORPH-ICDR) versions of CMORPH is evaluated.

Four drought episodes (the 1998–2004 western U.S. drought, the 2006–2007 Southeast U.S. drought, the 2010–2012 Texas–Mexican drought over the Southern Plains, and the 2012 summer Midwestern U.S. drought) serve as case studies to assess the monitoring and prediction capabilities of drought products, as defined by the Drought Task Force (DTF) Protocol released in April 2013. These drought episodes, which influenced the development of the National Integrated Drought Information System (NIDIS) early warning system, are all within the period of record of the CMORPH-CDR dataset (1998–present).

Following the assessment metrics in the DTF Protocol, the SPI products are evaluated on the basis of their ability to estimate drought onset and recovery, drought duration and severity, probability of drought condition, and the value given at the observed period. The goal of this work is to transition to operations a fully functional implementation of the daily SPI using CMORPH-CDR and CMORPH-ICDR that will be used to detect and monitor drought episodes globally. Operational SPI products will be provided to the public through an Interactive Global Drought Information Dashboard. Near-real-time drought conditions will be accessible to the public via interactive visualization techniques.

Accomplishments

During the last year, the monthly and daily SPIs were implemented using precipitation satellite data from CMORPH-CDR/ICDR (since 1998) and PERSIANN-CDR (since 1983). The SPI algorithms were refined, and two methods are currently used for the computation of the SPI. Both CMORPH-CDR/ICDR and PERSIANN-CDR present the same global patterns. However, some significant differences are observed locally in terms of SPI values and drought classification. In addition, both monthly and daily SPIs present the same timing and area for the major drought episodes over CONUS and the globe. Over CONUS, the comparison of

satellite-based time series and drought frequency with in situ drought monitoring products, such as the U.S. Drought Monitor (USDM), showed variable agreement as a function of the location, with a clear difference between eastern and western U.S. states (not shown). Globally, the comparison of satellite SPI with in situ GPCC_Di (Global Precipitation Climatology Centre drought index) showed comparable patterns for droughts events around the globe but important differences over areas with limited precipitation (not shown).

Monthly and daily SPI values are routinely calculated globally from CMORPH-CDR and CMORPH-ICDR. A Near-real-time global daily SPI is currently available within 1-day to the current day. Figure 1 presents the drought conditions (SPI values) computed for the day of March 16, 2020, for the different time scales from 30-, 90-, 180-, 270-, 365-, and 730-day as an example.

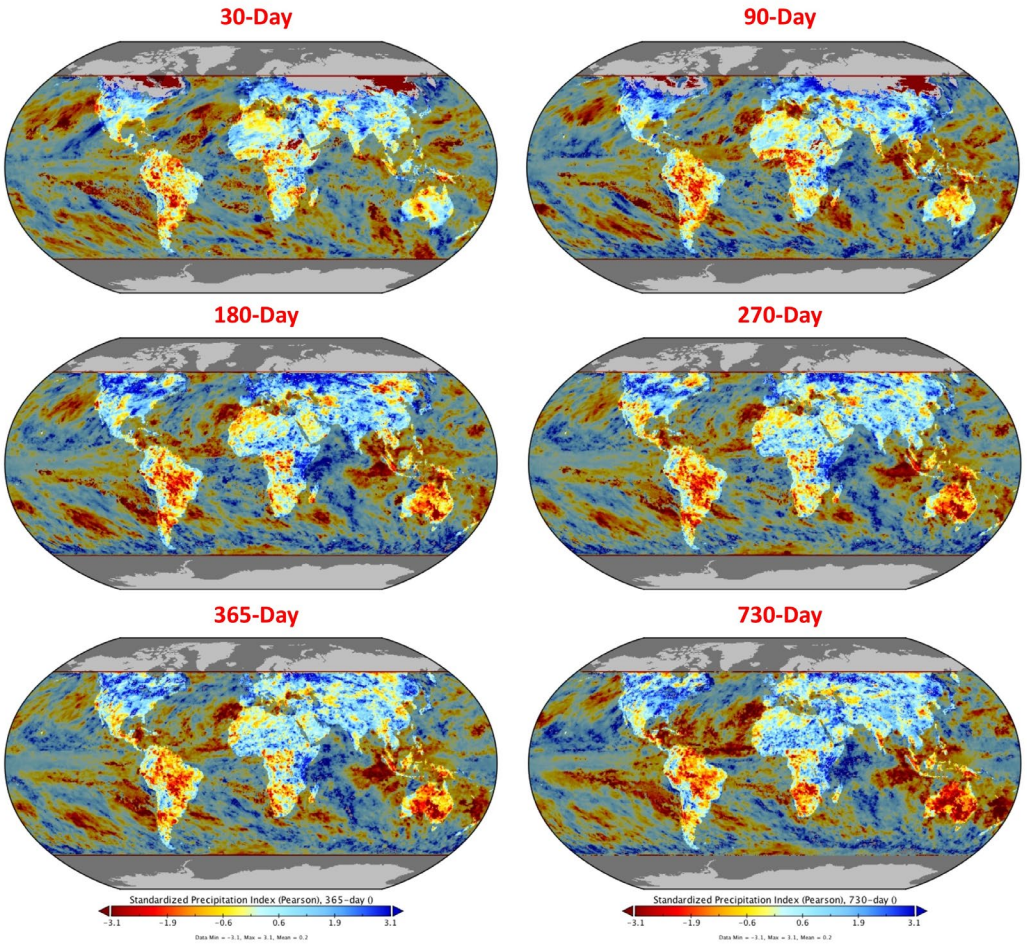

Figure 1. *Operational global drought conditions for March 16 2020. The daily SPI is derived from CMORPH-CDR and CMORPH-ICDR and computed for 30-, 90-, 180-, 270-, 365-, and 730-day time scales.*

The work currently in progress consists of validating the satellite precipitation products (SPP) SPI, as results may differ in terms of magnitude and severity when compared to SPI or other drought indices derived from in situ drought monitoring products (USDM, nClimGrid-derived SPI, GPCC_DI). The work also aims to further investigate the sensitivity to input precipitation data (CMORPH-CDR, PERSIANN-CDR, Integrated Multi-satellitE Retrievals for GPM [GPM IMERG]), SPP resolution (0.25°, 8 km), and SPI

algorithm formulation (McKee et al. 1993, Guttman 1998). For instance, we investigated the impact of the SPI algorithm (McKee et al. 1993, Guttman 1998). McKee et al. (1993) uses a two-parameter Gamma distribution (α: Shape, β: Rate = 1/Scale) for fit for of the precipitation accumulations, while Guttman (1998) uses an L-moment approach and a three-parameter Pearson III distribution (ξ: Location, β: Scale, γ: Skewness). Figure 2 presents an example of the parameters of the Pearson III distribution. The global patterns for the location (ξ) and scale (β) parameters comparable to average precipitation and variance patterns, respectively. They depend on the value of the accumulation period (i.e., 90-day vs. 270-day) and the day of the year (i.e., January 1st vs. July 1st). Desert areas exhibit positive skewness (γ), which indicates a heavier tail on the right-hand side of the distribution. The value of the skewness (γ) decreases with increasing accumulation period (i.e., 90-day vs. 270-day).

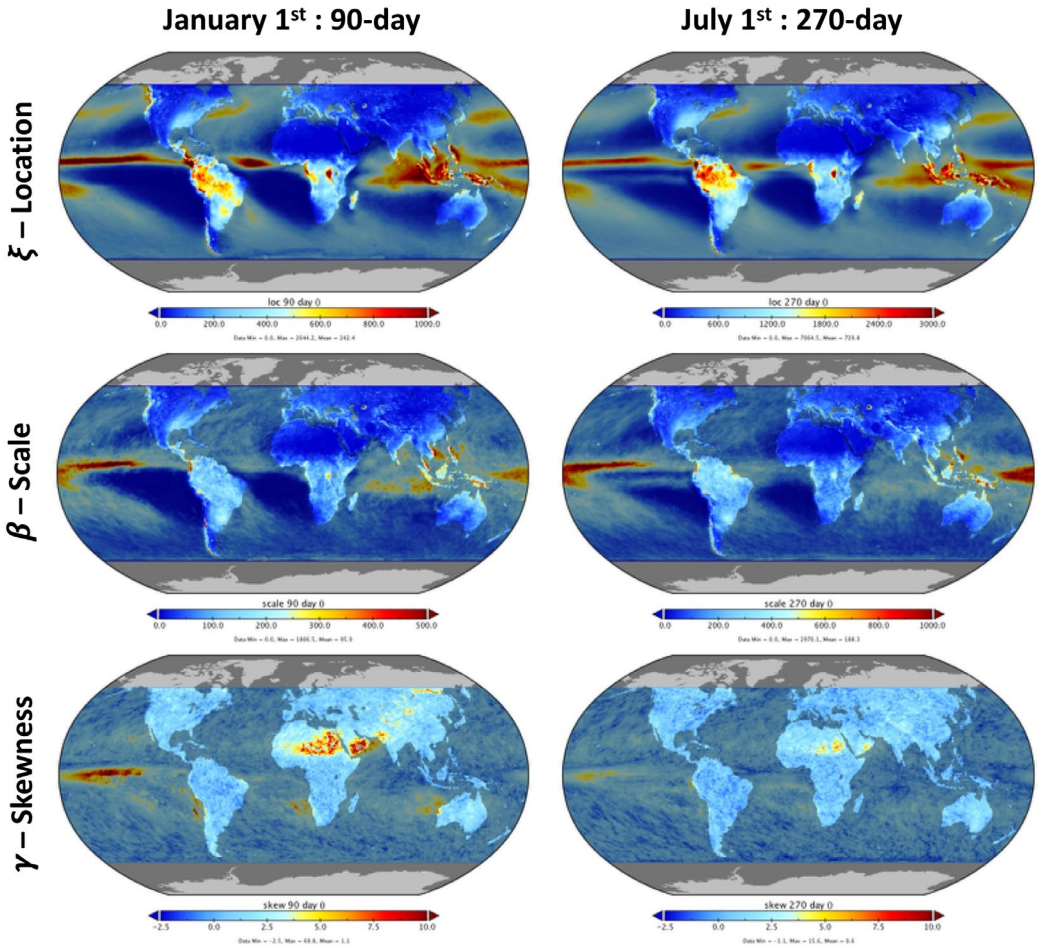

***Figure 2**. Global Pearson III distribution parameters: Location (ξ), Scale (β), and Skewness (γ) obtained from the Guttman (1998) SPI formulation that uses an L-moment approach and a Pearson III fit for the distribution.*

In the absence of a benchmark to compute the SPI, this work aims to provide information on when to use a Gamma or a Pearson III distribution (accumulation period, location). In addition, it is possible that those distribution parameters provide valuable information on drought onset and recovery. As a component to this work, NIDIS is developing an Interactive Global Drought Information Dashboard for near-real-time drought monitoring and to provide timely resources to mitigate drought information and assess disparities between global and regional scales. The operational near-real-time SPP SPI will be provided to

the public through the dashboard. A beta version of the near-real-time SPI products will be available for download through a NOAA NCEI website. It will complement existing in situ–derived drought indices (SPI, Standardized Precipitation–Evapotranspiration Index, Palmer Drought Severity Index), particularly in station-sparse areas.

Planned work

- Continue evaluation of the CMORPH-CDR daily and monthly SPI against in situ drought monitoring products (USDM, nClimGrid-derived SPI, GPCC_DI)
- Finalize a manuscript on the daily and monthly SPI derived from CMORPH and PERSIANN-CDR
- Quantify the amount of rain that would be needed to provide drought relief from the SPP SPI
- Extend the work to other SPP at higher resolution such as GPM IMERG or CMORPH-CDR at 8 km resolution

Products

- Operational near-real-time global daily SPP SPI that is currently available within 1-day
- An improved Geographic Information Systems–based visualization and analysis tool to display global droughts conditions in near real time as a complement to the Interactive Global Drought Information Dashboard

Presentations

Courtright, A. M., **O. P. Prat**, R. Bilotta, **R. D. Leeper**, B. R. Nelson, S. Ansari, K. Bevington, and A. Lang, 2019: Developing an interactive global drought information dashboard using remotely sensed near-real time monitoring. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco CA, December 13, 2019.

Prat, O. P., 2020: Near-real time drought monitoring using global satellite precipitation estimates from NOAA's Climate Data Record (CDR) program. *NCEI Seminar Series*, Asheville, NC, March 17, 2020.

Other

Finally, we advised a group of three NASA Develop students during the fall session of 2019. The students investigated the vegetation response to remote-sensing drought indices within the dry corridor of Central America using NASA Earth Observations such as GPM IMERG and MODIS. Information is found here: https://develop.larc.nasa.gov/2019/fall/CentralAmericaDryFoodAg.html

Performance Metrics	
# of new or improved products developed that became operational	**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	**2**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**3**

**While not fully operational, the global SPP SPI that uses CMORPH-CDR/ICDR is being generated daily.*

Developing and Validating Heat Exposure Products Using the U.S. Climate Reference Network	
Task Leader	Jared Rennie
Task Code	NC-SAS-17-NCICS-JR
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: Using hourly and sub-hourly data from the United States Climate Reference Network (USCRN), heat exposure indices including heat index, apparent temperature, and wet-bulb globe temperature (WBGT) are being developed and validated against nearby sites. These derived products will be used to address heat health, combining climate data with available socioeconomic and hospital data.

Background

NCEI oversees the observations of the United States Climate Reference Network (USCRN). This network consists of 114 sites across the conterminous 48 states, with additional sites in Alaska and Hawaii. Stations are sited and installed in areas with stable land cover and land-use conditions for several decades to come. At each site, a suite of meteorological parameters are monitored, including triple redundancy for primary air temperature variables. Other variables recorded at USCRN sites include solar radiation, relative humidity, and 1.5-meter wind speed. Because these variables can play a role in heat exposure, it makes sense to explore, develop, and test heat-related indices using high-resolution USCRN data.

Using data at hourly and 5-minute resolution, three separate heat exposure indicators are developed. The first is the heat index (HI), which uses heat and humidity information, and is commonly used in National Weather Service (NWS) products. The second is apparent temperature (AT), defined by Steadman (1984), which uses temperature, relative humidity, and wind to differentiate between indoor and outdoor exposure. The third is wet-bulb globe temperature (WBGT), which is commonly used in industry, sports, and the military to determine outdoor human exposure. WBGT incorporates air temperature, wet-bulb temperature, and black-globe temperature (BgT), the latter requiring solar radiation information. The 5-minute values of these variables can be accumulated to better understand the total exposure to a heat event. For this project, data are validated using nearby networks maintained by the State Climate Office of North Carolina, and results are used to examine case studies of recent extreme heat events.

Accomplishments

A *Python* script has been developed to take both hourly and 5-minute data from USCRN stations and calculate heat exposure indices, including HI, AT, and WBGT. In order to calculate WBGT, the BgT must be available. If a black-globe thermometer is not provided, it can be estimated one of two ways. The first is a method developed by the NWS office in Tulsa, OK, and the second is an algorithm developed by Argonne National Laboratory. Both methods were tested on USCRN data and used to create two different versions of WBGT.

In order to validate these methods, stations from the North Carolina State Climate Office's mesonet, known as ECONet, were used. Half of these stations have black-globe thermometers installed, which allows for BgT and WBGT comparisons between estimated USCRN data using the Argonne algorithm and direct observations from ECONet. Two sites were selected where USCRN and ECONet stations are within 5 miles of each other (Asheville, NC, and Durham, NC). All data were considered since the black-globe thermometers were installed at the ECONet sites in April 2018, but two specific heat events were analyzed. The first was in July 2019, and the second was in late September and early October of 2019. The latter event was unprecedented, as temperatures hit 100°F on October 1st in the Raleigh/Durham area.

Results show the Argonne method is better at producing BgT, and thus WBGT, with r-squared values of both variables ranging between 0.85 and 0.90. Individual variables at USCRN sites were also compared to their ECONet counterparts, including air temperature (known here as dry-bulb temperature), relative humidity, solar radiation, and wind speed. All data matched well, with the exception of wind speed. Results had r-squared values around 0.6, with even lower values at nighttime. This is due to radiational and land-cover effects that can occur in microclimates, which can result in varying wind speeds, even at close distances. We conclude that while wind speed values can vary, especially during calm wind occasions, the resulting values of BgT and WBGT provided by the Argonne algorithm can be used to accurately create derived versions of BgT and WBGT at USCRN sites.

In order to compare values of HI, AT, and WBGT, hourly data of these variables were compared against each other during the two heat events in July and September/October of 2019. The first event is shown in Figure 1. A heat event here is defined as the dry-bulb temperature exceeding the 90th percentile for a period of three days or more. Due to local terrain, this threshold is different in the mountains of Asheville compared to the Piedmont area of Durham (86°F and 89.6°F, respectively). The graphs show that the number of hours above their respective thresholds can vary depending on the heat metric used. For example, the HI exceeded this threshold for 76 hours in Durham, but the WBGT value never exceeded this threshold. While WBGT values follow the Fahrenheit scale, they tend to have lower values. This creates a communication issue for the public, who may perceive an 85°F WBGT as not being that bad, while the NWS considers it dangerous to be outside under those conditions. The NWS is proposing an index, similar to the Air Quality Index or the Drought Monitor, that can help overcome these messaging challenges and improve the effectiveness of heat event warnings.

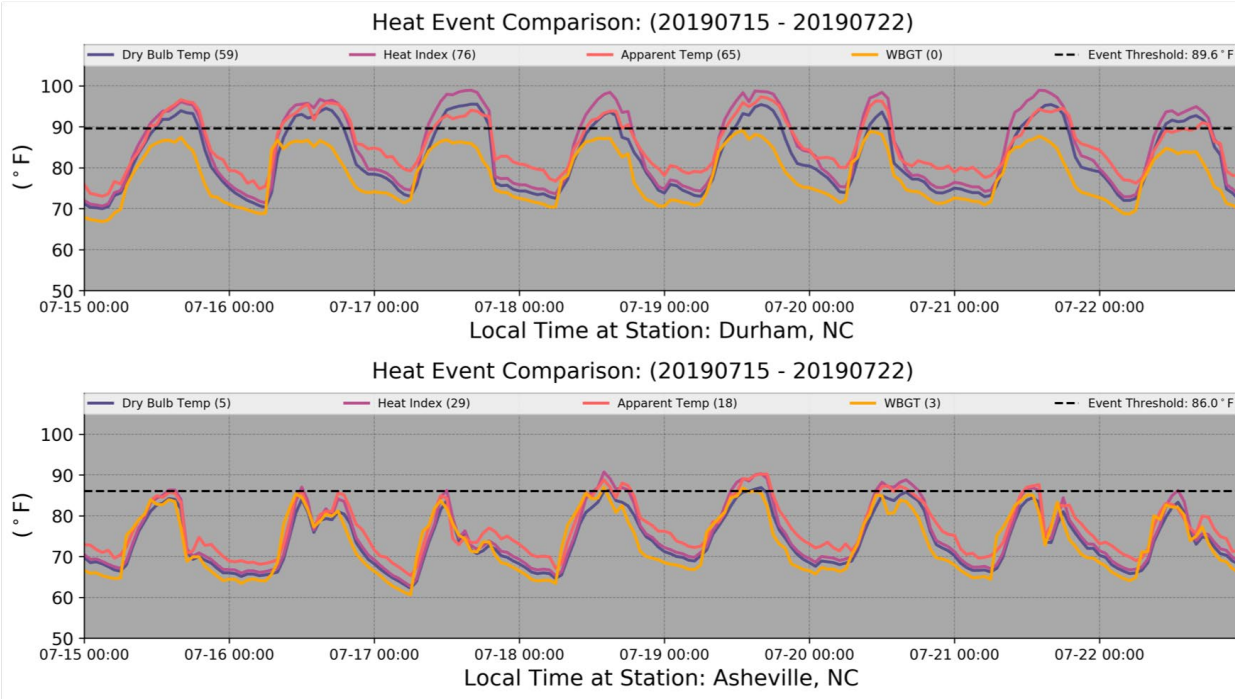

***Figure 1**. Time series of hourly heat indices for a heat event taking place between July 15*th *and July 22*nd*, 2019, in Durham, NC (top), and Asheville, NC (bottom). Number of hours above the heat event threshold are also displayed.*

Planned work

- Analyze heat indices at other USCRN locations, including those in different climates, such as the semi-arid climates of the western United States
- Validate BgT and WBGT values at other sites, using available neighboring stations with black-globe thermometers installed
- Use archived data from the NWS National Digital Forecast Database (NDFD) to reconstruct a climatology of WBGT for the contiguous United States from 2017–present
- Incorporate WBGT data to build a heat vulnerability index, using the latest climate, socioeconomic, and health data for parts of the United States

Product

Hourly and sub-hourly heat exposure indices, including heat index (HI), apparent temperature (AT), and wet-bulb globe temperature (WBGT)

Presentations

Rennie, J., 2020: Development of a Heat Vulnerability Index for the Southeastern United States. Poster. *100th AMS Annual Meeting*, Boston, MA, January 13, 2020.

Rennie, J., 2020: It's Not the Heat, It's the Humidity…and Wind and Solar: Developing and Validating Heat Exposure Products Using the U.S. Climate Reference Network. *100th AMS Annual Meeting*, Boston, MA, January 13, 2020.

Other

A NOAA Hollings Scholar, Mahima Kumara from Yale University, provided some preliminary work on this project, including developing a heat vulnerability index for the southeastern United States, focusing on North Carolina.

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	**2**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

The heat indices are considered a derived product of USCRN, and work is underway for them to become operational within the USCRN framework.

Development of the United States Climate Reference Network (USCRN) National Precipitation Index	
Task Leader	Jared Rennie
Task Code	NC-SAS-18-NCICS-JR
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: The CISESS project team is working to transition the previously developed National Precipitation Index (NPI) into NCEI operations.

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 facilitate precipitation comparisons like those available for NTI, the USCRN team has developed its own version of a National Precipitation Index (NPI).

An algorithm to build the NPI was developed and finalized under the prior cooperative institute agreement. Data for 2006–2019 from 107 USCRN station sites were used in this analysis. 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.

The CISESS project team will continue the transition of NPI from research to operations.

Accomplishments

The project team began planning for the NPI transition from research to operations. Next steps will include porting over the code base to NCEI monitoring systems, updating figures when new data become available, and initiating an operational readiness review (ORR).

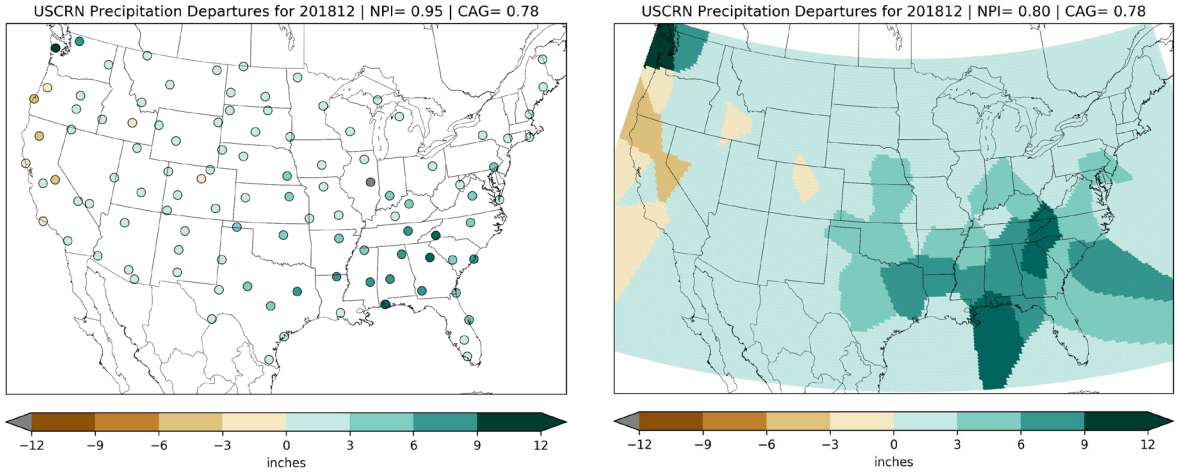

Figure 1. *Prototype of the monthly USCRN National Precipitation Index for December 2018. (left) Values of NPI at individual USCRN stations; (right) gridded values after interpolation scheme applied.*

Planned work

- Work with NCEI monitoring team to transition the NPI into operations on NCEI's website
- Develop NOAA technical report
- Begin the process for ORR

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	**0**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

NCEI Innovates: Developing 1991–2020 Normals along the Northeast and Mid-Atlantic Coasts	
Task Leader	Jared Rennie
Task Code	NC-SAS-19-NCICS-JR
NOAA Sponsor	Jay Lawrimore/Michael Palecki
NOAA Office	NESDIS/NCEI

Highlight: Coastal normals for 1991–2020 were developed for areas around the Northeast and Mid-Atlantic regions, and an *ArcGIS Online* tool was developed to allow users to interact with the data.

Background

Conventional NCEI Climate Normals represent the average conditions to be expected at a time and place for any given hour/day/month of the year. These are one of NCEI's best-known products, and they are required by many sectors and seen on media weathercasts every day. NCEI soon will be producing the 1991–2020 Climate Normals suite of products as required by our agreements with the World Meteorological Organization (WMO). In the past, NCEI has also leveraged this activity to produce normals customized for important user communities, such as agriculture, energy, and construction. Currently, new opportunities exist to expand normals to coastal and oceanic variables of importance to the expanded NCEI user community. An NCEI Innovates pilot project expands normals production to meet the needs of coastal tourism and recreation and other coastal user communities by assembling a set of quality normals representing both atmospheric and oceanic conditions along the U.S. Mid-Atlantic/Northeast coastline.

The NCEI Innovates team collaborated with members of the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) and their partners in the Mid-Atlantic region (MARACOOS).

Accomplishments

The first step was to understand which data should be used for the project. The following datasets were used: For land data, the product uses monthly gridded temperature and precipitation data from NCEI's nClimGrid product. Over the ocean, it uses 0.25° gridded temperature data from ERA5 reanalysis from the European Centre for Medium-Range Weather Forecasts. Precipitation data from the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN) climate data record are provided by NCEI. Additional gridded ocean data is provided through the World Ocean Database, including temperature and salinity, provided at multiple depths. Point data near and around the coast are being addressed, using available wind data from both the Automated Surface Observing System and buoys.

Climatologies were calculated for 1991–2019 for all datasets. It is hoped that the data will be updated in early 2021 to complete the standard 30-year normal. To provide a clear picture of surface temperature and precipitation, an algorithm was developed to merge nClimGrid data with its respective ocean dataset (ERA5 for temperature, PERSIANN for precipitation). Check-ins were coordinated to ensure there were no gaps in the data, while maintaining dataset integrity.

Using all available data, a tool has been developed using *ESRI's ArcGIS Online* software. A prototype of this interactive web mapping application is provided in Figure 1. Users are able to toggle layers on and off and zoom in, depending on their specific needs. An innovative feature is the ability to interact with the map by clicking on a specific grid point or point location to see relevant information. Depending on the area, a graphic can also be provided, including wind roses and ocean temperature and salinity profiles. An example of the latter is provided in Figure 2. The team is working with NCEI to have this map made operational on their NOAA Geoportal page.

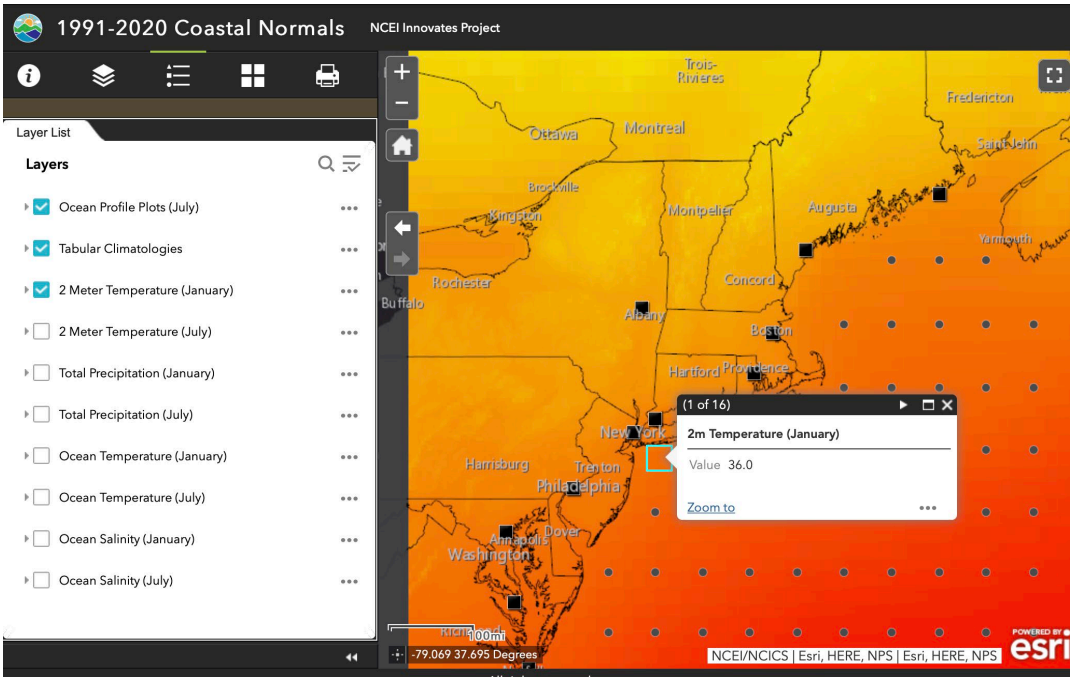

Figure 1. *Prototype of the ArcGIS Online interactive tool for the Coastal Normals project. Users can toggle layers on and off, and the map is interactive, displaying relevant normals data and images.*

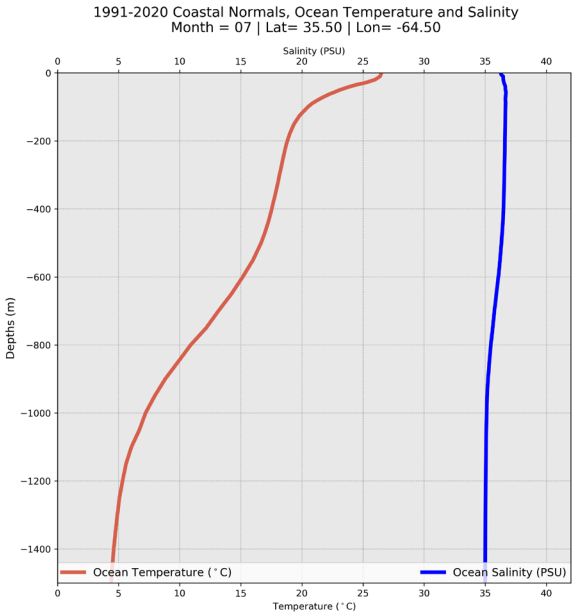

Figure 2. *Profile of ocean temperature salinity for July in an area in the Northwest Atlantic. Data are from the World Ocean Database, and multiple depths are indicated.*

Planned work

- Work with collaborators at NERACOOS and MARACOOS to finalize data sources, merging methodology and relevant visualizations
- Work with members of the NOAA Geoportal to move the current *ArcGIS Online* prototype into NCEI systems and optimize the tool for public consumption
- Update data to incorporate the full 30-year record once 2020 data are available

Products

- Coastal normals data from 1991–2019 for areas in and around the U.S. Northeast and Mid-Atlantic
- ArcGIS Online interactive web map displaying the coastal normals

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	**2**
# of peer-reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Coastal normals dataset and an ArcGIS Online mapping tool.

Collaborative Climate and Human Health Activities	
Task Leader	Jennifer Runkle
Task Code	NC-SAS-20-NCICS-JR
NOAA Sponsor	Jeff Privette/Russell Vose
NOAA Office	NESDIS/NCEI (CDC)

Highlight: In support of NOAA and Centers for Disease Control and Prevention (CDC) mutual interests and objectives, initial project efforts focused on conducting a needs assessment with two CDC programs, Climate and Health and the Environmental Public Health Tracking Network, to identify their environmental data product needs.

Background

NOAA and the Centers for Disease Control and Prevention (CDC) have mutual interests in the linkages between the health of the environment, humans, and animals and the shared responsibilities to protect human health and address environmental, social, and economic needs. They support Earth observation and surveillance and the integration and use of relevant environmental data and information to model, map, assess, predict, and communicate public health impacts to better inform decision and policy making and to reduce public and community health threats while adapting to global change.

NCEI and CDC formalized a five-year interagency agreement that recognizes a "One Health" approach to apply atmospheric, environmental, oceanographic, and ocean health knowledge, expertise, and methods to understand, assess, predict, communicate, and reduce public health impacts of climate change. Under the agreement, NOAA and CDC will engage in projects and programs of mutual interest and responsibility; exchange, integrate, and interpret data and leverage mutual expertise; and develop innovative and sustainable partnerships capitalizing on the strengths of both agencies to address existing or emerging public health issues.

CISESS NC will undertake research and other activities in support of NOAA and CDC's ongoing mutual interests and objectives. Since CDC's public health priorities will understandably change over time, the focus of project efforts will be determined on an annual basis; however, anticipated activities will include some or all of the following:

- update of current CDC environmental data holdings;
- review and identification of relevant NCEI data products for epidemiologic studies and their applicability for public health practitioners;
- environmental data processing and interpretation to facilitate use for health applications;
- studies to better define and understand Earth system and public health interactions;
- investigations into extreme event health impacts to better respond to and/or reduce those impacts; and
- creation of new and/or merged environmental/health data products to enable CDC and its public health partners to understand, communicate, and respond to current or potential health risks.

Accomplishments

Initial project efforts focused on meeting with representatives from the CDC NCEH (National Center for Environmental Health) Climate and Health and Environmental Public Health Tracking Network programs to assess their environmental data needs. NCEH programs and staff collaborate with state, local, tribal, and territorial health departments on a range of public health issues such as extreme heat, drought,

flooding, hurricanes, wildfires, and aeroallergens. These collaborations require high-quality, historical, real-time, and projected data and would greatly benefit from improved access to various NCEI data products. Each data product differs in its applicability to public health, and many require transforming the data product into a dataset with more direct public health utility (e.g., at the county level). There is also a need for enhancing the volume and frequency of real-time or near-real-time data updates, which will require technical solutions for the routine transition of data to the CDC.

An assessment was completed for both near- and long-term needs, and a monthly collaboration meeting schedule was established.

Planned work

- Co-development of joint agency research and product development
- Co-development of a data product and storytelling guide to aid local health officials in climate and health preparedness planning

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 Monitoring	
Task Leader	Carl Schreck
Task Code	NC-SAS-21-NCICS-CS
NOAA Sponsor	Jeff Privette/Imke Durre
NOAA Office	NESDIS/NCEI

Highlight: nClimGrid-Daily and IBTrACSv4 are being incorporated into NCEI's monthly State of the Climate reports to improve tracking of sub-monthly weather patterns and tropical cyclones.

Background

NCEI products are the gold standard for climate monitoring, which includes producing monthly and annual reports on climate anomalies, ranks, and extremes. However, several emerging NCEI datasets like IBTrACSv4 and nClimGrid-Daily have yet to be fully tapped in these monitoring activities. Most of NCEI's monitoring reports can also be classified as describing "what" more than "why." Users are increasingly interested in the why, not only in terms of the effects of climate change but also to better understand the patterns and teleconnections that lead to significant weather events and anomalies. This project strives to provide answers to those questions while exploiting under-utilized NCEI datasets.

Accomplishments

This project contributed to the Tropics Chapter of the *Bulletin of the American Meteorological Society* (*BAMS*) State of the Climate Report for 2019 and several new innovations in the monthly NCEI State of the Climate Reports:

- Incorporating maps based on nClimGrid-Daily to illustrate sub-monthly anomalies
- Using the National Centers for Environmental Prediction–National Center for Atmospheric Research Reanalysis to produce in-house maps of 500-hPa geopotential heights
- Plotting the evolution of key teleconnection indices to identify significant drivers such as the record Arctic Oscillation in February 2020 (Figure 1)
- Using the new IBTrACSv4 dataset to provide semiautomated reports of tropical cyclone activity, including historical ranks (Figure 2)

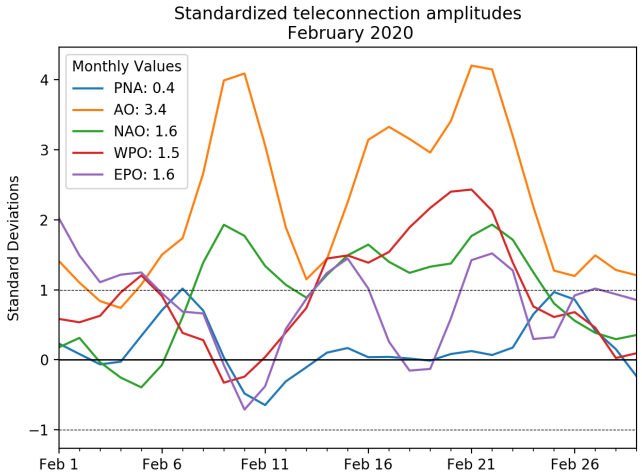

Figure 1: *Time series of the daily teleconnection indices for February 2020.*

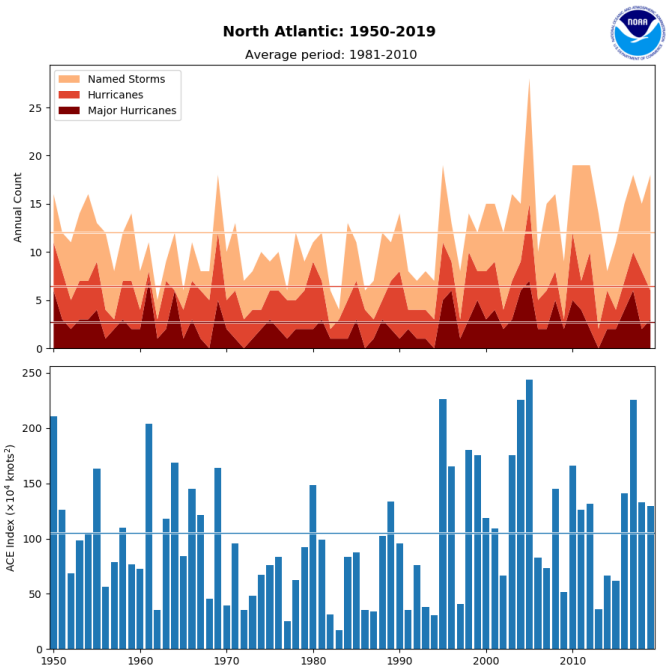

Figure 2. *Atlantic tropical cyclone counts and accumulated cyclone energy (ACE) for 1950–2019. Horizontal lines denote climatological values for 1981–2010.*

Planned work

- Revise and publish the *BAMS* State of the Climate for 2019
- Prepare and edit the *BAMS* State of the Climate for 2020
- Draft the monthly NCEI State of the Climate "Synoptic Discussions" and "Tropical Cyclone" reports

Products

- Synoptic Discussions for NCEI's State of the Climate August 2019–March 2020. For example: https://www.ncdc.noaa.gov/sotc/synoptic/201908

- Hurricanes and Tropical Storms reports for NCEI's State of the Climate August–November 2019. For example: https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201908

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	**0**
# of graduate students supported by your task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Global Historical Climatology Network–Hourly (GHCN-H)	
Task Leader	Scott Stevens
Task Code	NC-SAS-22-NCICS-SS
NOAA Sponsor	Jeff Privette/Jay Lawrimore
NOAA Office	NESDIS/NCEI

Highlight: The project team is working to add global, standardized hourly data to the Global Historical Climatology Network dataset for use in climate applications. Networks are being added to the data flow, processes are being developed to standardize their format, and an initial survey of existing hourly quality control checks is taking place.

Background

NCEI is seeking to add an hourly component to existing Global Historical Climatology Network (GHCN) daily and monthly datasets. The result will capture hourly and sub-hourly data from dozens of networks around the world, applying a consistent quality-control process and producing a standardized format that is familiar to users who have experience working with existing GHCN data.

Accomplishments

Work is in early stages, in conjunction with the Copernicus Climate Change Service group in the United Kingdom and Ireland, who are developing a similar dataset for their own use. Networks are being added to the data flow and processes developed to standardize their format. An initial survey of existing hourly quality control checks is taking place, with the intent of replicating and streamlining as many as possible.

Planned work

- Summarize existing quality control processes among current hourly datasets
- Compare against checks being run through Copernicus
- Begin implementing these processes on newly developed output

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 task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

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, CISESS 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 CISESS.

Research faculty. Senior CISESS 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 CISESS 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. CISESS 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. NCICS initiated its program in workforce development through the hiring of an initial group of post-doctoral research scholars working on applied research topics in Climate Data Records and Surface Observing Networks. CISESS continues to hire post-docs for a 2- to 3-year commitment to support identified project needs. Senior scientists from CISESS and NCEI provide mentoring for these post-docs. CISESS currently hosts one post-doctoral scholar:

- Douglas Rao (PhD, Geographical Sciences, University of Maryland) began his first year at CISESS working with Jessica Matthews and collaborating on developing global blended temperature data using in situ and satellite data. (See project report under Surface Observing Network.)

Students (graduate/undergraduate/high school). CISESS 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 CISESS and NCEI mentors. CISESS 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.

Spring 2020:

- *Matthew Watts*, NCSU GIS program graduate student, is working with Ronald Leeper on applying U.S. Climate Reference Network soil moisture standardization methods to remotely sensed soil moisture data to provide a measure of agricultural drought conditions across the globe.
- The NASA DEVELOP team composed of Adelaide Schmidt (Delta State University), Jessica Ganim (University of Delaware graduate), Isabelle Runde (University of California, Santa Barbara, graduate), and Kayleigh DeBruyne (Pacific University graduate) completed their science project, "Ohio River Basin Water Resources: Monitoring Flash Drought Potential in the Upper Ohio River Basin Using NASA Earth Observations," under science advisor Ronald Leeper. The team evaluated a series of drought indicators for a pronounced flash drought event in September 2019 over the Ohio River drainage basin.

Ongoing:

- *Robert Van Der Drift*, NCSU undergraduate dual Meteorology and Applied Mathematics major, is being mentored by Jessica Matthews through the NCSU's 2019 Goodnight Fellows Program.
- *Maria Cesarini*, Tufts University Master's student in mathematics, is working with Ronald Leeper and Jessica Matthews on a project to examine relationships between start of season and air, surface, and soil temperatures, with a paper forthcoming.
- *Geneva Gray,* NCSU PhD student, is working with Kenneth Kunkel on the multi-institutional, National Science Foundation–sponsored Urban Resilience to Extremes—Sustainability Research Network (UREx SRN) project.
- *Sridhar Mantripragada*, NCSU PhD student, is working with Carl Schreck on his NASA project, using NASA's new Cyclone Global Navigation Satellite System (CYGNSS) retrievals to investigate the surface interactions between Kelvin waves and easterly waves.

Other Projects

The vision of the North Carolina Institute for Climate Studies (NCICS) 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.

The vision of CISESS is to advance NOAA's ability to generate data and information from the constellation of global observing platforms in order to understand and predict the different components of the Earth system through collaborative and transformative research and to transition this research into operational applications that produce societal benefits. 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 CISESS NC projects and activities under the CISESS cooperative agreement remain primary within NCICS, NCICS scientists also participate in and receive partial support from other sponsored research programs through competitive proposal solicitations. Individual and collaborative climate science proposals are submitted through NCSU to relevant federal solicitations from the National Aeronautics and Space Administration, the National Science Foundation, NOAA, the Department of Energy, the Department of Defense, and the National Institutes of Health (including the Centers for Disease Control and Prevention and the National Institute for Occupational Safety and Health), as well as to various other non-federal entities.

Changes in the Frequency of Freezing Precipitation	
Task Leader	Pavel Groisman
Task Code	NC-OTH-01-NCICS-PG
Other Sponsor	Multiple

Highlight: Several international environmental change studies focused on the northern extratropics were conducted to better inform vulnerable societies and prepare them for potential future environmental change.

Background

Contemporary environmental changes are not restricted to changes in major climatic characteristics such as temperature and precipitation, but are multi-faceted, affect and are affected by human activities, and may manifest themselves differently in different regions of the world and feedback to other regions. These manifestations and feedbacks are not well understood and require thorough attention and integrated multidisciplinary approaches to assess, as they may affect the environment, including in regions many miles away from the areas of initial forcing, in unexpected ways.

The overarching goal of this project is to improve our understanding of future changes in hazardous cold/shoulder season precipitation, especially occurring near 0°C. Achieving this requires an understanding of past and present changes and a consideration of future conditions. The project entails examining data requirements and availability, understanding the climatology of key variables and phenomena, simulating and understanding key driving processes, and assessing projections and their shortcomings. Studies of near-0°C precipitation also assess its impact and suggest mitigation measures. The frequency of freezing events has recently increased at high latitudes (from Alaska to Northern Europe) and in some mountainous regions (Tian Shan).

Accomplishments

Simulation and understanding of the freezing precipitation processes. A parameterization using a new microphysics scheme was developed to simulate freezing rain and ice pellets. It considers gradual melting and freezing of precipitation without adding significant computing time. Examination of many CMIP5 models over North America showed that the near-0°C region will move northward, but there is large variation in the actual displacement across the country. Projections have been made on changes to ice loading on infrastructure across North America in association with changing freezing rain patterns.

Northern Eurasia Future Initiative (NEFI). NEFI (http://nefi-neespi.org) was launched in 2017 to elucidate all aspects of ongoing environmental change, inform societies, and better prepare them for future developments. Presentations were given at NEFI-related sessions at both the American Geophysical Union and Japan Geoscience Union conferences. (Project role: Project Scientist)

Rapid Arctic environmental Changes (RACE): Implications for well-being, resilience and Evolution of Arctic communities. This new Belmont Forum project brings together scientists from Norway, France, Russia, and the USA. It will use the best available datasets from in situ and satellite observations and reanalyses with CMIP6 climate model simulations to develop improved regional assessments of Arctic Social Indicators. (Project role: Co-Investigator)

Atmospheric Moisture Transport and European climate Extremes. This is a new collaborative project between the University of Grenoble-Alpes, France, and the Russian Institute of Oceanology. (Project role: Principal Investigator)

Arctic Hydrological Cycle Changes: Impacts on environment sustainability and natural resources. This new collaborative project focuses on an assessment of the current state of the Arctic environment due to hydrological cycle changes. (Project role: Co-Investigator).

Publications

Aidaraliev, A. A., G. M. Henebry, Q. Chi, **P. Groisman**, M. Tomaszewska, M. S. Baihodjoev, and K. A. Kelgenbaeva, 2019: Climatic impacts on mountainous livelihood in Kyrgyzstan. *Proceedings of the International Conference Dedicated to the 15th Anniversary of the Foundation of CAIAG "Remote and Terrestrial Research of the Land in Central Asia,"* Bishkek, Kyrgyzstan, 148–153, http://bit.ly/2rVgLUD.

Chen, Y., X. Fei, **P. Groisman**, Z. Sun, J. Zhang, and Z. Qin, 2019: Contrasting policy shifts influence the pattern of vegetation production and C sequestration over pasture systems: A regional-scale comparison in Temperate Eurasian Steppe. *Agricultural Systems*, **176**, 102679, https://doi.org/10.1016/j.agsy.2019.102679.

Danilovich, I., S. Zhuravlev, L. Kurochkina, and **P. Groisman**, 2019: The Past and Future Estimates of Climate and Streamflow Changes in the Western Dvina River Basin. *Frontiers in Earth Science*, **7**, https://doi.org/10.3389/feart.2019.00204.

Chen, J., Z. Ouyang, R. John, G. M. Henebry, **P. Y. Groisman**, A. Karnieli, M. Kussainova, A. Amartuvshin, A. Tulobaev, E. T. Isabaevich, C. Crank, K. Kadhim, J. Qi, and G. Gutman, 2020: Chapter 10: Social-ecological systems across the Asian Drylands Belt (ADB). In: *Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems*, Gutman et al., Ed., Springer, 191-225, https://www.springer.com/gp/book/9783030307417.

Groisman, P. Y., O. N. Bulygina, G. M. Henebry, N. A. Speranskaya, A. I. Shiklomanov, Y. Chen, N. M. Tchebakova, E. I. Parfenova, N. D. Tilinina, O. G. olina, A. Dufour, J. Chen, R. John, and P. Fan, 2020: Chapter 2: Dry Land Belt of Norther Eurasia: Contemporary Environmental Changes. In: *Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems*, Gutman et al., Ed., Springer, 11-23, https://www.springer.com/gp/book/9783030307417.

Presentations

Groisman, P., 2019: Progress in NEFI (formerly NEESPI) and the Role of LCLUC Caucasus Projects. *NASA LCLUC Spring Science Team Meeting*, Rockville, MD, April 10, 2019.

Groisman, P., A. I. Shiklomanov, I. B. Yesserkepova, et al, 2019: Northern Eurasia Future Initiative (NEFI) Focus on Human-Associated Extreme Events. *Japan Geoscience Union Meeting 2019*, Makuhari Messe, Chiba, Japan, May 26, 2019.

Danilovich I., V. Loginov, and **P. Y. Groisman**, 2019: Recent baric and climatological conditions over East Europe with a focus on Belarus. *Japan Geoscience Union Meeting 2019*, Makuhari Messe, Chiba, Japan, May 26, 2019.

Groisman, P., 2019. Northern Eurasia Future Initiative (NEFI), Update. Poster. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 10, 2019.

Danilovich I., S. Zhuravlev, L. Kurochkina, and P. Ya. **Groisman**, 2019: Recent and future climate and streamflow changes in the Western Dvina River Basin. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 10, 2019.

Groisman, P., 2020: Environment Changes in the Eurasian Arctic. *Voeikov* Geophysical *Observatory*, Russia, February 12, 2020.

Groisman P. Ya., D. A. Streletskiy, E. A. Kukavskaya, and G. M. Henebry, 2020: Northern Eurasia Future Initiative (NEFI), Update. *International Workshop on Snow Cover Changes and Its Modeling over Northern Eurasia* Hirosaki, Japan, February 19, 2020.

Groisman P. Ya., E. G. Bogdanova, O. A. Bulygina, and V. N. Razuvaev , 2020: In situ precipitation and snow cover observations over Northern Eurasia: Observation changes and problems for climatic studies that they created. *International Workshop on Snow Cover Changes and Its Modeling over Northern Eurasia* Hirosaki, Japan, February 20, 2020.

Groisman, P., 2019: Progress in NEFI (formerly NEESPI) and the Role of LCLUC Caucasus Projects. *NASA LCLUC Spring Science Team Meeting*, Rockville, MD, 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/book chapters	5
# of NOAA technical reports	0
# of presentations	9
# of graduate students supported by your CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

The Urban Resilience to Extremes Sustainability Research Network (UREx SRN)	
Task Team	Kenneth Kunkel (Lead), Geneva Gray
Task Code	NC-OTH-02-NCICS-KK/GG
Other Sponsor	Arizona State University/NSF

Highlight: The NCSU team on this collaborative multi-institution National Science Foundation (NSF) project conducted studies using the Weather Research and Forecasting (WRF) model to successfully simulate extreme precipitation amounts. A new method was also developed to create the pseudo-global warming scenarios.

Background

The Urban Resilience to Extremes Sustainability Research Network (UREx SRN) is a multi-institutional project funded by the National Science Foundation (NSF) and led by Arizona State University. The project team is developing and implementing a new framework for integrating Social, Ecological, and Technical Systems (SETS) dimensions for conceptualizing, analyzing, and supporting urban infrastructure decisions in the face of climatic uncertainty in a more holistic way.

Climate change is widely considered one of the greatest challenges to global sustainability, with extreme events being the most immediate way that people experience this phenomenon. Urban areas are particularly vulnerable to these events depending on their location and given their population density and increasingly complex and interdependent infrastructure. The highly interdisciplinary and geographically dispersed UREx SRN team is developing a diverse suite of methods and tools to assess how infrastructure can be resilient, provide ecosystem services, improve social well-being, and exploit new technologies in ways that benefit all segments of urban populations. The team is working with several pilot cities to co-produce the knowledge needed to transition to resilient SETS infrastructure in the future. The cities include Portland (Oregon), Phoenix, New York City, Baltimore, Syracuse, Miami, San Juan (Puerto Rico), Hermosillo (Mexico), and Valdivia (Chile). This portion of the project will include characterizations of recent historical trends of climate extremes and the development of future climate extreme scenarios.

Serving as members of the Climate and Hydrologic Extremes Working Group (CHExWG) of UREx SRN are CISESS scientists Dr. Kenneth Kunkel (lead) and Geneva Gray (NCSU PhD student). The CHExWG is tasked with developing climate extremes products for the nine cities, tailored to the city-specific vulnerabilities, and communicating information about those products to other members of the network. These products will be supported by the development and analysis of statistically downscaled datasets and/or the application of dynamically downscaled simulations as available and appropriate.

Accomplishments

Progress continued towards meeting the UREx SRN project goals with work focused in two task areas:

LOCA-downscaled gridded climate model data analyses for pilot cities

The Localized Constructed Analogs (LOCA) technique statistically downscales climate model data (maximum/minimum temperature, precipitation, and humidity) to a ~6 km grid over the contiguous United States and regions of Mexico and Canada. The project team continued analysis of the 32 LOCA-downscaled climate models (from the Coupled Model Intercomparison Project 5 [CMIP5]) for each of the seven UREx SRN pilot cities within this domain: Baltimore, Hermosillo, Miami, New York City, Phoenix, Portland, and Syracuse. Humidity data were recently added to the LOCA dataset. These new data were used to estimate the heat index, a parameter used by the National Weather Service (NWS) to estimate the combined effects of heat and humidity on human comfort. An analysis of future changes in the

number of days above thresholds used by the NWS was completed for New York City (Figure 1). This analysis indicates that future changes in humidity will result in many more days above dangerous heat levels than indicated by temperature changes alone.

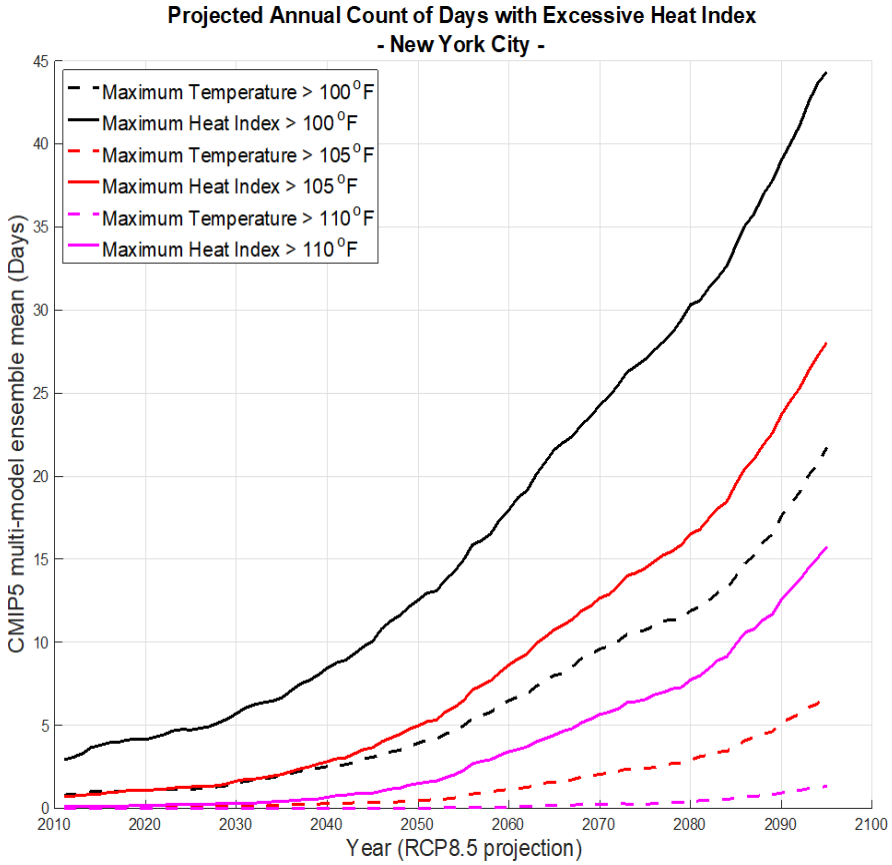

Figure 1. *The multimodel ensemble-mean number of days exceeding thresholds of 100°, 105°, and 110°F for daily maximum temperature and daily maximum heat index for New York City.*

High-resolution modeling of extreme precipitation events

The Weather Research and Forecasting (WRF) model was used to perform simulations of the Ellicott City, Maryland, flood event of July 2016 and the October 2015 event in Portland, Oregon. Analysis of these simulations indicated that the extreme precipitation amounts could be simulated. The spatial distribution of the Portland extreme precipitation was quite accurate; however, in some of the Ellicott City simulations, the heavy precipitation was south of the observed peaks.

A new method was developed to create the pseudo-global warming scenarios. This method is based on the approach of "constructed analogues" to determine realistic vertical profiles of temperature and humidity that can be used to evaluate future changes. This method produced substantially different, but more plausible, boundary conditions for the future climate simulations than traditional methods.

Planned work

- Complete additional WRF simulations of the 2016 Ellicott City flood event and the 2015 Portland event to examine the potential impact of global warming using the pseudo-global warming methodology

- Work with Baltimore and Portland practitioners to evaluate how to incorporate the results of the simulations into practice
- Identify historical extreme precipitation events in other UREX cities
- Use WRF to simulate these events and examine potential impacts of global warming on precipitation amounts and spatial distribution

Publications

Shiva, J. S., D. G. Chandler, and **K. E. Kunkel**, 2019: Localized Changes in Heatwave Properties across the USA. *Earth's Future*, **In Press**. http://dx.doi.org/10.1029/2018EF001085

Presentations

Kunkel, K., 2019: Observed Climatological Relationships between Precipitable Water and Extreme Precipitation in the Contiguous United States. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

Kunkel, K., 2020: Observed climatological relationships between precipitable water and extreme precipitation in the contiguous United States. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.

Other

- **K. Kunkel** is the PhD advisor of Geneva Gray in NCSU's Marine, Earth, and Atmospheric Sciences Department.
- **K. Kunkel** advised and examined (as a PhD committee member) CHExWG graduate student Javad Shafiei Shiva (Syracuse University) on his UREx SRN research related to the changing nature of heat waves in different network cities. He passed his final defense.

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	**2**
# of graduate students supported by your task	**1**
# of graduate students formally advised	**2**
# of undergraduate students mentored during the year	**0**

Incorporation of Climate Change into Intensity–Duration–Frequency Design Values	
Task Team	Kenneth Kunkel (Lead), James Biard, Sarah Champion, Katharine Johnson, Ronnie Leeper, Angel Li, Olivier Prat, Laura Stevens, Scott Stevens, Liqiang Sun
Task Code	NC-OTH-03-NCICS-KK/et.al.
Other Sponsor	Army Corps of Engineers/SERDP

Highlight: The Strategic Environmental Research and Development Program (SERDP) project team is working to develop a framework for incorporating the potential impact of future climate change into estimates of heavy precipitation Intensity–Duration–Frequency (IDF) design values. Analysis of historical climate data shows that water vapor is the primary determinant of the amount of precipitation falling in extreme events. Future changes in IDF values will be mainly dependent on changes in water vapor.

Background

There is overwhelming evidence that today's climate system is non-stationary and is expected to remain so for the foreseeable future. Primary drivers include human-caused changes in atmospheric greenhouse gas concentrations. Increases in heavy precipitation events are one of the more robust climate change signals in the observed record. Previous work examined the meteorological causes of historical trends in the U.S. and found significant upward trends in the number of events from fronts and tropical cyclones but no increases from other meteorological causes. The likelihood is considered high that heavy precipitation will continue to increase because atmospheric water vapor concentrations will increase with global warming. Thus, the capacity of the atmosphere to produce intense precipitation will be higher in a warmer world. At the local scale, actual changes in heavy precipitation event occurrence will arise from changes in atmospheric capacity and opportunity (the frequency and intensity of weather systems causing heavy precipitation). While it is virtually certain that capacity will increase, it is less certain how opportunities will change, and it is likely that the changes in opportunity will be spatially variable, modulating water vapor increases.

The overriding objective of this project is to develop a framework for incorporating the potential impact of future climate change into estimates of heavy precipitation Intensity–Duration–Frequency (IDF) values. Actual changes in IDF values will result from changes in atmospheric capacity (water vapor concentrations) and opportunity (the number and intensity of heavy precipitation-producing storm systems). In this project, these two components will be evaluated to determine the potential impact for a wide range of frequencies and durations used by civil engineers. Then a means for adjusting and delivering the IDF values and uncertainty estimates, similar to the NOAA Atlas 14, will be provided.

Accomplishments

Continued analysis explored the potential role of atmospheric water vapor in the observed upward trends in extreme precipitation. These analyses showed that extreme precipitation amounts are closely related to water vapor content, increasing monotonically with precipitable water (PW) (Figure 1a). However, there is no systematic relationship of extreme precipitation amounts with upward vertical motion (Figure 1b). When precipitation amounts are scaled with PW, the scaling factor (herein called the amplification factor) is high for low PW values, is approximately constant for moderate values, and increases at high PW values (Figure 1c). The conclusion from this is that extreme precipitation amounts follow a relationship that is consistent with Clausius–Clapeyron (CC) scaling for moderate PW values, but super-CC scaling is evident at high PW values.

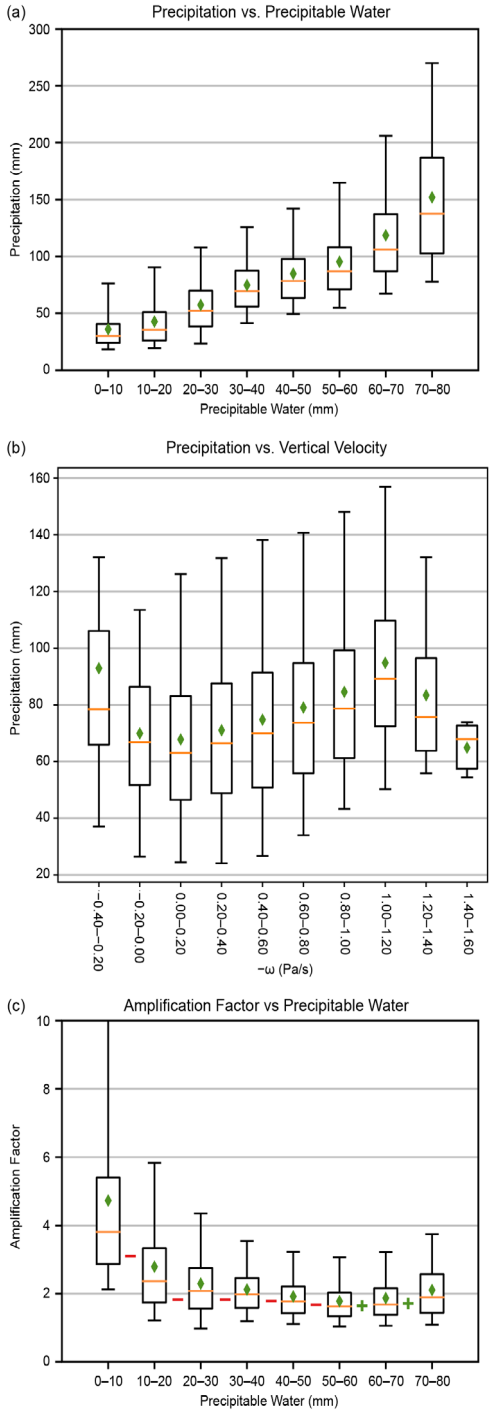

Figure 1. *Boxplot distributions for the 1-yr, 1-dy Partial Duration Series of (a) precipitation event amount vs the same-day 3-hour maximum PW sorted into 10mm interval bins; (b) as in panel (a) but for upward vertical motion (-ω), and (c) as in panel (a) but for the amplification factor* ***A*** *(EP/PW). Boxplot parameters include mean (green diamonds), median (orange horizontal lines), 25th and 75th percentiles (box limits), and 5th and 95th percentiles (whiskers). Statistical significance (0.05 level) of the difference between* ***A*** *across adjacent intervals of PW is denoted where "-" and "+" denote a significant decrease and increase, respectively (the value of* ***A*** *in the higher PW bin minus lower PW bin). The 95th percentile value for the panel (c) bin 0–10 is 10.75.*

The other major component proposed for IDF adjustments is weather system changes. Two sets of analyses were performed. An analysis of the largest (top 100) multi-day precipitation amounts averaged over an area of ~50,000 km^2 found that most of those events (59%) were caused by fronts (Figure 2). Another 25% were caused by tropical cyclones. The other analysis examined the causes of extreme events for a network of 3,104 stations in the U.S. Time series of causes averaged over regions were created. Seasonal correlation coefficients were calculated between the number of 1-year, 1-day extreme events from a specific weather system type and the total number of weather systems of that type.

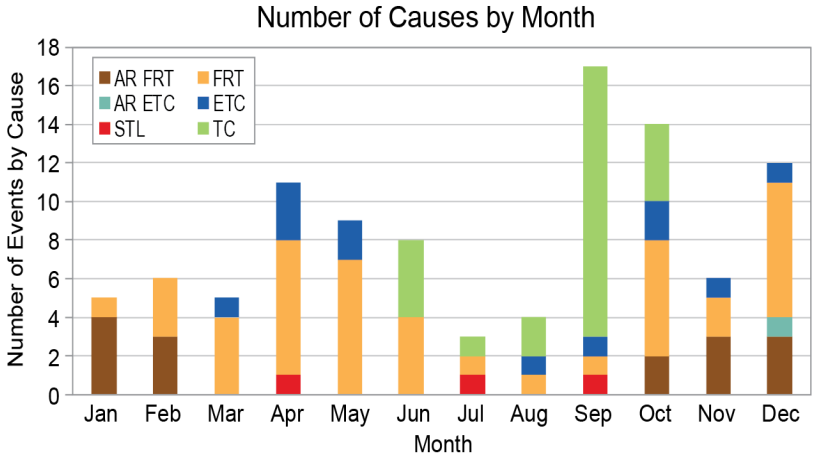

***Figure 2**. Seasonal distribution of the top 100 4-day events and their causes for an area size of ~50,000 km^2. Category abbreviations are tropical cyclone (TC), fronts associated with an extratropical cyclone (FRT), extratropical cyclone but not co-located with one of the fronts (ETC), a front with an associated atmospheric river (AR FRT), an ETC with an associated atmospheric river (AR ETC), and a subtropical low (STL).*

A beta version of a website to disseminate project information was completed. The website applies adjustment factors to IDF values in NOAA Atlas 14 and displays the values in a tabular form. The user can select the future time period (2025, 2035, 2045, 2055, 2065, 2075, 2085, and 2095) and one of two future emissions scenarios (RCP4.5, RCP8.5; RCP stands for Representative Concentration Pathways). A dropdown menu provides a list of Department of Defense installations. A user can also select a location by clicking on a map.

Planned work

- Complete the development of factors for adjusting current IDF values for future climate change to include water vapor and weather system type changes
- Complete the correlation of causes and extreme events for multiple return periods and durations
- Complete analysis of selected CMIP6 models, which are just becoming available
- Complete development of the website in response to any comments from SERDP management

Publications

Kunkel, K.E., T.R. Karl, M.F. Squires, X. Yin, **S. Stegall,** and D.R. Easterling, 2020: Precipitation extremes: Trends and relationships with average precipitation and precipitable water in the contiguous United States. *J. Appl. Meteor. Climatol.,* **59**, 125-142, https://doi.org/10.1175/JAMC-D-19-0185.1.

Biard, J.C., and **K.E. Kunkel**, 2019: Automated detection of weather fronts using a deep learning neural network. *Advances in Statistical Climatology, Meteorology and Oceanography*, **5**, 147–160, https://doi.org/10.5194/ascmo-5-147-2019.

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. *Geophys. Res. Lett*., **46**, 13,500–13,506. https://doi.org/10.1029/2019GL085034.

Presentations

Kunkel, K., 2019: Developing Intensity-Duration-Frequency (IDF) Curves Associated with Climate Change Pathways. *Urban Resilience to Extremes (UREx) Sustainability Research Network project 2019 All Hands Meeting*, Baltimore, MD, April 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., 2019: Machine learning and frontal systems. *DOE* Precipitation *Metrics Workshop*, Rockville, MD. July 2, 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.

Biard, J., 2019: Atmospheric Fronts in Climate Models: Inter-comparison Across Historical and Future Scenarios. *CISESS Science Meeting 2019*, College Park, MD, November 13, 2019.

Kunkel, K., 2019: Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values. Poster. SERDP*/ ESTCP Symposium 2019: Enhancing DoD's Missions Effectiveness*, Washington, DC, December 3, 2019.

Kunkel, K., 2019: Update: IDF Design Value Improvement. *SERDP/* ESTCP Symposium *2019: Enhancing DoD's Missions Effectiveness*, Washington, DC, December 3, 2019.

Kunkel, K., 2019: Update: IDF Design Value Improvement. *Inter-Agency Forum* on Climate *Risks, Impacts & Adaptation*, Washington, DC, December 6, 2019.

Kunkel, K., 2019: Observed Climatological Relationships between Precipitable Water and Extreme Precipitation in the Contiguous United States. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

Kunkel, K., 2019: Extreme Precipitation Trends and Weather System Influences. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.

Kunkel, K., 2020: Extreme precipitation trends and weather system influences. Poster. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.

Kunkel, K., 2020: Observed climatological relationships between precipitable water and extreme precipitation in the contiguous United States. *100th AMS* Annual *Meeting*, Boston, MA, January 14, 2020.

Kunkel, K., 2020: Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values. *Annual SERDP In-Progress Review Meeting*, Arlington, VA, February 5, 2020.

Kunkel, K., 2020: Extreme Precipitation and Climate Change: Observations and Projections. *FEMA National Dam Safety Program Technical Seminar* (ND SPTS) No. 27: Dam and Levee Resiliency in the Era of Intensifying Natural Hazards and Climate Conditions in Emmitsburg, MD, February 19, 2020.

Other

Kenneth Kunkel is advising project scientist Sarah Champion (NCSU Department of Marine, Earth, and Atmospheric Sciences) in her PhD research efforts, which support the project objectives.

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	**3**
# of NOAA technical reports	**0**
# of presentations	**14**
# of graduate students supported by your task	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Operational Transition of Novel Statistical-Dynamical Forecasts for Tropical Subseasonal to Seasonal Drivers	
Task Leader	Carl Schreck
Task Code	NC-OTH-04-NCICS-CS
NOAA Sponsor	OAR/CPO

Highlight: Metrics developed for the Madden–Julian Oscillation (MJO) monitoring page highlight the most predictable signals for NOAA's Climate Prediction Center (CPC). ncics.org/mjo

Background

Subseasonal to seasonal (S2S) forecasting has emerged as one of the frontiers for atmospheric predictabilty. These time scales of weeks to months are at the heart of the mission for NOAA's Climate Prediction Center (CPC), which has been particularly focused on expanding and improving their 3- to 4-week forecasts. Dynamical S2S models have improved significantly over recent years, but they have yet to fully tap the potential predictability of coherent tropical modes like the Madden–Julian Oscillation (MJO).

A unique approach to this problem has been implemented on ncics.org/mjo. This website takes recent observations and appends them with 45-day forecasts from the Climate Forecast System Version 2 (CFSv2). The combined data are then Fourier filtered in space and time for some of the dominant modes of S2S variability in the tropics: the MJO, convectively coupled equatorial waves, and low-frequency variability such as the El Niño–Southern Oscillation (ENSO). This filtering highlights the most predictable aspects of the S2S system. The website includes numerous maps, Hovmöller diagrams, and indices for identifying and predicting these modes. It has been updating daily since 2011 with several upgrades and iterations over the years. These diagnostics have become routine inputs for CPC's Global Tropics Hazards (GTH) outlook. This level of maturity makes them prime candidates to be transitioned into operations at the CPC.

Accomplishments

Significant progress was achieved on the two primary prongs of this research:

1. The operational transition of the existing products continued. It is successfully running in a test environment at CPC. However, current CPC computing resources restrict the processing to being run serially, which has prevented timely creation of the products. We are currently exploring options for running these processes in parallel, as is done on the NCICS high-performance computing system.
2. We are working to educate CPC forecasters on tool usage. A key component of that was publishing a paper detailing the skill of the product. For example, Figure 1 shows times when the MJO increases the overall forecast skill over the low-frequency variability alone (red dots) and when the MJO actually detracts from that skill (blue dots). These results were also presented in face-to-face meetings with the forecasters in July 2019.

The final year of the project will see the completion of both of these tasks as well as significant progress towards the project's third goal of integrating these tools into other aspects of CPC's forecasts, such as the Weeks 3–4 outlook for North America.

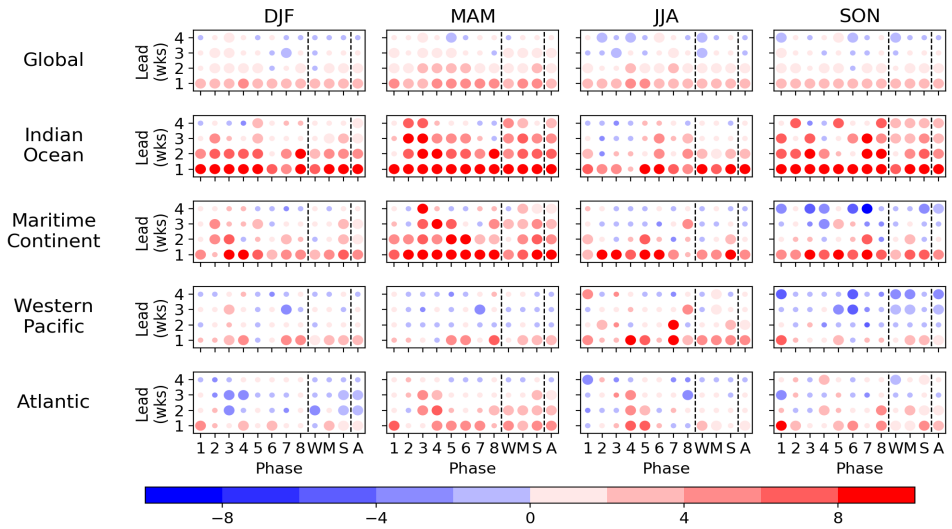

Figure 1. *Difference between HSS for LF+MJO and LF for each region (rows), season (columns), forecast lead, and RMM phase. Red dots indicate LF+MJO is more skillful, blue dots show LF is more skillful. Large dots denote differences that are 95% statistically different from zero. RMM phases are used only when the RMM amplitude is >1. W indicates weak MJO (RMM < 0.9), M is moderate MJO (0.9 ≤ RMM < 1.5), S is strong MJO (RMM ≥ 1.5), and A is for all dates regardless of RMM phase or amplitude.*

Planned work

- Complete operational transition of ncics.org/mjo diagnostics
- Extend diagnostics to forecasts from the European Centre for Medium-Range Weather Forecasts
- Investigate leveraging operational products to improve CPC Weeks 3–4 North America outlooks

Publications

Schreck, C. J., M. A. Janiga, and S. Baxter, 2020: Sources of Tropical Subseasonal Skill in the CFSv2. *Mon. Wea. Rev.*, **In Press**, https://doi.org/10.1175/MWR-D-19-0289.1.

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: Sources of Tropical Subseasonal Skill in the CFSv2. *NOAA Climate Diagnostics and Prediction Workshop*, Durham, NC, October 22, 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	**1**
# 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**

Kelvin Waves and Easterly Waves in CYGNSS	
Task Leader	Carl Schreck
Task Code	NC-OTH-05-NCICS-CS
Other Sponsor	NASA

Highlight: Atmospheric Kelvin waves enhance the strength of easterly waves through barotropic energy conversion related to an increased the meridional gradient of zonal winds.

Background

Kelvin waves and easterly waves are among the most prominent modes of synoptic-scale convective variability in the tropics. Recent studies suggest that interactions between these waves can lead to tropical cyclogenesis. However, many questions remain regarding how these waves affect one another and how cyclogenesis ensues.

Two of the most significant ways that Kelvin waves might affect easterly waves relate to their modulation of low-level winds, which may alter the background shear and gradient of vorticity and enhance wave–mean flow interaction. The Kelvin wave westerlies could also enhance surface enthalpy fluxes within the easterly wave, which would lead to intensification through diabatic heating. While the kinematic view of the interaction appears simple, the inherent dynamics are expected to be complex and nonlinear.

The recent launch of NASA's Cyclone Global Navigation Satellite System (CYGNSS) provides an unprecedented opportunity to observe and model these interactions. The high spatial and temporal resolution of CYGNSS is ideally suited for studying Kelvin waves and easterly waves, which have a phase speed of ~20 m s^{-1} relative to one another and each have wavelengths of 2,000–4,000 km.

Accomplishments

A manuscript in preparation examines how the eddy kinetic energy (EKE) budget varies for African Easterly Waves (AEWs), between those that occur within the convective phase of a Kelvin wave and those that happen during the suppressed phase. Figure 1a shows an example that highlights how the barotropic energy conversion increases following the passage of the Kelvin wave. That increase is largely driven by an increase in the background meridional gradient of zonal wind associated with the Kelvin wave passage (Figure 1b). These results were presented at the CYGNSS Science Team Meeting and will be submitted for publication in the coming year.

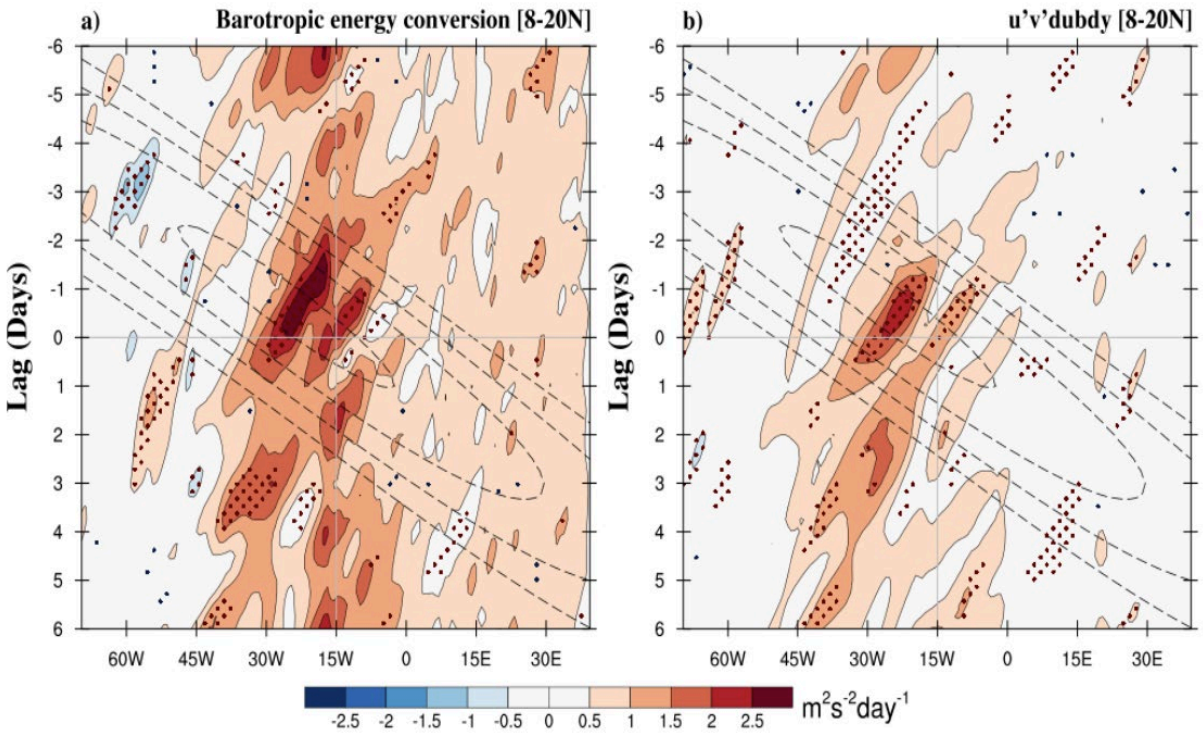

Figure 1. *Composite Hovmöller of barotropic energy conversion for AEWs occurring within the convective phases of Kelvin waves.*

Planned work

- Publish budgets of moist static energy and EKE for the Kelvin waves to identify their impacts on the easterly waves
- Investigate case studies of Kelvin waves from the CYGNSS period

Presentations

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.

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	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Appendix 1: CISESS Personnel and Performance Metrics

CISESS Personnel	Numbers*		CISESS Subcontractors	Numbers**
Scientists working ≥ 50% time	**18**		Scientists working ≥ 50% time	**0**
Scientists working < 50% time	**3**		Scientists working < 50% time	**10**
Scientists working at no cost	**1**		Scientists working at no cost	**0**
Total Scientists	**22**		**Total Scientists**	**10**
Administrative/technical staff	**9**		**Administrative/technical staff**	**5**
Graduate Students	**2**		Graduate Students	**2**
Undergraduate Students	**0**		Undergraduate Students	**3**
High School Students	**0**		High School Students	**0**
Total Students	**0**		**Total Students**	**5**
Total Personnel	**33**		**Total Personnel**	**20**

**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	**17**
# of products or techniques submitted to NOAA for consideration in operations use	**12**
# of peer reviewed papers	**9**
# of NOAA technical reports	**0**
# of presentations	**82*****
# of graduate students supported by your CICS task	**5**
# of graduate students formally advised	**11**
# of undergraduate students mentored during the year	**15**

****Presentations: 72 science presentations; 10 outreach and engagement presentations.*

Appendix 2: CISESS Publications 2019–2020

Aidaraliev, A. A., G. M. Henebry, Q. Chi, **P. Groisman**, M. Tomaszewska, M. S. Baihodjoev, and K. A. Kelgenbaeva, 2019: Climatic impacts on mountainous livelihood in Kyrgyzstan. *Proceedings of the International Conference Dedicated to the 15th Anniversary of the Foundation of CAIAG "Remote and Terrestrial Research of the Land in Central Asia,"* Bishkek, Kyrgyzstan, 148–153, http://bit.ly/2rVgLUD.

Biard, J. C., and **K. E. Kunkel**, 2019: Automated detection of weather fronts using a deep learning neural network. *Advances in Statistical Climatology, Meteorology and Oceanography*, **5**, 147–160, https://doi.org/10.5194/ascmo-5-147-2019.

Brewer, M. J., A. Hollingshead, **J. Dissen**, N. Jones, and L. F. Webster, 2019: User Needs for Weather and Climate Information: 2019 NCEI Users' Conference. *Bulletin of the American Meteorological Society*, **In press**, https://doi.org/10.1175/BAMS-D-19-0323.1.

Chen, J., Z. Ouyang, R. John, G. M. Henebry, **P. Y. Groisman**, A. Karnieli, M. Kussainova, A. Amartuvshin, A. Tulobaev, E. T. Isabaevich, C. Crank, K. Kadhim, J. Qi, and G. Gutman, 2020: Chapter 10: Social-ecological systems across the Asian Drylands Belt (ADB). In: *Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems*, Gutman et al., Ed., Springer, 191-225, https://www.springer.com/gp/book/9783030307417.

Chen, Y., X. Fei, **P. Groisman**, Z. Sun, J. Zhang, and Z. Qin, 2019: Contrasting policy shifts influence the pattern of vegetation production and C sequestration over pasture systems: A regional-scale comparison in Temperate Eurasian Steppe. *Agricultural Systems*, **176**, 102679, https://doi.org/10.1016/j.agsy.2019.102679.

Danilovich, I., S. Zhuravlev, L. Kurochkina, and **P. Groisman**, 2019: The Past and Future Estimates of Climate and Streamflow Changes in the Western Dvina River Basin. *Frontiers in Earth Science*, **7**, https://doi.org/10.3389/feart.2019.00204.

Groisman, P. Y., O. N. Bulygina, G. M. Henebry, N. A. Speranskaya, A. I. Shiklomanov, Y. Chen, N. M. Tchebakova, E. I. Parfenova, N. D. Tilinina, O. G. olina, A. Dufour, J. Chen, R. John, and P. Fan, 2020: Chapter 2: Dry Land Belt of Norther Eurasia: Contemporary Environmental Changes. In: *Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems*, Gutman et al., Ed., Springer, 11-23, https://www.springer.com/gp/book/9783030307417.

Kunkel, K. E., D. R. Easterling, **A. Ballinger**, S. Bililign, **S. M. Champion**, D. R. Corbett, K. D. Dello, **J. Dissen**, G. M. Lackmann, J. Luettich, R. A., L. B. Perry, W. A. Robinson, **L. E. Stevens**, **B. C. Stewart**, and A. J. Terando, 2020: *North Carolina Climate Science Report*. 233 pp. https://ncics.org/nccsr/.

Wilson, T. B., H. J. Diamond, J. Kochendorfer, T. P. Meyers, M. Hall, N. W. Casey, C. B. Baker, **R. Leeper**, and M. A. Palecki, 2020: Evaluating time domain reflectometry and coaxial impedance sensors for soil observations by the U.S. Climate Reference Network. *Vadose Zone Journal*, **19**, https://doi.org/10.1002/vzj2.20013.

Appendix 3: CISESS Presentations 2019–2020

Science / Project Presentations

- Abadi, A., 2020: Droughts and all-cause mortality in all age groups in Nebraska. *100th AMS Annual Meeting*, Boston, MA, January 15, 2020.
- Abadi, A., and **J. Bell**, 2019: Drought Severity and All-cause Mortality Rates in Nebraska: Are Heat Waves to Blame Partially? *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 9, 2019.
- 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.
- Barros, A., 2020: Evaluation and Elucidation of SCaMPR Performance in Complex Terrain Leveraging GOES-R Observations and Ground-based Precipitation Measurements, JPSS Hydrology Initiative: Project Overview. Remote. *Joint Polar Satellite System Hydrology Initiative*, Greenbelt, MD, February 4, 2020.
- Bell, J. 2020: Drought and human health in the United States: an evaluation of knowledge. *100th AMS Annual Meeting*, Boston, MA, January 15, 2020.
- **Biard, J.**, 2019: Atmospheric Fronts in Climate Models: Inter-comparison Across Historical and Future Scenarios. *CISESS Science Meeting 2019*, College Park, MD, November 13, 2019.
- Brewer, M., A. Hollingshead, N. Jones, and **J. Dissen**, 2020: Use-Inspired Science at NOAA's National Centers for Environmental Information: Incorporating User Feedback into Product Improvement. *100th AMS Annual Conference*, Boston, MA, January 14, 2020. (Link)
- **Champion, S.**, 2020: Metadata Quality and The National Climate Assessment. *ESIP 2020 Winter Meeting*, Bethesda, MD, January 7, 2020.
- Courtright, A. M., **O. P. Prat**, R. Bilotta, **R. D. Leeper**, B. R. Nelson, S. Ansari, K. Bevington, and A. Lang, 2019: Developing an interactive global drought information dashboard using remotely sensed near-real time monitoring. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.
- Danilovich I., Loginov V., and **P. Y. Groisman**, 2019: Recent baric and climatological conditions over East Europe with a focus on Belarus. *Japan Geoscience Union Meeting 2019*, Makuhari Messe, Chiba, Japan, May 26, 2019.
- Danilovich I., S. Zhuravlev, L. Kurochkina, and P. Ya. **Groisman**, 2019: Recent and future climate and streamflow changes in the Western Dvina River Basin. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 10, 2019.
- Easterling, D., **K. Kunkel**, and **J. Dissen**, 2020: ICIMOD Scoping Discussion. *The International Centre for Integrated Mountain Development (ICIMOD) Meeting*, Kathmandu, Nepal, January 28, 2020.
- Easterling, D., **K. Kunkel**, and **J. Dissen**, 2020. Capacity Building, Technology and Finances for Achieving Forestry Sector NDCs in India. *TERI – NOAA/NCICS Roundtable*, The Energy Resources Institute, New Delhi, India, January 31, 2020.
- Easterling, D., **K. Kunkel**, **J. Dissen**, and **E. Scott**, 2020: Climate Projections for Considerations in Land Use Planning. *2020 World Sustainable Development Summit*, New Delhi, India. January 29, 2020.
- Fox, J., 2019: Mountain Workshops. *North Carolina Climate Risk Assessment and Resiliency Plan Workshops*, Sylva, NC, October 15, 2019.

- Fox, J., 2019: Mountain Workshops. *North Carolina Climate Risk Assessment and Resiliency Plan Workshops*, Hickory, NC, October 16, 2019.
- Gardiner, N. and J. Fox, 2019: The Path Forward. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop*, Raleigh, NC, September 27, 2019.
- Gardiner, N. and J. Fox, 2019: Workshop One: Explore Hazards. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop*, Raleigh, NC, October 11, 2019.
- Gardiner, N., J. Fox, and A. Patel, 2019: Developing a Shared Understanding of Vulnerability and Risk. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop,* Cary, NC, December 5, 2019.
- Gardiner, N., J. Fox, and A. Patel, 2020: Chapter 5 Review and Discussion. *North Carolina Climate Risk Assessment and Resiliency Plan Workshop*, Raleigh, NC, February 7, 2020.
- Gardiner, N., J. Fox, and K. Rogers, 2019: Explore Hazards. *The Steps to Resilience: Learn to Develop Workable Solutions to Climate-Related Risks, a One-Day Workshop*, The Collider, Asheville, NC, September 25, 2019.
- Gardiner, N., J. Fox, and K. Rogers, 2019: The Steps to Resilience. *The Steps to Resilience: Learn to Develop Workable Solutions to Climate-Related Risks, a One-Day Workshop*, The Collider, Asheville, NC, September 25, 2019.
- Gleason, K., D. Arndt, **C. Schreck**, and C. Fenimore, 2019: NCEI Daily Gridded Data and Selected Derived Products. *44th Annual Climate Diagnostics and Prediction Workshop*, Durham, NC, October 22, 2019.
- **Groisman P. Ya**., 2019: Human-Associated Extreme Events. *III International Scientific Conference, IV All-Russian Scientific Youth Forum*, Sochi, Russia, May 15, 2019.
- **Groisman P. Ya.,** 2020: About the history of one of the ideas of Mikhail I. Budyko, to which I was slightly linked. *International Conference on Ecology and Climate*, St. Petersburg, Russia, February 25, 2020.
- **Groisman P. Ya**., D. A. Streletskiy, E. A. Kukavskaya, and G. M. Henebry, 2020: Northern Eurasia Future Initiative (NEFI), Update. *International Workshop on Snow Cover Changes and Its Modeling over Northern Eurasia,* Hirosaki, Japan, February 19, 2020.
- **Groisman P. Ya**., E. G. Bogdanova, O. A. Bulygina, and V. N. Razuvaev, 2020: In situ precipitation and snow cover observations over Northern Eurasia: Observation changes and problems for climatic studies that they created. *International Workshop on Snow Cover Changes and Its Modeling over Northern Eurasia,* Hirosaki, Japan, February 20, 2020.
- **Groisman, P.**, 2019: Norther Eurasia Future Initiative (NEFI) Focus on Human-Associated Extreme Events. *CITES 2019 International Young Scientists School and Conference on Computational Information Technologies for Environmental Sciences,* Moscow, Russia, June 6, 2019.
- **Groisman, P.**, 2019: Northern Eurasia Earth Science Partnership Initiative: Science Plan, Achievements, and its successor, Norther Eurasia Future Initiative (2002-2019). *10th Annual Russian-American Science Association (RASA)-America Conference*, Chapel Hill, NC, November 9, 2019.
- **Groisman, P.**, 2019: Progress in NEFI (formerly NEESPI) and the Role of LCLUC Caucasus Projects. *NASA LCLUC Spring Science Team Meeting*, Rockville, MD, April 10, 2019.
- **Groisman, P.**, 2019. Northern Eurasia Future Initiative (NEFI), Update. Poster. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 10, 2019.
- **Groisman, P.**, 2020: Environment Changes in the Eurasian Arctic. *Voeikov Geophysical Observatory*, Russia, February 12, 2020.

- **Groisman, P.**, A. I. Shiklomanov ,I. B. Yesserkepova, et al, 2019: Northern Eurasia Future Initiative (NEFI) Focus on Human-Associated Extreme Events. *Japan Geoscience Union Meeting 2019*, Makuhari Messe, Chiba, Japan, May 26, 2019.
- **Groisman, P**., O. Bulygina, D. Streletskiy, **G. Peng**, N. Speranskaya, and N. Tchebakova, 2020: Environmental Changes in the Eurasian Arctic. *International Workshop on Snow Cover Changes and Its Modeling over Northern Eurasia* Hirosaki, Japan, February 20, 2020.
- **Groisman, P**., O. Bulygina, S. Gulev, A. Dufour, D. Streletskiy, **G. Peng,** N. Speranskaya, and N. Tchebakova, 2020: Environmental Changes in the Eurasian Arctic. *Sixth International Symposium on Arctic Research (ISAR-6)*. Web conference. March 27, 2020.
- Hill, J., 2019: Gauge and satellite data comparison programming. *2019 NOAA/NESDIS/Cooperative Research Program (CoRP) Science Symposium*, College Park, MD, August 29, 2019.
- Hollingshead, A., M. Brewer, **J. Dissen**, and N. Jones, 2020: Town Hall: 2019 NCEI Users' Conference – Debrief and Path Forward. *100th AMS Annual Conference*, Boston, MA, January 14, 2020. (Link)
- Hollingshead, A., M. Brewer, N. Jones, and **J. Dissen**, 2020: Model for Engagement: 2019 NCEI Users' Conference. *100th AMS Annual Conference*, Boston, MA, January 13, 2020.
- **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.**, and D. R. Easterling, 2020: North Carolina Climate Science Report. *NCICS Media Release*, Asheville, NC, March 11, 2020.
- **Kunkel, K. E.**, and D. R. Easterling, 2020: North Carolina Climate Science Report. *North Carolina Interagency Council Meeting*, Raleigh, NC, January 22, 2020.
- **Kunkel, K.**, 2019: Developing Intensity-Duration-Frequency (IDF) Curves Associated with Climate Change Pathways. *Urban Resilience to Extremes (UREx) Sustainability Research Network project 2019 All Hands Meeting*, Baltimore, MD, April 16, 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.
- **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: Extreme Precipitation Trends and Weather System Influences. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.
- **Kunkel, K.**, 2019: Fourth National Climate Assessment: Southeast U.S. *East Carolina University Ocean Global Change Biology class*, Greenville, NC, November 26, 2019.
- **Kunkel, K.**, 2019: Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values. Poster. *SERDP/ ESTCP Symposium 2019: Enhancing DoD's Missions Effectiveness*, Washington, DC, December 3, 2019.
- **Kunkel, K.**, 2019: Machine learning and frontal systems. *DOE Precipitation Metrics Workshop*, Rockville, MD. July 2, 2019.
- **Kunkel, K.**, 2019: Observed Climatological Relationships between Precipitable Water and Extreme Precipitation in the Contiguous United States. *2019 American Geophysical Union (AGU) Fall Meeting*, San Francisco, CA, December 13, 2019.
- **Kunkel, K.**, 2019: Update: IDF Design Value Improvement. *Inter-Agency Forum on Climate Risks, Impacts & Adaptation*, Washington, DC, December 6, 2019.

- **Kunkel, K.**, 2019: Update: IDF Design Value Improvement. *SERDP/ ESTCP Symposium 2019: Enhancing DoD's Missions Effectiveness*, Washington, DC, December 3, 2019.
- **Kunkel, K.**, 2020: Analysis of Heavy Multi-day Precipitation Events In CMIP6 Model Simulations in Support of the Fifth National Climate Assessment. *U.S. Nuclear Regulatory Commission* 5th Annual Probabilistic Flood Hazard Assessment Workshop, Rockville, MD, February 19, 2020.
- **Kunkel, K.**, 2020: Extreme Precipitation and Climate Change: Observations and Projections. *FEMA National Dam Safety Program Technical Seminar* (ND SPTS) No. 27: Dam and Levee Resiliency in the Era of Intensifying Natural Hazards and Climate Conditions in Emmitsburg, MD, February 19, 2020.
- **Kunkel, K.**, 2020: Extreme precipitation trends and weather system influences. Poster. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.
- **Kunkel, K.**, 2020: Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values. *Annual SERDP In-Progress Review Meeting*, Arlington, VA, February 5, 2020.
- **Kunkel, K.**, 2020: NCICS Journey in Developing a N.C. Climate Science Report. *100th AMS Annual Meeting*, Boston, MA, January 16, 2020.
- **Kunkel, K.**, 2020: Observed climatological relationships between precipitable water and extreme precipitation in the contiguous United States. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.
- **Leeper, R. D., B. Petersen**, and M. A. Palecki, 2020: Development and Characterization of U.S. Drought Monitor Based Drought Events, at the *100th AMS Annual Meeting*, Boston, MA, January 13, 2020.
- **Mantripragada, S.**, A. Aiyyer, and **C. J. Schreck**, 2019: Surface variability and tropical waves over the Atlantic. *NASA CYGNSS Science Team Meeting*, Ann Arbor, MI, June 7, 2019.
- **Matthews, J.**, 2019: Long-Term HIRS-Based Temperature and Humidity Profiles. Poster. *AMS 2019 Joint Satellite Conference*, Boston, MA, October 2, 2019.
- **Maycock, T.**, Veasey, S., and G. Hammer, 2019: Poster Production Creation- A whole new approach. *NCEI Seminar Series*, Asheville, NC, October 1, 2019.
- Miller, D.K., 2019: Fellowship of the rain (gauge network). *NOAA STAR Seminar, Satellite Climate Studies Branch*, College Park, MD, September 12, 2019.
- Miller, D.K., 2020: Influence of atmospheric rivers on long-duration freezing rain events in eastern North America. *100th AMS Annual Meeting*, Boston, MA, January 15, 2020.
- Nelson, B. R., **O. P. Prat**, and A. Arguez, 2020: Alternative precipitation normals based on NEXRAD quantitative precipitation estimates. *100th AMS Annual Meeting*, Boston, MA, January 14, 2020.
- **Peng, G.**, 2020: NOAA's Data Stewardship Maturity Matrix – Stewardship Maturity Scores and Quality Information. *ESIP 2020 Winter Meeting*, Bethesda, MD, January 8, 2020.
- **Peng, G.**, N. Ritchey, C. Lief, and I. Maggio, 2020: Use and Re-use of a Data Stewardship Maturity Assessment Model for Institutional Research Data Management Support. *15th International Digital Curation Conference*, Dublin, Ireland, February 19, 2020.
- **Petersen, B.**, **R. D. Leeper**, and M. A. Palecki, 2020: Evaluating Flash Drought Detection Utilizing In Situ Soil Moisture Observations, *100th American Meteorological Society Annual Meeting*, Boston, MA, January 16, 2020.
- **Prat, O. P.**, 2020: Near-real time drought monitoring using global satellite precipitation estimates from NOAA's Climate Data Record (CDR) program. *NCEI Seminar Series*, Asheville, NC, March 17, 2020.

- **Rennie, J.**, 2020: Development of a Heat Vulnerability Index for the Southeastern United States. Poster. *100th AMS Annual Meeting*, Boston, MA, January 13, 2020.
- **Rennie, J.**, 2020: It's Not the Heat, It's the Humidity…and Wind and Solar: Developing and Validating Heat Exposure Products Using the U.S. Climate Reference Network. *100th AMS Annual Meeting*, Boston, MA, January 13, 2020.
- **Schreck, C.**, 2019: Sources of Tropical Subseasonal Skill in the CFSv2. *NOAA Climate Diagnostics and Prediction Workshop*, Durham, NC, October 22, 2019.
- **Schreck, C.**, 2019: The MJO and Equatorial waves in the CFSv2. *University of Maryland – College Park*, College Park, MD, July 24, 2019

Outreach and Engagement Presentations

- **Copley, L.**, and **Y. Rao**, 2020: Programming and Professions in Computer Sciences. *Buncombe Community High School,* Swannanoa, NC, March 11, 2020.
- **Dissen, J.**, **J. Runkle**, and **L. Stevens**, 2019: Careers and professional development in climate science. NASA DEVELOP panel discussion. *National Centers for Environmental Information*, Asheville, NC, November 15, 2019.
- **Maycock, T.**, S. Veasey, and G. Hammer, 2019: Poster Production Creation- A whole new approach. NCEI Seminar Series, *National Centers for Environmental Information* (NCEI), Asheville, NC, October 1, 2019.
- **Rao, Y**, 2020: Weather and Climate (remote). Skype a Scientist, *Ponderosa Elementary School*, Post Falls, ID, February 5, 2020.
- **Rennie, J. J.**, 2019: Weather and Climate (remote). Skype a Scientist, *Monett Elementary School*, Monett, MO, October 24, 2019.
- **Rennie, J. J.**, 2019: Weather and Climate (remote). Skype a Scientist, *Shepherd Glen Elementary School*, Hamden, CT, October 29, 2019.
- **Rennie, J. J.**, 2020: Coding Weather and Climate Data. *Christ School*, Arden, NC, February 6, 2020.
- **Rennie, J. J.**, 2020: NCEI use of weather station data in monthly climate reports. Applied Climatology class, *UNC-Asheville*, Asheville, NC, February 11, 2020.
- **Schreck, C.**, 2019: Are hurricanes getting warmer, larger, and wetter? *The Collider*, Asheville, NC, September 24, 2019. case.simpletix.com/e/47619
- **Schreck, C.**, 2019: Climate Change, Hurricanes, and North Carolina. *Buncombe County Schools Secondary Professional Development Day,* Asheville, NC, October 28, 2019.

Appendix 4: CISESS Products 2019–2020

- Institute Communications
  - One issue of *Trends* newsletter

- Development and Support of NOAA Climate Products and Services
  - U.S. Climate Resilience Toolkit (https://toolkit.climate.gov)
  - Climate Explorer v3.0 (https://crt-climate-explorer.nemac.org/)
  - USGCRP Indicator graphics (http://www.globalchange.gov/browse/indicators)

- NOAA Big Data Project Support
  - *Cloud Run* serverless functions

- Assessment Technical Support Activities
  - Updated Ozone Assessment website
  - NCA4 website updates
  - New Assessments Collaboration Environment website

- Common Ingest Agile Development Team
  - Common Ingest components deployed in NCEI production:
    - Common Ingest v2.15.8a Batch cleanup to tarByDir algorithm
    - Common Ingest v2.15.8b Deploy cronTrigger queue for *Quartz* cron jobs
    - Common Ingest v2.15.6 Add logging for *Quartz* cron
    - Common Ingest v2.15.3 Disallow hard-linked zero-size files in tar files

- NCEI Infrastructure Architecture Planning and Implementation
  - Common Data Services deployed to NCEI test tier, with completed operational readiness review
  - Continuous *NiFi* retrieval streams of live datasets within NCEI tiered infrastructure
  - Common Ingest split-stream aggregation functionality

- Drought-related health impacts: advancing the science for public health applications
  - Midwest Drought and Health Workshop
  - Southwest Drought and Health Workshop

- GOES-R-Based Products
  - Algorithm to evaluate near-real-time surface solar absorption from GOES-R data

- Toward Earlier Drought Detection Using Remotely Sensed Precipitation Data from the Reference Enviromental Data Record CMORPH
  - Operational near-real-time global daily SPP SPI that is currently available within 1-day
  - An improved Geographic Information Systems–based visualization and analysis tool to display global droughts conditions in near real time as a complement to the Interactive Global Drought Information Dashboard

- Developing and Validating Heat Exposure Products Using the U.S. Climate Reference Network
    - Hourly and sub-hourly heat exposure indices, including heat index (HI), apparent temperature (AT), and wet-bulb globe temperature (WBGT)

- NCEI Innovates: Developing 1991–2020 Normals along the Northeast and Mid-Atlantic Coasts
    - Coastal normals data from 1991–2019 for areas in and around the U.S. Northeast and Mid-Atlantic
    - ArcGIS Online interactive web map displaying the coastal normals

- Climate Monitoring
    - Synoptic Discussions for NCEI's State of the Climate August 2019–March 2020. For example: https://www.ncdc.noaa.gov/sotc/synoptic/201908

    - Hurricanes and Tropical Storms reports for NCEI's State of the Climate August–November 2019. For example: https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201908

- Changes in the Frequency of Freezing Precipitation
    - Algorithm of defining weather conditions conducive to freezing rain (WCCFR) was refined and applied to North America and Northern Eurasia reanalysis data