COOPERATIVE INSTITUTE FOR SATELLITE EARTH SYSTEM STUDIES (CISESS)

Annual Scientific Report

CISESS NC TASK REPORTS

For the period:

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CISESS NC Director

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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 National Centers for Environmental Information (NCEI) and NOAA's Office of the Chief Information Officer (OCIO) 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 OCIO, the National Weather Service (NWS), Oceanic and Atmospheric Research's (OAR's) Climate Program Office (CPO). 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) Other Projects

These streams are currently supported by the different divisions in NCEI; NOAA Line and Staff Offices including the NESDIS, OAR, NWS and OCIO; and North Carolina State University. Other Projects led by the Institute's investigators 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 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), the U.S. Department of Defense (DoD), and several non-federal sponsors.

Administration [NCSU/NOAA]

Institute Information Technology Support Services: Institute IT staff provide modern, scalable approaches to sustain the Institute 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, transitioning to remote working conditions, and beginning the migration to Red Hat Enterprise Linux 8.

Institute Communications: Key accomplishments this year included the co-production of a series of six climate change webinars in partnership with the State Climate Office of North Carolina, initiating of a new series of monthly science seminars, editorial support for multiple papers and reports, and graphic design and visual communication support for NCEI's annual State of the Climate Report, Spectrum Broadband, and the Extended Continental Shelf Report.

Access and Services Development [OCIO/CPO/NCEI]

NOAA Big Data Program Support: Utilizing the CISESS-NC-designed data hub/broker architecture, this project 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/

Strategic Engagement and Outreach for the Big Data Program: CISESS NC supported NOAA Big Data Program (BDP) engagement efforts with internal NOAA line offices, external cloud partners, and BDP partners focused on the data transfer process, which datasets to make available, cloud user engagement strategies, targeted GOES-R dataset informational user webinars and blogs, and the development of high-level data access monitoring dashboards and metrics.

Development and Support of NOAA Climate Products and Services: UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with managing the U.S. Climate Resilience Toolkit, maintaining Climate Explorer 3, designing an author "sandbox" for the National Climate Assessment, updating USGCRP Indicators graphics, and redesigning NIDIS drought.gov. This effort provides support for the overall advancement of NOAA's Climate Products and Services activities.

Scientific Data Stewardship for Digital Environmental Data Products: A version of the World Meteorological Organization (WMO) Stewardship Maturity Matrix for Climate Data (SMM-CD), adapted from the NCEI Data Stewardship Maturity Matrix (DSMM), for National and Regional Purposes (SMM-

CD_NRP) was baselined by the WMO Expert Team on Data Development and Stewardship (ET-DDS). A paper was published on the SMM-CD and CMM-CD_NRP with use cases of global and regional datasets.

Assessment Activities [NCEI/CPO/DOS]

Assessment Scientific and Data Support Activities: The Assessment science/data team completed development of the Assessment Collaboration Environment (ACE) version 1.0. A comprehensive update of the NOAA State Climate Summaries was initiated and preliminary planning for the Fifth National Climate Assessment with the USGCRP National Coordination Office continues.

Assessment Technical Support Activities: The Assessment technical support team successfully deployed the Assessment Collaboration Environment (ACE) version 1.0 to the Cloud. The North Carolina Climate Science Report (NCCSR) was updated with improved accessibility for users with visual limitations. The team began preparation and planning for the Fifth National Climate Assessment (NCA5).

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, the addition of a new indicator, and a highly successful indicators development workshop. http://www.globalchange.gov/indicators

U.S.–India Partnership for Climate Resilience Activities Support: CISESS NC progressed U.S.–India Partnership for Climate Resilience Phase II capacity-building activities with India-based partner The Energy and Resources Institute (TERI) in data analysis using modern downscaling methods and planning for a forestry focused workshop to train India forestry managers on future climate change impacts.

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 are collaborating on plans for a technical training seminar (or webinars) for India-based forestry managers on understanding climate projections and their use in the State Action Planning for Climate Change as required by each state in India.

Information Technology Services [NCEI]

Global Historical Climatology Network-Daily (GHCNd) Graph Database: The long-range objective of this project is to complete a graph structured database analog for GHCNd. Project progress was accomplished in three important ways this year: a new software repository was created, the database design was set, and an assessment of database performance through benchmarking trials was completed.

User-Centered Requirements for NCEI Archive Inventory, Catalog & Administration: A survey of NCEI staff involved in the inventorying and cataloging processes of NOAA data was completed. Survey responses identified three primary requirements for the development of a new cloud-based inventorying system. The current role of the survey participant (data inventorying or data cataloging) was a key factor in their identification of the most critical function of the NOAA Archive.

NCEI Infrastructure Architecture Planning and Implementation: This project team and its collaborators drive the development of NCEI and NCICS IT infrastructure and architecture that will support a modern, flexible, distributed approach to data science, archive, and access capabilities. An analysis of cloud capabilities was completed. A high-performance workflow data processing system, NiFi, is supporting several NCEI projects and NiFi URMA retrieval stream monitoring was improved.

Science and Services [NCEI/CDC/CPO/STAR/]

Scientific Subject Matter Expertise Support: CISESS NC scientists served as subject matter experts on 1 Climate Data Record Integrated Product Team, as Product Leads for 26 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 a regional workshop on drought and health for the Carolinas. The project team is evaluating the impact of historical drought events on mortality and morbidity in Nebraska.

Strategic Engagement and Outreach: CISESS NC supported a number of NOAA engagement activities including the development of the NCEI Information Services Roadmap, initiating a case study to build understanding of climate risk to the real-estate sector, NCEI engagement activities at the 2021 American Meteorological Society Virtual Annual Meeting, and a number of virtual "Skype a Scientist" and other outreach presentations.

Optimum Interpolation Sea Surface Temperature (OISST) Algorithm Upgrades: The scientific task team completed reprocessing of the OISST dataset and reformatting of the metadata to transition to OISST v2.1. Reprocessing of the historical dataset using the NOAA Pathfinder Advanced Very High Resolution Radiometer (AVHRR) sea surface temperature (SST) product is nearing completion. The new product was used to investigate marine heat waves in the Arctic seas. https://www.ncdc.noaa.gov/oisst

GOES-R-Based Products: Research conducted using US Climate Reference Network (USCRN) in situ data and data from the NOAA-operated Surface Radiation Network (SURFARD) revealed that changes in the daytime land surface temperature (LST) track the changes in the SSA parameter under most sky conditions, with potential advantages for to filling in gaps in the LST time series retrieved from geostationary satellites such as GOES-R.

HIRS-Like Data from New-Generation Sensors: A full year (2015) of Infrared Atmospheric Sounding Interferometer (IASI) data was processed and used to generate brightness temperatures, and a new scheme for limb correction was developed and applied. Software has been implemented to support in-house production of the IASI data**.** https://www.ncdc.noaa.gov/isccp

U.S. Climate Reference Network (USCRN) Applications and Quality Assurance: The on-going quality-control review of USCRN Acclima sensor observations led to the identification of several processing issues which significantly impacted the sensor records' quality. The issues were resolved and the evaluation of the quality-controlled data reflects the new Acclima sensors are impacting soil moisture and temperature layer averages.

Standardization of U.S. Climate Reference Network (USCRN) Soil Moisture Observations: A daily soil moisture-based drought index was developed from the standardized soil moisture dataset and made publicly available through CISESS NC. Comparisons between USCRN and the European Space Agency's (ESA) Climate Change Initiative (CCI) remotely sensed soil moisture dataset were evaluated for both volumetric (raw) and standardized measures.

Exploring the Impacts of Drought Events on Society: U.S. Drought Monitor (USDM) weekly maps of drought conditions from 2000 to 2019 were placed on a 5 km resolution and used to define historical

drought event climatologies across the U.S. and Puerto Rico. Analysis of the drought characteristics (i.e., frequency of occurrence, duration, seasonality, flash droughts, etc.) were loaded into an online application to support the interactive dissemination of this climatological drought dataset.

Machine Learning Based Quality Control: a USCRN Soil Moisture and Temperature Test Case: Binary and multiclass learning algorithm operators were applied to U.S. Climate Reference Network (USCRN) soil moisture observations with preliminary results showing the binary algorithm successfully detected 96% of the observations manually flagged under current quality control processes.

Evaluation of air and soil temperatures for determining the onset of growing season: NDVI satellite estimates of start of season (SOS) were reevaluated to correct for geolocation discrepancies which improved the spatial comparisons between satellite and USCRN station-based SOS estimates. Analyses reflected greater similarity of station to NDVI SOS estimates using soil moisture

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. A cloud mask developed by MeteoSwiss was installed, configured, compiled, and successfully executed with test METEOSAT data on CISESS NC 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. QPE errors exhibit distinct seasonal behavior with overestimation in the cold season and underestimation in the warm season.

Evaluation and Elucidation of SCaMPR Performance in Complex Terrain Leveraging GOES-R Observations and Ground-based Precipitation Measurements (UNC Asheville): Completed summer and fall 2020 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 (1990–2019) of daily, monthly, seasonal and annual gridded USCON temperature and precipitation fields were computed using NCEI's daily gridded dataset (nClimGrid), with the developed software in Fortran and initial data files provided to NCEI.

Value-Added Precipitation product suite from CDRs: The three satellite precipitation products (SPPs) were renamed to avoid confusion with in situ Normals products, and an evaluation of the SPSs was completed for the years up to 2018, including a more complete evaluation for CONUS with comparisons to USCRN data.

Toward the Development of Climate Data Records (CDRs) for Precipitation: Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs): The project team conducted a long-term assessment of the different satellite-based precipitation products from four Climate Data Records (PERSIANN-CDR; GPCP; CMORPH-CDR; AMSU A-B Hydro-bundle) and derived long-term global precipitation characteristics at fine spatial and temporal resolution. The performance of each SPP with respect to warm/cold precipitation was evaluated over CONUS using USCRN stations and multiple papers have been submitted.

Drought Detection Using Remotely Sensed Precipitation Data from the Climate 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. Comparison of satellite SPI with an in situ drought index showed comparable patterns for drought events around the globe but important differences over areas with limited precipitation. Operational global daily SPIs were computed from CMORPH-CDR and CMORPH-ICDR to monitor drought conditions.

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

Supporting the development of artificial intelligence within NOAA and CISESS: The team assisted in the development of the NOAA Center for Artificial Intelligence, began planning for 11th International Conference of Climate Informatics, and developed a CISESS NC virtual AI training series.

Maintenance and Streamlining of the Global Historical Climatology Network-Monthly (GHCNm) Dataset: The next iteration of NOAA's global temperature product (GHCNm version 4.0.1) was developed and is now operational. The codebase was put under version control and has been tested in the cloud. Other updates are ongoing and provided as necessary. www.ncdc.noaa.gov/ghcnm/

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool: A sub-monthly tool for monitoring impacts of temperature extremes in the United States has been created and described in an article in an American Meteorological Society journal. The resulting dataset can be used to assess heat extreme events in the United States as far back as 1895 and can be compared against other relevant data. The code base was upgraded to Python version 3. https://ncics.org/portfolio/monitor/sub-monthly-temperatures/

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, including heat index, apparent temperature, and wet-bulb globe temperature (WBGT), have been developed and validated against data from nearby sites. A manuscript describing project methods has been submitted for peer-review. 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 NC project team is working to transition the previously developed National Precipitation Index (NPI) into NCEI operations. Data have been updated through December 2020 and planning is underway for the research-to-operations transition.

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* website was developed to allow users to interact with the data. https://coastal-normals-ncsu.hub.arcgis.com

ARC Data Derivative Product for Health Users: Work is underway to develop an NCEI data product consisting of a daily time series for Tavg, Tmax, Tmin, and Precipitation using nClimGrid for each county in the U.S. (1981-present).

Collaborative Climate and Human Health Activities: The team identified data gaps for extreme heat metrics and corresponding candidate observed and projected extreme heat metrics, worked on building a drought data pipeline with weekly data refreshes, and established baseline surveillance data to be used in an early warning system for harmful algal blooms.

Environmental Information and Analysis for the Real Estate Development Sector: This stakeholder engagement study focuses on identifying the specific environmental data requirements and applications needed for effectively analyzing wildfire risk and exposure for the real estate sector value chain. Current environmental data utilization and sector climate risk management practices were analyzed and a sector value chain climate risk/potential impact matrix was completed.

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. The monthly tropical cyclone report was expanded from a national report to a global report, and a new annual Synoptic Discussion was introduced.

Calibration of High-resolution Infrared Radiation Sounder (HIRS) Brightness Temperatures: High-resolution Infrared Radiation Sounder (HIRS) measurements of brightness temperature must be calibrated in order to provide a consistent dataset for use as a Climate Data Record (CDR). A subset of the data that can be used for calibration of HIRS brightness temperature between satellites has been identified and calibration is being performed, with calibration coefficients calculated for the NOAA 14-19 and METOP 1 and 2 satellites.

Workforce Development [NCEI / NSF / NASA / NCSU]

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

Other CISESS PI Projects

Climate Change Impacts in the Arctic and International Coastal Ocean Regions: Collaborative international research teams are investigating global environmental change challenges and impacts. Current projects are focused on the northern extratropics and five coastal ocean regions. The U.S. team completed an assessment of the costs of climate change impacts on critical infrastructure in the Circumpolar Arctic and updated the project's circumpolar infrastructure database for additional analysis.

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 project team completed development of heavy rainfall design values that incorporate future climate change and a project website was deployed that disseminates these adjusted values. The dominant factor influencing future changes in these values is increases in atmospheric water vapor.

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

Impact of COVID-19 on Health and Society: Researchers explored the myriad ways in which COVID-19 impacted the health and well-being of vulnerable populations across the United States. A participatory surveillance tool was created to 1) connect residents with needed healthcare and testing resources and 2) provide close to real-time data for situational monitoring in health officials.

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 subseasonal to seasonal system signals for NOAA's Climate Prediction Center (CPC) through a new web interface on CPC servers (https://ftp.cpc.ncep.noaa.gov/fews/novella/mjo/).

Kelvin Waves and Easterly Waves in CYGNSS: This project is investigating the interactions between Kelvin Waves and Easterly Waves utilizing NASA CYGNSS data to observe the interactions of their surface winds. 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 activities include institute and office administration, accounting and finance, pre-award proposal development/support, post-award contracts and grants management, human resources, information technology, national and international linkages, internal and external communications, oversight and management of CISESS NC–initiated consortium projects, and coordination with CISESS and 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 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 salary 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

Highlight: Institute IT staff provide modern, scalable approaches to sustain the Institute 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, transitioning to remote working conditions, and initiating the migration to Red Hat Enterprise Linux 8.

Background

Institute 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.

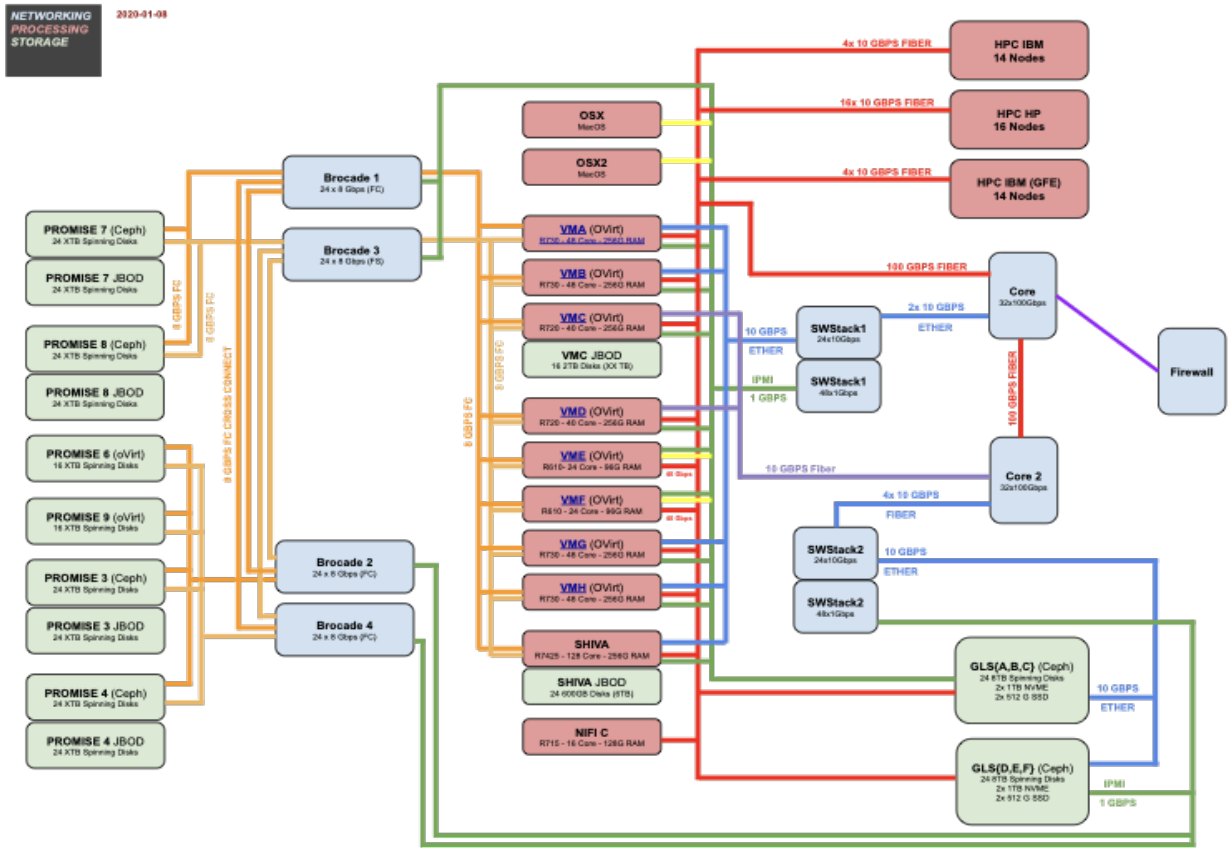


Figure 1. Network and System Diagram.

A building-wide wireless network with 37 current access points provides CISESS NC and other building partners with strong-signal, fast wireless coverage which allows CISESS NC to quickly integrate and work side by side with NCEI partners. 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.

Accomplishments

Cloud Computing Support. IT staff are supporting the transition to cloud-based services by providing accounts, training, standing up Virtual Machines (VMs) on Google and Amazon, and other assistance to staff looking to process Big Data Partnership (BDP) datasets stored in the cloud. IT staff support includes projects utilizing Amazon SageMaker for Machine Learning processes and Jupyter Notebooks utilizing Dask Clusters on Amazon Fargate to interrogate the Coupled Model Intercomparison Project (CMIP) version 6 data in support of the Fifth National Climate Assessment (NCA-5).

***Pandemic response*.** In March 2020, the Institute responded to state and county COVID-19 work-from-home executive orders. The IT team efficiently assisted other institute staff in provisioning equipment for remote use. Institute VPN licenses were doubled to support additional concurrent users while usage tripled. Changes were also made to JAMF package management to accommodate newer operating systems, more flexible working hours, and sometimes slower network connections. Videoconferencing capability was expanded with increased utilization of Google Meet and the addition of Zoom and WebEx.

RedHat Operating system updates. New hosts were created with the latest version of the RedHat Enterprise operating system (RHEL8). Where appropriate, Ansible playbooks were created to automate recreation of these hosts. This upgrade also necessitated updates to various other software packages. All hosts in Phase I were successfully upgraded by the end of 2020.

Environmental Issues. A server room chiller outage caused the loss of three Storage Area Network (SAN) controllers. The redundant nature of the Ceph storage infrastructure facilitated continued operation with minimal interruption despite a loss of access to 192TB of raw disk space. Replacement controllers were ordered and Ceph storage was brought back to full redundancy with zero downtime when the new controllers were installed.

NOAA and other building tenant support. CISESS NC provides its partners in the Veach Baley Federal building with IT support including regular WiFi, audiovisual, and video conferencing access; server support for various meetings, customer engagements, and training classes; and support to augment existing resources and provide IT functionality for NCEI-wide meetings and events. The Institute typically provides workstations, WiFi, video conferencing, virtualization, and high-performance computing resources for NCEI workforce development programs (e.g., NASA DEVELOP, NOAA Hollings Scholars, etc.). Due to the short internship period (10–12 weeks), interns are often without access to federal resources until they are halfway through the program. Institute-provided equipment enables a fully productive internship.

Planned work

- Ongoing monitoring and maintenance tasks.
- Improve security scanning regularity and address issues.
- Continue support for federal partners and internship programs.
- *Kubernetes* cluster development.
- Assist users with leveraging cloud-based technologies.

Institute Communications	
Task Team	Tom Maycock, Jessicca Allen, Angel Li, Andrea McCarrick
Task Code	NC-ADM-02-NCICS-TM/JA/AL/AM

Highlight: Key accomplishments this year included the co-production of a series of six climate change webinars in partnership with the State Climate Office of North Carolina, initiating of a new series of monthly science seminars, editorial support for multiple papers and reports, and graphic design and visual communication support for NCEI's annual State of the Climate Report, Spectrum Broadband, and the Extended Continental Shelf Report.

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 the Institute's website and *Trends* newsletter, press releases, social media, and outreach events. Other activities include working to improve science communication support for Institute staff, including editorial and graphic design support for papers, presentations, and reports.

CISESS staff also provide graphic design, science writing, and editing to NCEI's Communications and Outreach Branch. Graphics support includes image creation and editing for accuracy and readability, preparing graphics for various pre-release drafts, and publication layout design. The Science Public Information Officer (PIO) coordinates communication efforts between the Institute and its various stakeholders, including NCEI, NCSU, and UMD.

Accomplishments

State Climate Office Webinar Series. NCICS partnered with the State Climate Office (SCO) of North Carolina on a series of six webinars on climate change in North Carolina. The primary target audience for the series were the North Carolina Cooperative Extension service and related personnel. The NCICS PIO provided coordination support and served as a co-host, and several NCICS staff served as presenters. The webinars were recorded and are available on the SCO website along with copies of presentations, notes from the question-and-answer sessions, and relevant resources. Planning is underway to expand this communication and outreach partnership between NCICS and the SCO.
https://climate.ncsu.edu/ClimateChange_Webinars

***CISESS Science Seminar Series*.** In March 2021, CISESS presented the first in a new monthly series of online science seminars. The series is the result of a collaborative effort between the North Carolina and Maryland locations of CISESS and involved several months of planning. The talks are intended to appeal to a broad audience from across CISESS, NCEI, and STAR, with the goal of inspiring new research ideas and opportunities for collaboration and promoting better understanding of how NOAA and CISESS products and research are used by stakeholders. The series feature talks from external scientists as well as CISESS staff. Recordings of the seminars will soon be made available on https://ncics.org/.

Trends Newsletter. One issue of *Trends* was published featuring the extensive CISESS NC research efforts on drought monitoring and early warning, an accessibility update to the North Carolina Climate Science Report, institute COVID-19 impacts and response, recent staff recognition, and outreach and engagement activities.

Internal Editorial and Graphics Support. The communications team provided editorial and graphics support for a wide range of NCICS staff publications, presentations, reports, and grant proposals.

Social Media. Social media posts this year included efforts to extend awareness of Institute job and internship opportunities, highlight staff podcast and media appearances, and promote some key research outcomes and activities at major conferences. The Institute's social media accounts continued to see modest growth, with Twitter followers expanding from 578 to 680 and the Facebook audience growing from 743 to 808.

***NCEI communications support*.** The Institute visual communications specialist serves as a liaison between CISESS and NCEI's Communication and Outreach Branch to provide graphics design and production support for NCEI publications. Graphics support includes image creation and editing for accuracy and readability, preparing graphics for various pre-release drafts, and publication layout design. This year, graphics and layout support was provided for three major reports:

- *Bulletin of the American Meteorological Society State of the Climate in 2019*
- *Spectrum Pipeline Reallocation 1675–1680 MHz Engineering Study (SPRES) Program Final Report*
- *U.S. Extended Continental Shelf Project (ECS)*

Planned work

- Continue support for and coordination with NCEI's Communications and Outreach Branch.
- Produce two issues of *Trends* newsletter.
- Continue to build communications and outreach partnerships, including with the North Carolina State Climate Office.
- Continue producing news stories and press releases highlighting research papers.

Products

- One issue of *Trends* newsletter
- *CISESS Science Seminar Series*

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 continues 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 supports 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 Program Support	
Task Team	Otis Brown, Jonathan Brannock
Task Code	NC-ASD-01-NCICS-OB/JB

Highlight: Utilizing the CISESS-NC-designed data hub/broker architecture, this project 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 Program (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.

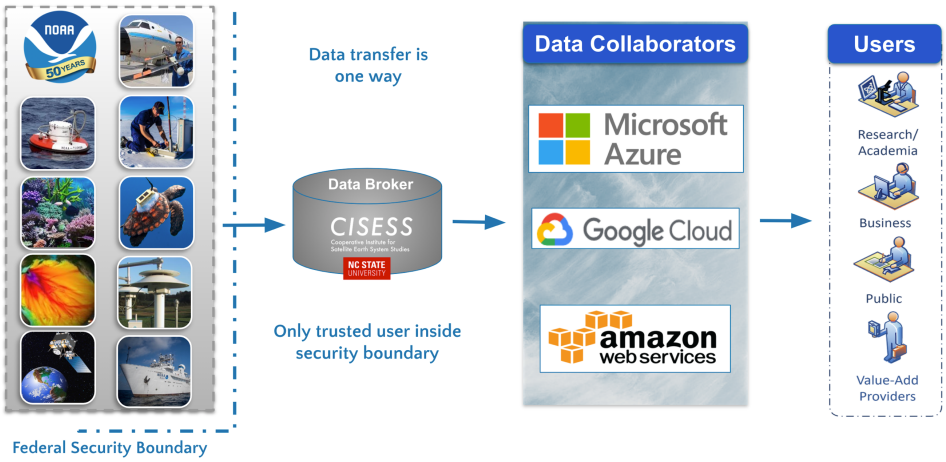


***Figure 1**. Data Hub/Broker Overview.*

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. Currently NOAA BDP datasets utilize ~10.5PB of cloud storage.

The CISESS NC 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. The team began working more closely with other NOAA line offices including the NOAA 1PB allocations discussions, GOES-R team interactions, and more recent interactions with NOAA Central Operations. Major data migration activities increased and presented new challenges requiring innovative software engineering solutions to achieve the desired

outcome. The goal is to automate day to day operations to not only achieve a high level of availability, but also be able to have graceful recovery from failures.

GOES-R Team Interactions. The BDP and GOES-R teams met bi-weekly. The BDP team utilized GOES-R support and requirements to deploy an Elasticsearch cluster on AWS and developed a log pipeline to perform extraction, transformation, and loading of data from S3 server access logs into Elasticsearch. Information is currently retained online for one month, but future work may include a longer-running dataset of hourly aggregations. Other work included user guide development and the addition of new GOES-R products to the Cloud. The latest GOES ice products were added and results of this dashboard activity were presented to the NOAA Environmental Data Management Committee (EDMC).

NCEP Central Operations (NCO) Team Interactions. The BDP team began working with the NCO on a demonstration project to support NOAA Operational Model Archive and Distribution System (NOMADS) operational model guidance dissemination utilizing BDP resources and free egress agreements. During phase 1 of the pilot, the data broker is responsible for maintaining the data transfers of the top 3 most-used NOMADS products. This utilizes the existing public infrastructure operated by NCO and extends the data availability into all three cloud providers. During phase 2, the operational transfer will be pushed to the cloud directly from the HPC infrastructure of the NOAA Weather and Climate Operational Supercomputing System (WCOSS) in order to support low latency access to this data.

NOAA Line Office Allocations. To kick-start NOAA's data transition to cloud services and utilize the resources made available under the NOAA BDP contracts, 1PB of cloud storage was allocated to each NOAA line office. The BDP team is working with the line offices and the EDMC to transition this data to the Cloud. To support this activity, AWS has provided an AWS account with resources and Google has provided two Google Cloud projects, one for Google Cloud Storage and the other for Google Big Query. Microsoft is providing Azure resources under the Microsoft AI 4 Earth Grant. Some datasets of note that have been setup include the Coastal Lidar data, CORS and G-ESTOFS while many additional datasets are in the pipeline bound for each cloud service provider partner.

New Datasets. The BDP team makes all of NOAA's public data available to each participating cloud service provider (CSP) free of charge. Under this approach, the cloud service providers agree to make the data they request freely available to the public. Each CSP has integrated these activities with their own Sustainability and Open Data initiatives. New datasets provided to the open data programs include

- S111
- GEFSv12 reanalysis and retrospective data
- World Ocean Database
- GFS Warm Restart Data
- Severe Weather Data Index (SWDI)
- UFS Prototype 5
- Water Column Sonar Data

Data Transfer activities. The BDP is responsible for providing the resources and expertise to transfer the data when NOAA does not have the current resources. The BDP Data Broker conducted these major transfer activities:

- Backfilled High Resolution Rapid Refresh (HRRR) data from the NOAA Environmental Security Computing Center (NESCC) via the Research and Development HPC System (RDHPCS) to Google.
- Transferred the entire 1.4PB HRRR dataset from Google to AWS.

- On-boarded the National Water Model in ZARR format as donated by the USGS.
- Moved the Water Column Sonar Data from NCEI's bucket to AWS.
- Backfilled two GOES-R products on the Azure cloud.
- Moved CO-OPS development data to a separate bucket.

Software Development. As BDP Data Broker, CISESS NC addressed a number of data transfer challenges with software development/software engineering solutions.

- Created a NIFI Process to generate WMO headers and archive the National Digital Forecast Database (NDFD) GRIB data.
- Wrote software to convert NDFD data into Cloud Optimized GeoTIFF format.
- Created software and functions to jump messages from AWS SNS to Google Pub/Sub.
- Containerized the WGRIB2 software and deployed it as serverless functionality to create GRIB2 Index files in an event driven way.
- Developed approaches to moving data to and between clouds using massively parallel processes for performance.
- Wrote software to extract information from the CLASS database utilizing their public website, enabling automatic coordination and placement of CLASS orders for substantial amounts of data without human intervention.

Operations and Automation Activities. CISESS NC performs various IT operations in each of the cloud service providers' clouds as well as on some on-premises computing resources as needed. When possible, processes are automated to reduce time and effort required to manage these many resources. Some of the new operations activities in the last year include:

- Set up Globus Grid FTP S3 Connector for AWS.
- Set up AWS Elasticsearch instance for Public BDP-Dashboard.cicsnc.org.
- Re-indexed all outdated Elasticsearch indices to newer versions.
- Moved Flows out of custom Cloud Ingest software into Apache NiFi.
- Automated deployments of Elasticsearch and NiFi using Ansible to deploy AWS
- Automated deployments of Elasticsearch and NiFi on Google using Git and Docker.
- Reconfigured NCEI dataflows after NCEI migrated services from their old NCDC domain name.
- Ongoing updates to NiFi, Elasticsearch, Cloud Ingest, and other software used.

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

GOES-R supported BDP Dashboard

New or enhanced datasets now available through BDP cloud service provider partners

- S111
- World Ocean database
- Global Forecast System (GFS)
- GFS Warm Restart Data
- Global Ensemble Forecast System (GEFS)
- GEFSv12 reanalysis and retrospective data

- Severe Weather Data Index (SWDI)
- UFS Prototype 5
- Water Column Sonar Data
- Additional GOES-R data products
    - EXIS Instrument
    - MAG Instrument
    - SEIS Instrument
    - New ABI Level 2 ice products
    - ABI Level 2 Downward Motion Winds Vapor component (DMWV)
- Coastal Lidar data
- CORS
- G-ESTOFS
- National Bathymetric source data
- HRRR (full period of record)
- National Water Model (NWM: GRIB2; ZARR format)
- National Blend of Models (NBM)
- National Digital Forecast Database (NDFD)
- Rapid Refresh (RAP)

Software development

- NIFI Process to generate WMO headers and archive the National Digital Forecast Database (NDFD) GRIB data.
- NDFD data conversion to Cloud Optimized GeoTIFF format.
- Parallel processing approaches to move data to and between clouds.
- Automated information extraction from the CLASS database utilizing their public website

Presentations

- Brannock, J., 2020: BDP Dashboard. Virtual. *NOAA Environmental Data Management Committee Meeting*, October, 14, 2020.

Strategic Engagement and Outreach for the Big Data Program	
Task Leader	Jenny Dissen
Task Code	NC-ASD-02-NCICS-JD

Highlight: CISESS NC supported NOAA Big Data Program (BDP) engagement efforts with internal NOAA line offices, external cloud partners, and BDP partners focused on the data transfer process, which datasets to make available, cloud user engagement strategies, targeted GOES-R dataset informational user webinars and blogs, and the development of high-level data access monitoring dashboards and metrics.

Background

NOAA's Big Data Program (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. BDP works with three Cloud Service Providers (CSPs)—Amazon Web Services, Google Cloud and Microsoft–to provide access to NOAA data via their respective public cloud platforms. While the general public and broader user community have historically been challenged with access to and understanding of environmental data, a continuing reciprocal challenge for NOAA is in understanding user needs and applications. While NOAA's shift to cloud-enabled access helps address the broader access issue, it adds complexity to user engagement and outreach efforts including ethical and legal considerations and/or requirements. User statistics can also be skewed given the machine-to-machine communication and processing.

CISESS NC and predecessor cooperative institute, the Cooperative Institute for Climate and Satellites (CICS-NC) have supported NCEI user engagement efforts for the past ten years. CISESS NC now supports BDP user engagement efforts promoting dynamic iterative and innovative approaches to help NOAA to gain value for its data. Activities include 1) user interaction and use-case stories collaborating with cloud partners; 2) experimenting with modern and dynamic engagement modes that reach cloud users; 3) summaries, stories and blogs discussing how an end user may gain value in their decision-context due to cloud-enabled access; and 4) support to NOAA line offices with user engagement value as their data is accessed via the Cloud.

CISESS NC also works closely with the BDP partner cloud service providers (CSPs) to understand their goals and efforts in connecting with end users, and where and how to build the bridge between NOAA data and the socioeconomic sectors that reach end users. These iterative interactions between NOAA, CSPs, and end users have provided early findings that have helped NOAA and BDP note the value proposition of enabling cloud-based access and analysis. This early feedback has further developed internal NOAA user engagement support for line office interactions.

Accomplishments

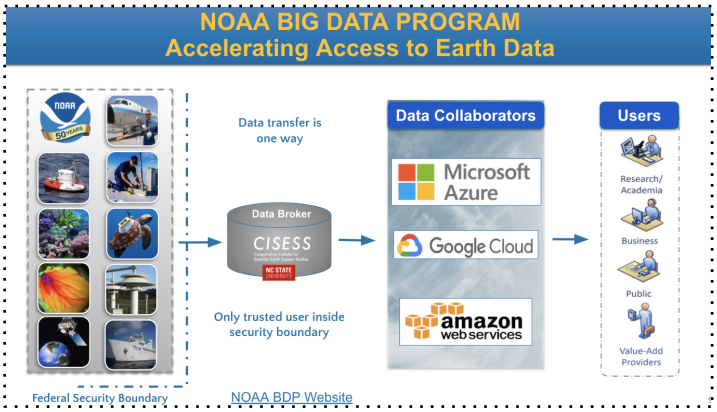
CISESS BDP engagement activities over the past year

- Provided advisory and program management support to NOAA's Big Data Program in internal line office user engagement, external cloud partners, and BDP partners.
- Advanced targeted user connections for use-case stories, as well as broad portrayal of BDP program to reach under-served and/or diverse user groups.

The NOAA Big Data Program provides public access to NOAA and NCEI environmental data on commercial cloud platforms through public-private partnerships with CSPs. CISESS NC BDP engagement support activities include engagement with internal NOAA line offices, with CSPs, and ultimately activities that

engage with end users. The past year's activities also included the development of high-level monitoring dashboards and metrics to support NOAA line offices' understanding of data usage and user access.

CISESS NC engagement support efforts include identifying high-interest datasets to transition to the Cloud, involving data and program overviews, process, value, technical aspects of data transfer, access, analytics, and service to the internal line office. CISESS NC leads engagement activities with the NOAA NESDIS GOES-R datasets, supporting data egress, GOES data analytics via Kibana software, and designing strategic user engagement perspectives for the data, including creating user webinars and developing blogs and other social media information to improve user understanding.



Working with the NOAA BDP team, CISESS NC provides engagement support in cloud partner interactions regarding selection of which NOAA datasets to make available. This entails providing information and data product background via informational sessions and discussions on potential use and application of the data. CISESS NC arranges information-exchange sessions with NOAA data experts and cloud partners, which is then extended to user community forums that use the Cloud.

Blogs, tutorials, user workshops, conferences, informational sessions, and webinars are designed to reach both internal federal and external private-sector user communities.

Planned work

- Continue building NOAA Big Data Program engagement activities, including:
  - NOAA line office engagement and awareness,
  - GOES-R interactions, planning for 3 webinars on GOES-R datasets with each CSP,
  - AWS, Google, and Microsoft interactions to develop ways to reach users and describe user stories,
  - Develop program-level methodology for communication and engagement with the general public and internal NOAA.

Presentations

Dissen, J., 2020: NOAA Big Data Program overview and case study. Virtual. *IEEE Workshop on Interconnections of Renewables & Energy Storage to Electric Grids,* December 4, 2020.

Dissen, J., 2020: Artificial Intelligence for Environmental Sustainability. Panel Discussion. Virtual. *Microsoft Federal Research Virtual Summit*, October 20, 2020.

Kent, J., J. O'Neil, A. Simonson, P. Keown, P., **J. Dissen**, **O. Brown**, and **J. Brannock**, 2021: NOAA Big Data Program. Virtual. *Coastal Coupling Community of Practice Webinar*. February 22, 2021.

Keown, P., J. O'Neil, A. Simonson, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Data In The Cloud: What's Next? Virtual. *2020 Environmental Data Management Workshop*, August 21, 2020.

Kunkel, K., and **J. Dissen**, 2020: EPRI Climate Impacts. Virtual. Climate Data for Electric Companies. *Environmental Power Research Institute (EPRI)*, December 3, 2020.

O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Big Data Program - Advancing Environmental Sustainability. Virtual. *Microsoft Federal Research Virtual Summit*, October 20, 2020.

O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Big Data Program --- Transforming Access to NOAA Data. iPoster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting*, December 16, 2020.

O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Big Data Program --- Transforming Access to NOAA Data. Virtual. *IEEE Workshop on Interconnections of Renewables & Energy Storage to Electric Grids*, December 4, 2020.

O'Neil, J., **J. Dissen,** A. Privette, J. Oyler, M. Tribble, V. Lakshmanan, B. Nuno, A. Simonson, P. Keown, J. Kent, **O. Brown,** and **J. Brannock**, 2021: NOAA Big Data Program. Virtual. *2021 AMS Annual Meeting*, January 12, 2021.

O'Neil, J., J. Kent, and **J. Dissen**, 2021: NOAA Big Data Program Overview. Focus Forward: Beyond the Cloud. Virtual. *West Virginia Public Education Collaborative*, March 17, 2021.

O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: Strategies for Advancing Access and End User Interactions of NOAA Data in Collaboration with Cloud Service Providers. Panel Discussion. Virtual. *2020 Environmental Data Management Workshop*, August 26, 2020.

Simonson, A., and **J. Dissen**, 2021: In Focus - The Road Ahead. Panel. Virtual. Climate Risk Summit: North America 2021: Measuring, managing and mitigating the threat from climate change. *The Economist*, March 15-18, 2021.

Other

- Building collaboration and partnership with ESIP and Pangeo activities
- Support NOAA ESIP AWS sandbox environment access for NOAA research projects

Development and Support of NOAA Climate Products and Services

Task Leader Karin Rogers

Task Code NC-ASD-03-UNCA-KR

Highlight: UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with managing the U.S. Climate Resilience Toolkit, maintaining Climate Explorer 3, designing an author "sandbox" for the National Climate Assessment, updating USGCRP Indicators graphics, and redesigning NIDIS drought.gov. This effort provides support for the overall advancement of NOAA's Climate Products and Services activities.

Background

NOAA 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 a continuing need for expertise and resources to support the 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, community engagement, outreach, and environmental science to address NOAA's 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)/Climate Explorer (CE): Project staff worked with CPO staff in the continuing CRT and CE development and/or enhancement and editorial/content management.

- Author team coordination and development of new regional sections of the CRT website for the Southeast, Northern Great Plains, and U.S. Caribbean regions
- CRT site content updates, including four new case studies (total of 156) and 36 new tools (total of 471)
- Editorial team meetings and management of public inquiries via the CRT email address
- Final delivery of white paper assessing the economic impact of NOAA's investment in the CRT
- Collaborated in the design of, and conducted usability and user research with, a prototype for a new training module based on training videos from the Water Utility Climate Alliance (WUCA)
- Developed new content types in the CRT's dev environment for the new training module
- Developed content for the new training module based on WUCA content
- Minor bug fixes and adjustments to Climate Explorer

- Stakeholder engagement, including collaborative work on the interoperability of content with Georgetown Climate Center and EcoAdapt and participation with the engagement team on the Chicago Regional Climate Action Plan
- Completed analysis report for CPO, *The Economic Impact of the U.S. Climate Resilience Toolkit: A Case Study Approach.*

National Climate Assessment (NCA): The project team worked with CISESS NC and the Assessment Technical Support Unit (TSU) to develop an NCA sandbox prototype.

- Redesigned the sandbox prototype after feedback from the TSU
- Initial development of the sandbox tool with a focus on streamlining the interaction between authors and the TSU. Work included:
    - Bar and line graphs that display precipitation and temperature thresholds
    - Enable users to switch the bar and line between yearly averages and time-period averages, and moving averages
    - Downloads for CSV, PNG, and SVG
    - Ability to choose regions: national, NCA region, state
    - Ability to send created figure settings to TSU for final figure
    - Ability to embed figure settings as an interactive figure in website

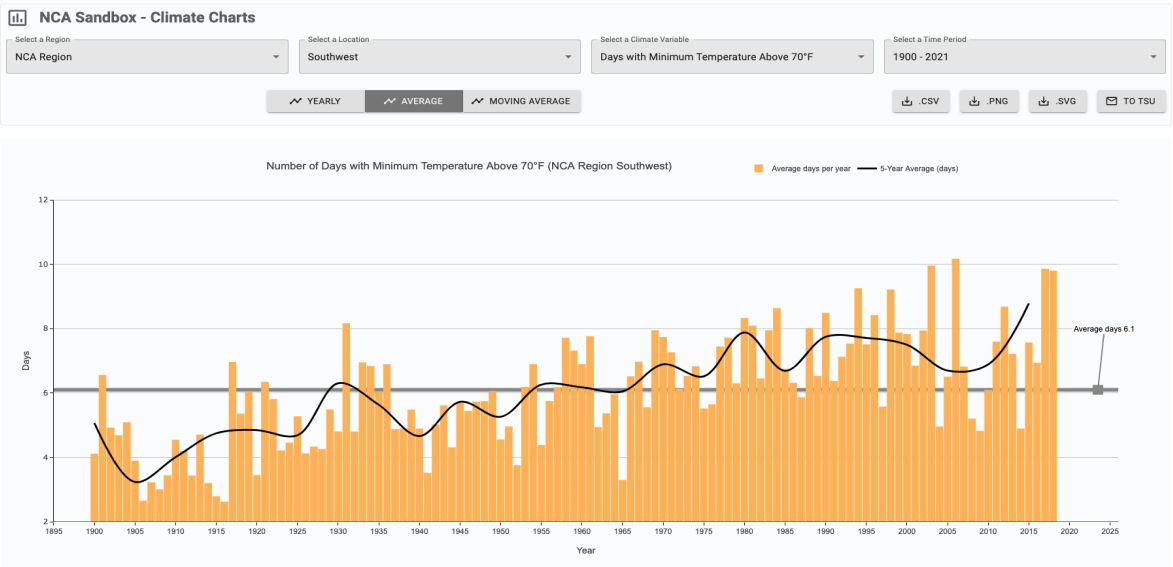


Figure 1. *The sandbox as of 03/01/2021.*

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

- Billion Dollar Disasters
- Frost-Free Season
- Global Monthly Average Carbon Dioxide Concentration
- Annual Greenhouse Gas Index
- Annual Sea Surface Temperature (2019 data update)
- Annual Start of Spring (2019 data update)
- Average September Arctic Sea Ice Extent (Figure 2)
- Annual Global Surface Temperature Change for Land and Ocean (2019 data update)

- Ocean Chlorophyll Concentrations
- Terrestrial Carbon Storage
- U.S. Surface Temperatures (2019 data update)
- Marine Species Distribution
- Global Monthly Average Atmospheric Carbon Dioxide
- Heating and Cooling Degree Days (2019 data update)

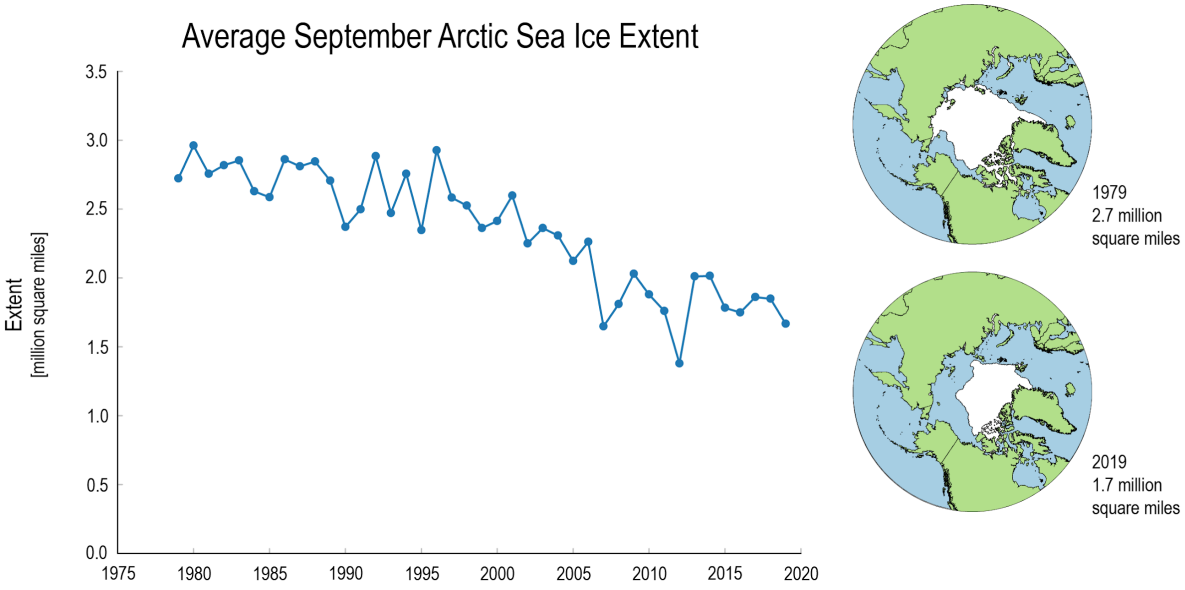


Figure 2. *Figure for the Average September Arctic Sea Ice Extent Indicator.*

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

- Performed six rounds of usability and user research on various parts of the new drought.gov website, including Current Conditions, Historical Conditions, Local pages, By Sector pages, mobile menus, News, and Events
- Performed tree-jack study to identify optimal location for soil moisture data
- Participated in weekly calls to understand future user testing needs
- Load-tested new Drought.gov production site before launch to ensure that the site could handle a large number of users
- Created user profiles based on user research to guide future Drought.gov needs
- Reviewed, developed, edited, and cross-linked content for new website

Planned work

- Site maintenance and content development/management for the CRT website
- Continue development and deployment of the new training module for the CRT website
- Updates and improvements to Climate Explorer v3, as needed
- Climate Portal and CRT stakeholder engagement
- Continue development and user testing of the NCA sandbox tool
- Continue usability testing of the new NIDIS drought.gov website
- Continue graphics support for the NCA Indicators team

Products

- U.S. Climate Resilience Toolkit (https://toolkit.climate.gov) enhancements

    - 3 new regional sections
    - 4 new case studies
    - 36 new tools
- USGCRP Indicator graphics (http://www.globalchange.gov/browse/indicators) updates
    - Graphics updated for 14 Indicators
    - Data updates for 5 Indicators
- U.S. Drought Portal (https://drought.gov) redesign

Presentations

Rogers, K., 2020: Community Resilience Solutions. Virtual. *American Society of Adaptation Professionals / Civic Spark*, May 28, 2020.

Other

Four UNC Asheville undergraduate students were mentored in writing/editing internships for the CRT and/or NIDIS and one undergraduate student was mentored in usability.

Scientific Data Stewardship for Digital Environmental Data Products	
Task Leader	Ge Peng
Task Code	NC-ASD-04-NCICS-GP

Highlight: A version of the World Meteorological Organization (WMO) Stewardship Maturity Matrix for Climate Data (SMM-CD), adapted from the NCEI Data Stewardship Maturity Matrix (DSMM), for National and Regional Purposes (SMM-CD_NRP) was baselined by the WMO Expert Team on Data Development and Stewardship (ET-DDS). A paper was published on the SMM-CD and CMM-CD_NRP with use cases of global and regional datasets.

Background

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

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

Data stewardship begins with preservation and includes documenting data sources and quality-control procedures for data product traceability, lineage, and provenance. Any improvement process requires knowledge of the current stage as well as what needs to be done to improve to the next stage. To address this need, NCEI and predecessor cooperative institute scientists and subject matter experts jointly developed a unified framework for measuring stewardship practices for a specific dataset. In collaboration with the NOAA OneStop program, NCEI's Data Stewardship Division, and NCEI's Center for Weather and Climate, the Data Stewardship Maturity Matrix (DSMM) has been applied to over 800 individual datasets to assess the quality of stewardship practices applied to digital environmental datasets, with the goal of providing consistent information, such as the state of data integrity and usability, to users and stakeholders. The DSMM has garnered international attention, with the Committee on Earth Observation Satellites' Working Group on Information System and Services Data Stewardship Interest Group adapting the DSMM for global use in 2017 and the WMO Commission for Climatology, now a part of WWMO Services Commission, adapting the DSMM for global and regional datasets since 2019.

Accomplishments

The WMO Stewardship Maturity Matrix for Climate Data (SMM-CD), an adaptation of the DSMM, is one of the three building blocks of WMO High Quality Global Data Management Framework for Climate (HQ-GDMFC). A version of SMM-CD for National and Regional Purposes (SMM-CD_NRP) was baselined by the WMO Expert Team on Data Development and Stewardship (ET-DDS). A peer-reviewed paper on both SMM-CD and SMM-CD_NRP along with use cases of global and regional datasets was published by Data Science Journal (Dunn et al., 2021).

Additionally, a virtual international workshop was organized by the Earth Science Information Partners (ESIP) Information Quality Cluster co-chair to explore the needs, challenges, and impacts of sharing quality information about individual datasets, with a workshop summary report (Peng et al., 2020a) and a call-to-action statement paper submitted to an open access journal (Peng et al., 2020b).

Planned work

- Lead an international effort to develop community guidelines for sharing dataset quality information.
- Support WMO as a member of the Expert Team on Data Requirements for Climate of Services Commission and as co-chair of the Expert Team on Information Management of Infrastructure Commission.
- Engage stakeholders and the Earth science community by participating in national and international data stewardship working groups and attending relevant conferences.

Publications

Carlson, D., K. Elger, **G. Peng**, J. Wagner, and J. Klump, 2020: Promoting Global Sharing of Earth System Science Data Through Free and Open Access Data Publication. *Open Science Framework*. https://osf.io/cq9rz

Dunn, R., Lief, C., **Peng, G.**, Wright, W., Baddour, O., Donat, M., Dubuisson, B., Legeais, J.-F., Siegmund, P., Silveira, R., Wang, X.L. and Ziese, M., 2021. Stewardship Maturity Assessment Tools for Modernization of Climate Data Management. *Data Science Journal*, 20(1), p.7. DOI: http://doi.org/10.5334/dsj-2021-007

IOC/IODE Inter-sessional Working Group, 2020: First interim progress report of the IOC/IODE Inter-sessional Working Group to propose a Strategy on Ocean Data and Information Stewardship for the UN Ocean Decade (IWG- SODIS) Paris: UNESCO, 19pp. 2020. (Reports of Meetings of Experts and Equivalent Bodies, International Oceanographic Commission, 2020). Version: 23 July 2020.

Peng, G., C. Lacagnina, R. R. Downs, I. Ivanova, D. F. Moroni, H. Ramapriyan, Y. Wei, and G. Larnicol, 2020a: Laying the Groundwork for Developing International Community Guidelines to Effectively Share and Reuse Digital Data Quality Information – Case Statement, Workshop Summary Report, and Path Forward. *Open Science Framework,* https://doi.org/10.31219/osf.io/75b92

Presentations

Buttigieg, L., ..., **G. Peng**, et al, 2020: Towards a Strategy on Ocean Data and Information Stewardship for the UN Decade of Ocean Science for Sustainable Development. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 17, 2020.

Carlson, D., K. Elger, J. Klump, **G. Peng**, J. Wagner, 2020: Practical data sharing with tangible rewards through publication in ESSD. Virtual. *EGU General Assembly 2020*, May 4, 2020. https://doi.org/10.5194/egusphere-egu2020-4169

Elger, K., D. J. Carlson, P. A. Fox, A. L. Hufton, J. Klump, and **G. Peng ,**2020: What do I need to know about data journals? Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 4, 2020. http://doi.org/10.5281/zenodo.4439349

Hammer, G., **G. Peng,** J. Fulford, T**. Maycock**, A. Anderson, T. Foreman, 2020: In Real Life: How Social Media Propelled One Study. Virtual*. 2020 NOAA Environmental Data Workshop*, August 21, 2020.

Lief, C., **G. Peng**, O. Baddour, W. Bright, and D. Stuber, 2020: WMO High Quality Global Data Management Framework for Climate (HQ-GDMFC) - A Collaborative Framework for Improving Data Access and Quality. Virtual. *WMO Data Conference*. Nov 18, 2020.

Moroni, D., H. Ramapriyan, B. Downs, **G. Peng**, and Y. Wei, 2020: Exploring new perspective and formulating best practices for data uncertainty information - Part 1 and 2. Virtual. *2020 ESIP Summer Meeting*. July 15, 2020.

Peng, G., 2020: ESIP IQC/BSC Pre-ESIP Workshop Report Out. Lightning Presentation. Virtual. *ESIP 2020 Summer Meeting Highlights Webinar*, August 13, 2020.

Peng, G., 2020: Evaluating the FAIRness of Environmental Data. Virtual. *9th RDA FAIR Data Maturity Model Working Group Workshop*, May 20, 2020.

Peng, G., 2020: Fun facts and preliminary results from the pre-ESIP Workshop. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.

Peng, G., and **S. M. Champion**, 2020: Towards Developing Community Guidelines for Sharing and Reuse of Digital Data Quality Information. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 8, 2020.

Peng, G., A. Milan, N. Ritchey, et al, 2020: Providing Structured and Rich Dataset Quality Information. Poster. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 18, 2020.

Peng, G., C. Lacagnina, R. Downs, I. Ivánová, G. Larnicol, D. Moroni, H. Ramapriyan, and Y. Wei, 2020: Challenges of Consistently Curating and Representing FAIR Dataset Quality Information - IQC/BSC Pre-ESIP Workshop Report Out. Virtual. *2020 ESIP Summer Meeting*, July 22, 2020.

Peng, G., C. Lacagnina, R. Downs, I. Ivánová, G. Larnicol, D. Moroni, H. Ramapriyan, and Y. Wei, 2020: Developing Community Guidelines for Consistently Curating and Representing Dataset Quality Information. Virtual*. Pre-2020 ESIP Summer Meeting Workshop*. July 13, 2020.

Peng, G., H. Ramapriyan, and D. Moroni, 2020: ESIP Information Quality Cluster and Multi-dimensions of data and information quality. Session. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.

Peng, G., J. Privette, S. Hausman, E. Kearns, **O. Brown**, and **T. Maycock**, 2020: An Integrated Framework for Supporting Evidence-Based Institutional Research Data Management and Stewardship. Poster. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 19, 2020.

Wei, Y., Ramapriyan, H., R. Downs, D. Moroni, **G. Peng**, G. Newman, and A. Bower, 2020: Citizen Science Data and Information Quality. Virtual. *2020 ESIP Summer Meeting*, July 22, 2020.

Wright, W., C. Lief, **G. Peng**, O. Baddour, P. Siegmund, D. Berod, R. Dunn, A. Cazenave, and M. Brunet, 2020: High-Quality Global Data Management Framework for Climate: A Collaboration Framework for Assessing, Validating and Sharing Datasets for Climate Monitoring. Virtual. *EGU General Assembly 2020*, May 5, 2020. https://doi.org/10.5194/egusphere-egu2020-22552

References

WMO-No.1238, 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, continues 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 continues 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 Team	Kenneth Kunkel (Lead), Sarah Champion, Linda Copley, Katharine Johnson, Angel Li, Laura Stevens, Scott Stevens, Liqiang Sun
Task Code	NC-AA-01-NCICS-KK/et al

Highlight: The Assessment science/data team completed development of the Assessment Collaboration Environment (ACE) version 1.0. A comprehensive update of the NOAA State Climate Summaries was initiated and preliminary planning for the Fifth National Climate Assessment with the USGCRP National Coordination Office continues.

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), two Support Scientists (Laura Stevens and Scott Stevens), Data Lead (Sarah Champion), Web Developer/GIS Specialist (Katharine Johnson), Web Developer (Angel Li), and a Software Engineer (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

Assessment Collaboration Environment (ACE): In an ongoing effort to comply with the EBPA and IQA, and as part of the sustained assessment process, work was finalized on design and capability improvements to the content management system. Improvements include a migration from a dual software platform to a single software platform, a complete user interface upgrade and redesign, smart implementation of connected user profiles and permissions to streamline documentation records, a suite of author guidance modeled after Wiki templates, a library for technical inputs and project materials, and a complete redesign of the metadata survey. The Assessment Collaboration Environment (ACE) version 1.0 was successfully deployed to the Cloud, culminating nearly two full years of careful development and implementation of requirements from both the TSU and the USGCRP NCA staff. Team staff continued a collaboration with NOAA General Counsel and the NOAA/Department of Commerce Chief Data Officer on EBPA and IQA applications to the NCA enterprise, to include legally sound documentation on intellectual property and

copyright permission for author contributions of text, figures, computer code, and data. Work will continue on the ACE collaborative system to improve project management, reporting, dataset library records, past project data migration, content syncing into the Global Change Information System (GCIS), and the development and redesign of a new metadata viewer in support of both the 2020 update to NOAA's State Climate Summaries and the Fifth National Climate Assessment (NCA5).

Fifth National Climate Assessment (NCA5): The science and data team continued NCA5 planning, including numerous virtual meetings with the USGCRP National Coordination Office staff.

State Climate Summaries: Work commenced on a comprehensive update of "NOAA's State Climate Summaries for the United States." Each state summary is 4 pages in length and summarizes historical climate trends as well as projections of temperature and precipitation. The TSU science team completed data analyses for all 50 states, plus Puerto Rico and the U.S. Virgin Islands, including the use of temperature and precipitation data from NOAA's Climate Divisional Database (nClimDiv) and Global Historical Climatology Network (GHCN). More than 350 core figures and more than 1,000 supplemental figures have been updated with data through 2020. The project also includes extensive writing, editing, graphics development, metadata, web development, and informal/formal review.

Data Sandbox: In support of the open data initiative of the EBPA, the TSU also explored development of a Data Sandbox. This tool is meant, in part, to assist NCA authors with exploring the visualization of NCA and other climate data and parameters as part of figure development, but will also eventually serve a broad user community. This tool is still in development and is a collaborative effort with the National Environmental Modeling and Analysis Center (NEMAC), with an anticipated deployment in time for NCA5 author use.

Extremes Research: Research on extreme precipitation events found a very strong correlation between the magnitude of the events and the amount of atmospheric water vapor. Because future increases in water vapor if greenhouse gas concentrations continue to rise is one of the most confident projections associated with global warming, this provides a firm foundation for incorporating climate considerations into rainfall design values. The research also found that historical upward trends in extreme precipitation occur over a wide range of event duration and recurrence intervals.

Planned work

- Initiation of CMIP6 climate model data analysis, in anticipation of NCA5.
- Continued updates of the NOAA State Climate Summaries for 2021 release.
- Update of the project management and content syncing features in the TSU collaborative system.
- Improvement of capabilities to provide access to NCA data, including GIS formats, standardized color palettes, and mapping standards.
- Completion of the TSU Data Sandbox tool.
- New TSU Metadata Viewer.
- Assembly of North Carolina Climate Science Report (NCCSR) figure metadata and other data to meet federal Information Quality Act standards and creation of a website for dissemination and an improved metadata viewer.

Products

- Assessment Collaboration Environment (ACE) v1.0 and v1.1

Publications

Dello, K., W. Robinson, **K. Kunkel**, **J. Dissen**, and **T. Maycock**, 2020: A hotter, wetter, and more humid North Carolina. *North Carolina Medical Journal*, **81,** 307. http://dx.doi.org/10.18043/ncm.81.5.307

Dong, Q., W. Wang, **K. E. Kunkel**, Q. Shao, W. Xing, and J. Wei, 2020: Heterogeneous response of global precipitation concentration to global warming. *International Journal of Climatology*. http://dx.doi.org/10.1002/joc.6851

Presentations

Champion, S. M., 2020: Information Quality and the National Climate Assessment. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.

Champion, S. M., 2020: Information Quality and the NCA. Virtual. *Fifth National Climate Assessment (NCA5) Federal Steering Committee* meeting, June 23, 2020.

Champion, S. M., 2020: Let Them Eat Cake: An Untraditional Guide to Navigating the National Climate Assessment Data Marketplace. Virtual. 6th Annual Climate Adaptive Design Symposium. *American Institute of Architects and CASE Consultants International*, November 6, 2020.

Champion, S. M., 2020: Quality Climate Data for All: How the National Climate Assessment Connects Users to Actionable Climate Information. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 17, 2020.

Johnson, K. M., **S. M. Champion**, **L. B. Copley**, **A. Li**, **L. E. Stevens**, **K. E. Kunkel**, and **J. Allen**, 2020: From Data to Decisions: Use of NOAA Datasets in the Fourth National Climate Assessment. *2020 NOAA Environmental Data Management Workshop*, Virtual, August 20, 2020.

Kunkel, K. E., 2020: Climate Scenarios and their Use in Decision-making. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.

Kunkel, K. E., 2020: Climate Science. Virtual. Illinois Climate Assessment author team meeting. *The Nature Conservancy*, April 10, 2020.

Kunkel, K. E., 2020: Hurricane Florence: Is that our Future? Virtual. *North Carolina Cooperative Extension Webinar*, October 20, 2020.

Kunkel, K. E., 2020: North Carolina Climate Science Report. Virtual. *2020 Appalachian Clean Energy CLE workshop*, August 28, 2020.

Kunkel, K. E., 2020: North Carolina Climate Science Report. Virtual. *Southeast Climate Monthly Webinar,* April 14, 2020.

Kunkel, K. E., 2020: North Carolina Climate Science Report: An Overview of Climate Change in North Carolina. Virtual. *North Carolina Cooperative Extension Webinar*, September 3, 2020.

Kunkel, K. E., 2020: North Carolina Climate Science Report: An Overview of Climate Change in North Carolina. Virtual. *North Carolina Corn Growers Association* board meeting, November 5, 2020.

Kunkel, K. E., 2020: Our Rapidly Changing Climate. Virtual. Osher Lifelong Learning Institute class, *North Carolina State University*, October 6, 2020.

Kunkel, K. E., 2020: Probabilities of Extreme Climate Events. Virtual. *Quantitative Analysis of Climate Change Science class, NC State University*, August 18, 2020.

Kunkel, K.E., 2020: The Future Climate of the Southeast U.S. - Uncharted Waters, invited presentation, *45th A&WMA Information Exchange Conference*, December 9, 2020.

Kunkel, K. E., and D. R. Easterling, 2020: Science Needs of the Fifth National Climate Assessment. Virtual. *NOAA Climate Program Office CMIP6 Task Force*, April 21, 2020.

Kunkel, K. E., and **J. Dissen**, 2020: EPRI Climate Impacts. Virtual. Climate Data for Electric Companies. *Environmental Power Research Institute (EPRI)*, December 3, 2020.

Sun, L., 2020: Future Changes of Tropical and Extratropical Cyclones. Virtual. Regional Climate and Climate Impacts class, *Columbia University*, September 22, 2020.

Sun, L., **K. E. Kunkel**, D. R. Easterling, et al, 2021: Dynamical Downscaling Projections of Landfalling Tropical Cyclone Activity over the United States: CMIP5/RCP4.5 Scenarios. Virtual. *2021 AMS Annual Meeting*, January 15, 2021.

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 is a NOAA online, open source tool which provides offers customizable graphs, maps, and data downloads of observed and projected climate variables for every county in the United States.

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

Highlight: The Assessment technical support team successfully deployed the Assessment Collaboration Environment (ACE) version 1.0 to the Cloud. The North Carolina Climate Science Report (NCCSR) was updated with improved accessibility for users with visual limitations. The team began preparation and planning for the Fifth National Climate Assessment (NCA5).

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 NC and NCEI management as well as USGCRP management and staff with project planning and coordination, including development of the overarching NCA project timeline. They also help develop guidance documents that serve as foundational guidelines for NCA authors.

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

The web team—Angel Li and Katharine Johnson, with support from 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) Accessibility Update

The TSU editorial team led an effort to enhance the accessibility of the NCCSR, particularly for users with visual limitations. The two main accomplishments were developing alternative text descriptions for all report figures and improving compatibility of the PDF with screen reader software. Alternative text is a brief yet comprehensive description of non-text content, such as graphs and photographs. The report

contained more than 120 figures, tables, and images requiring alternative text scripts. The editorial team wrote and reviewed all of the scripts for completeness, comprehensibility, and accuracy. Significant revisions were made to the structure of the PDF files to ensure that all of the text, figure captions, and alternative text descriptions of figures are processed in the proper order by screen readers. The updated report, which also include corrections to for figures, was released in September 2020. The full report, a shorter document with the Report Findings and Executive Summary, and a Plain-Language Summary are available at https://ncics.org/nccsr.

The NCCSR was also a key input for the 2020 North Carolina Climate Risk Assessment and Resilience Plan released in June 2020 by the North Carolina Department of Environmental Quality. The Report Findings and Executive Summary from NCCSR are presented in Chapter 3 of the resilience plan, and the full NCCSR is included as an appendix. In addition, several NCICS staff members served as technical experts and advisors for the resilience plan, which is available at: https://deq.nc.gov/energy-climate/climate-change/nc-climate-change-interagency-council/climate-change-clean-energy-17

Assessment Collaboration Environment (ACE) Website Deployment

The Web and Data teams successfully deployed versions 1.0 and 1.1 of the Assessment Collaboration Environment to an Amazon Web Services (AWS) cloud framework. The site supports major aspects of report development, including collaboration on report text, figure development and management, and collecting metadata for figures. The site will also provide functionality that was previously on other systems, including draft management and sharing, and the ability to filter and browse technical inputs submitted through Federal Register Notices (FRNs) and assessment staff. The site will also provide a resources library housing material from NCA5 and previous reports, and enabling users to search and filter documents and other resources that support the assessment process.

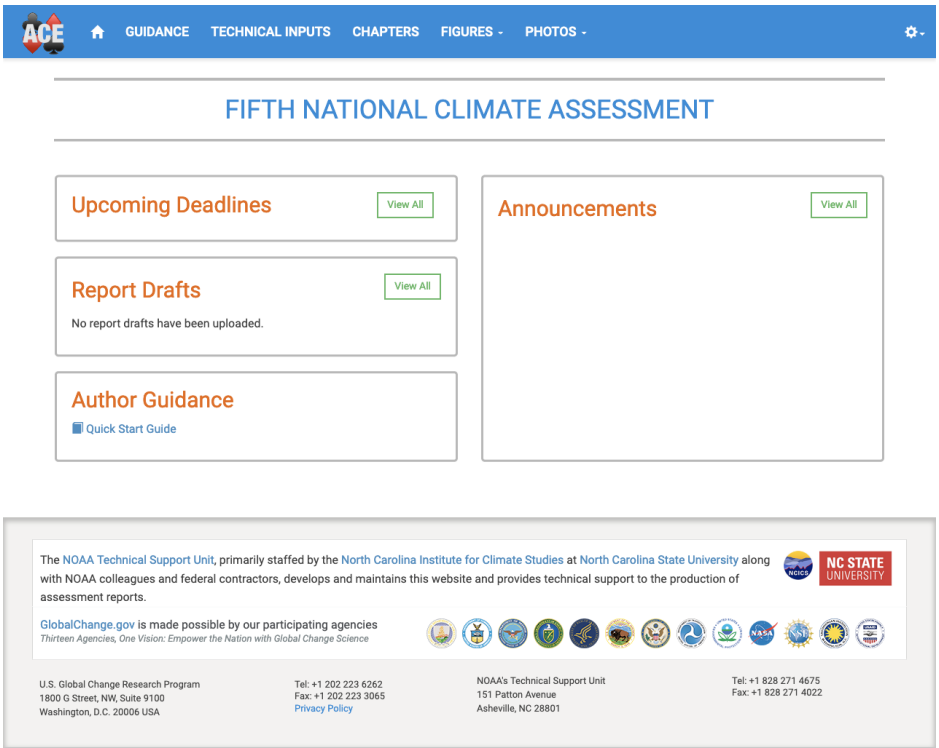


Figure 1. *The ACE website supports a broad range of collaborative activities related to producing climate assessment reports. Work continues on minor releases to improve certain aspects of the site.*

The Fifth National Climate Assessment (NCA5)

The TSU continues working with USGCRP on NCA5 planning. Members of the editorial team worked with USGCRP management to complete a detailed timeline defining the development of report content, as well as the review and production processes. Additionally, TSU members have advised on the structure of the report and attended multiple meetings focused on other aspects of NCA5 planning.

The editorial team, along with other TSU teams and USGCRP management, engaged in a major effort to create and revise guidance documents spanning dozens of topics for NCA5 authors. The team also implemented the guidance on the Assessment Collaboration Environment (ACE) website, providing authors with user-friendly, web-based guidance that will help them navigate and understand the overall NCA framework.

Members of the editorial, data/science, web, and graphics teams engaged in a major effort with USGCRP to train new chapter points of contact at the National Coordination Office (NCO) within USGCRP. TSU members helped develop the overall curriculum for the training sessions, created materials for, and led the training sessions on various topics, such as chapter components, writing guidance, visual communication, and information quality requirements. Editorial and data/science team members continue to engage on planning efforts for NCA5 author training sessions to be held in the fall.

State Climate Summaries

Work commenced on a comprehensive update of "NOAA's State Climate Summaries for the United States." Each state summary is 4 pages in length and summarizes historical climate trends as well as projections of temperature and precipitation for each state, plus Puerto Rico and the U.S. Virgin Islands. The project includes extensive scientific analyses, writing, editing, graphics development, metadata, web development, and informal/formal review. TSU staff also began coordination with experts at NOAA's six Regional Climate Centers (RCCs) for input and review of all 51 summaries. Jessicca Allen provided graphic design support services, including coordinating the workflow of the graphics and executing figure edits to two of the seven RCC regions containing ~200 graphics.

Products

- New Assessments Collaboration Environment website
- North Carolina Climate Science Report (NCCSR) accessibility updates

Presentations

Copley, L., and **T. Maycock**, 2020: Survey of Programs Related to Climate Science Fields at America's HBCUs. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting*. December 10, 2020.

Griffin, J., **L. E. Stevens**, and **S. M. Champion**, 2020: Using Teamwork as a Tool for Scientific Communication. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.

Maycock, T. K., **L. E. Stevens**, **K. M. Johnson**, **A. McCarrick**, **J. Allen**, S. Veasey, and **B. C. Stewart**, 2021: Making Climate Change Assessments Accessible. Virtual. *2021 AMS Annual Meeting,* January 13, 2021.

Stevens, L. E., **K. M. Johnson**, **T. K. Maycock**, **A. McCarrick**, **J. Allen**, S. Veasey, and **B. C. Stewart**, 2020: Accessibility Considerations in Climate Communication: Efforts and Lessons Learned from the Fourth National Climate Assessment. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 7, 2020.

Planned work

- Provide NCA5 project management, development of author training sessions, science communication, editorial support, and graphics development support.
- Provide user and technical support for NCA5 activities.
- Release NCA4 errata updates.
- Update the State Climate Summaries, including updated web content for 2021 release.
- Migrate data from all Drupal 6 project websites (NCA3, Climate and Health report, State Summaries v.1) into ACE and retire those sites. 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.
- Begin requirements gathering for the NCA5 website.

Climate Change Indicators	
Task Leader	Laura Stevens
Task Code	NC-CAA-03-NCICS-LS

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, the addition of a new indicator, and a highly successful indicators development workshop. http://www.globalchange.gov/indicators

Background

Indicators are observations or calculations that can be used to track conditions and trends. Indicators of climate change are designed to communicate key aspects of our changing environment, aid in assessing vulnerabilities, and inform decisions about policy, planning, and resource management. Such indicators provide foundational science in support of the sustained National Climate Assessment (NCA), including the upcoming Fifth National Climate Assessment (NCA5).

A set of climate change indicators is managed by the U.S. Global Change Research Program (USGCRP), a consortium of 13 federal agencies, including NOAA. The current suite of 17 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 Platform supports NCA reports and provides 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 and maintenance of the USGCRP Indicators effort.

CISESS and NCEI are working with the IndIWG to broker and administer the USGCRP Indicators set, based on the synergy with, and similarity to, the work of the Technical Support Unit (TSU). Laura Stevens (CISESS) and Jessica Blunden (NCEI) support 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 Indicators staff participate in monthly calls with the IndIWG and engage with partner agencies in order to foster the development of new indicators. Recent efforts focused on a comprehensive update of the full indicator suite and the addition of a new ecosystems-focused indicator. As part of the indicator update and development 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. New indicators currently in the planning stage include Tropical Cyclone Activity, Regional Sea Level/Coastal Flooding, and Bark Beetle Prevalence.

Twelve indicators were updated this year, including incorporation of the most up-to-date data, updated descriptions, and full metadata compilation. Comprehensive metadata are collected for each indicator in order to provide full transparency, traceability, and reproducibility, in line with NCA efforts to satisfy the Information Quality Act (IQA).

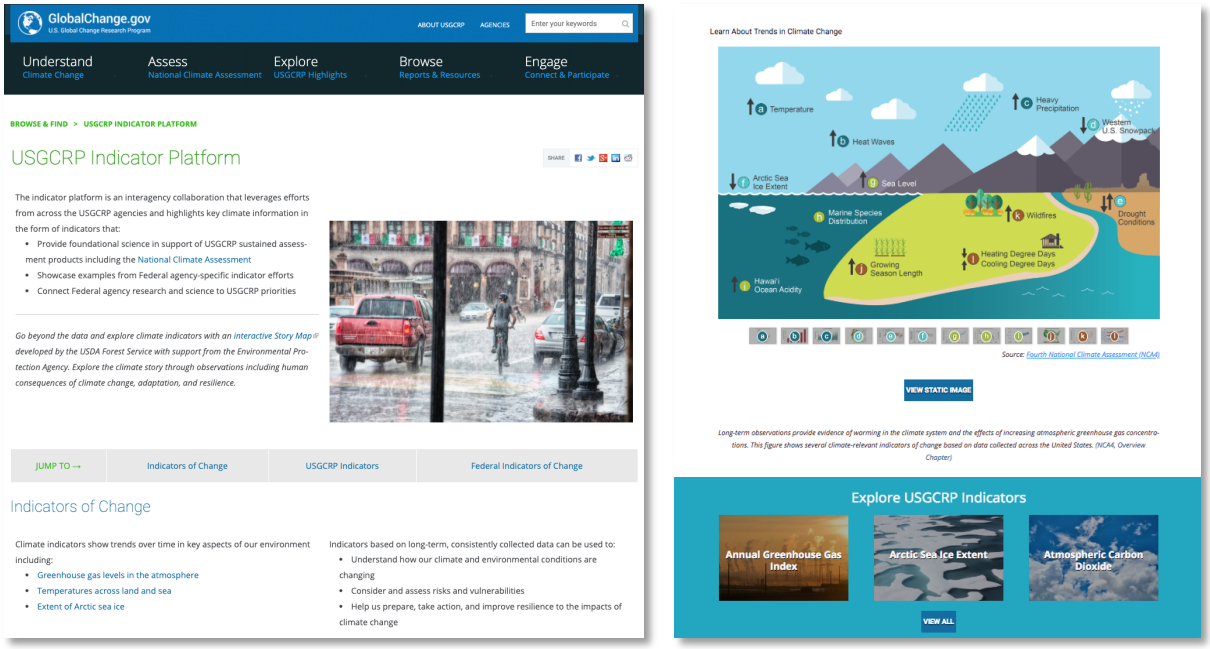


Figure 1. *The USGCRP Indicator Platform at* globalchange.gov/indicators.

A new indicator, Marine Species Distribution, was developed and added to the Platform. This indicator, a collaboration between the EPA and NOAA, depicts how U.S. coastal populations of fish, shellfish, and other marine species are shifting to cooler waters both along the northeastern U.S. coast and in the eastern Bering Sea (Figure 2). TSU Indicators staff helped facilitate the development of an expanded version of the indicator featuring additional regional data, which was the focus of a Climate.gov web story. TSU members also worked with the NCEI Communications and Outreach Branch to produce several social media posts highlighting USGCRP indicators, and support was provided for a Climate Change Indicators Story Map produced by the USDA Forest Service.

To foster the advancement of indicator research, the IndIWG facilitated a virtual "Indicators Development Workshop" in which U.S. Forest Service experts shared information on various datasets and potential climate indicators relevant to U.S. forest health and forest disturbances. This multi-part workshop was a prototype to help engender more complete participation and sectoral representation across USGCRP's 13 agencies, and to encourage, inspire, identify, advance, and prioritize work on climate-relevant indicators (particularly non-physical-climate indicators) in support of the USGCRP Indicator Platform. Much of the workshop format, materials, and details were developed by the TSU, with a goal of making this repeatable for other agencies soon.

Indicators are integral to the National Climate Assessment and an indicators appendix is currently being planned for NCA5 in order to more purposefully incorporate indicators into the report. Scientific and technical support will be provided by TSU members and the IndIWG as the chapter is developed.

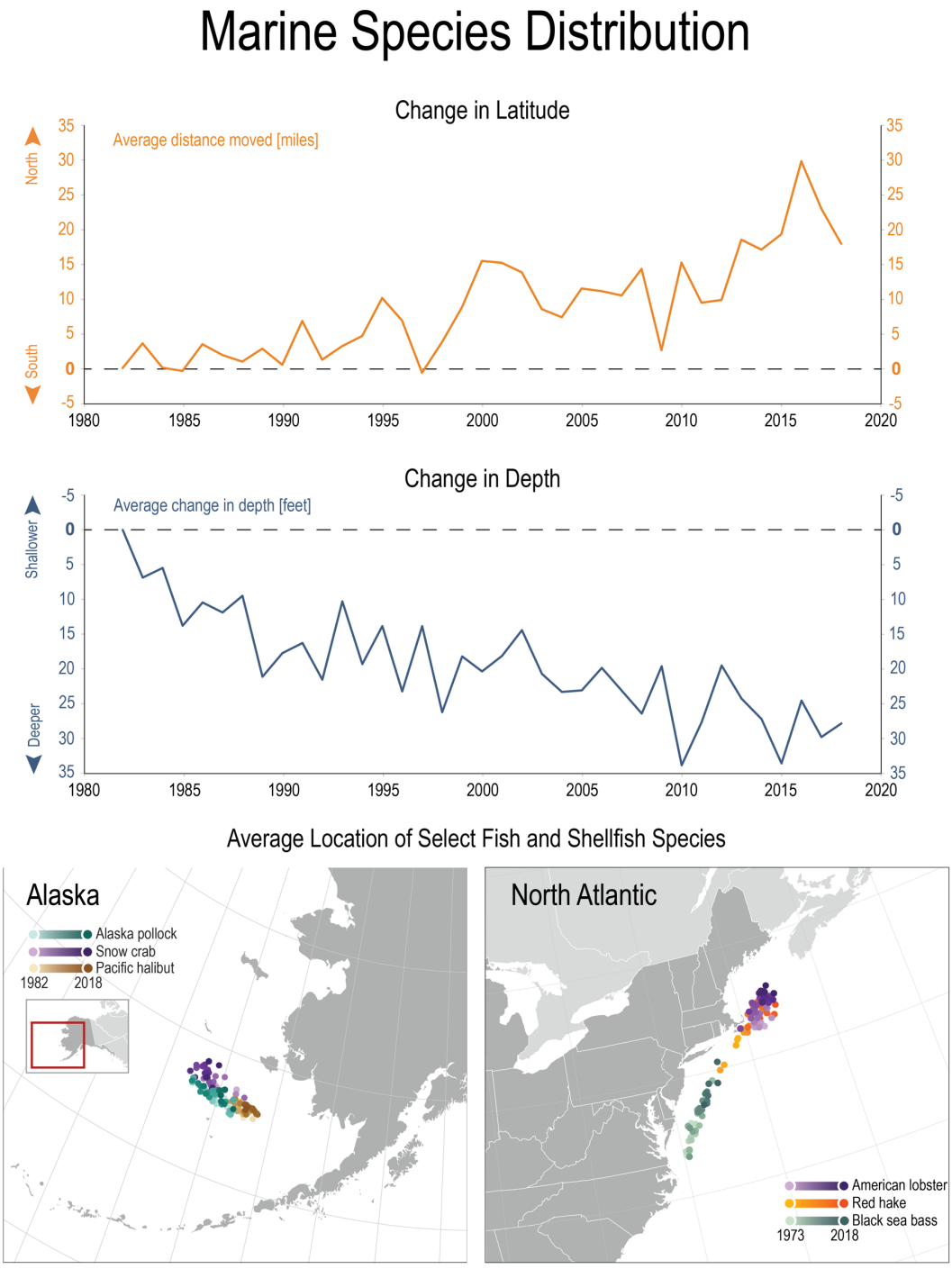


Figure 2. *The Marine Species Distribution indicator is the latest addition to the USGCRP Indicator Platform. Graphs show the annual change in latitude (orange line; movement in miles) and depth (blue line; depth change in feet) of 140 marine species along the northeastern U.S. coast and in the eastern Bering Sea. Maps show the annual centers of biomass for three species (Alaska pollock, snow crab, and Pacific halibut) in the eastern Bering Sea from 1982 to 2018 (left) and for three species (American lobster, red hake, and black sea bass) along the northeastern U.S. coast from 1973 to 2018 (right). See https://www.globalchange.gov/browse/indicators/marine-species-distribution for a full description of this indicator.*

Planned work

- Update current indicators annually.
- Develop 3–5 new indicators.
- Support an indicators appendix chapter for NCA5.
- Plan additional agency engagement workshops.

Presentations

Stevens, L. E., 2020: From Data to Indicator. Virtual. *USGCRP Forest Related Climate Indicators Development Workshop*, July 30, 2020.

Stevens, L. E. and D. S. Arndt, 2020: Advancing Indicator Science Through Agency Engagement. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.

Stevens, L. E., D. Arndt, J. Blunden, and D. R. Easterling, 2021: Cultivation, Management, and Value of Interagency Indicators. Poster. Virtual. *2021 AMS Annual Meeting*, January 15, 2021.

Products

- Twelve updated USGCRP Indicators: Annual Greenhouse Gas Index, Arctic Sea Ice Extent, Atmospheric Carbon Dioxide, Billion Dollar Disasters, Frost-Free Season, Global Surface Temperatures, Heating and Cooling Degree Days, Ocean Chlorophyll Concentrations, Sea Surface Temperatures, Start of Spring, Terrestrial Carbon Storage, U.S. Surface Temperatures
- One new USGCRP Indicator: Marine Species Distribution

U.S.–India Partnership for Climate Resilience Activities Support	
Task Leaders	Kenneth Kunkel, Jenny Dissen
Task Code	NC-CAA-04-NCICS-KK/JD

Highlight: CISESS NC addressed U.S.–India Partnership for Climate Resilience Phase II capacity-building activities with India-based partner The Energy and Resources Institute (TERI) in data analysis using modern downscaling methods and planning for a forestry focused workshop to train India forestry managers on future climate change impacts.

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.

NCEI and the Cooperative Institute for Climate and Satellites-North Carolina (CICS-NC, predecessor to CISESS) with their National Climate Assessment scientific and technical expertise and experience 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

Following last year's January 2020 activities, which involved a session, "Forest – A Tool for Adaptation and Mitigation of Climate Change," at TERI's 2020 World Sustainable Development Summit and a roundtable discussion, "Concept Note for Roundtable: Capacity building, technology and finances for achieving forestry sector NDCs in India," focused on forestry specific needs, the CISESS team began discussions with TERI to design and develop a targeted technical workshop for India-based forestry managers on understanding climate projections and their use in the State Action Planning for Climate Change as required by each state in India. The U.S. and India team discussed understanding of key indicators of forestry that would be relevant as the U.S. applies modern downscaling methods to India data for the State of Uttrakhand. Due to the global pandemic, the workshop was postponed and the team also discussed alternative formats for a series of webinars.

Over the past year, the bilateral US and India team collaborated on workshop / webinar planning activities, including:

- Understanding targeted goals and objectives for workshop (now webinar) discussions
- Identifying target audience, collaborating with India's Forestry Survey Institute forestry managers
- Gathering and conducting data analysis

- Developing a working draft of the workshop agenda, including development of Pre-workshop training and resources for participants

The table below notes key areas of progress made in webinar planning and discussions.

Goals/Objectives	Goals/Outcomes (Yogesh, TERI) - Provide hands-on technical training to forestry managers for use in management purposes, not just theoretical - Support the targeted audience during their forestry service period with the opportunity to generate the data and the importance to promote the data acquisition - Support the exposure, understanding and expertise in the intersection with SAPCC (forms of modeling, needs of modeling, and interpreting the results)
Target Audience	- Forestry Survey of India (proposed) - Forestry managers and leaders - State Action Planners
Virtual Webinar Logistics and Coordination	- Due to the on-going global pandemic, the in-person workshop is now being framed as a series of several webinars - Timing is to be finalized
Data Analysis	- TERI team provided gridded data for Uttarakhand - U.S. team to analyze and interpret results using empirical-statistical downscaled climate projections with a new Seasonal Trends and Analysis of Residuals Framework (STAR-ESDM) - U.S. team to conduct Generalized Extreme Value distribution analysis (GEV) with a time covariate for extreme precipitation analysis
Workshop Agenda	- Develop working draft of agenda by key session and topic areas - Develop virtual workshop format to align with agenda topics

Planned work

- Conduct data analysis per the aforementioned topic areas.
- Further progress concept note and workshop announcement based on data analysis outcomes.
- Continue collaboration with India-based partners on the webinar planning and coordination.

The Energy and Resources Institute Supporting the U.S.–India Partnership for Climate Resilience	
Task Leader:	Dr. Yogesh Gokhale
Task Code	NC-AA-05-TERI

Highlight: The Energy and Resources Institute (TERI), NCEI, and CISESS as part of the U.S.–India Partnership for Climate Resilience (PCR) Phase II activities are collaborating on plans for a technical training seminar (or webinars) for India-based forestry managers on understanding climate projections and their use in the State Action Planning for Climate Change as required by each state in India.

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

Following last year's January 2020 collaborative activities, TERI and CISESS team began discussions to design and develop a targeted technical workshop for India-based forestry managers on understanding climate projections and their use in the State Action Planning for Climate Change as required by each state in India. However, due to the on-going global pandemic, the workshop was initially postponed and then re-envisioned as a series of webinars. The past year was spent in workshop / webinar planning activities to identify goals and objectives, target audience, logistics, and topics for the sessions.

Planned work

- Continue training activity planning in collaboration with the CISESS team
- Contribute to execution of training activity in collaboration with CISESS team

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.

Global Historical Climatology Network-Daily (GHCNd) Graph Database	
Task Leader	Bjorn Brooks
Task Code	NC-ITS-01-NCICS-BB

Highlight: The objective of this project is to complete a cloud resident, graph structured database analog for GHCNd. Project progress was accomplished in three important ways this year: a new software repository was created, the database design was set, and an assessment of database performance through benchmarking trials was completed.

Background

The Global Historical Climatology Network-Daily (GHCNd) is a continually updated daily weather observation product that is assembled and standardized across more than 100,000 surface weather stations from more than a dozen different sensor networks. Each individual observation has been subjected to a common quality assurance methodology that vets the data to ensure that it is accurate and can be used as a climactically representative summary observation.

GHCNd's dataflow process consists of a custom research code base that is run on machines in-house. GHCNd contains over 3 billion weather observations. While the database is growing at a rate of about only 1% per year in data volume, the GHCNd processing platform is already facing challenges to its daily updating quality control process. Graph structured database technology is proposed as a solution because its native structure eliminates the need for several kinds of calculations and greatly enhances the speed with which other necessary calculations and station-to-station comparisons can be made. This project selected Neo4j as the graph database software choice, which is portable across commercial cloud vendors.

Updating the GHCNd code base to Neo4j's cypher language is a long-term deliverable, but has the advantage of substantially reducing the amount of code that needs to be maintained (by several multiples), and puts the code into an SQL-like format that is native to databases and very similar to easy to understand by database managers. This will make it easier for GHCNd to be supported by IT professionals in the future.

Accomplishments

The GHCNd graph database made progress in three important ways this year: a new software repository, the design of the database, and the assessment of database performance. These improvements were presented at a NOAA conference on environmental data management. They were also described in a brief technical letter that may be accepted as a blog post on the graph database software company's website.

A project repository was created on GitHub and currently serves as the software code archive and documentation archive for the GHCNd graph database. The code archive contains two main branches where revisions to cypher, Fortran, and BASH code are tracked. One branch is designed for generic Linux systems with Neo4j installed, and the second is optimized for Bitnami installations of Neo4j in the cloud.

Documentation for the GHCNd graph database is also archived and tracked with versioning in the same repository. Because the documentation, controlled by Doxygen, is drawn from the code, current and future users of GHCNd graph database will always have an exact guide to the system that they are using. Version control will also enable users to look back to any previous version in the case of any comparison analysis between versions.

The second progress milestone was the design of the graph database itself. The structure of the database is critical to performance and usage because graph databases draw much of their speed and efficiency from their flexible relationship-based structure. That is, the GHCNd data set was partitioned into a set of 4 different kinds of data groups. Each data group was related to one or more other data groups in a cascading framework of groups that accelerate data access and computational efficiency. The basic concept is that of a pathway from general to specific that excludes the maximal amount of irrelevant data from any query as early as possible in the query process. The figure below gives an illustration of this graph structure for GHCNd data, which is the central advantage that graph databases provide.

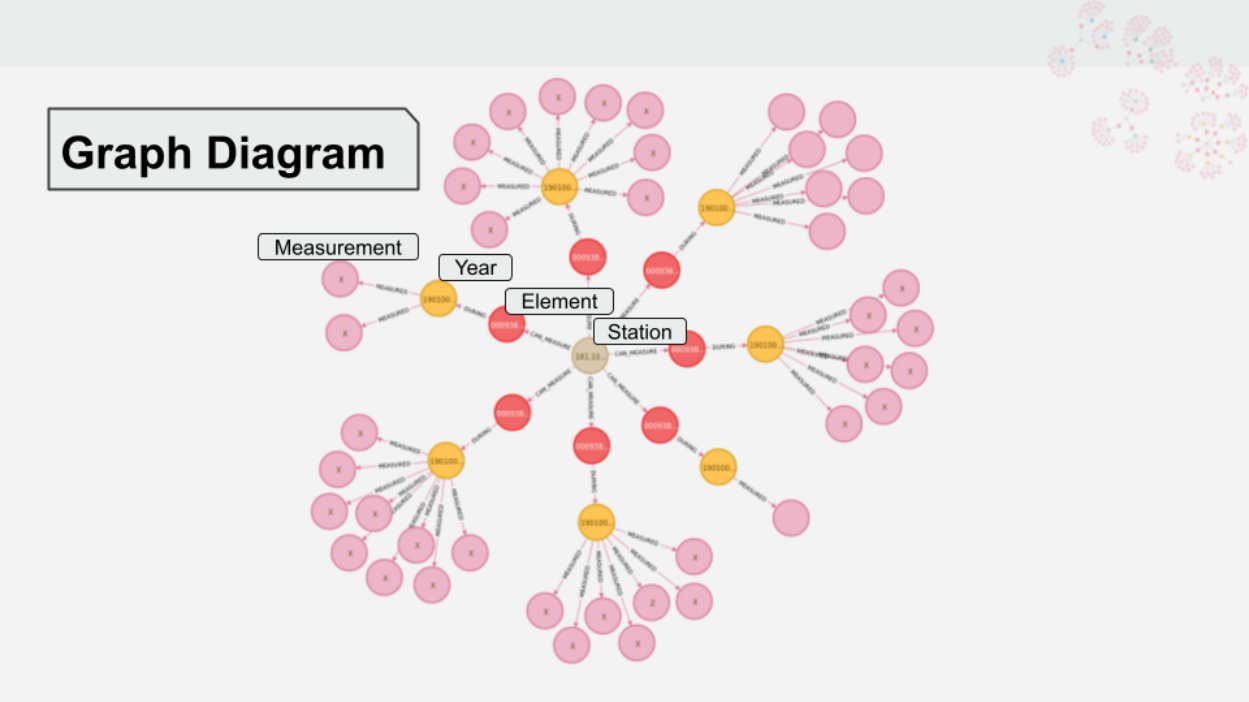


Figure 1*. This figure shows the 4 different data group types (node types) of the GHCNd graph database: Stations, Elements, Years, Measurements. Partitioning the data in this way, rather than in a conventional row and column table, allows for faster access to the weather measurement data of interest.*

The third milestone was an assessment of the database performance. This was done through a set of benchmarking trials that established the computational time required for each of the steps in GHCNd processing. Figure 2 shows that the vast majority of computational time for this GHCNd hybrid system is spent reformatting (.csv to .dly) the data files. In the future, when this system no longer relies on Fortran code, there will be no need for reformatting, which will reduce computational time by about two-thirds.

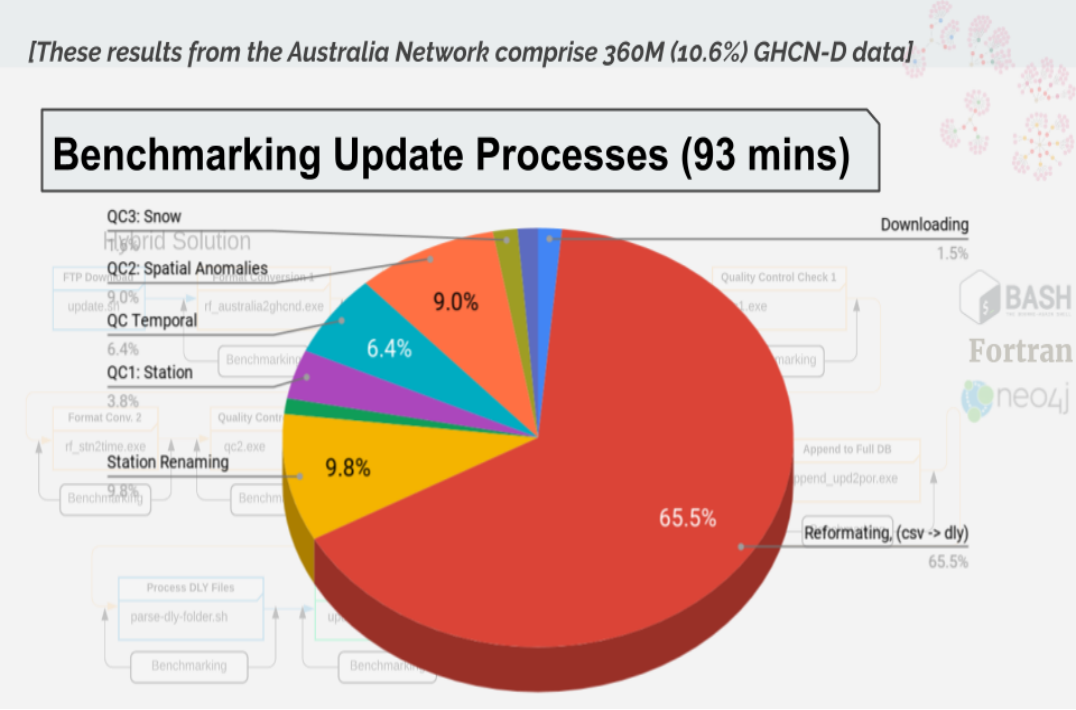


Figure 2. *This figure breaks down the total processing time of the GHCNd hybrid system for updating the GHCNd database by specific tasks. Note that most of the time is spent reformatting data, which will be eliminated by converting to a fully graph-based database.*

Planned work

- Publish current project results in a technical climate and big data journal.
- Convert the GHCNd Fortran update code to Neo4j cypher and BASH.
- This project will result in a graph-based GHCNd database that can be queried through a web API.

Products

- GHCNd graph database design.

Presentations

Brooks, B., 2020: Transitioning local to cloud-native data processing, lessons from an environmental dataset. Virtual. *2020 NOAA Environmental Data Management Worksho*p, August 19, 2020.

Other

• Intern: Undergraduate student Parvathy Menon (NCSU)

User-Centered Requirements for NCEI Archive Inventory, Catalog & Administration	
Task Leader	Bjorn Brooks
Task Code	NC-ITS-02-NCICS-BB

Highlight: A survey of NCEI staff involved in the inventorying and cataloging processes of NOAA data was completed. Survey responses identified three primary requirements for the development of a new cloud-based inventorying system. The current role of the survey participant (data inventorying or data cataloging) was a key factor in their identification of the most critical function of the NOAA Archive.

Background

As part of NOAA's broader migration to the cloud, NCEI sought to understand the needs of staff specialists involved in the inventorying and cataloging processes of NOAA data. Participants representing a range of roles from archivists to database administrators were surveyed with a series of nine guided questions focused on establishing each participant's functional role and identifying their primary requirements and expectations for the development of a new cloud-based inventorying system.

Survey participants fell into either of two groups: Data Inventorying or Data Cataloging. Participants used a variety of tools for inventorying and cataloging such as S2N, ATRAC, IAF and Common Ingest. Data cataloging was defined by users as data stewardship activities and the construction of metadata conforming to desired end-user services. In contrast, those more involved in data inventorying defined it as being focused on data manifests and accurate data object retrieval. This distinction highlighted the importance of identifying role when interpreting a user story for information about inventorying requirements.

Through surveying, participants reported the single most critical function that the NOAA Archive currently provides. These results were assembled, analyzed, and categorized. In general, it was found that the role of the participant was a strong predictor of the response given, as to what the most critical function is that the NOAA Archive serves. This again underscores the importance of role in determining requirements for a new cloud-based Archive inventory system from user stories.

Accomplishments

A qualitative analysis was conducted of the survey responses. The analysis results were compiled into a report that was submitted to NCEI's Data Stewardship Division leadership for review and a presentation was made to this group to explain the study in greater detail.

Survey responses readily identified the minimum requirements (Figure 1) for any new cataloging or inventorying system including

1. Flexible framework: Any new system must at a minimum maintain my current capabilities. A new system should assist users in their existing workflows and allow for custom tools they build to interface with it.
2. Inventory-Archive Agreement: A new inventory system should support accurate data object retrieval by reproducing exact copies of the original data.
3. Simplified Data Discoverability: A new system should replace the 3 or 4 systems that currently must be used to locate data objects. It should include the explicit location of data objects but also make it simple to access them.

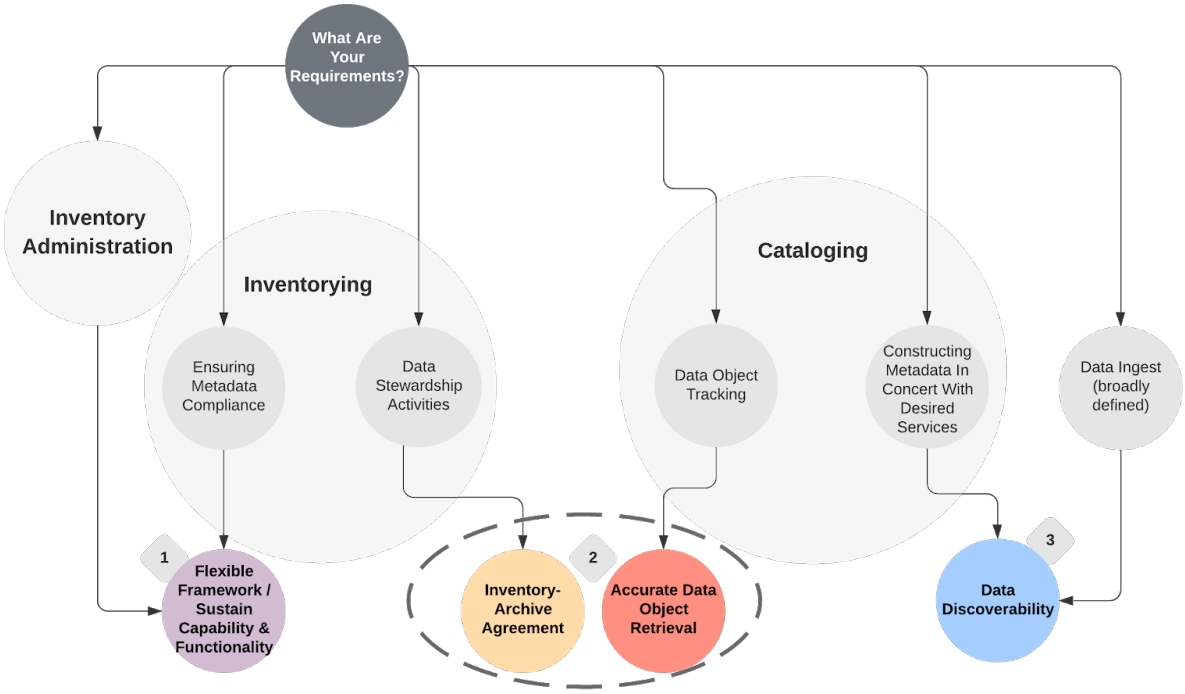


Figure 1. *This diagram illustrates the 3 common responses given for a new cloud-based inventorying and cataloging system. This also shows that the answers correspond to the particular user's role in the inventory system (i.e., those involved in administration and compliance tended to respond that a flexible framework was the most important requirement).*

Planned work

This project was completed.

Presentations

Brooks, B., 2020: Inventory, Catalog, and Archive administration User Stories and Requirements Project Plan. Virtual. *NCEI Data Stewardship Council Meeting*, August 5, 2020.

Other

• Intern: Drew Hamilton, University of Maryland undergraduate student

NCEI Infrastructure Architecture Planning and Implementation	
Task Leader	Lou Vasquez
Task Code	NC-ITS-03-NCICS-LV

Highlight: This project team and its collaborators drive the development of NCEI and NCICS IT infrastructure and architecture that will support a modern, flexible, distributed approach to data science, archive, and access capabilities. An analysis of cloud capabilities was completed. A high-performance workflow data processing system, NiFi, is supporting several NCEI projects and NiFi URMA retrieval stream monitoring was improved.

Background

As NCEI user needs grow in volume, existing on-premises systems become untenable, failing to meet the expanding community requests for environmental data. Cloud services, while capable of scaling to the demand, require resources, time, and system overhaul to use effectively. Legacy systems promote continued existence, creating friction in moving to modern approaches. Increasing the core capabilities, ingest, archive, access, and discoverability, is critical to meet the expanding volume. Most importantly, improving these core capabilities promotes community use, advancing the NOAA mission to understand and predict changes in climate, weather, oceans and coasts.

The following projects are all related to moving the center towards distributable, scalable architectures. The Archive Review Board (ARB) is dedicated to promoting new, viable technologies within the centers' policies and processes. The Cloud Pilot Integrated Project Teams (IPTs) recognize the need to create solutions in the cloud and help forge a path that others can follow. NiFi, while not an inherently cloud-based system, takes advantage of container-based growth and promotes scalable architecture such as partitioning, event-driven processes, backpressure, and functional processors. The DIVER project has embraced change as its goal at the center despite existing inertia otherwise. And lastly, the Cloud Architecture project is explicitly tasked with exploring the concept of archive and how it could change its form when using wide-column document-based databases, object-based storage, and event driven workflows to merge them into a system that solves a non-trivial problem.

CISESS NC is well suited to learning, testing and advising on new approaches, reducing NCEI resource re-allocation while moving us forward at low risk and with high value. CISESS NC readily moves into cloud arenas as well, with fewer restrictions and other limitations commonly experienced within NCEI. This task brings value to the partnership by improving environmental data access for science and the community.

Accomplishments

Cloud Architecture. The existing systems at centers were investigated to advise on implementation in a scalable cloud-oriented environment. CISESS NC led two distinct rounds of interviews with key NCEI people involved in archive, metadata, and related services. A significant result of this investigation highlighted difficulties obtaining tools permitting domain experts from participating early and directly in implementation. This resulted in a Generalized Framework recommendation identifying tools and design approaches that would enable the benefit of these experts' engagement.

Documents generated from the interviews and cloud expertise addressing user story needs of NCEI IPT were compiled and delivered as a NCEI Action. This was done to align NESDIS and NCEI needs for creating Inventory, Catalog, and Archive Administration capabilities in NESDIS Common Cloud Framework (NCCF). Documents included:

- Detailed User Stories spreadsheet with various breakdowns towards implementation concepts
- High-Level Findings summary/analysis of interviewees
- Generalized Framework presentation (Figure 1) recommending capabilities required to address concerns of interviewees.
- NCEI Action, process for disseminating documents across center to managers for review and response.

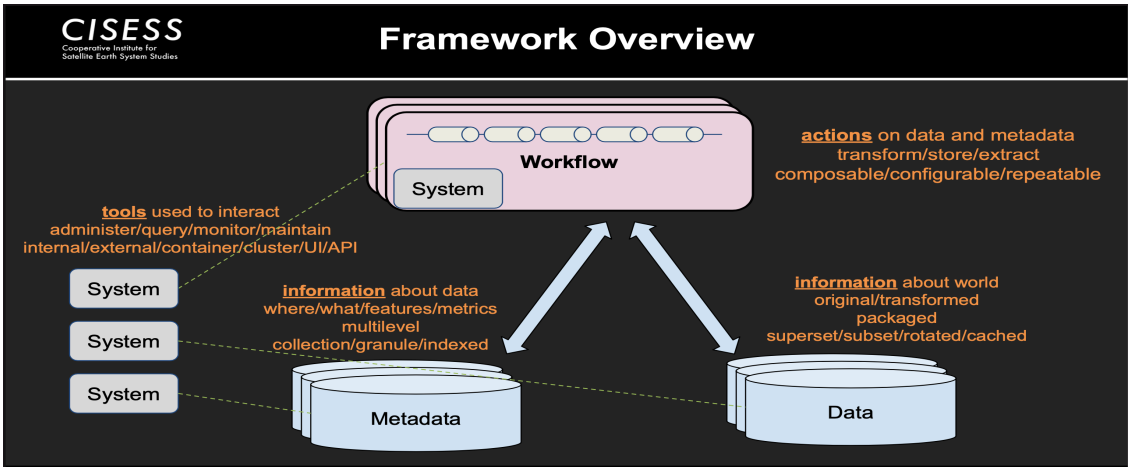


Figure 1. *Generalized Framework Overview slide.*

NiFi development. The team promoted production implementation of NiFi in Center's writing process, permissions, and roles document explaining how systems can be deployed to production in NCEI. IT Security identified this as a key gap preventing deployment to production in prior years.

The team provided updates and general assistance to NCEP Unrestricted Mesoscale Analysis (URMA) project NiFi flows, implementing monitoring, working to recover from system outages, and parallel upgrade of data flow from Cloud.gov to NCEP FTP source. They also trained users on flow, demonstrating approach and details used to accomplish ongoing, automated data transfer.

CISESS worked with the NCEI Data Integration Visualization Exploration and Reporting (DIVER) project on NiFi solution detailed in the DIVER section below. While awaiting availability of features to rapidly test/demonstrate/generate data flows and to maintain broad scope training of team, they created multiple container sandbox systems within the CISESS NC network. The capabilities provided included redis cache, MongoDB, Elasticsearch, script tools access, Graylog log monitoring, Grafana visualization, and multi-tenancy authorization/authentication. Early training of the team occurred on CISESS NC systems and included working example flows for all noted capabilities, as well as examples of REST API and Python API toolset, NiPyApi.

Data Integration Visualization Exploration and Reporting (DIVER). CISESS participated in the NCEI DIVER project, with a team of data managers, domain and metadata experts, and developers, to both archive NOAA DIVER data and improve the processes at NCEI. We facilitated an understanding of archive systems at NCEI to CLASS via Common Ingest (CI), including limitations and potential strategies for improvement. A pre-ingest validation process was designed in a scalable directed acyclic-graph (DAG) based NiFi system, with diagrams of different architectures. CISESS also helped direct the team towards solutions that best utilized scalability of cloud-oriented approaches available.

A multi-tiered NiFi flow (Figure 2) was developed to efficiently perform validation checks on incoming data packages for archive. The flow reduced load on the content repository through splitting and merging such that package content was minimally accessed and not unnecessarily reproduced in the flow. Checks included content filenames, manifest listing, and checksum validation. The workflow was integrated and run against known packages for testing. System integration connects with S3 and SFTP for simulated provider and archive data flow.

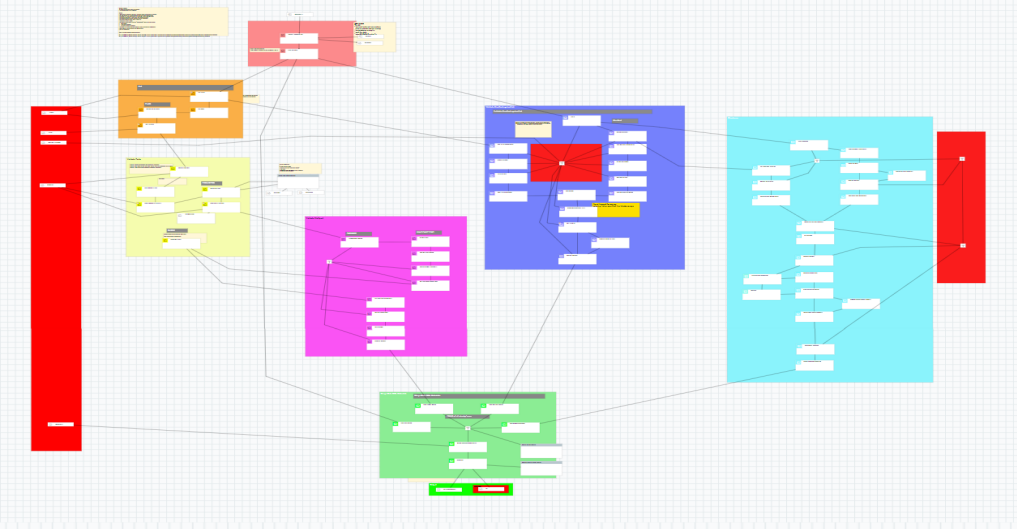


Figure 2. *Validate Content NiFi Workflow.*

A pre-ingest package identifier was investigated to offer tracking of submissions to archive and access, as well as reference to metadata and download pages for user data. CISESS staff spoke with internal and external groups to identify the purpose and constraints regarding the ID, and created a notional NiFi draft design to expedite implementation.

Architecture Review Board (ARB). The Board was assembled to achieve NCEI infrastructure and project goals jointly across divisions, branches, and services. The advantage of this board is that individual projects have limited ability to obtain resources from other divisions, and may do so at the cost of, rather than in alignment with, combined Center goals. Goals advanced included improvements to the Approved Software List process, including a matrix document so that all interests were considered when projects made requests. Other notable projects that moved forward, often into production, were, Object Store, Flask adoption, and Multibeam dataset.

Other. The Ingest dev team was trained for the NCEI GitLab CICD system, as well as advised on a Kafka aggregation approach to improve ingest capacity. Two Cloud Pilot IPT phases included advising on plans for transitioning the centers' systems from on-premises to various cloud-oriented solutions.

Planned work

- Assist NCEI to transition NiFi into production.
- Cloud pilot III IPT investigating NASA CMR for potential metadata repository use.
- Promote cloud-oriented solutions at NCEI as part of SDS.
- Participate in ARB to guide center towards accomplishable solutions across division goals and capabilities.

Products

- NCEI Inventory, Catalog, and Archive Administration User Stories and Requirements
- NiFi Unrestricted Mesoscale Analysis (URMA) retrieval stream monitoring improvements
- NIFi Pre-ingest system implementation
- Integrated System Granule Identification concept

Other

• Intern: Lisi Wang, Clemson University graduate student

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, Jared Rennie, Carl Schreck
Task Code	NC-SAS-01-NCICS-JM/AI/RL/GP/OP/JR/CS

Highlight: CISESS NC scientists served as subject matter experts on 1 Climate Data Record Integrated Product Team, as Product Leads for 26 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 NC staff have been enlisted as Product Leads for 26 of NCEI's 204 products and as Product Area Leads for 3 of 15 product areas.

Accomplishments

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

- Sea Ice Concentration – Annual (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 NC scientists acted as Product Lead for the following products during this reporting period:

- 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 Ice Concentration CDR (Peng)
- Sea Surface Temperature – WHOI CDR (Peng)
- Near Surface Atmospheric Properties over Ocean CDR (Peng)
- Heat Fluxes over Ocean – CDR (Peng)
- Sea Ice Normals (Peng)
- Daily Gridded Temperature Climatologies (Peng)
- Gridded In Situ Normals (Peng)
- Precipitation – CMORPH (Prat)
- Standard Precipitation Index using CMORPH (Prat)
- Advanced Standard Precipitation Index using Precipitation CDRs (Prat)
- Extreme Snowfall (Rennie)
- ISTI (Rennie)
- Outgoing Longwave Radiation – Monthly CDR (Schreck)
- Outgoing Longwave Radiation – Daily CDR (Schreck)
- Sectoral Engagement (Dissen)

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 NC 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.

Drought-related health impacts: advancing the science for public health applications

Task Leader Jesse E. Bell

TASK Code NC-SAS-02-UNMC-JB

Highlight: CISESS Consortium partner University of Nebraska Medical Center and the National Integrated Drought Information System (NIDIS) conducted a regional workshop on drought and health for the Carolinas. The project team is evaluating the impact of historical drought events on mortality and morbidity in Nebraska.

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 and by advancing this understanding, 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. This work will 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. This study investigates the relationship between drought exposure and all-cause mortality in Nebraska from 1980 to 2014. Initial analysis focused on Standard Precipitation Evapotranspiration Index (SPEI) and county-level mortality data for identifying drought's impact on changes in mortality. The second stage of the analysis evaluates the impact of drought measured by Evaporative Demand Drought Index (EDDI), investigates the role of different types of drought from short-term meteorological drought to long-term hydrological on mortality, and 3) develops and tests a new methodology of Bayesian modeling.

The assessment was made by subpopulation broken down into 13 age groups, three race groups, gender, and urbanization levels of Metro vs Non-Metro. Main findings indicate that there is no significant association between different types of drought (1-month, 6-month, and 12-month metrics) and all-cause mortality on the total population. However, when the analysis is stratified by subpopulations, there are increased risks of mortality among white males and females in the state.

The drought effect of annual mortality varied across different types of drought. Short-term drought affects white females aged 25–34 in the Metro counties and white females aged 45–54 in the Non-metro counties. Short to medium term drought significantly increases the mortality risks among white males aged 55–64 in the metro area and white females aged 45–54 in the Non-metro counties. Long-term

drought in Nebraska showed the highest number of associations between drought and mortality in different subpopulations and indicate an increase in mortality risks among white females aged 25–34, 45–54 and white males aged 55–64 in the Metro counties. In the Non-metro counties, the long-term drought increased the mortality risks among white males and females aged 45–54. (Figure 1)

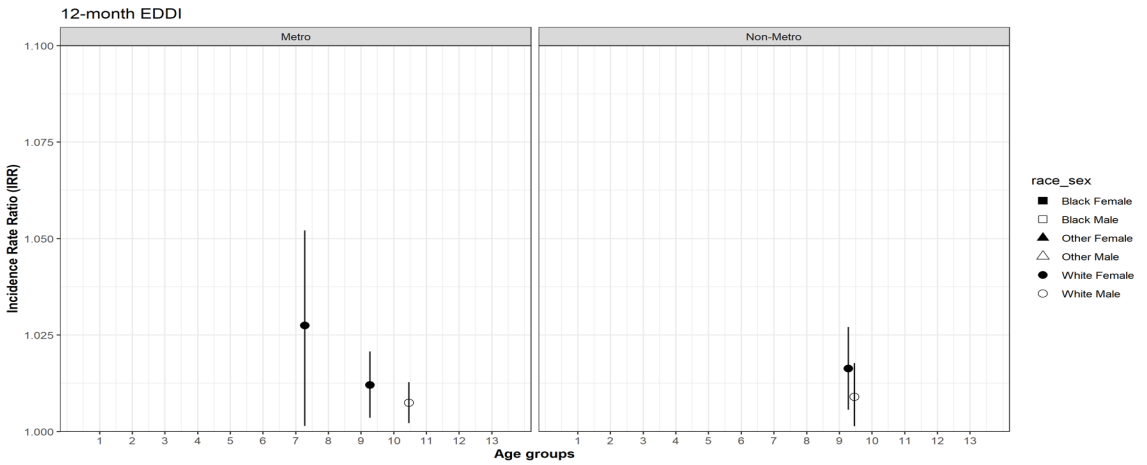


Figure 1. *Incidence rate ratios of the marginal effect of long-term drought (12-month EDDI) on all-cause mortality in age-race-sex population strata in Metro and Non-metro counties across Nebraska from 1980 to 2014. Only the significantly positive results are presented in this figure. IRR greater than 1 suggests an increase in mortality with increase in the drought score.*

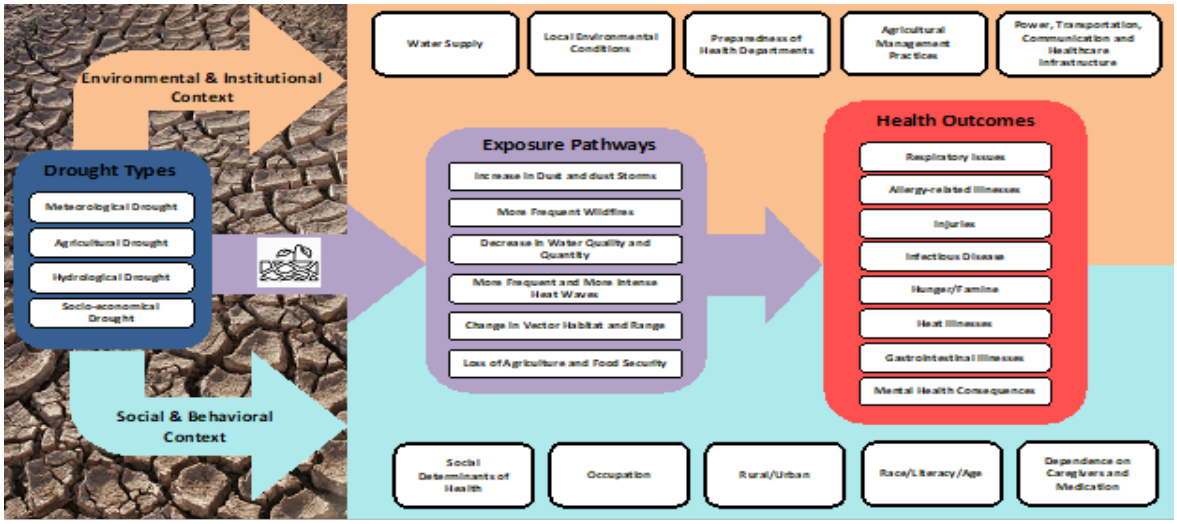


Figure 2. *The pathways from a drought event to health outcomes and the environmental, institutional, social, and behavioral contexts that influence these health outcomes.*

Interaction opportunities between the drought and public health communities. This project focuses on conducting state-level drought and health workshops following the same framework as the National Drought and Public Health Summit held in June 2019. The workshops aim to provide participants with a better understanding of the health impacts of drought; to engage participants across academic,

healthcare, public health, and other sectors to encourage cross-sector collaboration; and to discuss strategies for addressing and minimizing the health impacts of drought.

Due to the COVID-19 pandemic, the 2020 regional workshop hosted for the Carolinas was transitioned from an in-person venue to a virtual workshop. To continue the work on collecting information from state-level partners, a survey for state health departments and state climatologists was developed with anticipated implementation during the summer of 2021.

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.
- Implement survey for state health departments and climatologists.

Products

- Carolinas Drought and Health Virtual Workshop, September 23-24, 2020

Publications

Abadi, A. M., A. Vander Stoep, K. Foster, S. Clayton, J. E. Bell, and J. Hess, 2020: Mental health in water scarce cities: an unrecognized climate change pressure point. *BMJ* 2020; 371:m2936

Hunt, E. D., J. I. Christian, J. B. Basara, L. Lowman, J. A. Otkin, J. E. Bell, K. Jarecke, R. A. Wakefield, and R. M. Randall, 2020: The flash drought of 1936. *J. Appl. Serv. Climatol.*, 2020(4). doi:10.46275/JOASC.2020.11.001.

Lookadoo, R. E., and J. E. Bell, 2020: Public health policy actions to address health issues associated with drought in a changing climate. *The Journal of Law, Medicine & Ethics*, 48(4), 653-663. DOI:10.1177/1073110520979372

Lynch, K. M., Lyles, R. H., Waller, L. A., Abadi, A. M., Bell, J. E., & Gribble, M. O., 2020: Drought severity and all-cause mortality rates among adults in the United States: 1968–2014. *Environ Health,* 19(52), 1-14. Doi:10.1186/s12940-020-00597-8

Presentations

Li, Q., A. M. Abadi, H. Dai, and J. Bell, 2020: Effects of Climate on Variability in Coccidiomycosis (Valley Fever) Incidence in Arizona and California. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting*, December 2020. https://agu2020fallmeeting-agu.ipostersessions.com/default.aspx?s=BD-38-39-E5-A8-CD-A8-B5-CC-1B-B4-B1-6E-05-6B-8B

Li, Q., J. Bell, A. M. Abadi, and H. Dai, 2021: Effects of Climate on Variability in Coccidiomycosis (Valley Fever) Incidence in Arizona and California. Virtual. *2021 AMS Annual Meeting*, January 12, 2021. https://ams.confex.com/ams/101ANNUAL/meetingapp.cgi/Paper/383291

Other

- Postdoctoral researcher mentored: Dr. Babak J-Fard
- PhD students mentored: Qianqian Li, Jagadeesh Puvvula, and Abdoulaziz Abdoulaye
- MPH student mentored: Conor O'Neill
- Undergraduate student mentored: Katie Williams (MIT)

Strategic Engagement and Outreach	
Task Leader	Jenny Dissen
Task Code	NC-SAS-03-NCICS-JD

Highlight: CISESS NC supported a number of NOAA engagement activities including the development of the NCEI Information Services Roadmap, initiating a case study to build understanding of climate risk to the real-estate sector, NCEI engagement activities at the 2021 American Meteorological Society Virtual Annual Meeting, and a number of virtual "Skype a Scientist" and other outreach presentations.

Background

CISESS NC compliments and extends NOAA mission and operational activities by designing different methods for understanding the Earth system science and data and applying interdisciplinary approaches for stakeholder engagement. The user community has historically been challenged with access to and understanding of environmental information. As NOAA embarks on transformation journeys to cloud-enabled access, CISESS NC supports NOAA, via NCEI in user engagement activities by developing interdisciplinary and modern methods for connecting with a broader and more diverse user community of stakeholders that span public and private sectors.

CISESS NC utilizes and emphasizes multilateral engagement activities with the user community, building upon traditional modes for engagement and outreach to enable synchronous and asynchronous methods, particularly in light of cloud-enabled access. Engagement spans business and industry, economic sectors, organizations, foundations, academia, other scientists, and the general public. Activities include framing and analyzing the information exchange, developing case studies, co-authoring blog stories, organizing sector-based engagement discussions and webinars, and building networks and partnerships that support capacity building. Leveraging modern cloud-based technology methods and collaboration with cloud partners, engagement activities reach diverse user groups and build experience with diverse platforms. CISESS NC furthers NOAA's mission goals by working with partners to connect with user communities, ultimately in support of advancing adaptation, resilience, and a robust climate services sector.

Accomplishments

During the past year, engagement activities included

- Advisory support to NOAA NCEI Engagement and Information Services in 3 key areas: 1) NESDIS User Engagement, 2) the NCEI Information Services Roadmap, and 3) a sector case study focused on environmental data in real-estate sector.
- Identification and execution of new ideas for catalyzing climate services regionally, and
- Supported advancement of STEM activities through outreach and education.

NCEI Information Services Support

CISESS NC supports NCEI's Climate Services and Support Division (CSSD) on strategic and operational sectoral engagement activities, and Task Leader Jenny Dissen continues to serve as the Product Lead for CSSD sectoral engagement. CISESS NC collaborates with the NCEI engagement team in leveraging the customer relationship management (CRM) tool to develop insights for the engagement, data, and science needs as noted from user interactions. CISESS NC advises on the new framing of the NCEI State of the Services summary report intended for NCEI leadership and for external users on how NCEI reaches its users. The customer analytics tool and State of the Services reports are shared as illustrative examples to other parts of NESDIS and NOAA on various operational aspects of user engagement that are developing from frameworks and processes.

CISESS NC supported NCEI in the development of the 2021 NCEI Information Services Roadmap, a collaborative NCEI integrated document outlining the current and desired approaches for advancing and modernizing NOAA/NESDIS/NCEI engagement activities. CISESS NC involvement spanned both strategic and execution support, involving the framework, report development methodology, plan and process, and authoring of "Modes of Engagement" and "Recommendations/Next Steps" chapters. CISESS NC worked closely with NCEI report lead Heather McCullough in report development, internal stakeholder communication, chapter authoring, and collaborating with the Roadmap team to address and resolve various challenges. This Roadmap is noted as an NCEI effort to integrate both OGSSD and CSSD activities, and integrating engagement activities from the DSD and CoB divisions of NCEI.

To advance sector-based understanding for user engagement, CISESS NC is conducting a detailed/deep-dive case study, partnering with Willis Towers Watson (formerly Acclimatise) to build understanding of climate risk to the real-estate sector. The collaborative research project includes exploration of risks facing the sector, noting that wildfires and inundation are part of the primary environmental parameters most important to assessing the risks. The research study includes understanding the opportunities for using environmental data related to wildfires, which requires current and real-time access to the environmental data, best accessed through cloud-based analysis. The study involves developing a stakeholder map and engagement plan, where stakeholders provide understanding of uses and applications of environmental data and needs from the burgeoning solution providers community as they apply modern computational methods using environmental data to address wildfire risks. Results of the research study will be publicly summarized, serving as sector-based guidance and scholarly guidance to the research community.

To continue engagement with scientific and academic organizations, CISESS NC continued to build NCEI Users' Conference activities, collaborating with NCEI contractor Riverside staff to plan and execute engagement activities at the 2021 American Meteorological Society Virtual Annual Meeting, which included: co-authoring 2 NCEI Engagement presentations (Brewer); co-chairing 2 sessions; and facilitating 2 Town Hall discussions on the topics of NOAA BDP and Committee on Partnerships.

Other engagement activities included developing blogs, tutorials, user workshops, conferences, informational sessions and webinars to reach both internal federal and external private sector user communities.

Education and General Public Outreach Activities

CISESS NC staff engage in an interdisciplinary outreach program which includes activities that reach K-12, higher education, and the general public. The Institute conducts a robust student internship program and 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 normally support and respond to a variety of outreach requests throughout the region. While some of these activities have been curtailed due to the COVID-19 pandemic, staff were still able to provide a number of remote presentations for both local groups and to schools across the United States.

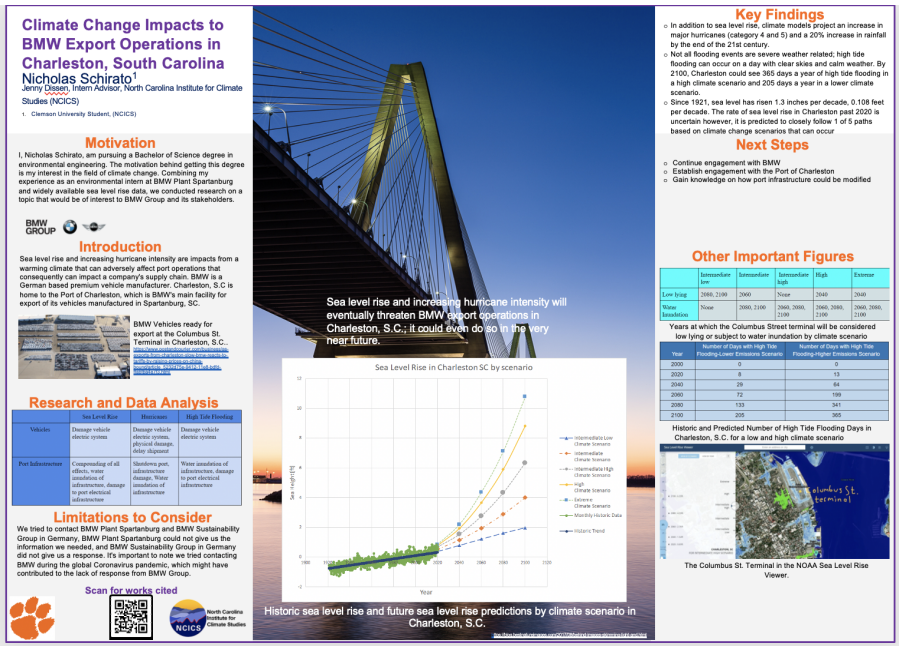


Figure 1. *Final project report for CISESS NC intern Nicholas Schirato, a Clemson University undergraduate environmental engineering student who completed an investigation on climate change impacts to regional BMW operations.*

CISESS NC outreach events included

- 6/12: French Broad River Garden Club, Asheville, NC. Douglas Rao gave a remote presentation, Climate Change," with ~40 members in attendance.
- 7/7: NCICS/NCEI Summer Intern Seminar Series. Bjorn Brooks gave a remote presentation on his career and work at NCICS to NCEI and CISESS NC summer interns.
- 8/4: NCICS/NCEI Summer Intern Seminar Series. Laura Steven, gave a remote presentation on her career and work at NCICS to NCEI and CISESS NC summer interns.
- 9/17: Codington Elementary School. Wilmington, NC. Jared Rennie gave a remote "Skype a Scientist" presentation on meteorology, weather, and climate to ~40 5th graders.
- 10/6: Chiganois Elementary School. Debert, Nova Scotia, Canada. Jared Rennie gave a remote "Skype a Scientist" presentation on weather and climate in the U.S. and Canada to ~25 4th graders.
- 10/20: TC Roberson High School, Asheville, NC. Douglas Rao gave a remote presentation on climate change, to ~120 high school students.
- 11/5: NASA DEVELOP intern meeting. Jared Rennie gave a remote presentation on his career and work at NCICS to 4 interns.
- 12/4: Binford Middle School, Richmond, VA. Bjorn Brooks gave a remote "Skype a Scientist" presentation on his career and work at NCICS to 17 middle school students.
- 1/5: Binford Middle School, Richmond, VA. Bjorn Brooks gave a remote "Skype a Scientist" presentation on his career and work at NCICS to ~20 middle school students.
- 2/11: Graham Elementary and Middle School, Columbus, OH. Carl Schreck gave a remote "Skype a Scientist" presentation on how to become a meteorologist to ~30 kindergartners.
- 2/12: Riddle Brook School, Bedford, NH. Carl Schreck, Skype-a-Scientist gave a remote "Skype a Scientist" presentation on clouds and energy to ~25 4th graders.
- 2/18: Town and Country Garden Club, Asheville, NC. Douglas Rao gave a remote presentation, "Birds & Gardens: Observing the changing climate in our neighborhood" with 12 in attendance.

- 2/18: Western Carolina University, Cullowhee, NC. Douglas Rao participated remotely as a judge for the Region 8 Western Regional Science & Engineering Fair.
- 3/2: Apex Elementary School, Apex, NC. Douglas Rao gave a remote presentation on weather and climate to ~100 5th graders.
- 3/2: Dwight School, New York City, NY. Carl Schreck gave a remote "Skype a Scientist" presentation on hurricanes and natural disasters to 36 2nd graders.
- 3/10: Asheville Rotary Club, Asheville, NC. Kenneth Kunkel remotely presented "Sea Level Rise and Our Coasts" to club members.

Planned work

- Complete development and stakeholder engagement of NCEI Information Services Roadmap.
    - Develop strategic plan working with OGSSD engagement lead on actionable engagement plan on high priority OGSSD data products.
    - Host webinar on new Climate Normals with cross-sector involvement.
    - Analyze recommendations from the IS Roadmap and provide implementation details for priority areas.
- Continue sector stakeholder engagement, provide NCEI updates, and provide summary reports and presentations on the real-estate sector case study.
- Support NCICS Outreach in various outreach related requests, including collaboration with Asheville Museum of Science on summer camp planning, STEM teacher activities, and mentoring.

Presentations

Brewer, M., T. Houston, A. Hollingshead, J. Okrend, and **J., Dissen**, 2021: The Value of Environmental Data from NOAAs National Centers for Environmental Information. Virtual. *2021 AMS Annual Meeting*, January 14, 2021.

Brewer, M., A. Hollingshead, **J. Dissen**, J., Okrend, 2021: Innovating NCEI Customer Engagement Approaches. Virtual. *2021 AMS Annual Meeting*, January 13, 2021.

Lazo, J., Hooke, W., and **J. Dissen,** 2020: Economics of the Weather, Water, and Climate Enterprise 2021; An Inquiry on Sector-Based Approaches to Climate Information Services. Session. Virtual. *2021 AMS Annual Meeting,* January 14, 2020.

Shea, E., and **J. Dissen**, 2021: Session 8 Ninth Symposium on the Weather, Water, and Climate Enterprise – Enhancing the Weather, Water, and Climate Enterprise through Partnerships. Session. Virtual. *2021 AMS Annual Meeting,* January 13, 2021.

Other

- Attended 2 Electric Power Research Institute Advisory Council Meetings, and continued to develop partnership with EPRI on climate information exchange opportunities
- Support Asheville Museum of Science in environmental data needs, and transition to CISESS NC colleague for Board level involvement and engagement
- Dissen continues to serve on the External Engagement Steering Team for the North Carolina School of Science and Mathematics Morganton Campus (http://ncssm.edu/)
- Dissen mentored two interns: Nicholas Schirato (Clemson University) and Marlee Burgess (UNC Asheville)

Optimum Interpolation Sea Surface Temperature (OISST) Algorithm Upgrades	
Task Leader	Garrett Graham
Task Code	NC-SAS-04-NCICS-GG

Highlight: The scientific task team completed reprocessing of the OISST dataset and reformatting of the metadata to transition to OISST v2.1. Reprocessing of the historical dataset using the NOAA Pathfinder Advanced Very High Resolution Radiometer (AVHRR) sea surface temperature (SST) product is nearing completion. The new product was used to investigate marine heat waves in the Arctic seas. https://www.ncdc.noaa.gov/oisst

Background

NOAA's Optimum Interpolation Sea Surface Temperature (OISST) product has been one of the world's leading satellite-based sea surface temperature data sets since the original version's launch in 1981. Since its inception, the scientific team responsible for OISST has augmented the operational algorithm with numerous fixes and upgrades, in response to emergent challenges and increasingly sophisticated mathematical and statistical techniques. In 2020, the OISST team published version 2.1 of the algorithm to address quality issues that had originated from improvements in ship intake thermometers and from a reduction in available buoy data (which itself was caused by a migration in data transmission protocols). The newest version of OISST now presents an excellent platform for additional research and development of even more sophisticated versions of the algorithm.

Accomplishments

The project team completed the transition to OISST v2.1, which included reprocessing the dataset from 1981 to the present and reformatting the metadata to be fully compatible with modern NetCDF4 standards. In addition, historical dataset reprocessing using NOAA's Pathfinder AVHRR SST product is nearly complete. This reprocessing will enable a complete evaluation of differences between the real-time satellite-based product and one that has been processed using a quarterly-updated historical AVHRR product which was subject to more extensive quality-control standards than the real-time satellite data. The team performed extensive comparisons between OISST v2.1 and other publicly available real-time SST products and utilized the updated dataset to investigate marine heat waves in Arctic seas and oceans.

Planned work

- Complete reprocessing of a new version of OISST v2.1 using the Pathfinder AVHRR product.
- Upgrade OISST v2.1's ship bias correction method to be the same as NOAA's Extended Reconstruction SST (ERSST v5).
- Incorporate Banzon et al's improved sea ice-to-SST estimation algorithm into the current version of OISST, as described in their 2020 paper "Improved Estimation of Proxy Sea Surface Temperature in the Arctic" and published in the *Journal of Atmospheric and Oceanic Technology*.

Publications

Huang, B., C. Liu, V. Banzon, E. Freeman, **G. Graham**, B. Hankins, T. Smith, and H.-M. Zhang, 2021: Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1. *Journal of Climate*, **34,** 2923-2939. http://dx.doi.org/10.1175/jcli-d-20-0166.1

Product

Optimum Interpolation Sea Surface Temperature v2.1

GOES-R-Based Products	
Task Leader	Anand Inamdar
Task Code	NC-SAS-05-NCICS-AI

Highlight: Analyses using US Climate Reference Network (USCRN) in situ data and data from the NOAA-operated Surface Radiation Network (SURFARD) revealed that changes in the daytime land surface temperature (LST) track the changes in the Surface Solar Absorption (SSA) parameter under most sky conditions, with potential advantages for to filling in gaps in the LST time series retrieved from geostationary satellites such as GOES-R.

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

This work follows the successful implementation of an algorithm to estimate surface solar absorption (SSA) in near real time using the CERES FLASHFlux (Fast Longwave And SHortwave Radiative Fluxes) data retrieved from the NASA Langley Research Atmospheric Science Data Center. Further study conducted using in situ data from the US Climate Reference Network (USCRN) in addition to the NOAA-operated Surface Radiation Network (SURFARD) reveal that changes in the daytime land surface temperature (LST) track the changes in the SSA parameter under most sky conditions (Fig. 1). This has potential advantages in applications related to filling in gaps in the time series of LST retrieved from geostationary satellites such as GOES-R. Sample validation results are shown in Figure 1 for a recent time period.

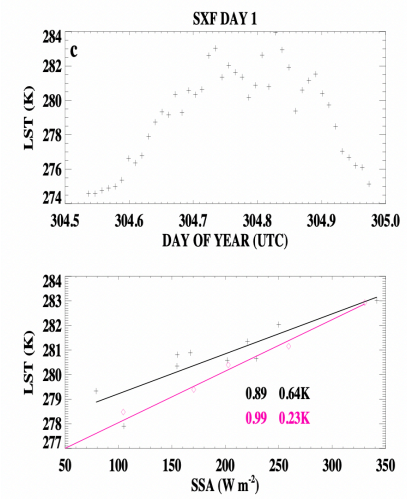


Figure 1. *Top panel shows in situ LST (K) for the Sioux Falls (ND) site for Nov 1, 2019. Bottom panel shows correlation between SSA and LST for each of the ascending (sunrise to peak LST of day in dark line) and descending (time of peak LST to near sunset hour in magenta line). The symbols are the in situ measurements and continuous lines represent*

mean linear regression fits. Pairs of numbers inset refer to the Pearson's correlation coefficient and RMS error for each of the ascending and descending legs.

Planned Work

- Investigate using additional GOES-R channels to enhance product accuracy.
- Publish peer-reviewed paper on project results.

Presentations

Inamdar, A., and **R. D. Leeper**, 2020: Filling in the Spatio-Temporal Gaps in the GOES-R Land Surface Temperature Product. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 7, 2020.

Products

- Algorithm to improve the GOES-R land surface temperature product including all-weather information

HIRS-Like Data from New-Generation Sensors	
Task Leader	Anand Inamdar
Task Code	NC-SAS-06-NCICS-AI

Highlight: A full year (2015) of Infrared Atmospheric Sounding Interferometer (IASI) data was processed and used to generate brightness temperatures in a form which mimics HIRS data, and a new scheme for limb correction was developed and applied. Software has been implemented to support in-house production of the IASI into HIRS-Like data**.**
https://www.ncdc.noaa.gov/isccp

Background

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

The project team is exploring use of Infrared Atmospheric Sounding Interferometer (IASI) measurements from 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

- A full year of IASI data for 2015 was downloaded and processed, and code was implemented to generate brightness temperatures from radiances.
- A scheme to apply Limb correction was developed and applied to all months of data for 2015. Figure 1 shows images of swaths of IASI brightness temperatures without limb correction (top) and with limb-correction (bottom) for one of the channels for a specific day (May 2, 2015).
- Histograms of differences between IASI-simulated HIRS (I-HIRS) and HIRS track each other very well (Fig 2).
- The software for producing IASI data from files downloaded from CLASS holdings was implemented providing the capability to produce the IASI data in-house.

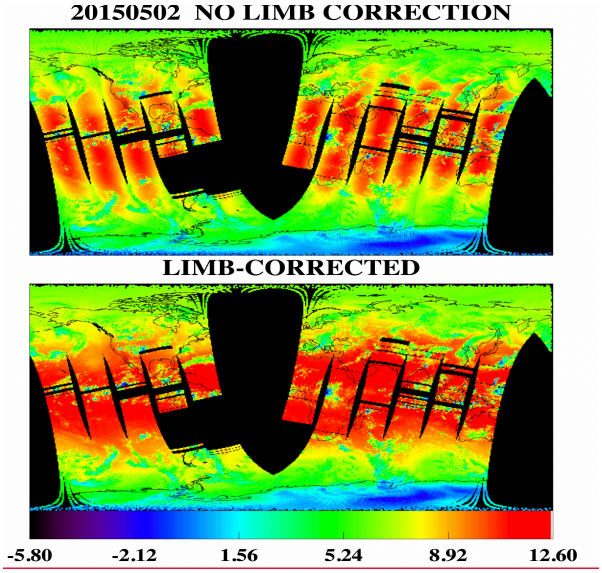


Figure 1. *Difference between no limb correction and limb-corrected brightness temperatures for IASI.*

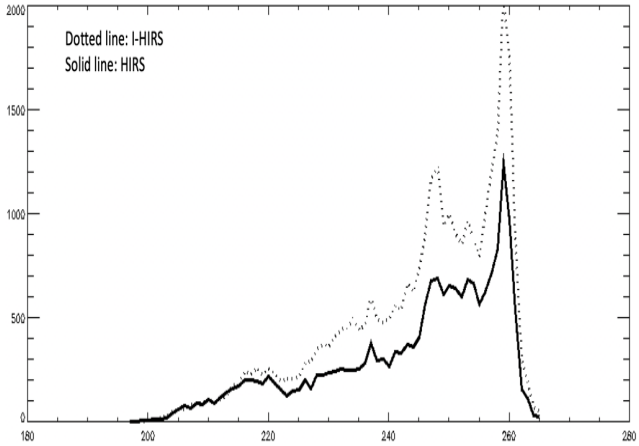


Figure 2. *Histograms of IASI-simulated HIRS(I-HIRS) and HIRS.*

Planned work

- Develop tables and code to perform inter-satellite calibration to produce HIRS-like data.
- Process back-data from year 2006.
- Prepare publication for peer-reviewed journal.

U.S. Climate Reference Network (USCRN) Applications and Quality Assurance	
Task Leader	Ronald D. Leeper
Task Code	NC-SAS-07-NCICS-RL

Highlight: On-going quality-control review of USCRN *Acclima* sensor observations led to the identification of several processing issues which significantly impacted the sensor records' quality. The issues were resolved and the evaluation of the quality-controlled data reflects the new *Acclima* sensors are impacting soil moisture and temperature layer averages.

Background

The U.S. Climate Reference Network (USCRN) is a systematic and sustained network of climate monitoring stations deployed across the contiguous United States, Hawaii, 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 initiated an evaluation of a new soil sensor (*Acclima*) to improve the network's capacity to monitor soil moisture conditions in high-clay-content soils, mostly in the southeastern U.S. This transition is expected occur over several years as the new *Acclima* sensor slowly replaces the original *HydraProbe*.

Accomplishments

Soil. A thorough quality-control review of *Acclima* sensor observations continued through 2020. This led to the discovery of two issues impacting *Acclima* sensor quality that were corrected by the Atmospheric Turbulent Diffusion Division (ATDD). The quality-controlled data were then evaluated to explore how the transition to *Acclima* sensors has impacted layer averages of soil moisture and temperature. Overall, the addition of *Acclima* sensors slightly reduced higher measures of volumetric soil moisture conditions, mainly at high clay content stations where *Acclima* sensor technology is less impacted by cat-ion exchanges (Fig. 1). Despite the subtle changes in soil moisture between the two sensors, *Acclima* layer averages tended to have much warmer daytime conditions and slightly cooler evening soil temperatures compared to the Hydra sensors (Fig. 1). Further analysis is needed to determine if this is an artifact of the sensor's housing.

Precipitation. Precipitation extremes for both USCRN and the Hourly Precipitation Dataset (HPD) and their frequency of exceedance against NOAA Atlas-14 thresholds were updated. A nearest-neighbor analysis was completed to evaluate the importance of network density on the detection of extreme conditions and if the more recent period has a higher likelihood exceedance. A paper documenting the evaluation of the quality control algorithm for HPD was published in the *Journal of Hydrolometeorology*.

Planned work

- Evaluate impact of the *Acclima* sensor transition on newly released standardization and drought index products.
- Explore techniques to recalculate *Hydra*-based volmetric observations using station specific soil characteristics.
- Finalize and submit a manuscript on the NOAA-Atlas 14 precipitation threshold exceedance analysis**.**

Publications

Lawrimore, J. H., D. Wuertz, A. Wilson, **S. Stevens**, M. Menne, B. Korzeniewski, M. A. Palecki, **R. D. Leeper**, and T. Trunk, 2020: Quality control and processing of Cooperative Observer Program hourly precipitation data. *Journal of Hydrometeorology*, **21,** 1811-1825. http://dx.doi.org/10.1175/jhm-d-19-0300.1

Presentations

Leeper, R. D., 2020: Comparisons of In Situ Ground Observations and Satellite Measurements of Soil Moisture Standardizing Using a Consistent Method. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 7, 2020.

Scott, E., **R. D. Leeper**, and M. A. Palecki, 2021: Extreme Precipitation Event Frequency Observed by the U.S. Climate Reference Network (USCRN). Virtual. *2021 AMS Annual Meeting*, January 11, 2021.

Stevens, S. E., and **R. D. Leeper**, 2020: Advances in NCEI's U.S. Hourly Precipitation Dataset for Assessing Extremes in Urban Areas. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 14, 2020.

Standardization of U.S. Climate Reference Network (USCRN) Soil Moisture Observations	
Task Leader	Ronald D. Leeper
Task Code	NC-SAS-08-NCICS-RL

Highlight: A daily soil moisture-based drought index was developed from the standardized soil moisture dataset and made publicly available through CISESS NC. Comparisons between USCRN and the European Space Agency's (ESA) Climate Change Initiative (CCI) remotely sensed soil moisture dataset were evaluated for both volumetric (raw) and standardized measures.

Background

Soil moisture observations are challenging to interpret and use from a monitoring perspective. 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 made available at five depths (5, 10, 20, 50, and 100 cm) as well as Top (5 and 10 cm) and Column (5 through 100 cm) layer aggregates, resulting in soil moisture climatologies, anomalies, and percentiles that augment station observations.

Accomplishments

Weekly measures of mean standardized soil moisture anomalies and fraction of hours below and above the 30th percentile were generated at all five depths as well as top (5 and 10 cm) and column (5 through 100 cm) layer aggregates. These weekly values were compared against changes in U.S. Drought Monitor conditions, focusing on weeks of drought onset, intensification (degradation in drought status), and amelioration (improving drought status). Results showed that shorter averaging times (less than 3-weeks) of soil moisture conditions near the surface (20cm and less) were more responsive to changes in drought conditions. Analysis of threshold exceedances revealed that both the mean standardized anomaly and fraction of hours below the 30th percentile were reliable indicators of drought intensification (amelioration) within the first (last) three weeks of drought onset (termination; Fig. 1).

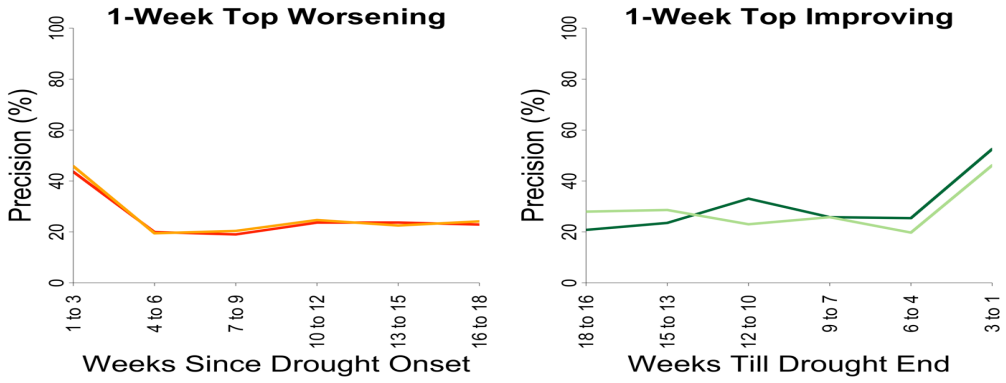


Figure 1. *(left) 1-week Top Layer precision for the (red) 0.15 fraction of hours below the 30th percentile threshold and (orange) 0.00 anomaly threshold by weeks since drought onset for worsening USDM weeks, and (right) (dark green) 0.15 fraction of hours above the 30th percentile threshold and (light green) 0.00 anomaly threshold by weeks until drought end for improving USDM weeks.*

Comparisons of the European Space Agency's (ESA) combined remotely sensed soil moisture with USCRN stations revealed the two datasets had high correlations due to similar seasonal trends in soil moisture wetting and drying, but large measures of error (i.e., RMSE) because of persistent offsets. (Fig. 2). These offsets were largely removed when remotely sensed soil moisture observations were standardized. Statistical significance testing revealed that station and satellite differences in standardized soil moisture conditions were insignificant for most stations, meaning that the two measures were very similar.

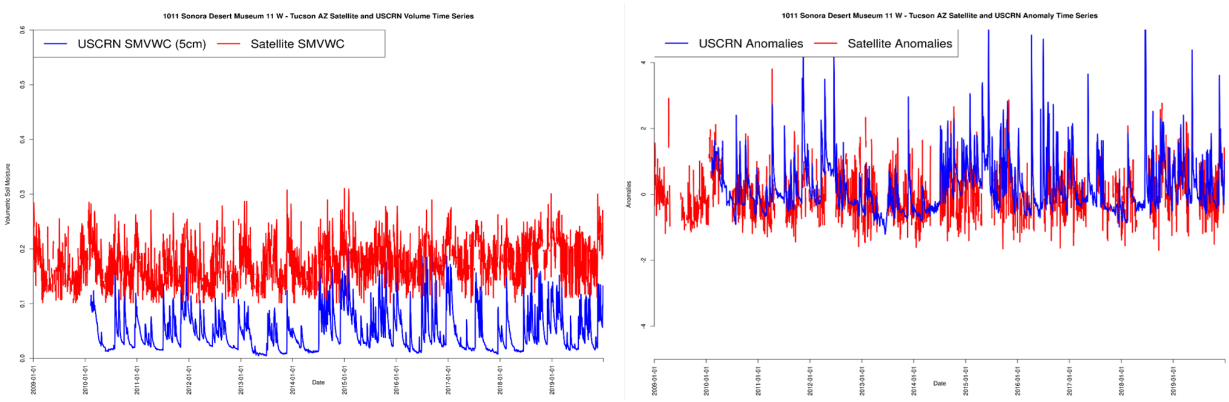


Figure 2. *(left) volumetric and (right) standardized soil moisture observations from the (blue) USCRN and (red) ESA's remotely sensed datasets.*

NASA DEVELOP teams worked on developing a composite moisture index (CMI) prototype for application to HUC-6 regions. Preliminary analysis suggests that antecedent standardized soil moisture conditions and accumulated snowfall over the winter season were well correlated with April to August accumulated stream flow. This is very useful information for dam operators and the stream flow forecast office.

Planned work

- Evaluate role of base periods on standardized soil moisture conditions during drought conditions.
- Complete comparisons between USCRN and remotely sensed soil moisture.
- Support efforts to operationalize both the standardized soil moisture and drought index products.

Products

- Drought index based on daily soil moisture.

Presentations

Leeper, R. D., 2020: Applications of USCRN's Standardized Soil Moisture Dataset. Virtual. *NCEI Tuesday Seminar Series*. August 11, 2020.

Leeper, R. D., 2020: Exploring the use of Standardized Soil Moisture Datasets as an Indicator of Drought. Virtual. *2020 National Soil Moisture Workshop*, August 9, 2020.

Leeper, R. D., B. Peterson, and M. A. Palecki, 2021: Exploring the use of Standardized Soil Moisture as a Drought Indicator. Poster. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.

Other

• Intern: Matthew Watts, NCSU
• Fall 2020 NASA DEVELOP team: Dean Berkowitz, Egla Ochoa-Madrid, Chloe Schneider, Julie Sorfleet
• Spring 2021 NASA DEVELOP team: Catherine Buczek, Bevan Pearson, Madelyn Savan, Chloe Schneider

Exploring the Impacts of Drought Events on Society	
Task Leader	Ronald D. Leeper
Task Code	NC-SAS-9-NCICS-RL

Highlight: U.S. Drought Monitor (USDM) weekly maps of drought conditions from 2000 to 2019 were were sampled at 5 Km resolution and used to define historical drought event climatologies across the U.S. and Puerto Rico. Analysis of the drought characteristics (i.e., frequency of occurrence, duration, seasonality, flash droughts, etc.) were loaded into an online application to support the interactive dissemination of this climatological drought dataset.

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 placed onto a 5 Km grid similar in spatial extent and resolution to NCEI's gridded Global Historical Climatology Network (GHCN) dataset known as nClimGrid. Unique non-overlapping drought events (Fig. 1) were then defined for each of the 300,000 plus grid cells across the U.S. and Puerto Rico to characterize climatological drought conditions from 2000 to 2019. Analysis of the historical drought events revealed sharp contrasts in the frequency and duration of the drought events across the contiguous U.S., topographic features of Hawaii, and the high latitudes of Alaska (Fig. 2). Climatological rasters of the aggregated drought events were included in an ArcGIS Online application to make this dataset more broadly accessible. The potential for this to become an operational product is being explored.

U.S. county-based drought events generated last year were updated through 2019. These data were combined with U.S. Department of Agriculture (USDA) county-level insured losses. For each U.S. County, monthly insured agricultural losses were accumulated over the separate drought events and then ranked by total losses. Preliminary analysis results suggest that drought severity may not be the sole contributor to agricultural losses.

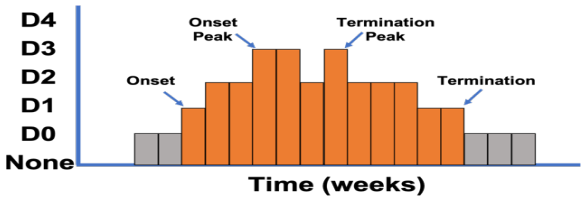


Figure 1. *Schematic representation of a drought event (orange) with onset occurring the first week of D1 conditions, onset and termination peaks the first and last week of peak USDM status over the drought event, and drought termination the last week of D1 conditions followed by three weeks or more of D0 or None statuses.*

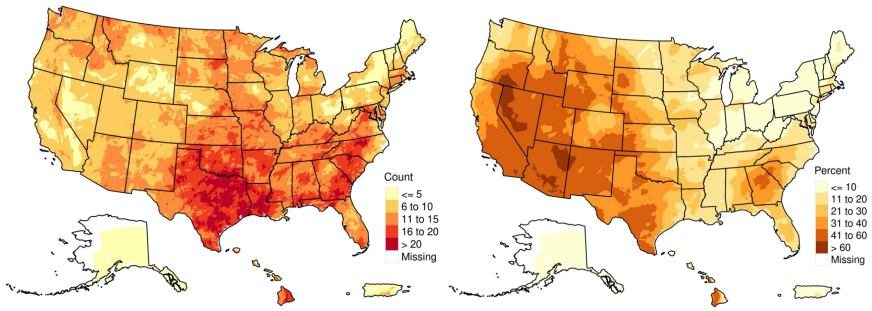


Figure 2. *(left) a county of the number of unique drought events and (right) percent of time in D1 or worse USDM conditions from 2000 through 2019.*

Planned work

- Publish project results in the *Bulletin of the American Meteorological Society*.
- Continue evaluation of the relative importance of drought severity and timing with agriculturally based insured losses.
- Explore the relationship between drought events and accompanying heatwaves with adverse health outcomes.

Other

- Interns: Andrew Coleman (UNC Asheville) and Emma Hughes (Duke University)

Machine Learning Based Quality Control: a USCRN Soil Moisture and Temperature Test Case	
Task Leaders	Ronald D. Leeper and Garrett Graham
Task Code	NC-SAS-10-NCICS-RL/GG

Highlight: Binary and multiclass learning algorithm operators were applied to U.S. Climate Reference Network (USCRN) soil moisture observations with preliminary results showing the binary algorithm successfully detected 96% of the observations manually flagged under current quality control processes.

Background

The U.S. Climate Reference Network (USCRN) operates over 1500 soil sensors across the U.S. These hourly observations are manually maintained to ensure quality of observations, requiring up to 60 hours a month of quality control work. A majority (75%) of manual flags relate to data spikes (upward or downward) that, when numerous (more than 20 hours), result in over-flagging, with the entire month flagged. The development of an automated algorithm utilizing machine learning techniques to quality control soil moisture observations will greatly reduce manual QC effort, reduce over-flagging, and should result in increased availability of high-quality soil moisture data. This work will continue in a new 2021 NCEI INNOVATES project.

Accomplishments

Binary and multiclass learning algorithm operators were trained on manually flagged soil moisture observations since 2017. Results from the binary operator were very promising (Fig. 1), with 96% of the anomalous observations detected by the algorithm.

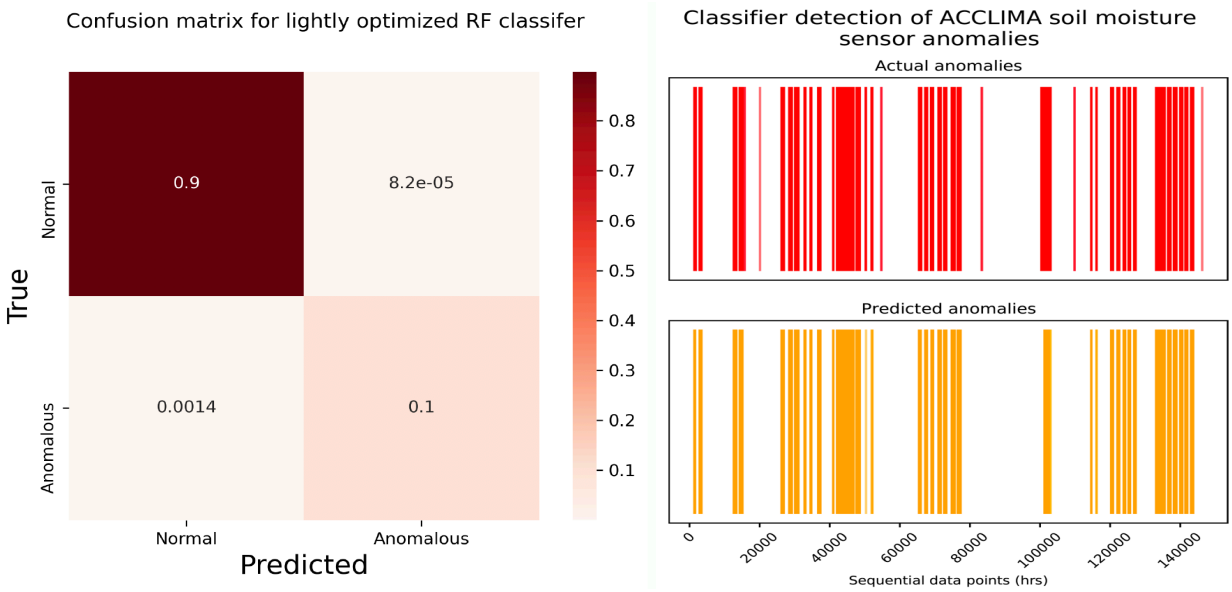


Figure 1. *Weighted confusion matrix (left) of the binary operator, and timeseries (right) of USCRN manually flagged (red) and machine learned algorithm detected (orange) hourly anomalous soil moisture observations since 2017.*

Planned work

- Evaluate efficiency gains from the use of an automated QC algorithm compared to manual effort.
- Evaluate algorithm performance by flag type.
- Evaluate algorithm application on the network's older Hydra sensor dataset not used in the training phase.

Evaluation of air and soil temperatures for determining the onset of growing season	
Task Team	Ronald D. Leeper and Jessica Matthews
Task Code	NC-SAS-11-NCICS-RL/JM

Highlight: NDVI satellite estimates of start of season (SOS) were reevaluated to correct for geolocation discrepancies which improved the spatial comparisons between satellite and USCRN station-based SOS estimates. Analyses reflected greater similarity of station to NDVI SOS estimates using soil moisture.

Background

Climate observations of growing season are essential for understanding plant phenology and physiological development. Air temperature has traditionally been used to define the onset and end of the growing season when phenology measurements are not available. However, soil temperature conditions have recently been shown to be an indicator of root nutrient uptake and vegetative growth. Using start of season (SOS) estimates derived from remotely-sensed MODIS normalized difference vegetation index (NDVI) data, comparisons were made with in situ-based SOS estimates from air, surface, and soil temperatures as measured by the U.S. Climate Reference Network (USCRN).

Accomplishments

Analyses comparing NDVI satellite estimates of SOS were reevaluated to correct for geolocation discrepancies and a new approach to comparisons was performed that showed there were more stations similar to NDVI estimates of SOS using soil temperature estimates than air temperature (Table 1). The correction for geolocational errors was found to improve the spatial comparisons between satellite and station-based estimates of SOS (Figure 1).

Measure	Best Choice	Total Cases	Best Choice Fraction
Air	203	2183	0.0930
Surface	181	2192	0.0826
5 cm	300	1848	0.1623
10 cm	252	1707	0.1476
20 cm	208	1306	0.1593

Table 1. *Counts of cases where each temperature-based SOS date was closest to the NDVI-based SOS date.*

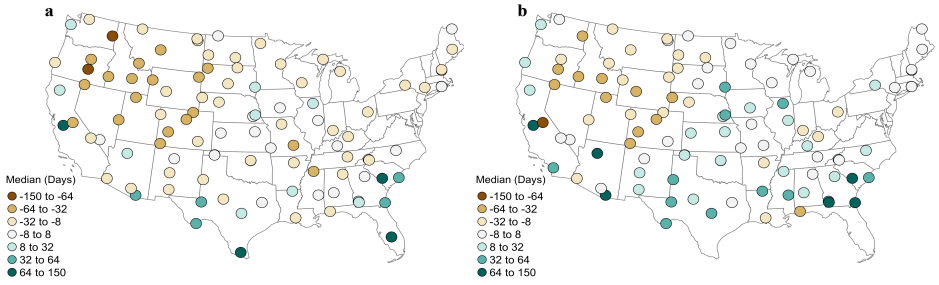


Figure 1. *SOS date differences computed as NDVI minus (a) air temperature at 0°C threshold dates and (b) 5cm soil temperature 5 ºC threshold dates.*

Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES Data	
Task Leader	Jessica Matthews
Task Code	NC-SAS-12-NCICS-JM

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. A cloud mask developed by MeteoSwiss was installed, configured, and successfully executed with test METEOSAT data on CISESS NC 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 (ECV) by the Global Climate Observing System. In support of the Sustained, Coordinated Processing of Environmental satellite data for Climate Monitoring (SCOPE-CM), NOAA/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, CISESS NC 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 AREA 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. 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 NC computing servers. Currently, plans are being made to reformat the GOES archive from AREA format to netCDF, a requirement for the cloud mask implementation.

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 NC team is collaborating with statisticians from University of California, Santa Cruz, to create a framework leveraging spatial statistics methods. Exploratory work has been done over CONUS to calibrate spatial models to observations (Figure 1). Next steps will be to characterize the differences in model parameterizations for the same locations as viewed by different satellite positions, leading to a model of the discrepancy and an understanding of true albedo values independent of satellite position.

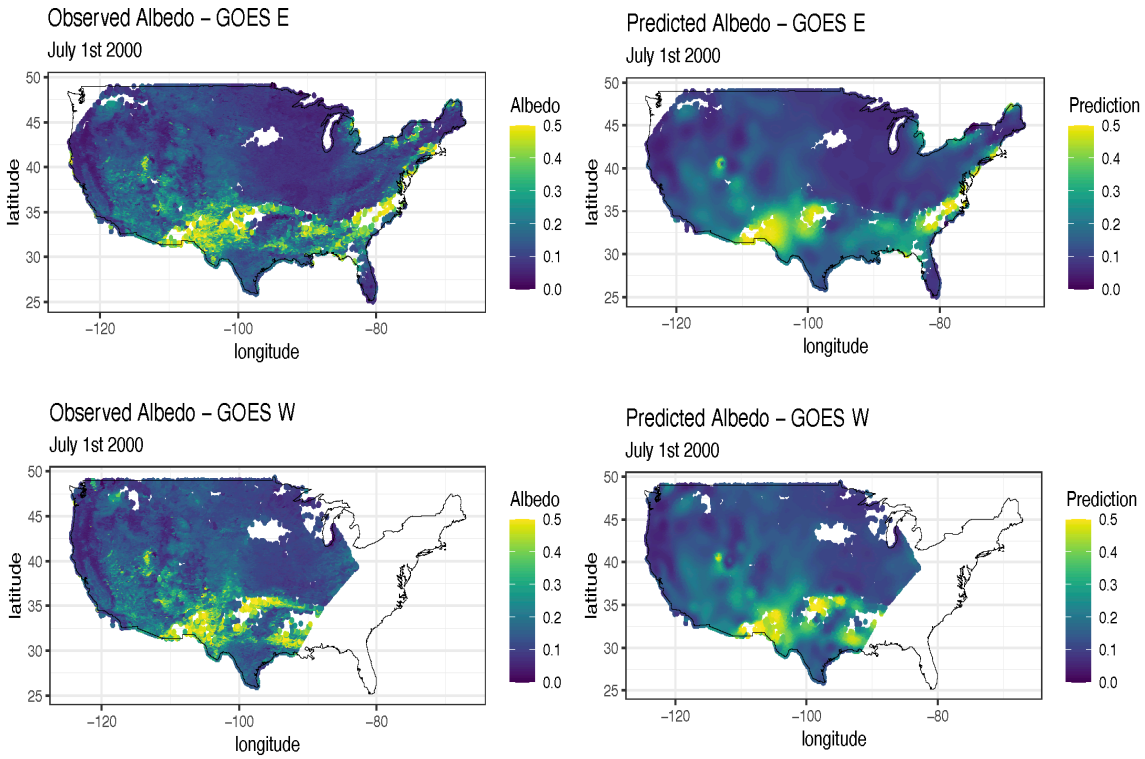


Figure 1. *Albedo observations (left) versus spatial model predictions (right) for GOES-E (top) and GOES-W (bottom) positions on July 1, 2000.*

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.
- Continue development of flexible spatial statistics models to blend massive geostationary-derived climate data records.

Other

- Student: Kelsey Blackstone (University of California Santa Cruz)

HIRS Temperature and Humidity Profiles	
Task Team	Jessica Matthews, Yuhan (Douglas) Rao
Task Code	NC-SAS-13-NCICS-JM/YR

Highlight: The team is applying neural networks to High-Resolution Infrared Radiation Sounder (HIRS) data to develop a global temperature and humidity profile dataset for 1978–present. The dataset has been extended through 2019 and a new cloud screening process is under development to address limited data over oceans.

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 CO_2 data, were used as inputs to a neural network. The neural networks were calibrated according to surface pressure bins. There are two different neural nets, one for surface pressures lower than 850 mb and one 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, v4, 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, 2) creating a new dataset version incorporating a new approach to cloud-clearing, and 3) 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).

A primary user of the dataset, the International Satellite Cloud Climatology Project (ISCCP), requested extension of the dataset through 2019. Previously, the dataset ended mid-2017 due to instability in the

HIRS sensor aboard the M-02 satellite. Intersatellite calibration of raw HIRS brightness temperatures was performed for M-01. The resultant calibrated HIRS input data from M-01, along with PATMOS-x data from M-01, was used to produce the dataset extension.

The team initiated the process to begin the research-to-operations transition with the formal request to archive the dataset with NCEI. While the request is under consideration, work continues to achieve archive milestones such as developing the code to convert the current ASCII format to netCDF output format and creating supporting algorithm theoretical basis documentation.

Previous analysis of the version 4 HIRS profile data revealed that the cloud-screening process is too conservative, which led to limited data availability over ocean. The team has been developing a new cloud-screening procedure using the PATMOS-x cloud property CDR. Considering HIRS has coarser resolution comparing to PATMOS-x data, the new cloud-screening process will take this resolution difference into consideration by looking at both the mean value and the variability of PATMOS-x cloud fractions and probabilities within a HIRS pixel. This new cloud-screening procedure also improves the accuracy of cloud flag indicators in the retrieved HIRS profiles.

Additionally, during the reprocessing of HIRS to its next version (version 5), analysis reflected that there are notable differences of HIRS brightness temperature (BT) over multiple channels for overlapping areas between two adjacent orbits (Figure 1). For example, Channel 12 exhibited notable differences (with median value of –0.13 K) which may affect the retrieved temperature and humidity profiles. To address this issue, the team will add additional filters to remove observations with large BT differences in the overlapping areas between two orbits.

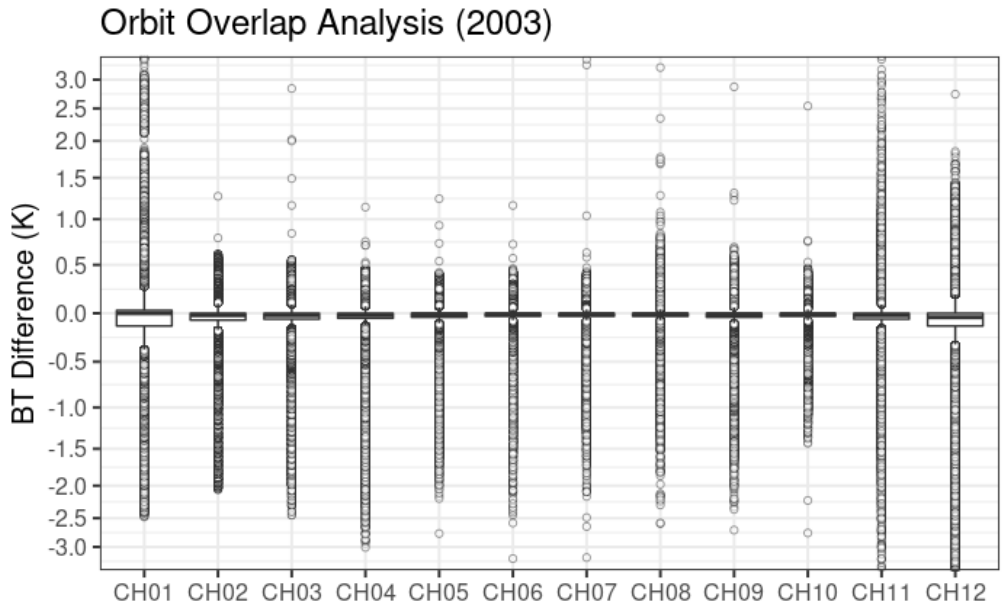


Figure 1*. The boxplot of brightness temperature differences for 12 HIRS channels in the overlapping areas between two adjacent orbits for Metop-2 data in 2003.*

During the transition from version 4 to version 5 of HIRS profile data, the team is refactoring the version 4 code using a modern programming language (i.e., Python) to streamline the data processing in version 5 product generation.

Planned work

- Complete development of a new dataset version and produce reprocessed time series of HIRS temperature and humidity profiles to present.
- Complete code development 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).

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-14-Duke-AB

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. QPE errors exhibit distinct seasonal behavior with overestimation in the cold season and underestimation in the warm season.

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).

Due to a delayed project start, effort was focused on two project 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.

Accomplishments

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

Task 2. SCaMPR precipitation estimates from 2017 and 2018 were evaluated against rain gauge measurements from the SAM Duke network. The results confirm previous analysis with SCaMPR that show 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. One finding from the intercomparison of co-georeferenced SCaMPR and raingauge measurements is the distinctive behavior with season between the western, inner and eastern regions. In particular, we find that in the cold season, SCaMPR overestimates the precipitation intensity.

Planned Work

This portion of the project is ending due to discontinuation of funding.

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-15-UNCA-DM

Highlight: Completed summer and fall 2020 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 13-year (July 2007–June 2020) record of precipitation observations continues and significant findings have emerged and are in the process of being published (e.g., Miller et al. 2021a, b).

Since 2016, NOAA's National Environmental Satellite, Data and Information Service (NESDIS) has helped support the extension of the Duke GSMRGN period of observations in collaboration with CISESS consortium partner UNC Asheville.

Accomplishments

Gauge visitation in support of the Duke GSMRGN occurred over 9–10 days spanning 5–7 weeks during each of the following cycles: summer 2020 (2 - 31 July) and fall 2020 (3 October–13 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 was 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 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 2020; 3 – 31 July

Field supervisor Miller made the visits and performed the required work along with one volunteer at the Waynesville Watershed. It was the first season that uniform electronic contact cleaning was performed at every rain gauge between the logger leads and the gauge switch connector. Over the 12+ years, residue had built up to a significant point, and multiple gauges were experiencing a significantly reduced number of tips due to poor contact between the data logger leads and the gauge switch connector.

Gauge maintenance and data logger condition monitoring included the following:

- *Lithium battery replacement.* Lithium batteries were replaced in the data loggers at three gauge locations due to a surprising amount of battery power drainage since they were last replaced in the spring 2020 gauge campaign.
- *"TA" resets for several data loggers.* The "Time Adjust" on some of the older loggers makes poor 'decisions' on correcting for time errors and must be set to "off" at several gauges [g107: Lookout

Point; g011: near Camp Daniel Boone; g112: Ore Knob; g307: Balsam Mtn Trail; g005: Deep Gap]. This will have to be monitored and, if problems persist, replace old loggers with new.

Specialized tasks completed:

- *g300 (Camel Hump Knob)* ML1-420 data logger was replaced by an older ML1-FL logger as the 420 was a consistent battery hog (drained power much too quickly).

The primary challenges encountered during some of the gauge visits in the summer 2020 centered around the active convection season on and after 17 July 2020. No data was lost between the spring and summer 2020 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-FL loggers. It is likely these will have to be gradually replaced over the next two years of the study. A *Davis Pro* weather station has been installed near the Mount Sterling fire tower, next to g310. The owner of the weather station (and data) at Duke Power has yet to respond to repeated inquiries about the sharing of weather data helpful in discerning the source of bucket tips (falling rain or melting ice/snow).

Fall 2020; 3 October – 13 November

Nine 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 three ML1 loggers (g301 {new ML1 logger!}, g107, and g109), TA error "At least 12hrs must elapse!"
- *ML1 logger time adjust* was set to "off" at g307, g304, g107, and g005 in the hope the adjustment will self-correct during visits in the spring 2021, following the extended winter period. Reinstalled ML1 firmware at g005 in the hope that the TA self-correct will improve.
- *Tree limb removal* was performed at two gauge sites (g308, g311) via the GSMNP arborist.
- *Replaced data logger* at g302 with a new ML1-FL data logger and replace data logger at g011 and g008 with old 'reliable' ML1-FL data loggers.
- *The g010 rain gauge and base were found knocked over* (presumably by a bear) on 30 October 2020. This is the second October in a row that this has happened at this location. The tip observations indicated that the tip-over likely happened on 3 October 2020. The gauge was righted, and adjustments to the logger and gauge level were made.
- *The rain gauge outer ring at g109* was found to be off the rain gauge base and also had a significant underestimate of tips, particularly during tropical systems Delta and Zeta. Replaced old switch with new and replaced funnel outer ring to its proper position. The outer ring at g110 had also been removed and was replaced to its proper position.

Challenges encountered during some of the gauge visits in the autumn 2020 were a result of diminishing daylight hours and a relatively rainy autumn season. 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 2020:
http://www.atms.unca.edu/dmiller/GSMRGN_report_2aug2020.pdf
https://drive.google.com/file/d/1279Pfx0EsnWRzCjhXd_5NsWwOCNXgiY2/view?usp=sharing

Fall 2020:
http://www.atms.unca.edu/dmiller/GSMRGN_report_18nov2020.pdf
https://drive.google.com/file/d/1T_fFKWnvyEm7kOmhgi0q-PsWG3FWCQYR/view?usp=sharing

Planned work

• Spring 2021 (March – May) gauge visitation

In addition to the general visit tasks, all rain gauges will be calibrated (the last calibration was completed in spring 2020). 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 2021

The summer and fall gauge visitations will focus on normal collection of precipitation observations and maintenance tasks, cleaning electronic contact between data logger leads and the gauge switch (summer 2021) and replacing data logger lithium batteries (fall 2021).

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 2020–2021 academic year technician roster includes Meredith Avison, Marlee Burgess, Lyn Comer, Andrew Hill, Alice Monroe, Zachary Moss, Samuel Peterson, Riley Ross, and Paige Stedina. New students will be recruited in fall 2021, as three students will graduate from UNC Asheville in May 2021.

Products

Bob Kuligowski's group continues to use Duke GSMRGN observations as part of research validation efforts. Results are being incorporated into a two-part paper led by PI Miller examining two heavy rainfall events that occurred in the southern Appalachian Mountains early in 2020. Observations of the Duke GSMRGN are one of the cornerstones for interpreting the severity and timing of the two flooding events.

Presentations

Miller, D.K., 2020: Water Fight at Cataloochee Creek. Virtual. *JPSS Initiative meeting*, June 22, 2020.

Other

Nine UNC Asheville undergraduate students received field research credit for project activities.

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., 2014: NASA GPM-Ground Validation: Integrated Precipitation and Hydrology Experiment 2014 Science Plan, Duke University, Durham, NC, 64 pp.

Miller, D.K., Hotz, D., Winton, J., Stewart, L., 2018: Investigation of atmospheric rivers impacting the Pigeon River Basin of the southern Appalachian Mountains. Wea. Forecasting, 33, 283 - 299

Gridded In Situ USCON Temperature and Precipitation Normals	
Task Leader	Ge Peng, Carl Schreck
Task Code	NC-SAS-16-NCICS-GP/CS

Highlight: Thirty-year averages (1990–2019) of daily, monthly, seasonal and annual gridded USCON temperature and precipitation fields were computed using NCEI's daily gridded dataset (nClimGrid).

Background

The aim 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 also 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

- Developed software in Fortran to compute daily, monthly, seasonal, and annual normals of gridded in situ USCON temperature (average, maximum, and minimum) and precipitation fields based on the similar methodology for station normals.
- Provided the provisional software, data files of 1990–2019 gridded normals, and images of spatial distributions of the normals to NCEI.

Planned work

- Compute daily, monthly, seasonal, and annual normals (1991–2020) of gridded in situ USCON temperature (average, maximum, and minimum) and precipitation fields, improving the software if needed.
- Support the development of a paper on NCEI normals.
- Examine decadal variability or carry out analysis of gridded normals if time permits.

Products

- Gridded temperature and precipitation normal for 1990-2019

Value-Added Precipitation product suite from CDRs	
Task Leader	Olivier Prat
Task Code	NC-SAS-17-NCICS-OP

Highlight: The evaluation of satellite-based quantitative precipitation estimations (QPEs) are being used to develop value-added precipitation products (annual and monthly daily average precipitation, standard deviations, maximum precipitation, conditional means, percentiles, and percentage of rainy days) computed from satellite precipitation CDRs (GPCP, PERSIANN, and CMORPH). An evaluation of the three satellite precipitation products was completed up to 2018.

Background

Three satellite-based precipitation Climate Data Records (CDRs) were evaluated (PERSIANN-CDR; GPCP; CMORPH) 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 24-year record of daily-adjusted global precipitation. CMORPH is a 23-year record of daily and sub-daily adjusted global precipitation. Each product has been evaluated over their concurrent period. Product intercomparisons were performed at various temporal (annual, seasonal, monthly, daily) 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). The long-term evaluation of the different satellite-based quantitative precipitation estimations (QPEs) is used as a basis for developing a value-added precipitation product suite normal from satellite precipitation CDRs as well as Radar-based Stage IV precipitation estimates.

This task has been refocused to address Normals Product area concerns. The products (originally alternate precipitation normals) have been renamed to eliminate confusion with the in situ–based Normals products. Those value-added precipitation products include annual and monthly daily average precipitation, standard deviations, maximum precipitation, conditional means, percentiles, and percentage of rainy days. Those products are being 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; Stage IV since 2000), depending on each precipitation product (SPP, Stage IV) 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.

Accomplishments

Evaluations of the three satellite precipitation products (SPPs) were completed for the years up to 2018. Average precipitation was computed at various time scales. Although the SPP evaluation was performed globally, a more complete evaluation was performed over CONUS and compared with USCRN (average precipitation, standard deviations, maximum daily precipitation, number of rainy days, performance metrics, percentiles).

Figure 1 displays the value of the maximum daily precipitation and the number of rainy days. For the daily maximum rainfall, CMORPH displays higher values (Fig. 1c) while GPCP displays much lower values (Fig. 1e), with PERSIANN-CDR found between both (Fig. 1a). Large differences are also found in the number of rainy days. For land areas located along the equatorial belt, PERSIANN-CDR (Fig. 1b) displays the highest number of rainfall days, with GPCP (Fig. 1f) in close second and CMORPH displaying a significantly lower

number of rainy days further restricted to a smaller land area (Fig. 1d). Outside of the equatorial belt, CMORPH displays the lowest number of rainfall days (Fig. 1d) before PERSIANN-CDR (Fig. 1b) and GPCP (Fig. 1f). For CMORPH, patterns for rainy day counts align more distinctively with orographic land characteristics than for the other two SPPs; as can be seen with the frequency of rain events over CONUS where PERSIANN-CDR (and to a lesser extend GPCP) presents a higher number of rainy days.

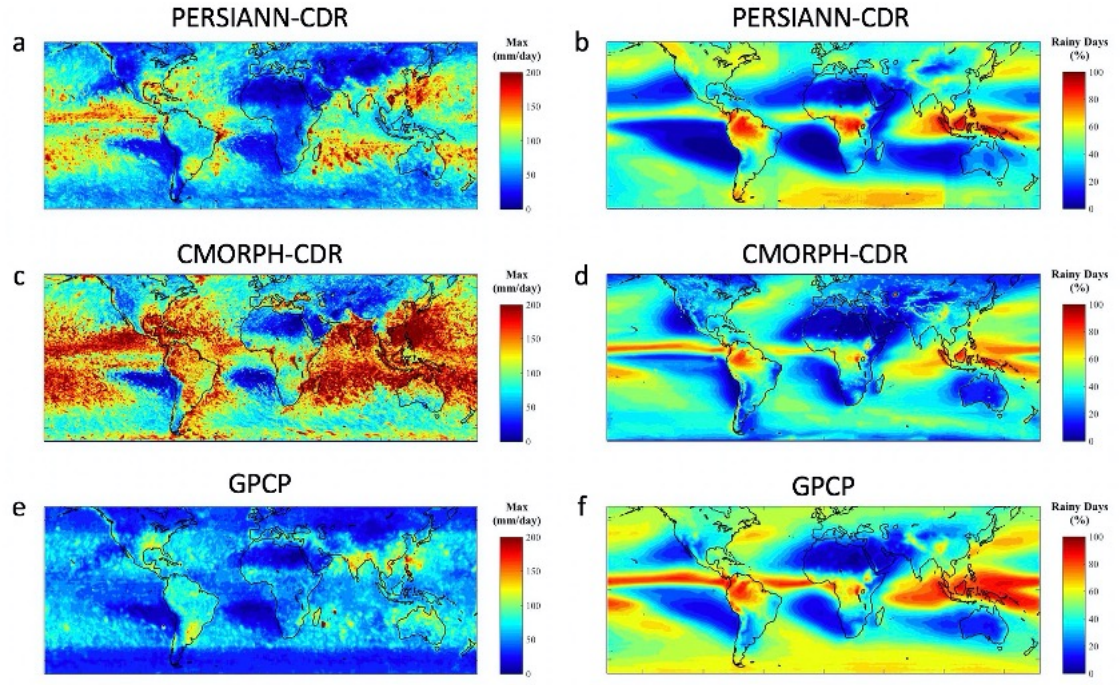


Figure 1. *Daily maximum rainfall (left column) and number of rainy days (right column) for PERSIANN-CDR (a-b), CMORPH (d-e), and GPCP (e-f) for the period 1998-2018.*

	SPP	Number of Events	Daily Rainfall (mm/day)								
			AVG	SDV	P25	P50	P75	P90	P95	P99	MAX
Unconditional (R≥ 0)	GPCP		2.35	6.61	0	0	1.18	7.25	13.63	32.55	147.46
	PERSIANN		2.31	5.49	0	0.23	2.07	6.62	11.61	26.28	193.64
	CMORPH		2.03	6.96	0	0	0.40	5.10	12.10	34.80	189.10
	USCRN		*2.27*	*7.87*	*0*	*0*	*0.30*	*5.90*	*13.80*	*38.30*	*349.30*
Conditional (R>0)	GPCP > 0	282867	6.01	9.48	0.56	2.43	7.45	16.11	23.86	45.81	147.46
	USCRN > 0	*203055*	*8.09*	*13.18*	*0.80*	*3.10*	*9.70*	*21.80*	*32.60*	*62.00*	*349.30*
	PERSIANN > 0	381903	4.36	6.93	0.74	1.87	4.97	11.15	16.93	33.39	193.64
	USCRN > 0	*202051*	*8.10*	*13.19*	*0.80*	*3.10*	*9.70*	*21.90*	*32.60*	*62.10*	*349.30*
	CMORPH > 0	248463	5.93	10.89	0.40	1.60	6.40	16.90	26.70	52.60	189.10
	USCRN > 0	*203055*	*8.09*	*13.18*	*0.80*	*3.10*	*9.70*	*21.80*	*32.60*	*62.00*	*349.30*

Table 1. *Statistics of daily rainfall distributions (average, standard deviation, percentiles, maximum) derived from the three SPPs (GPCP, PERSIANN, CMORPH) over CONUS for the period 2007-2018, and comparison against USCRN stations. Results are provided for unconditional (R ≥ 0) and conditional (R > 0) comparisons.*

Table 1 reports the statistics of the long-term evaluation of comparison of each SPP against USCRN stations for the period 2007-2018. Since USCRN stations are not used in the bias adjustment procedure of the three SPPs, this provides an independent evaluation of each SPP. Those evaluations are computed unconditionally (i.e., $R \geq 0$) and unconditionally ($R > 0$). Significant differences (average rainfall, percentiles, daily maximum rainfall, number of events) are observed between the three SPPs and between the SPPs and the in-situ data (USCRN).

Planned work

- Continue development of the Value-Added Precipitation product suite from CDRs as needed (update upon data availability, format).

Toward the Development of Climate Data Records (CDRs) for Precipitation: Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs)

Task Leader	Olivier Prat
Task Code	NC-SAS-18-NCICS-OP

Highlight: This effort is a long-term assessment of the different satellite-based precipitation products from four Climate Data Records (PERSIANN-CDR; GPCP; CMORPH-CDR; AMSU A-B Hydro-bundle). This year, the team evaluated the ability of three of the products to capture cold season precipitation.

Background

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

Accomplishments

The work regarding the global evaluation of satellite precipitation products (SPP) CDRs was extended to cold precipitation. The team evaluated the ability of different daily gridded satellite precipitation products (CMORPH-CDR, PERSIANN-CDR, GPCP) to capture cold season precipitation. The evaluation was performed at the daily scale over CONUS for the period 2007-2018. The daily precipitation measurements at the ground and the atmospheric conditions (temperature, relative humidity) were obtained from the US Climate Reference Network (USCRN). The USCRN network (including associated local networks) is composed of about 240 stations. Among those USCRN stations, 70 are located between latitudes 40°–60°N, and 65 are located above an altitude of 1500 m. The USCRN network provides sub-hourly (5-minute), hourly, and daily precipitation measurements from shielded gauges in addition to air temperature and wind speed information at 1.5-m. The evaluation was performed by using the usual mathematical toolbox, which includes bias (conditional and unconditional), Kling–Gupta efficiency (KGE), Pearson's correlation coefficient (CORR), bias (BIAS) and variability ratio (VAR), Contingency analysis (YY, NY, YN), Number of rainy days, Percentiles, Frequency Bias, False Alarm Ratio (FAR), Probability of Detection (POD), and Probability of False Detection (POFD).

Overall, CMORPH was found to perform better in terms of accuracy, FAR, POD, and POFD while PERSIANN-CDR displays higher FAR values than the two other SPPs. CMORPH presents smaller bias and higher correlation (conditionally, unconditionally) than PERSIANN-CDR and GPCP (Figure 1). All SPPs were found to miss a sizeable number of rainfall events observed at the ground (about 10–20%) and wrongly detect events that aren't observed at the ground (about 40–50%).

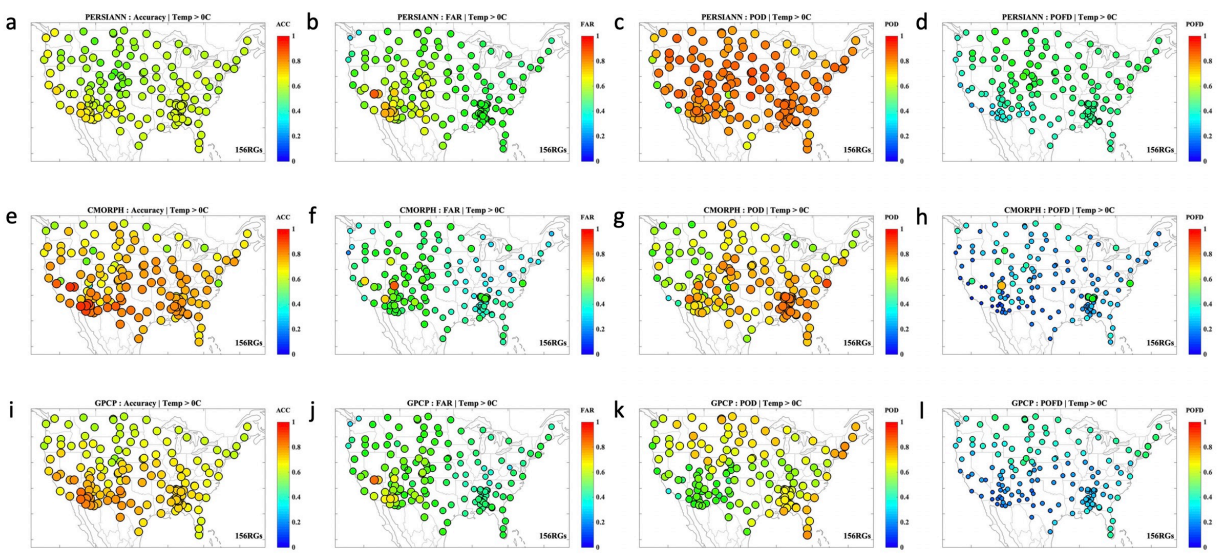


Figure 1. *Performance comparison (Accuracy, FAR, POD, POFD) for the three SPPs for days with an average temperature above 0°C at the USCRN station.*

During the cold season (Figure 2), CMORPH displays significant lower performance as indicated by the lower values of POD (Figure 2) and by the higher ratio of misses (not shown).

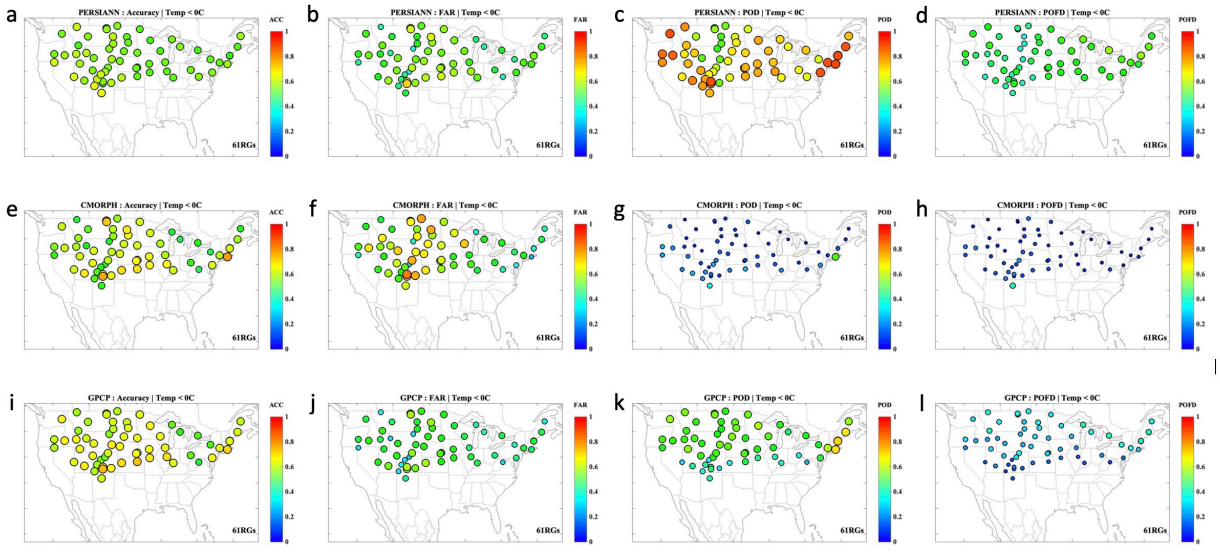


Figure 2. *Performance comparison for the three SPPs for days with an average temperature below 0°C at the USCRN station.*

On an annual basis (YEA) and during the warm season (JJA), CMORPH is more consistent in terms of performance (Kling–Gupta efficiency: KGE, Pearson's correlation coefficient, bias, variability ratio) (Table 1). However, during the cold season (DJF), CMORPH presents a lower KGE score (including the Pearson's correlation coefficient, the bias, and the variability ratio), than the two other SPPs. Those results are consistent when considering records simultaneously at the SPP/USCRN (conditional: Table 1) or at one or the other sensor SPP or USCRN (unconditional: not shown).

R>0 & S>0	PERSIANN			CMORPH			GPCP			Ideal Score
	YEA	JJA	DJF	YEA	JJA	DJF	YEA	JJA	DJF	
KGE	0.30	0.17	0.26	0.50	0.41	0.09	0.29	0.18	0.15	1
CORR	0.42	0.30	0.43	0.55	0.47	0.48	0.35	0.26	0.31	1
BIAS	0.71	0.72	0.65	0.93	0.92	1.12	0.93	0.87	0.99	1
VAR	0.82	0.70	0.89	0.99	0.90	1.22	0.94	0.81	1.14	1

***Table 1**. Kling–Gupta efficiency (KGE), Pearson's correlation coefficient (CORR), bias (BIAS) and variability ratio (VAR) for daily precipitation with respect to USCRN in-situ data for the three SPPs. Biases and correlations are computed conditionally (i.e., considering only non-zeros simultaneously at the USCRN station and at the corresponding satellite pixel).*

This long-term evaluation (11-years) is helpful in quantifying errors and biases of SPPs with respect to cold season precipitation and could provide an objective basis for rainfall retrieval algorithm improvement.

Planned work

- Finalize Journal of Hydrometeorology manuscript revisions (conditionally accepted).
- Submit a paper on SPPs performance in capturing cold precipitation and a paper on Stage IV precipitation estimates in Alaska (Remote Sensing).

Publications

Nelson, B. R., **O. P. Prat**, and **R. Leeper**, 2021: Using ancillary information from radar-based observations and rain gauges to identify error and bias. *Journal of Hydrometeorology*, **In press**. http://dx.doi.org/10.1175/jhm-d-20-0193.1

Presentations

Prat, O. P., B. R. Nelson, and **R. D. Leeper**, 2020: Evaluation of Cold-Season Precipitation Estimates Derived from Gridded Daily Satellite Precipitation Products. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 16, 2020.

Nelson, B. R., and **O. P. Prat**, 2020: An Assessment of a Gridded Gauge-Based Precipitation Estimates (nClimGrid) with National Centers for Environmental Prediction (NCEP) Stage IV Radar-Based Precipitation Estimates. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 15, 2020.

Drought Detection Using Remotely Sensed Precipitation Data from the Climate Data Record CMORPH	
Task Team	Olivier Prat, Ronald Leeper, Jessica Matthews
Task Code	NC-SAS-19-NCICS-OP/RL/JM

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 drought events around the globe but important differences over areas with limited precipitation. Operational global daily SPIs were computed from CMORPH-CDR and CMORPH-ICDR to monitor drought conditions.

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 focus has been on transferring the CMORPH-CDR SPI from research to (quasi)-operation. The daily CMORPH SPI that uses the gamma formulation (McKee et al. 1993) is part of the interactive drought interaction dashboard developed by the National Integrated Drought Information System (NIDIS). The new experimental SPI at high resolution derived from the CMORPH precipitation dataset is available at 30-, 90-, 180-, and 270-day time scale. The global SPI provides near-real time global drought conditions with daily updates within 48-hrs to the current day. Figure 1 presents the global SPI computed on June 1st 2020, September 1st 2020, and January 1st 2021, presented here for the 30-, 180-, and 270-day time scales. As illustrated by this example, differences in short term (30-day) and longer-terms (180-, 270-day) drought conditions are particularly noticeable in North and South America. Over

the United States, the drought conditions indicated by the CMORPH SPI, match the timing and intensity of the drought conditions from the Great Plains to the West Coast indicated by the US Drought Monitor (USDM).

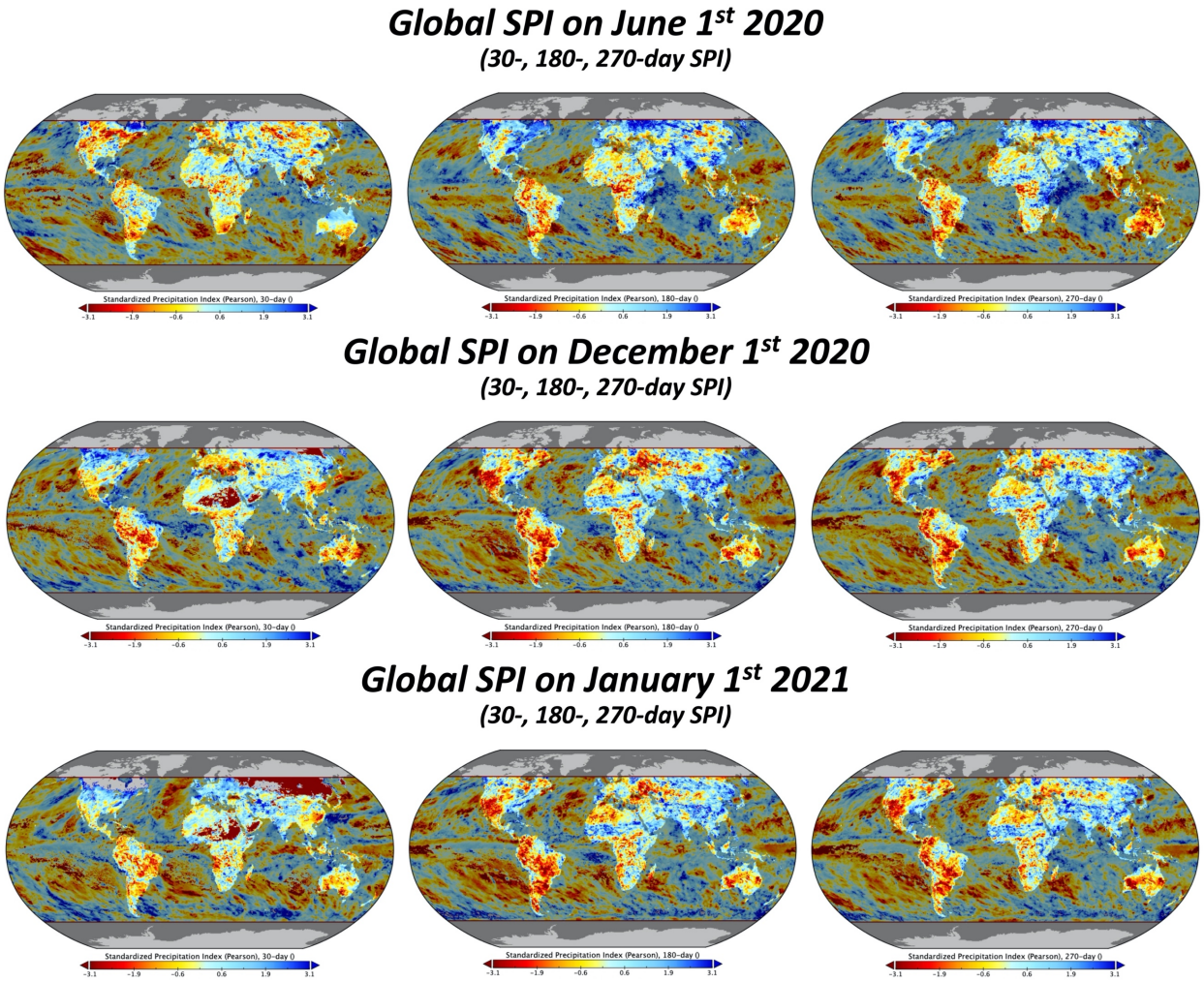


Figure 1. *Operational global drought conditions for June 1st 2020, December 1st 2020, and January 1st 2021. The daily SPI is derived from CMORPH-CDR and CMORPH-ICDR and computed for 30-, 90-, 180-, 270-, 365-, and 730-day time scales. Presented here, are the 30-, 180-, and 270-day global SPIs.*

Figure 2 displays the daily 270-day (i.e., 9-month) SPI on March 18th 2021 from the interactive dashboard. The dashboard provides drought monitoring resources such as interactive mapping, visualizations, and GIS data download capabilities. It builds upon previous work of NIDIS and the Global Drought Information System (GDIS) and CISESS NC. The GDIS website includes an interactive map hosted within the NOAA GeoPlatform (ArcGIS Online). There are currently 45 layers of drought indices and indicators available and among the daily CMORPH SPI.

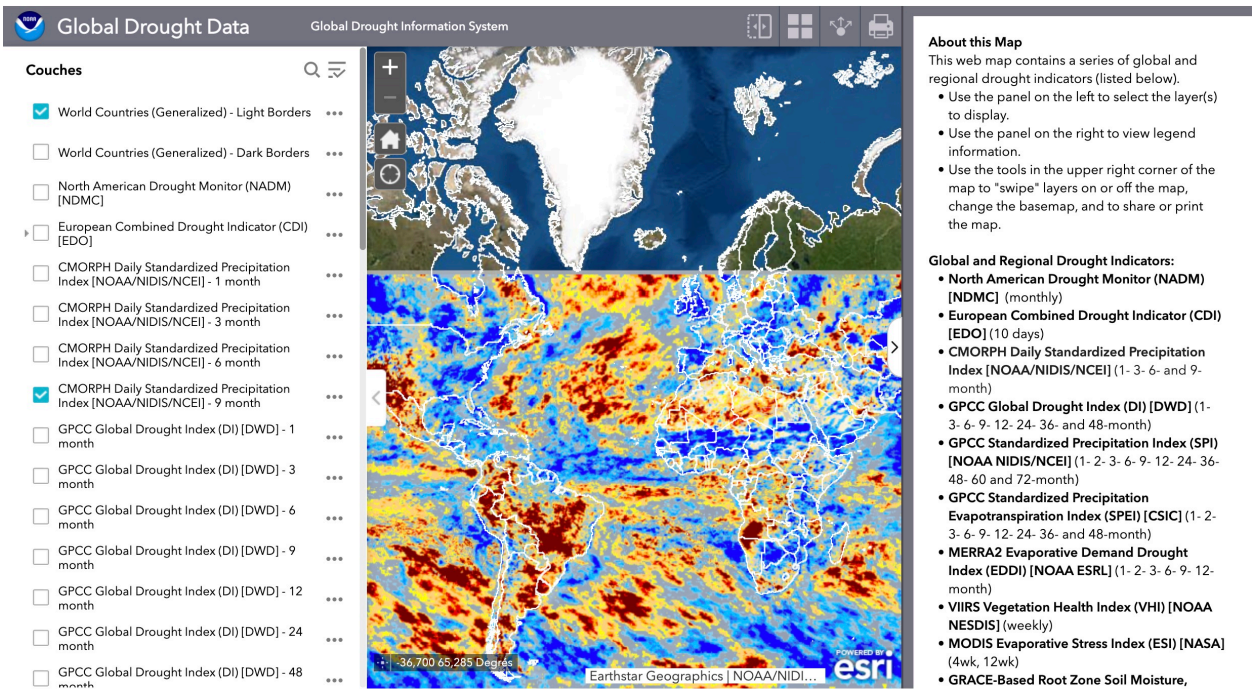


***Figure 2**. Screenshot of the drought information dashboard displaying the global daily SPI derived from the high resolution CMORPH-CDR precipitation dataset. Presented is the 270-day SPI on March 18th 2021.*

Current work will extend the framework developed for the CMORPH SPI and adapt the Python code to other datasets. Primarily, the code will be adapted to the high resolution (0.05°) in situ–based gridded precipitation product NCEI nClimGrid over CONUS from 1950 to the present time. Ultimately, developing a streamlined ingest process will allow consideration of other gridded precipitation datasets (e.g., CMORPH at 8-km resolution, IMERG at 0.1° resolution, Stage IV at 4-Km resolution) and in situ datasets (GHCN-D) alike. Another aspect of the work will be implementing additional drought indices such as the non-parametric SPI (Farahmand and AghaKouchak 2015) and performing benchmark comparisons with existing SPI formulations (Gamma distribution: McKee et al. 1993, L-moments and Pearson III distribution: Guttman 1998) in order to quantify differences between drought indices.

A new drought amelioration processing system is being implemented that is using SPI as the drought metric and NCEI nClimGrid precipitation dataset as input. The drought relief module will allow estimation of the precipitation amount that would be needed (i.e., rainfall deficit) for drought relief at each given location. The amount of rainfall that corresponds to the passage from a category D4 (extreme drought) to D3 (severe drought) for example (or any other combination Dx-Dy) will depend on the accumulation period considered (daily: 30-, 60-, 90-, 180-, 270-, 360-day). By using daily SPI instead of monthly SPI, we should be able to detect drought earlier than possible with monthly scales. Due to the flexible framework, it is also possible to compute the SPI at the weekly scale. The system will be flexible to allow amelioration based on a specified percentile of the input dataset, such as SPI, and also based on a percentile of a different dataset, such as the USDM. Possible long-term developments include the improved drought forecasting by ingesting short terms model predictions of seasonal rainfall predictions (3-m to 6-m). They also include the development of more complex drought indices. From precipitation driven indices only (SPI), we will incorporate other datasets such as gridded soil moisture, vegetation indices, and streamflow. NDVI datasets from the CDR program over the Southeastern United States are currently being analyzed.

Planned work

- On-going evaluation of the CMORPH-CDR daily SPI against in situ drought monitoring products (USDM, GPCC_DI).
- Adapt the existing Python code to ingest other precipitation datasets (nClimGrid).
- Implement additional indices (non-parametric SPI) along existing indices (Gamma, Pearson III).
- Implement and test the drought relief module to quantify the amount of rain needed to end a given drought (severity, accumulation period).
- Publish a paper on the daily and monthly SPI derived from CMORPH and PERSIANN-CDR.

Products

- Operational near-real-time global daily CMORPH SPI available within 48-hrs to the current day. The global CMORPH SPI is available via the Interactive Global Drought Information Dashboard (https://gdis-noaa.hub.arcgis.com/).

Presentations

Bilotta, R., A. M. Courtright, **O. P. Prat**, **R. D. Leeper**, B. R. Nelson, and S. Ansari, 2021: Visualizing Drought Indices Using Remotely Sensed Near-Real Time Monitoring. Poster. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.

Prat, O. P., A. M. Courtright, **R. D. Leeper**, B. R. Nelson, R. Bilotta, J. Adams, and S. Ansari, 2020: Operational Near-real Time Drought Monitoring Using Global Satellite Precipitation Estimates. Poster. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.

Prat, O. P., A. M. Courtright, **R. D. Leeper**, B. R. Nelson, R. Bilotta, J. Adams, and S. Ansari, 2020: Operational near-real time drought monitoring using global satellite precipitation estimates. Virtual. *2020 EGU General Assembly, Vienna, Austria*, May 7, 2020.

Other

• Intern: Caroline Zuber, NCSU undergraduate student

Developing a blended in situ and satellite global temperature dataset	
Task Leader	Yuhan (Douglas) Rao
Task Code	NC-SAS-20-NCICS-YR

Highlight: Machine learning is being utilized to integrate in situ measurements and satellite-derived surface temperature from HIRS to create a sub-daily gridded temperature dataset since 1978. During data preprocessing, a data availability issue was identified in the earlier version of HIRS-derived temperature data as a result of conservative cloud screening.

Background

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

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

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

Accomplishments

Initial project work focused on data preparation for the model training and pilot model development.

Data preparation for model development. The team has been reprocessing HIRS temperature profile retrievals using raw all-sky HIRS data (version 5), which will significantly improve the data availability over ocean compared to the earlier version (version 4). During the reprocessing for version 5 data, improved inter-satellite calibration coefficients were used to improve the data consistency across different satellite platforms. PATMOS-X CDR cloud products were used to create cloud masks for the new version of the HIRS temperature profile data. Where PATMOS-X cloud data are not available, the team will use the previously developed spatiotemporal homogeneity test for cloud screening. The reprocessed HIRS data will be transformed into a gridded file using NetCDF4 format.

The team completed the extraction of match-up data pairs between HIRS (version 4) and Global Summary of Day (GSOD) for 2000–2019 for land model development, since the data-availability issue is mostly over oceans. The large footprint of HIRS data (nearly 30 km for each pixel) can result in a large spatial mismatch with in situ measurements (i.e., point measurement). To reduce the effect of these spatial mismatches, the team converted the temperature values to temperature anomalies for both in situ and satellite data

in the extracted match-up data pairs between HIRS and GSOD. These match-up data pairs will be used for land model development in the next stage.

Pilot model development for ocean surface. The team used part of the ocean data to test the model framework's feasibility as a pilot study. The pilot model development focused on tropical Pacific Ocean region (i.e., 15°S - 15°N & 130°E - 90°W) where there is a fixed buoy array (TAO/TRITON) providing sub-daily surface temperature measurements at the same measurement height (3-m above sea surface). This unique in situ measurement network allowed modeling framework testing without having to consider the quality of height-adjustment algorithm for other ship-based temperature measurements from ICOADS.

The pilot model development used HIRS-TAO/TRITON match up data pairs from 2000–2019 for model training while using height-adjusted ship-based temperature measurements provided by collaborators from the UK National Oceanography Centre (NOC) for model evaluation. In the pilot model development, the team used two candidate ML models: random forest and rule-based regression ensemble (Cubist) models. Both models are tree-based ensemble models, but with different ensemble strategies, that have shown efficacy in previous studies in combine in situ and satellite observations.

All models were tuned for their hyperparameters using the leave-one-group-out (LOO) cross-validation strategy to define the optimum model structure. Once the model development was complete, we applied both the final random forest model and the final Cubist model to the independent matchup data pairs for height-adjusted ship-based MAT observations from ICOADS provided by NOC. The height-adjusted ship-based ICOADS MAT observations were used as the reference to evaluate the estimations from both the random forest model and the Cubist model. The density scatter plots (Figure 1) demonstrate the machine learning-based estimations compared with the ICOADS reference data.

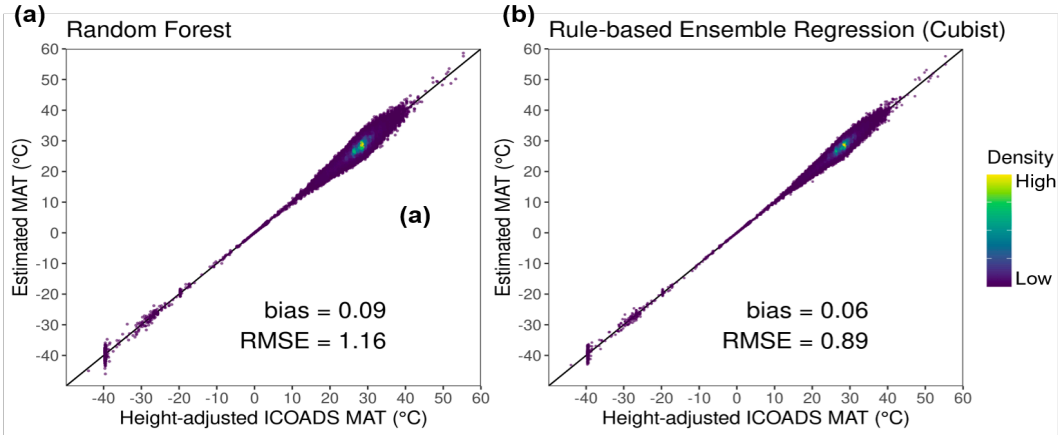


Figure 1. *The comparison of density scatter plots between machine-learning-based marine air* temperature estimation and the height-adjusted ship-based marine air temperature in the ICOADS archive for (a) the random forest model and (b) rule-based ensemble regression model *(Cubist). The bright colors show high point density and the dark colors show low point density.*

Both ML models provided accurate daily estimation of marine air temperature with very low bias between the estimation and the reference data. This small bias may be partly attributed to the different measurement heights between training and testing dataset. The reference MAT data for model training were measured at 3 meters from the TAO moored buoy while the independent reference ship-based MAT data is adjusted to the common height of 2 meters. The difference will be accounted for by using MAT

observations adjusted to the same reference height (i.e., 2 meters) during the full implementation of the project. Additionally, the Cubist regression model shows better performance with smaller root mean squared error (RMSE) in the model estimation. Preliminary results show that the machine learning framework can accurately estimate marine air temperature using satellite observations. during the full implementation of the project, we will explore a larger set of candidate ML models that are capable of completing the same task. Of these we will choose the best performing model based on independent evaluation to use for data production.

Planned work

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

Publications

Shen, M., N. Jiang, D. Peng, **Y. Rao**, Y. Huang, Y. H. Fu, W. Yang, X. Zhu, R. Cao, X. Chen, J. Chen, C. Miao, C. Wu, T. Wang, E. Liang, and Y. Tang, 2020: Can changes in autumn phenology facilitate earlier green-up date of northern vegetation? *Agricultural and Forest Meteorology*, **291,** 108077. http://dx.doi.org/10.1016/j.agrformet.2020.108077

Wang, S., J. Chen, **Y. Rao**, L. Liu, W. Wang, and Q. Dong, 2020: Response of winter wheat to spring frost from a remote sensing perspective: Damage estimation and influential factors. *ISPRS Journal of Photogrammetry and Remote Sensing*, **168,** 221–235. http://dx.doi.org/10.1016/j.isprsjprs.2020.08.014

Wang, S., **Y. Rao**, J. Chen, L. Liu, and W. Wang, 2021: Adopting "difference-in-differences" method to monitor crop response to agrometeorological hazards with satellite data: A case study of dry-hot wind. *Remote Sensing*, **13**. http://dx.doi.org/10.3390/rs13030482

Zhou, J., J. Chen, X. Chen, X. Zhu, Y. Qiu, H. Song, **Y. Rao**, C. Zhang, X. Cao, and X. Cui, 2021: Sensitivity of six typical spatiotemporal fusion methods to different influential factors: A comparative study for a normalized difference vegetation index time series reconstruction. *Remote Sensing of Environment*, **252,** 112130. http://dx.doi.org/10.1016/j.rse.2020.112130

Presentations

Rao, Y., 2020: A satellite based daily near-surface temperature data records for the Tibetan Plateau. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.

Rao, Y., 2020: A satellite-station blended daily surface air temperature dataset for the Tibetan Plateau. Virtual. *2nd NOAA Workshop on Leveraging AI in Environmental Sciences*, January 7, 2020.

Rao, Y., 2020: Creating a blended surface temperature dataset with satellite thermal data and in situ measurements for the Tibetan Plateau. Virtual. *Climate Informatics 2020*, September 23, 2020.

Rao, Y., 2020: What we wish we learned in grad school: A workshop to develop a mini data management training. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.

Other

- 2020 ESIP Catalyst Award recipient.

Supporting the development of artificial intelligence within NOAA and CISESS	
Task Leader	Yuhan (Douglas) Rao, Garrett Graham
Task Code	NC-SAS-21-NCICS-YR/GG

Highlight: The team assisted in the development of the NOAA Center for Artificial Intelligence, began planning for the 11th International Conference of Climate Informatics, and developed a CISESS NC virtual AI training series.

Background

Artificial intelligence (AI) is among NOAA's six science and technology strategies developed since 2019 to improve NOAA's mission. NOAA's AI strategy has five goals to transform and improve NOAA's mission, including "establish an efficient organizational structure and processes to advance AI across NOAA" and "promote AI proficiency in the workforce."

To accelerate the development of AI across all NOAA's mission areas, NCEI spearheaded the development of the NOAA Center for AI (NCAI) in the summer of 2020. The Center performs multiple functions, including coordinating communities of practice around AI across all NOAA line offices, facilitating workforce development across the entire agency, and establishing collaboration within NOAA and external partnerships. The NCAI development team included CISESS NC staff who co-led the development of the NCAI training framework with STAR and collaborated with team members to facilitate the effort to assess the AI-readiness of NOAA's data archive.

Within CISESS NC, the task team co-led the development and implementation of a virtual training series on machine learning and artificial intelligence. The training series is aimed at providing basic knowledge and tools for CISESS NC staff and partners to enable them to understand and use ML/AI in their own respective work. To further the engagement with the community using AI for climate studies, CISESS NC agreed to host the 11th International Conference on Climate Informatics, which focuses on the intersections between climate sciences and data sciences.

Accomplishments

NOAA Center for Artificial Intelligence

Formation of the NOAA Center for AI (NCAI) was authorized by the 2020 National Defense Authorization Act. CISESS NC participated on the NCAI development team in four major tasks:

- *Establishing the NOAA Community of Practice on AI*: In summer 2020, the NCAI development team began interviewing NOAA staff across all line offices to understand the current status and challenges of applying AI in different mission areas. Interviews led to the creation of the Community of Practices around AI for NOAA employees, affiliates, and partners. The Community of Practices currently has more than 200 registered members and is growing steadily.
- *Developing NCAI web presence*: To capture the steady development of NCAI and the Community of Practices, the NCAI development team worked with the NCEI Communications Team to develop a Google site providing resources and upcoming events to the Community of Practices. Additionally, the team initiated a monthly newsletter to share recent Center developments.
- *Developing NCAI training framework*: Working with colleagues from NESDIS/STAR, CISESS NC developed the framework for future workforce development on AI. The framework is based on open science practices and aims to create a curated training materials library from Community of Practices member contributions. To facilitate future curation, the training team developed a common template and guide for contributors, including guidance on reproducibility and

accessibility. The framework was well received by NOAA's AI Executive Committee and has received attention from NOAA partners, including the UK Met Office.

- *Initiating ESIP AI-ready data working group*: During the 2021 ESIP Winter Meeting, the team hosted a session to gather input on the definition and maturity matrix of AI-ready environmental data. A cross-agency working group on AI-ready data was established within ESIP. The working group will meet regularly to promote the development of AI-ready environmental data.

11th Climate Informatics Conference

NCICS/CISESS NC will host the 11th International Conference of Climate Informatics. This international conference series aims to bring together researchers and users across different disciplines and sectors to forge international collaboration between climate science, data science, and computer science; share state-of-art developments in climate data and informatics; and accelerate the rate of discovery in climate science and adaptation of climate applications. CISESS NC began planning efforts by engaging with NCEI leadership and external partners, including The Collider and various cloud service providers, to develop a scientific program for the conference and the accompanying hackathons.

NCICS/CISESS NC AI Training

The NCICS/CISESS NC AI training series was developed collaboratively by the CISESS NC task team (Douglas Rao and Garrett Graham) to introduce the basic concepts and tools of AI that allow CISESS NC staff and partners to leverage AI in their own research and develop potential collaborations. The training series has 47 registered participants from CISESS NC and NCEI. The training series began in April 2020 and includes fourteen sessions with lectures and interactive programming materials to allow hands-on learning. Most training sessions were recorded and are available to all CISESS NC staff and partners.

Planned work

- Develop 2-3 groups of training materials using the NCAI training framework.
- Host the virtual Climate Informatics conference hackathon using data from the NOAA Big Data Project.
- Coordinate the AI-ready data working group effort to define the maturity matrix for AI-ready environmental data.
- Conclude the NCICS/CISESS AI training series and improve all training materials produced in the training series.

Presentations

Rao, Y., C. Slocum, 2021: A Roadmap of Workforce Development for the NOAA Center for Artificial Intelligence. Virtual. *ESIP 2021 Winter Meeting*, January 29, 2021.

Products

- NCICS/CISESS NC AI training series (14 sessions).

Maintenance and Streamlining of the Global Historical Climatology Network-Monthly (GHCNm) Dataset	
Task Leader	Jared Rennie
Task Code	NC-SAS-22-NCICS-JR

Highlight: The next iteration of NOAA's global temperature product (GHCNm version 4.0.1) is now operational. The codebase was put under version control and was successfully pilot tested on a commercial cloud platform. www.ncdc.noaa.gov/ghcnm/

Background

Since the early 1990s, the Global Historical Climatology Network-Monthly (GHCNm) dataset has been an internationally recognized source of information for the study of observed variability and change in land surface temperature. Version 4 of this product has undergone many updates since its initial release in 2018 including incorporating monthly maximum and minimum temperature, improving processing run time, and providing user-driven products. Current version 4.0.1 includes over 25,000 stations globally.

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

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

Accomplishments

Updates are ongoing, based on an NCEI three-tiered system, i.e., development, test, and production environments. Nightly runs are performed internally and checked by the ISTI and GHCN teams to ensure adequate data quality. The code base for version control and portability were updated in 2020. Today, the code exists in an internal git repository and includes an installation script to execute the end-to-end process. A pilot project was performed by NESDIS to utilize the git repository, and run GHCNm version 4 using cloud technologies. Results were successful, with little change made to the code.

Work is underway to move this project from CISESS NC to NCEI staff. Testing is currently underway using the git repository and the CISESS NC test server environment. Once the code base has been set up and successfully run in production by NCEI staff, the work performed by CISESS NC will be complete.

Planned work

- Assist NCEI staff with version control and executing the GHCNm version 4 code base.
- Assist in NESDIS efforts to utilize the code base in cloud technologies.

Products

- Public, operational version of GHCNm version 4.0.1

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool	
Task Team	Jared Rennie, Kenneth Kunkel
Task Code	NC-SAS-23-NCICS-JR/KK

Highlight: The code base for the sub-monthly temperature tool was upgraded to Python version 3. The heat event database will be updated on an annual basis for use in continuing studies on extreme heat impacts on human health. https://ncics.org/portfolio/monitor/sub-monthly-temperatures/

Background

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

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

Accomplishments

An automated system was established to extract the latest version of the following datasets each day: GHCN-D, Northam, the 1981–2010 Normals, and nClimDiv. Using these datasets, monthly adjustments are applied to daily data, and then anomalies are created using a base climatology defined by the 1981–2010 Normals. Station data are aggregated to the state level and then region level (as defined by the National Climate Assessment; NCA). Daily plots are made to analyze U.S. temperature values and anomalies. Once daily averages for each state and NCA region are computed, probability distribution functions are generated to provide ranks on different time scales.

In 2020, the code base was upgraded to Python version 3. The heat event database will be updated on an annual basis and will be used in continuing heat/health studies and other analyses.

Planned work

- Continue to engage with monitoring product users.
- Upgrade normals period from 1981-2010 to 1991-2020.
- Utilize other temperature sources, including the new nClimGrid daily product, currently in beta.
- Work with the University of Nebraska Medical Center and other health-related organizations to identify heat events with available health and socioeconomic data.
- Compare dataset with other climate metrics, such as soil moisture.

Products

- Updated monitoring tool for sub-monthly data for the United States

Developing and Validating Heat Exposure Products Using the U.S. Climate Reference Network	
Task Leader	Jared Rennie
Task Code	NC-SAS-24-NCICS-JR

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), have been developed and validated against data from 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 where land cover and land-use conditions are predicted to be stable for several decades. At each site, a suite of meteorological parameters is 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 were 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 was 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 in 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. Validation was performed using both the North Carolina State Climate Office's mesonet, known as ECONet, as well as nearby ASOS stations. In 2020, this work was extended to incorporate all 139 USCRN sites, and a derived product of heat exposure indices from 2009-present was created. Data gaps were filled in using reanalysis data provided by Copernicus known as ERA5. Hourly climatologies were also developed, following the protocols of NCEI's 1981–2010 hourly normals.

From the derived data and associated climatology, two separate analyses were conducted. The first, based on standardized anomalies, places current heat in the context of a long-term climate record. In the second study, heat events were classified by time spent at various levels of severity and conditions. Figure 1 displays the time series of temperature, HI, AT and WBGT for the Durham, NC USCRN station on October

3, 2019. The standardized anomaly for this day is around two standardized units or higher for all variables, a considerably warm event for this time of the year.

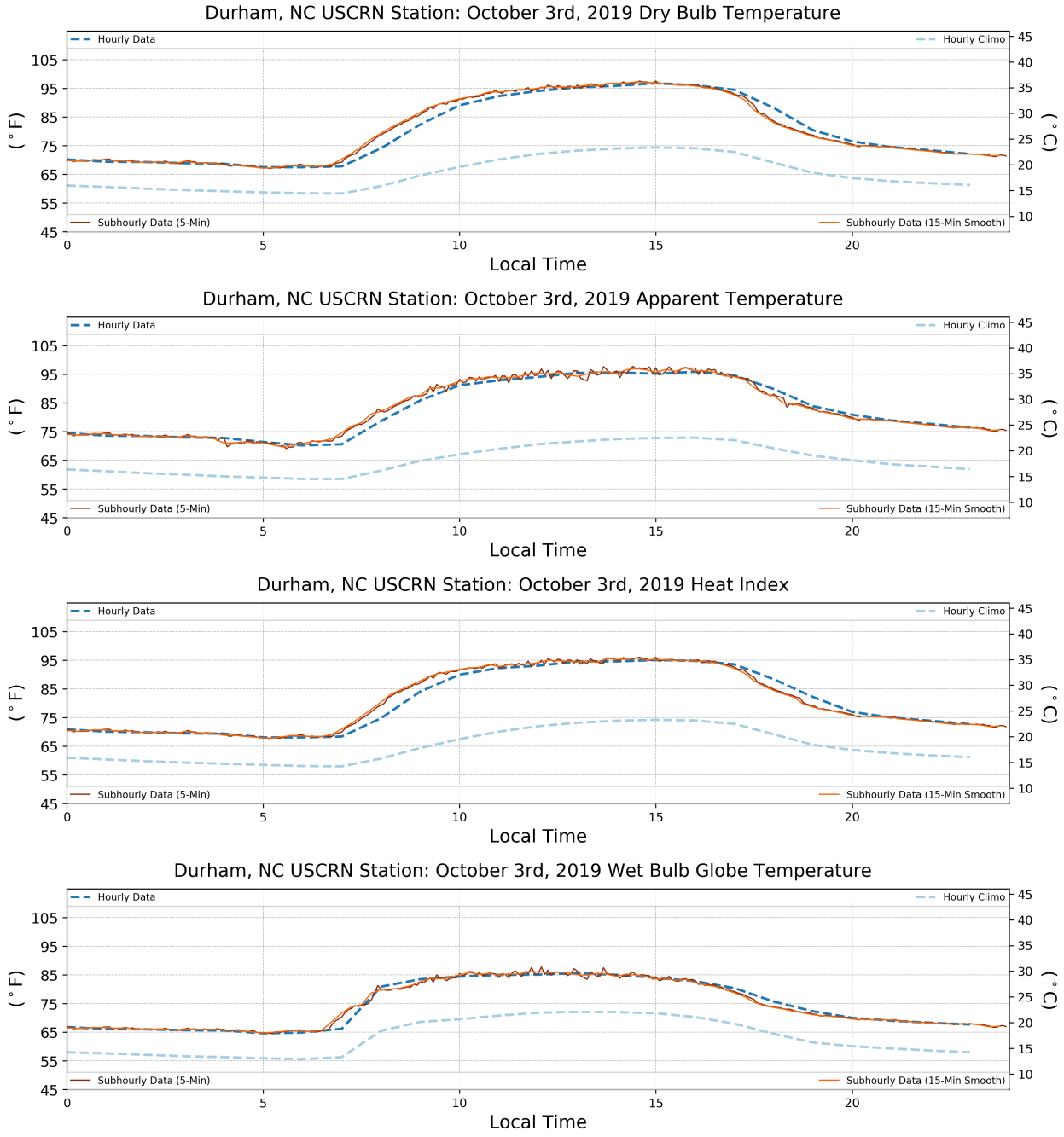


Figure 1*. Timeseries of T, AT, HI and WBGT at the Durham, NC USCRN site for October 3rd, 2019. Data includes hourly value (dark blue) and climatology (light blue), along with original (brown) and smoothed (orange) 5-minute data values.*

To assess local and seasonal heat variability, the 98th percentile for warm-season months are calculated at all USCRN sites (ex., Figure 2). Values can vary considerably, depending on location, as well as which metric is used. WBGT values tend to be lower than others, which can have implications if WBGT is used

for communicating heat information to the public, as dangerous WBGT values (e.g., 90F) may be perceived as not unusual or impactful enough to alter plans for outdoor activities.

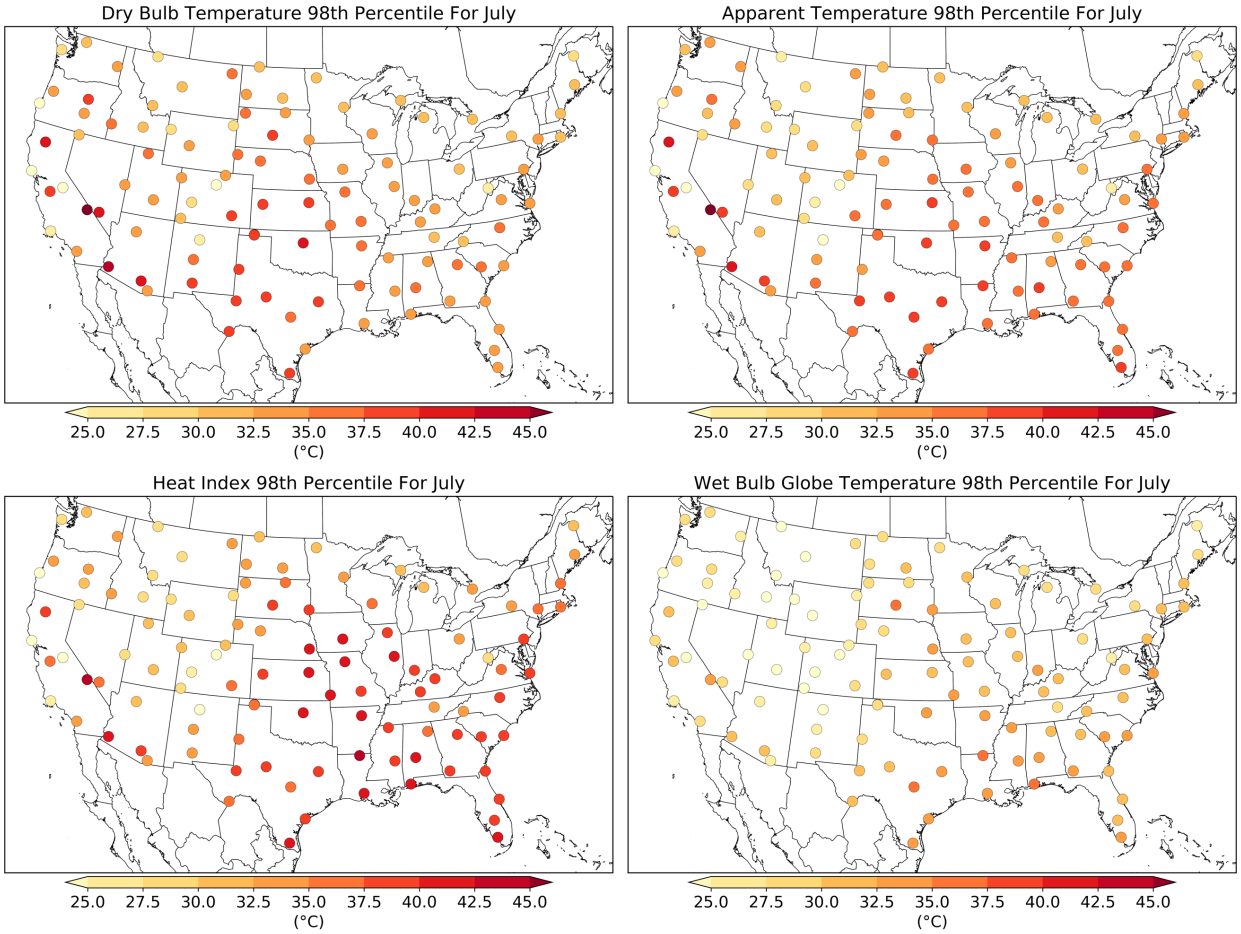


***Figure 2**. Climatological 98th percentile of July afternoon (12pm-6pm local time) T, AT, HI, and WBGT data at USCRN sites. Values are in °C.*

Work will continue to make this dataset operational within the USCRN framework. Future work includes extending this to other in situ networks, such as ASOS, as well as providing a gridded product using data from National Digital Forecast Database (NDFD), High Resolution Rapid Refresh (HRRR), and ERA5. A vulnerability study is also underway using available health and socioeconomic data provided by the Centers for Disease Control and Prevention (CDC).

Planned work

- Validate BgT and WBGT values at other sites, using available networks with black-globe thermometers installed.
- Extend the project to over 2,000 stations located at airports nationally.
- Reconstruct a climatology of WBGT for the contiguous United States using archived data from the NWS (NDFD) and ERA5 reanalysis.
- 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) (USCRN derived product)

Publications

Rennie, J. J., M. A. Palecki, S. P. Heuser, and H. J. Diamond, 2021: Developing and validating heat exposure products using the US Climate Reference Network. In Press. *Journal of Applied Meteorology and Climatology*, **In press**. http://dx.doi.org/10.1175/jamc-d-20-0282.1

Presentations

Rennie, J. J., and M. A. Palecki, 2021: Using Wet-Bulb Globe Temperature Estimations from the U.S. Climate Reference Network to Generate Standardized Anomalies and Evaluate Extreme Heat Events. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.

Development of the United States Climate Reference Network (USCRN) National Precipitation Index	
Task Leader	Jared Rennie
Task Code	NC-SAS-25-NCICS-JR

Highlight: National Precipitation Index (NPI) data have been updated through December 2020 and planning is underway for the research-to-operations transition.

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 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 from 107 USCRN station sites were used in this analysis. These precipitation values were calculated with the assistance of a wetness sensor beginning in 2006. A white paper describing the methodology was drafted and approved by members of the NCEI dataset section. The CISESS NC project team will continue the transition of NPI from research to operations.

Accomplishments

Data have been updated through December 2020. 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).

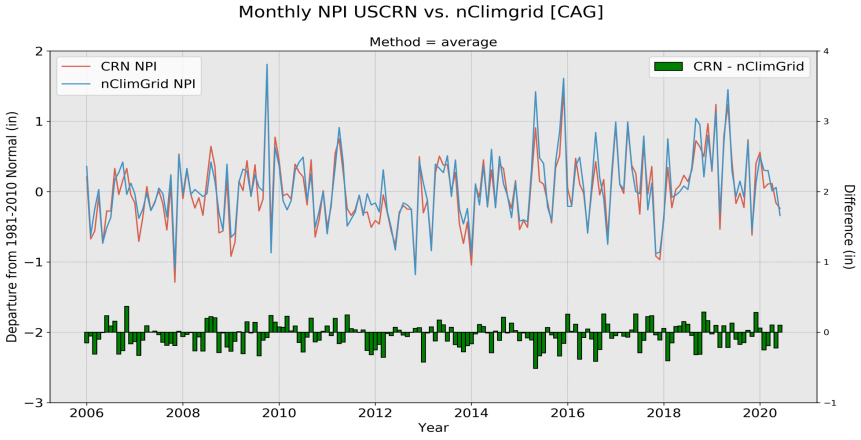


Figure 1. *Monthly time series of USCRN National Precipitation Index from 2006 to present (red) compared to precipitation data from NCEI's Climate at a Glance (CAG) tool (blue). Differences are noted in green.*

Planned work

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

NCEI Innovates: Developing 1991–2020 Normals along the Northeast and Mid-Atlantic Coasts	
Task Leader	Jared Rennie
Task Code	NC-SAS-26-NCICS-JR

Highlight: Coastal normals for 1991–2020 were developed for areas around the Northeast and Mid-Atlantic regions, and an *ArcGIS Online* website was developed to allow users to interact with the data. https://coastal-normals-ncsu.hub.arcgis.com

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 will soon be producing the 1991–2020 Climate Normals suite of products per agreement 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 expanded 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

Climatologies were calculated for 1991–2020 for all datasets. Working with partners at NOAA's Eastern Region Climate Services, the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS), and its respective office in the Mid-Atlantic region (MARACOOS), a public website was created (Figure 1) to display all layers for all months of the year. 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 (Figure 2) and ocean temperature and salinity profiles.

All code to generate the graphics and layers was placed in a git repository for reproducibility. The Southern Regional Climate Services program is currently working to produce the same results for their area of interest, which includes the Gulf of Mexico.

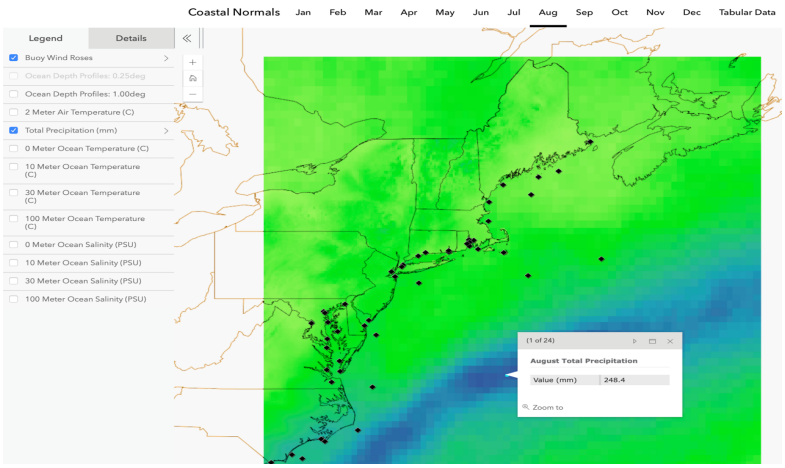


Figure 1. *ArcGIS Online interactive website for the Coastal Normals project. Users can choose a month at the top, and toggle layers on and off on the side. The map is intended to be interactive, displaying relevant normals data and images where applicable.*

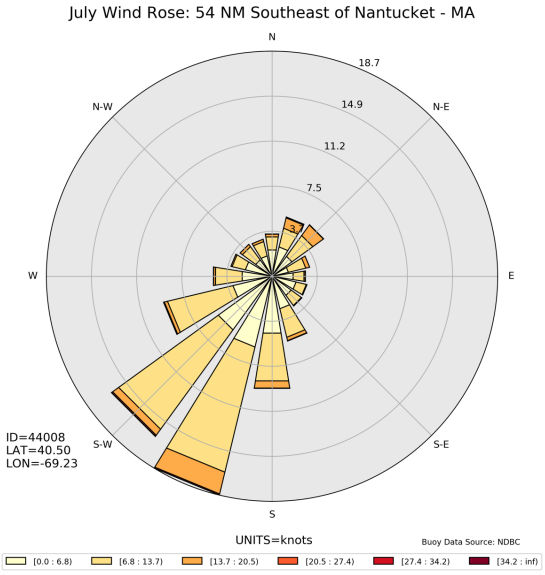


Figure 2. *Wind rose, taken from July data between 1991-2020, from a buoy off the coast of Nantucket, Massachusetts. Data are from NOAAs National Data Buoy Center.*

Planned work

- This project is complete; however, CISESS NC will assist the Southern Regional Climate Services program to provide results for their area of interest if needed.

Products

- Coastal normals data from 1991–2020 for areas around the U.S. Northeast and Mid-Atlantic
- ArcGIS Online interactive web page displaying the coastal normals layers

ARC Data Derivative Product for Health Users	
Task Leader	Jennifer Runkle
Task Code	NC-SAS-27-NCICS-JR

Highlight: The project team initiated development of an NCEI data product consisting of a daily time series for Tavg, Tmax, Tmin, and Precipitation using nClimGrid for each county in the U.S. (1981-present) to aid health and infectious disease modeling efforts.

Background

To address the need for daily time series of meteorological variables (e.g., temperature, humidity, precipitation) relevant to health and infectious disease modeling efforts, work was begun to develop a data derivative product to aid the health modeling community in accessing NOAA climate and weather data. The project team is composed of members representing NCEI, CISESS NC, and the NOAA Climate Program Office. To inform the development of the product, the team engaged in multiple meetings with CDC partners in the Climate and Health and the Environmental Public Health Tracking programs, as well as a diverse set of academic modelers from the Models of Infectious Disease Agent Study (MIDAS) group. The data product will be complemented by an R package to streamline access and include relevant analytic functions (e.g., population-weighting, interpolation) to aid end-users in locating, manipulating, and analyzing the data at a scale relevant to health applications. The product will also be more broadly applicable to end-users representing other sectors (e.g., energy, agriculture). This data product will also complement the team's NOAA Environmental Data Themed page on climate.gov and be accessible to a diverse set of environmental and health modelers.

Accomplishments

The team is currently working on *version 1* of the data product aimed at developing a daily time-series for Tavg, Tmax, Tmin, and Precip (nClimGrid daily metrics) for each county in the U.S. from 1981 to present. Data for each metric is being assembled into one county-level file for each state and the team is investigating options to automate data refresh and identify where the data will reside (e.g., Climate at a Glance, API).

Planned work

• Complete development of daily time-series for Tavg, Tmax, Tmin, and Precip (nClimGrid daily metrics) for each county in the U.S. from 1981 to present (v1. county).

- Develop methodology guidance for user community.
- Assemble expert group to obtain input on v1.0 of the data product.
- Develop communication/methodology materials for engagement of potential user communities.

• Develop a daily time-series for Tavg, Tmax, Tmin, and Precip (nClimGrid daily metrics) for each census tract and zip code in the U.S. from 1981 to present (v2. county + census tract and zip code).

- Examine feasibility of averaging gridded data to these two scales.
- Determine methodological approach to aggregate data to two scales.
- Expand data visualization tool/api to include these two scales.
- Assemble expert group to obtain input on v2.0 of the data product.

• Integrate additional metrics in response to feedback from user community (e.g., humidity).

- Explore re-analysis products (e.g., ERA-5, JA) and outline methods for integration into v2.0.
- Conduct literature search to examine best method for interpolation (e.g., smoothing spline and multinomial regression).

Publications

Runkle, J. D., M. M. Sugg, **R. D. Leeper**, **Y. Rao**, **J. L. Matthews**, and **J. J. Rennie**, 2020: Short-term effects of weather parameters on COVID-19 morbidity in select US cities. *Science of The Total Environment*, **740,** 140093. http://dx.doi.org/10.1016/j.scitotenv.2020.140093

Presentations

Runkle, J. D., M. M. Sugg, **R. D. Leeper, Y. Rao, J. L. Matthews**, and **J. J. Rennie**, 2020: Acute effects of meteorological parameters on COVID-19 morbidity in the US: a case-crossover study with a distributed lag nonlinear model. Virtual. International Symposium on climatological, meteorological, and environmental factors in the COVID-19 pandemic, *World Meteorological Organization,* August 4-6, 2020.

Collaborative Climate and Human Health Activities	
Task Leader	Jennifer Runkle
Task Code	NC-SAS-28-NCICS-JR

Highlight: Working with NCEI and CDC collaborators, CISESS NC identified extreme heat metrics derived from NOAA products to fill data gaps on the CDC's Environmental Public Health Tracking portal, worked to implement weekly refresh of drought data for the portal, and established baseline surveillance data to be used in an early warning system for harmful algal blooms (HABs).

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 climate 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 is undertaking research and coordinating 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

Despite significant disruptions due to the COVID pandemic, the team made progress on the following tasks:

- Identified data gaps for extreme heat metrics to be included on the CDC's Environmental Public Health Tracking portal and corresponding candidate observed and projected extreme heat metrics derived from NOAA products.

- NCEI and CDC partners worked to build a drought data pipeline to implement a weekly data refresh for the CDC's Environmental Public Health Tracking Portal.
    - Drought measures using data derived from the U.S. Drought Monitor (USDM) and the Standard Precipitation Evapotranspiration Index (SPEI) were identified (Fig. 1).
    - NCEI developed a NOAA Drought Data Refresh Development Guide and generated USDM drought indicators.
- Established baseline surveillance data to be used in an early warning system for harmful algal blooms (HABs):
    - Began collaborative work on 1) linking health risks from electronic health records with HABS and other relevant environmental drivers; 2) developing a severity index that can be used nationally and is relevant across states.
    - Established a multi-agency collaboration (CDC, NOAA, EPA, USGS, NASA) to extend an existing U.S.-based CyanoHabs monitoring project relying on satellite data records to include prediction of freshwater harmful algal blooms (HABs) for early warning.

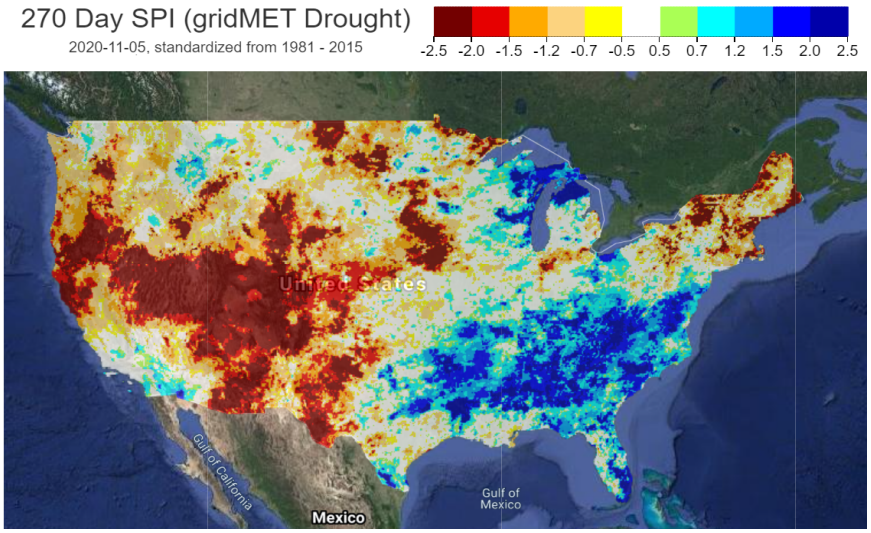


Figure 1*. Example static map product demonstrating daily SPEI drought metric for U.S. on September 27, 2020 compared to standardized SPEI 1981-2015. Credit: Rocky Bilotta (ISciences, LLC).*

Planned work

- Co-develop and facilitate a joint agency case study to explore the use of high-resolution local climate data to understand the short- and mid-term spatial and temporal patterns of air temperature and extreme heat days for a representative set of geographic typologies: 1) urban, inland; 2) urban, coastal; 3) semi-urban; and 4) rural communities sampled from current BRACE/EPHT grantees; and examine the performance of high-resolution local climate data in early identification of heat waves and associated effects on mortality.
- Begin pilot HABS project focused on Ohio to 1) develop indicators and measures to assess the frequency, geographic extent, and density of HABS in inland U.S. waters; 2) develop the methods/technology to use satellite imagery for early warning and operationalize the indicators and measures.
- Complete drought data refresh and data pipeline for SPEI drought indicators.
- Determine NOAA extreme heat indicators for incorporation into the EPHT portal.
- Co-mentor postdoc for EPHT/HABs projects.

Publications

Byrd, B., S. L. Richards, **J. D. Runkle**, and M. M. Sugg, 2020: Vector-borne diseases and climate change: North Carolina's policy should promote regional resilience. *North Carolina Medical Journal*, **81,** 324. http://dx.doi.org/10.18043/ncm.81.5.324

Gardiner, N., **J. Runkle**, J. Fox, and A. Patel, Eds., 2020: Ch. 5: Vulnerability, risk, and resilience strategies for addressing climate related hazards. *North Carolina Climate Risk Assessment and Resilience Plan: Impacts, Vulnerability, Risks, and Preliminary Actions. A Comprehensive Strategy for Reducing North Carolina's Vulnerability to Climate Change*, State of North Carolina, 5A-1—5N-3. https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf

Runkle, J. D., K. D. Michael, **S. E. Stevens**, and M. M. Sugg, 2021: Quasi-experimental evaluation of text-based crisis patterns in youth following Hurricane Florence in the Carolinas, 2018. *Science of The Total Environment*, **750,** 141702. http://dx.doi.org/10.1016/j.scitotenv.2020.141702

Sugg, M., **J. Runkle**, **R. Leeper**, H. Bagli, A. Golden, L. H. Handwerger, T. Magee, C. Moreno, R. Reed-Kelly, M. Taylor, and S. Woolard, 2020: A scoping review of drought impacts on health and society in North America. *Climatic Change*, **162,** 1177–1195. http://dx.doi.org/10.1007/s10584-020-02848-6

Presentations

Runkle, J., and M. Sugg, 2020: Exploring the Health Effects of Heat on Populations of Concern. Virtual. *North Carolina Cooperative Extension Webinar*, September 25, 2020.

Environmental Information and Analysis for the Real Estate Development Sector	
Task Leader	Amanda Rycerz
Task Code	NC-SAS-29-Willis (Acclimatise)-AR

Highlight: This stakeholder engagement study focuses on identifying the specific environmental data requirements and applications needed for effectively analyzing wildfire risk and exposure for the real estate sector value chain. Current environmental data utilization and sector climate risk management practices were analyzed and a sector value chain climate risk/potential impact matrix was completed.

Background

Over the past few years, U.S. wildfires, some of them the deadliest in the nation's history, have caused extensive property damage, business disruption and loss of life. Despite the high risk that wildfire poses to physical structures, development continues on the fringes of urban and forested areas in the wildland urban interface (WUI), where housing affordability and proximity to nature come with high risk. As development continues to expand into fire-prone areas, understanding and incorporating wildfire information into real estate planning and decision-making is of critical importance across the real estate value chain. Real estate stakeholders include those involved in finance (including insurance), asset management, property development, and ownership and transaction (including leasing and managing).

NOAA/NCEI collects environmental information (e.g., temperature, precipitation, drought, wind-speed, relative humidity, etc.) that are important inputs to tools and applications which can help end users in the real estate sector analyze and understand wildfire risk. As using climate and weather data involves a degree of technical literacy and time, current research shows that real estate stakeholders concerned with wildfire risk tend to use value-added tools to analyze wildfire risk and exposure.

This project focuses on three primary research questions: 1) What are the stakeholder-specific requirements for tools and information to support wildfire risk? 2) What are the tools and applications (public and private) available to support decision-making? 3) What are the gaps and/or potential areas for improvement that NOAA and service providers could address to provide more serviceable data, products, and tools for the real estate sector?

Accomplishments

Identification of current climate risk management practices. Sector research was conducted on current climate risk management practices through stakeholder engagement and a literature review. A stakeholder map was developed to reflect the project's stakeholder engagement. Thus far, interviews (one or more) have been conducted with six service providers (Pano AI, Cape Analytics, Redzone, Our Kettle, First Street, GRESB), an asset manager (Heitman), and an association (Urban Land Institute). Additional real estate stakeholders have been contacted for interviews and are awaiting confirmation.

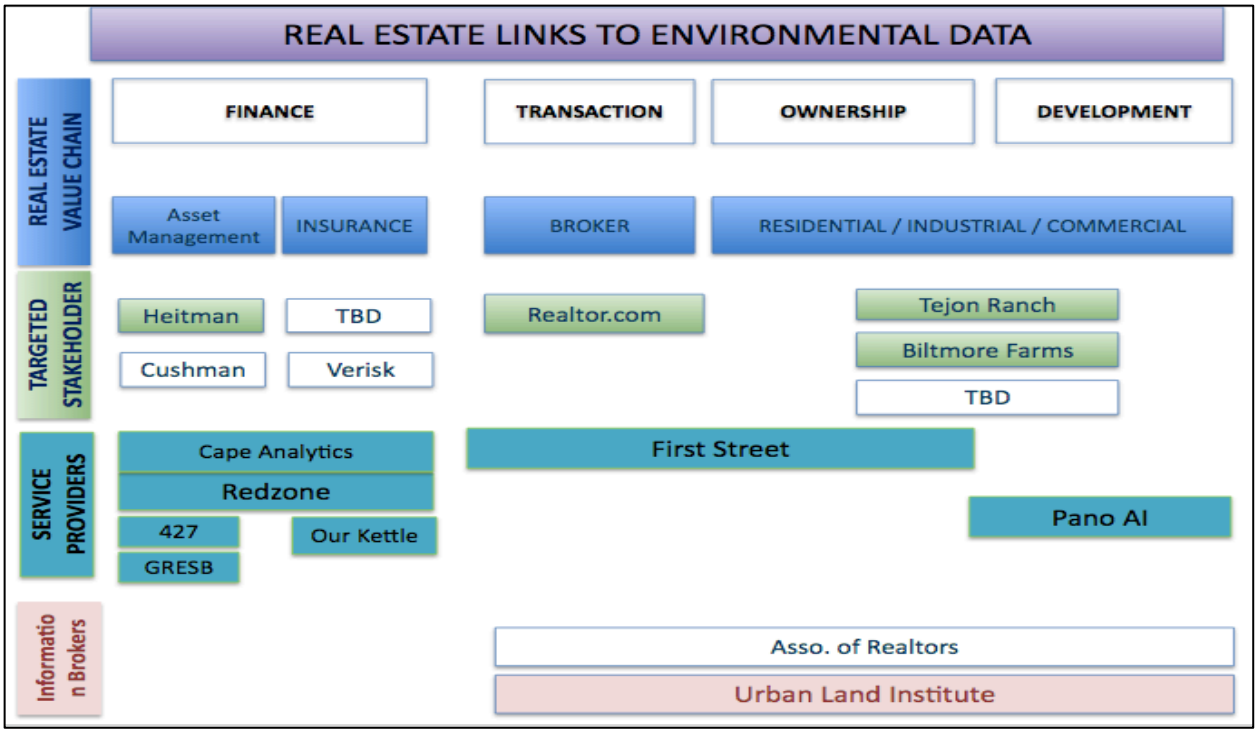


Figure 1. *Stakeholder mapping and engagement. Source: Author*

Analysis of current environmental data application and sector needs and requirements. A literature review was completed that focused on how environmental information is being used in the real estate sector, and sector needs and requirements (specifically related to property development, asset management and insurance, and ownership and transaction). The review results reflect that real estate stakeholders do not access NOAA data directly, and rather rely on third party providers that often integrate NOAA data as an input to their tools/applications.

The literature review and interviews with third-party service providers shows that many service providers are developing targeted tools for insurance and re-insurance providers in fire-prone areas. These value-added products can help insurers more adequately price policies (residential, commercial) in wildfire prone areas. This is a critically important component of the real estate value chain, as mortgages are contingent on home insurance, and most homeowners do not have the capital to pay for homes in cash. There are also several products targeted at serving asset/portfolio managers although these products tend to be more general 'climate risk screening tools' that consider a range of perils, including wildfires. Other tools focus on property level risk, for property buyers and realtors, and emergency response. There does not appear to be demand for wildfire analytics from property developers, who have a more transactional short-term role in the real estate sector, although this early-stage finding has yet to be validated.

Sector value chain climate risk/potential impact matrix. The completed matrix outlines acute and chronic physical climate risks against three segments of real estate: finance and insurance, real estate development (construction and siting), and ownership and transaction (selling, leasing managing).

Technical guidance document. A draft technical guidance document for the real estate development sector is in progress, which will incorporate the value chain risk/potential impact matrix and outline the relevant environmental information, sources, and guidance on how to access the information.

Project Planning. Initial planning for a real estate development stakeholder workshop is underway, as well as targeted participation in select real estate webinars or other on-line events to gain the broader real estate development sector perspective on the perceived environmental vulnerabilities and impacts on the sector in a changing climate, the success or challenges of current risk management and adaptation strategies, and what information would be most useful in their given sector area risk analysis.

Planned work

- Complete interviews with remaining stakeholders.
- Attend selected virtual real estate webinars.
- Finalize DRAFT guidance document.
- Plan and execute real estate development engagement.
- Finalize guidance document.

Climate Monitoring	
Task Leader	Carl Schreck
Task Code	NC-SAS-30-NCICS-CS

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. The monthly tropical cyclone report was expanded from a national report to a global report, and a new annual Synoptic Discussion was introduced.

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 such as 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 2020 and to the monthly NCEI State of the Climate Reports. Three new innovations were introduced into those monthly reports:

1. Additional automation of the month tropical cyclone reports using IBTrACSv4 has enabled those reports to be expanded from a national report (North Atlantic and East Pacific during their tropical cyclone season May–November) to a global report (all seven tropical cyclone basins and all 12 months). Figure 1 shows an example of the global tropical cyclone statistics from the debut November report:

Global Tropical Cyclone Season Counts January-November 2020

STORM TYPE	COUNT	1981-2010 MEAN	1981-2020 RANK*	1972-2020 RECORD
Tropical Storm *Winds ≥39 mph (34 kts)*	96	80.8	2nd	98 *(2018)*
Tropical Cyclone *Winds ≥74 mph (64 kts)*	43	44.7	21st *(tied with 6 other seasons)*	56 *(1990, 1992, 2018)*
Major Tropical Cyclone *Winds ≥111 mph (96 kts)*	20	22.2	26th *(tied with 4 other seasons)*	38 *(2015)*
Accumulated Cyclone Energy *ACE×10^4 kt^2*	535.1	719.8	38th	1,101.7 *(1992)*

Figure 1. *Table of global tropical cyclone activity January–November 2020.*

2. The Synoptic Discussion has traditionally been a monthly report that discusses the primary climate drivers behind climate anomalies over the U.S. This year, a new annual Synoptic Discussion (https://www.ncdc.noaa.gov/sotc/synoptic/202013) was introduced. This new report mirrors the monthly one; however, the monthly report looks at submonthly variability and drivers while the

annual report examines the key seasonal anomalies and drivers (Fig. 2) that contributed to the annual means.

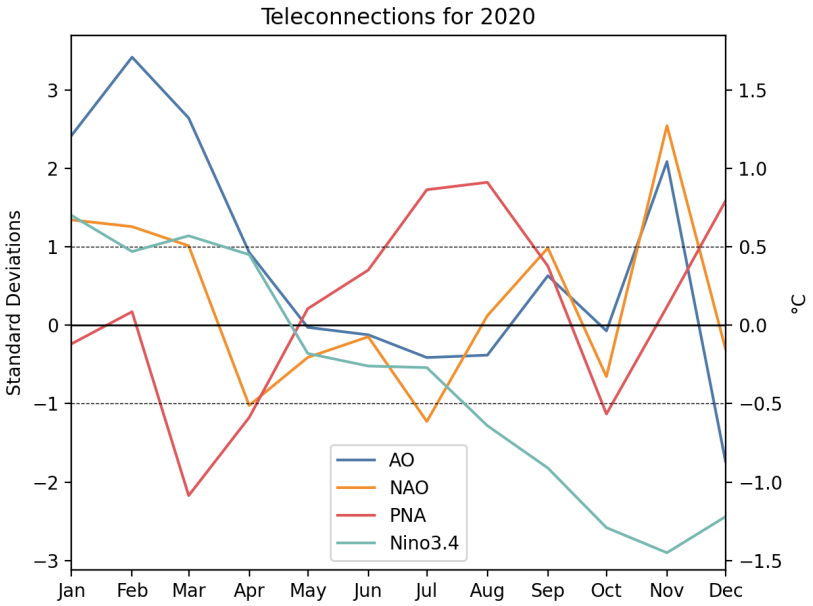


Figure 2. *Monthly values of the AO, NAO, PNA, and the Niño 3.4 indices. Niño 3.4 is in °C on the right axis, other indices are in standard deviations on the left.*

3. In preparation for the implementation of NOAA's new Rapid-response Attribution Team, the February synoptic report discussed the extreme Texas cold wave in the context of climate change based on key findings from the National Climate Assessment. This is a preliminary first step towards the team's planned attribution work.

CISESS NC is actively working on new tropical cyclone products. The team is in discussions with USGCRP on the development of a new climate change indicator for tropical cyclone activity and is collaborating with the National Hurricane Center and the Climate Prediction Center to identify the most appropriate climate epoch to use for hurricane season normals for the next decade. NOAA used 1951–2000 in the 2000s, and 1981–2010 in the 2010s. A normal based on 1991–2020 would indicate significantly higher average tropical cyclone activity, so the team is investigating whether a longer epoch would be more appropriate.

Planned work

- Revise and publish the *BAMS* State of the Climate for 2020.
- Prepare and edit the *BAMS* State of the Climate for 2021.
- Draft monthly NCEI State of the Climate "Synoptic Discussions" and "Tropical Cyclone" reports.
- Develop a global climatology of tropical cyclone activity.
- Develop a USGCRP climate change indicator for tropical cyclones.

Publications

Diamond, H. J., and **C. J. Schreck**, 2020: The tropics [in "State of the Climate in 2019"]. *Bulletin of the American Meteorological Society*, **101,** S185–S238. http://dx.doi.org/10.1175/bams-d-20-0077.1

Klotzbach, P. J., **C. J. Schreck, III**, G. P. Compo, S. G. Bowen, E. J. Gibney, E. C. J. Oliver, and M. M. Bell, 2020: The record-breaking 1933 Atlantic hurricane season. *Bulletin of the American Meteorological Society***,** 1–54. http://dx.doi.org/10.1175/BAMS-D-19-0330.1

Wood, K. M., P. J. Klotzbach, J. M. Collins, L.-P. Caron, R. E. Truchelut, and **C. J. Schreck**, 2020: Factors affecting the 2019 Atlantic hurricane season and the role of the Indian Ocean Dipole. *Geophysical Research Letters*, **47,** e2020GL087781. http://dx.doi.org/10.1029/2020gl087781

Products

- Synoptic Discussions for NCEI's Annual State of the Climate: https://www.ncdc.noaa.gov/sotc/synoptic/202013
- Global Tropical Cyclone reports for NCEI's State of the Climate beginning in November 2020: https://www.ncdc.noaa.gov/sotc/tropical-cyclones/202011

Calibration of High-resolution Infrared Radiation Sounder (HIRS) Brightness Temperatures	
Task Leader	Emma Scott
Task Code	NC-SAS-31-NCICS-ES

Highlight: Calibration of High-resolution Infrared Radiation Sounder (HIRS) measurements of brightness temperature is necessary to provide a consistent dataset for use as a Climate Data Record (CDR). A subset of the data that can be used for calibration of HIRS brightness temperature between satellites has been identified and calibration is being performed, with calibration coefficients calculated for the NOAA 14-19 and METOP 1 and 2 satellites.

Background

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

Accomplishments

Previous work resulted in a dataset that can be used for intersatellite calibration of HIRS brightness temperature. These data are a subset of the current clear-sky, limb-corrected HIRS data. To create a set of observations that could be used for direct comparison between satellites, points were identified where pairs of satellites had simultaneous nadir overpasses (SNOs) located within 0.2° latitude and longitude of each other within a 15-minute window of time. For each channel of HIRS measurements taken by each satellite pair, brightness temperature measurements that correspond to SNOs were sorted by latitude and filtered to create a dataset on which the calibration can be based without undue influence from outliers. The remaining data is placed into 10°C bins based on the brightness temperature measured in each channel by the first satellite of the pair, except for channel 12 which uses a 2°C bin size. Channel 12 encompasses a small range of temperatures and therefore requires a finer-scale approach.

Within each bin, the difference between the temperature measurements of both satellites is found, and then the median is taken to find a representative offset between the two satellites. This value is used as the calibration coefficient. Many satellite pairs only have SNOs located within polar regions due to the geometry and timing of their orbits, but some pairs have SNOs located across the full range of latitudes. In cases where overlapping data is only available at the poles, the higher part of the temperature range is supplemented with the mean of all monthly mean brightness temperatures taken over an area of the Pacific Ocean spanning from -20° to 20° latitude and 200° to 260° longitude. In these cases, the inter-satellite difference between the grid box monthly mean brightness temperature is used in place of the bin median in the calibration process. Differences between the two approaches can be seen in Figure 1, but remain minimal within the period of temperature overlap. Channel 4 also required special consideration, and employs a multiple linear regression to find a set of three calibration coefficients that take into

account values from the surrounding channels. Calibration coefficients have been calculated for satellite pairs that include the NOAA 14-19 and METOP 1 and 2 satellites. Data from these satellites spans the time-frame between the mid-1990s and the present. Work will continue on the calibration process, working backwards through satellite pairs in the NOAA series and expanding the period of record back to the early 1980s.

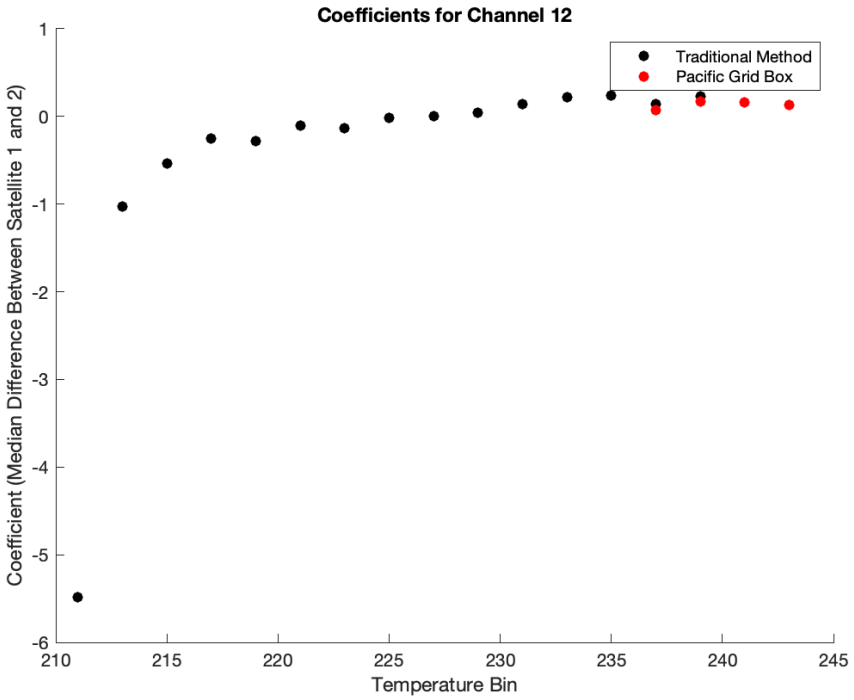


Figure 1. *Differences between calibration coefficients calculated using the normal approach and the approach encompassing the Pacific monthly mean brightness temperature for Channel 12 of the NOAA-15 and NOAA-16 satellite pair over the full range of temperatures measured. The final two Pacific grid box method points have no match using the traditional method because they occur in a part of the temperature range for which there were no traditional overlap point measurements.*

Planned work

- Continue current calibration process until all satellite pairs from the NOAA and METOP series carrying HIRS are covered.
- Release resulting calibrated data for use as a new CDR.
- Publish a methodology paper on the calibration process for reproducibility.

Presentations

Scott, E., and L. Shi, 2021: Colocation-Based Calibration of High-Resolution Infrared Radiation Sounder (HIRS) Brightness Temperatures. Poster. Virtual. *2021 AMS Annual Meeting*, January 12, 2021.

Workforce Development

Workforce development is the 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 NC employs a cadre of dedicated research staff and actively works to identify and train the next generation of scientifically and technically skilled climate scientists. Junior and/or aspiring scientists, including students and post-doctoral researchers, play an important role in conducting research at CISESS NC.

Research faculty. Senior CISESS NC scientists hold research faculty positions in the Department of Marine, Earth, and Atmospheric Sciences (MEAS) in the College of Sciences (COS) at North Carolina State University (NCSU) and provide mentorship to junior scientists and students both in CISESS NC and MEAS. Several junior scientists have also secured adjunct appointments in pertinent NCSU departments and at other universities to gain experience and exposure with their academic peers and to mentor graduate students. CISESS NC scientists also mentor students formally and informally (NCICS student interns, 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 CISESS 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 for the predecessor cooperative institute. CISESS NC continues to hire post-docs for a 2- to 3-year commitment to support identified current project needs. Senior scientists from CISESS NC and NCEI provide mentoring for these post-docs. CISESS NC currently hosts one post-doctoral scholar:

- Douglas Rao (PhD, Geographical Sciences, University of Maryland) spent his second year at CISESS NC working with Jessica Matthews and collaborating on developing global blended temperature data using in situ and satellite data, as well as co-leading a machine learning training series and contributing in the establishment of the NOAA Center for Artificial Intelligence. (See project reports under Science and Services.)

Students (graduate/undergraduate/high school). CISESS NC continues to be successful in recruiting and involving area undergraduate and graduate students in temporary student internships, providing an opportunity for the students to explore their interest in science and/or apply their ongoing education to current projects within the institute under the oversight of CISESS NC and NCEI mentors. CISESS NC

scientists also serve as mentors and advisors for NOAA Hollings Scholars and NASA DEVELOP team members who complete their 10-week internship projects at NCEI.

Summer 2020:

- *Marlee Burgess*, UNC Asheville undergraduate student, worked with Jenny Dissen on a project studying precipitation impacts on landslides in Western North Carolina.
- *Andrew Coleman*, UNC Asheville undergraduate student, worked with Ronald Leeper to investigate economic impacts of drought on agriculture.
- *Drew Hamilton*, University of Maryland undergraduate student, worked with Bjorn Brooks on cloud computing for optimizing weather dataset processing and delivery.
- *Sena McCrory*, Duke University graduate student, worked with Jennifer Runkle to investigate the impacts Climate Change Impacts on Reproductive Health.
- *Nicholas Schirato*, Clemson University undergraduate student, worked with Jenny Dissen on a project studying *BMW*'s climate adaptation and resilience efforts.
- *Lisi Wang*, Clemson University graduate student, worked with Bjorn Brooks and Lou Vasquez on Cloud computing for high-performance data archive software development.
- *Matthew Watts*, NCSU GIS program graduate student, worked 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.
- NOAA Hollings Scholar *Mya Sears* (Oklahoma University) worked with Jared Rennie and Scott Stevens to develop a 30 year mean difference for Puerto Rico, build an index, generate an *ArcGIS Online* map, and draft a Story Map of project results.
- NOAA Hollings Scholar *Alison Walker* (University of Miami) worked with Carl Schreck to study the Fujiwhara effect and tropical cyclone interactions.
- The NASA DEVELOP team composed of *Wilson Goode* (Davidson College graduate), *Richard Murray* (Millsaps College graduate), *Travis Newton*, (NCSU graduate student), and *Chloe Schneider* (UNC at Chapel Hill graduate) completed their science project, "Mapping Forest Composition and Health in the Southern Appalachians Using NASA Earth Observations to Enhance Drought and Watershed Health-Related Forest Management for the Eastern Band of the Cherokee Indians," under science co-advisor Bjorn Brooks. The team explored forest-monitoring data, detecting year-to-year changes in the forest canopy composition and measuring changes in forest health over time for a tribe-purchased land trust in western North Carolina.

Fall 2020:

- *Emma Hughes,* Duke University graduate student, worked with Ronald Leeper to investigate economic impacts of drought on agriculture.
- *Shrikanth Yadav*, NCSU graduate student, worked with Jennifer Runkle to investigate the impacts of climate on mental health.
- The NASA DEVELOP team composed of *Dean Berkowitz* (University of California at Berkeley graduate), *Egla Ochoa-Madrid* (Texas State University graduate), *Chloe Schneider* (University of North Carolina at Chapel Hill graduate), and *Julie Sorfleet* (University of California at Los Angeles graduate) completed their science project, "Developing a Composite Moisture Index Utilizing NASA Earth Observations for Drought Monitoring in the Missouri River Basin," under science advisor Ronald Leeper. The team worked to create a monthly Composite Moisture Index (CMI) that indicates regional moisture conditions during the winter months.
- *Sridhar Mantripragada*, NCSU graduate student, worked 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, and successfully defended his Master's thesis in December 2020.

Spring 2021:

- *Parvathy Menon*, NCSU undergraduate student, is working with Bjorn Brooks on combining GHCNd temperature observations with North Carolina energy grid data in a predictive AI model. The system will serve as an example of how to generate predictive results on the fly in the Cloud using cloud tools.
- *Eric Robinson*, University of Maryland undergraduate student, is working with Jessica Matthews and Douglas Rao to assess the quality of vegetation status simulated by CMIP6 models using climate data records.
- *Shrinkanth Yadav*, NCSU graduate student, continues work with Jennifer Runkle to investigate the impacts of climate on mental health.
- *Caroline Zuber*, NCSU undergraduate student, is working with Olivier Prat on analyzing NDVI datasets from the CDR program over the Southeastern United States.
- The NASA DEVELOP team composed of *Catherine Buczek* (Florida State University graduate), *Bevan Pearson* (University of Pennsylvania graduate), *Madelyn Savan* (California Polytechnic State University graduate), and *Chloe Schneider* (University of North Carolina Chapel Hill graduate) completed their science project, "Montana Water Resources II: Enhancing a Composite Moisture Index for Drought and Flood Monitoring in the Missouri River Basin" under science advisor Ronald Leeper. The team worked to improve forecasting of summer drought and flood conditions throughout the Missouri River Basin and improve enhance understanding of the relationship between fall-winter soil moisture conditions and spring-summer flood and drought events.
- *Maria Cesarini*, Tufts University graduate in Mathematics, completed her work 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.

Ongoing:

- *Kelsey Blackstone,* University of California Santa Cruz graduate student in Statistical Science, is working with Jessica Matthews to implement flexible statistical models to blend massive satellite climate data records as applied to surface albedo data.
- *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.

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.

Climate Change Impacts in the Arctic and International Coastal Ocean Regions	
Task Leader	Pavel Groisman
Task Code	NC-OTH-01-NCICS-PG
Other Sponsor	Multiple / NSF (Belmont Forum)

Highlight: Collaborative international research teams are investigating global environmental change challenges and impacts. Current projects are focused on the northern extratropics and five coastal ocean regions. The U.S. team completed an assessment of the costs of climate change impacts on critical infrastructure in the Circumpolar Arctic and updated the project's circumpolar infrastructure database for additional analysis.

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 Belmont Forum supports research focused on global environmental change challenges and impacts by teams of multinational researchers to promote more global solutions to these challenges.

Accomplishments

Northern Eurasia Future Initiative (NEFI). The NEFI (http://nefi-neespi.org) program supports international Earth systems science research focused primarily on climate change and other issues in northern Eurasia that are relevant to regional and global scientific and decision-making communities. The first NEFI Special Issue in *Environmental Research Letters is in preparation*. (Project role: Project Scientist)

Belmont Forum Collaborative Research: Rapid Arctic environmental Changes: Implications for well-being, resilience and Evolution of Arctic communities (RACE). This new project supports integrated teams of scientists and stakeholders addressing the impacts of rapid climate and environmental changes in the Arctic on infrastructure and pan-Arctic and regional population dynamics. Large-scale climate diagnostics and projections will be used and translated into social indicators and further into demographic variables by using socioeconomic and demographic models to provide regional projections of the Arctic population dynamics. (Project role: Co-Investigator)

Belmont Forum Collaborative Research: ARCTIC climate change and its impact on Environment, infrastructure, and Resource Availability (ARCTIC ERA). The U.S. team completed an assessment of the costs of climate change impacts on critical infrastructure in the Circumpolar Arctic and updated the circumpolar infrastructure database which will be used in the coming year to improve regional estimates of climate change impacts on Arctic infrastructure. (Project role: Co-Investigator)

Belmont Forum Collaborative Research: COAST (Coastal OceAn SusTainability in Changing Climate). This new project focuses on the sustainability of the coastal ocean under the impacts of ongoing and projected climate variability and change. The project will address impacts of climate change and increased human activity on five different coastal ocean regions by integrating the natural and social domains of the coastal ocean and tracking how changes will affect the use and the infrastructure of today and in different scenarios for the future. (Project role: Co-Investigator)

Other

- Panel Chair for Russian Science Foundation (RSF) MEGA GRANTS Earth Sciences competition
- Program committee member, IV International Scientific Conference “Science of the Future” for the V All-Russia Forum “Science of the Future – Science of the Youth” and Section Chair and Judge for Forum "Ecology, Energy, and Security" section.
- Editorial Board member for *European Research Communications* and *Ice and Snow*; Guest Editor for *Environmental Research Letters* NEFI Special Issue.
- PhD committee member for Oyudari Vova (Georg-August-Universitat, Göttingen Germany)

Presentations

Groisman, P. Y., 2020: Environmental, Socioeconomic and Climatic Changes in Northern Eurasia. Convener. Virtual. *JpGU-AGU Joint Meeting 2020*, July 14, 2020.

Groisman, P. Y., 2020: Environmental, Socioeconomic, and Climatic Changes in Northern Eurasia, Part I. Convener. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.

Groisman, P. Y., 2020: Environmental, Socioeconomic, and Climatic Changes in Northern Eurasia, Part II. Convener. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.

Groisman, P. Y., 2020: Northern Eurasia Future Initiative (NEFI), Update. Virtual. *International Conference on Environmental Observations, Modeling, and Information Systems (ENVIROMIS 2020)*, September 11, 2020.

Groisman, P. Y., 2020: Role of International Collaboration in Restoration of Earth Science Research after the USSR Collapse. Virtual. Science of the Future - Science of the Youth. *5th All-Russia Forum and Competition*, November 30, 2020.

Groisman, P. Y., and A. Georgiadi, 2020: Long-term Changes of Streamflow and Heat Transport of Two Largest Arctic Rivers of European Russia Severnaya Dvina and Pechora. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.

Groisman, P. Y., D. A. Streletskiy, E. A. Kukavskaya, and G. M. Henebry, 2020: Northern Eurasia Future Initiative (NEFI), Update. Poster. Virtual. *JpGU-AGU Joint Meeting 2020*, July 12-16, 2020.

Groisman, P. Y., E. P. Gordov, Y. E. Gordova, and A. A. Ryazanova, 2020: Qualitative Basis for Adaptation of Siberia to Climate Change impact. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.

Groisman, P. Y., G. M. Henebry, G. R. H. Allington, J. Chen, K. de Beurs, P. Fan, E. A. Mack, H. H. Shugart, A. J. Soja, and M. A. Tomaszewska, 2020: Looking Forward to 30 Years since the Disintegration of the USSR: Environmental and Socio-Economic Consequences of Fundamental Institutional Change amidst Changing Climates. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.

Groisman, P. Y., N. M. Tchebakova, E. Parfenova, N. Kuzmina, and S. Kuzmin, 2020: Climate change impacts on seed quality and distribution of light-needled Pinus sylvestris and Larix spp. in Northern Eurasia in a warming climate. Poster. Virtual. *JpGU-AGU Joint Meeting 2020*, July 12-16, 2020.

Groisman, P. Y., O. N. Bulygina, S. K. Gulev, A. Dufour, **G. Peng**, D. Streletskiy, N. A. Speranskaya, and N. M.Tchebakova, 2020: Environment Changes in the Eurasian Arctic. Poster. Virtual. *JpGU-AGU Joint Meeting 2020*, July 12-16, 2020.

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 and a new method based on constructed analogues to examine the potential impact of global warming.

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.

NCSU project researchers are members of the Climate and Hydrologic Extremes Working Group (CHExWG) of UREx SRN). 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. LOCA humidity 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.

High-resolution modeling of extreme precipitation events

The Weather Research and Forecasting (WRF) model was used to perform additional simulations of the Ellicott City, Maryland, flood event of July 2016 and the October 2015 event in Portland, Oregon, using the constructed analogues approach to examine the potential impact of global warming.

Education and Knowledge Exchange

Another component of this project focuses on education and knowledge exchange at all levels. The project has supported a cadre of graduate students and post-doctoral research fellows and incorporates a suite of interactive educational activities spanning the collaborating institutions and network. The current NCSU project graduate student contributed to the NCSU project research efforts as well as participating in a number of these educational activities:

- Organized, hosted, and participated in two (out of four) online symposia, *Get Ready, Get SETS: GI!* sponsored by UExSRN, with other current and former UExSRN graduate and postdoc fellows.
- Joined the NATURA early career network and attended two webinars.
- Began collaborating with other current and former UExSRN fellows to write an early career green infrastructure guiding principles document/white paper.
- Continued modeling efforts on extreme precipitation events under future warming scenarios for Baltimore, MD and Portland, OR.

Planned work

- As time allows, complete WRF simulations for extreme precipitation events in other UREX cities and examine potential impacts of global warming on precipitation amounts and spatial distribution.
- This project will end in June.

Other

- PI K. Kunkel is the PhD advisor of Geneva Gray (NCSU Marine, Earth, and Atmospheric Sciences Department).

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

Highlight: The project team completed development of heavy rainfall design values that incorporate future climate change and a project website was deployed that disseminates these adjusted values. The dominant factor influencing future changes in these values is increases in atmospheric 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 was 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

We used our automated software to create a master dataset of extreme precipitation events and associated meteorological causes for the 3000 stations used in the historical trend analysis. This dataset was analyzed to determine the distribution by meteorological cause for 10°×10° grid boxes. The results for 1-day duration events exceeding the 1-yr recurrence level threshold are shown in Figure 1. Fronts are the dominant cause in every box except for a single north-central box, where ETC events occur slightly more often than frontal events. Extratropical cyclones are the 2nd most common cause in every other box except for the Florida peninsula, where tropical cyclones (TCs) are the 2nd most common cause. In addition to the Florida peninsula, TCs cause more than 10% of events in south Texas, the south Atlantic coastal area, and the Northeast. The monsoon is responsible for more than 10% of events in the desert Southwest grid box.

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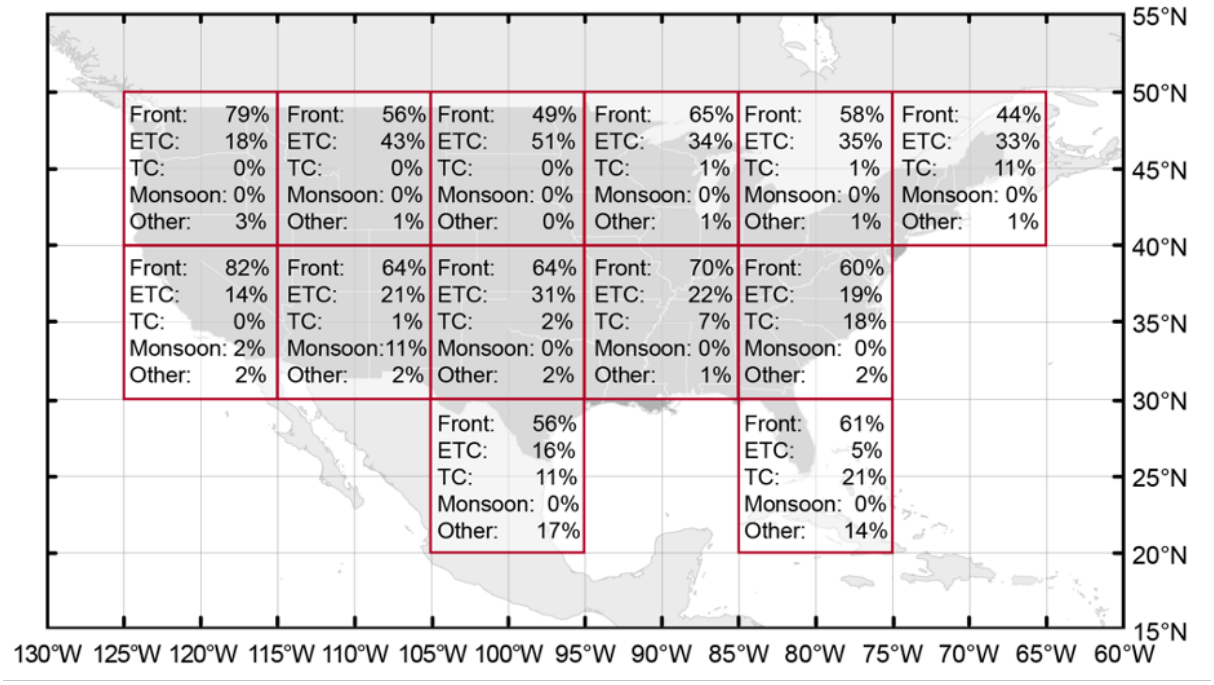

Figure 1*. Percentages of meteorological causes for 1-day duration extreme precipitation events for each 10°×10° grid box for 1980–2017.*

NOAA Atlas-14 (NA14) rainfall design values were the baseline for future rainfall design values. Estimated multiplicative adjustment factors were applied to the NA14 values. Two independent methods were used to calculate the adjustment factors. The factors were then averaged to produce the final product.

The first method (a new method developed in this project) incorporated future changes in water vapor and weather system frequencies into rainfall design values. There are two key features of this method. Based on a historical analysis of the relationship of extreme precipitation magnitude to precipitable water (PW), a functional relationship between these two variables was constructed. This is used to estimate future adjustments based on climate model simulations of future PW. The second feature used analyses of climate model simulations to estimate future changes in weather system frequencies.

The second method used traditional generalized extreme value (GEV) techniques. GEV analysis was applied to a statistically downscaled dataset known as LOCA. Adjustment factors were calculated from the difference between a 30-yr base period (1976–2005) and several future 30-year periods.

Figure 2 compares the separate adjustment factors computed from the two methods. These scatter plots represent adjusted NA14 values for the 3000 observation stations. For the lower emissions scenario (top panels), the differences are small. The differences are larger for the higher emissions (RCP8.5) scenario. By the late 21st century, the adjusted value using the Causes technique is larger than the scaled value using the GEV technique for most stations

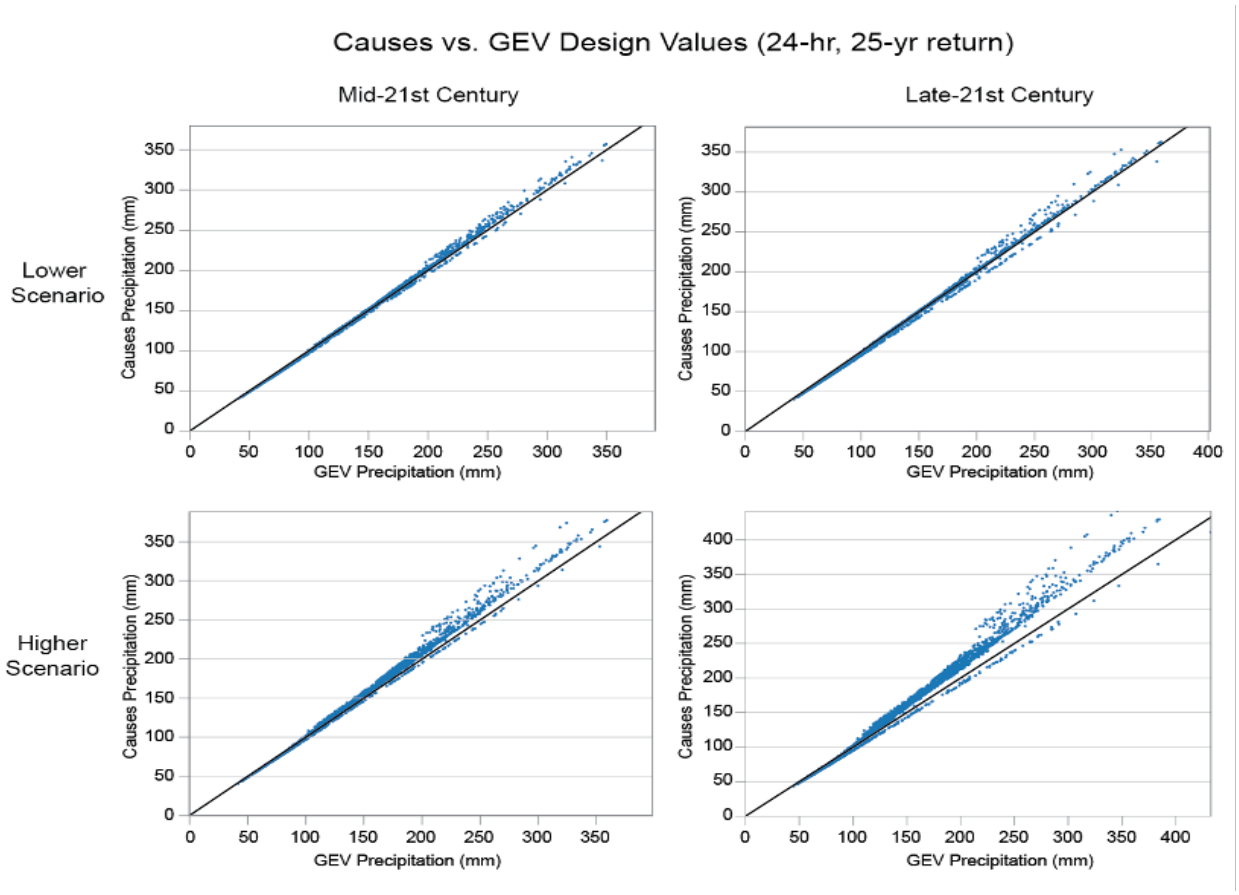

Figure 2. *Scatter plot comparison of scaled values of the 24-hr, 25-yr return level design values between the Causes method and the GEV downscaled method for (upper left) mid-21st century under the lower (RCP4.5) scenario, (upper right) late 21st century under the lower (RCP4.5) scenario, (lower left) mid-21st century under the higher (RCP8.5) scenario, and (lower right) late 21st century under the higher (RCP8.5) scenario. Each point represents a single estimated future value from the set of all observation stations.*

Planned work

The project ended in September 2020.

Products

• SERDP Website

Publications

Kunkel, K. E. 2020: Extreme precipitation and climate change: Observations and projections. *ASDSO Journal of Dam Safety*, **17(3)**, 22-28.

Kunkel, K. E., D. R. Easterling, T. R. Karl, **J. C. Biard**, **S. M. Champion**, B. E. Gleason, **K. M. Johnson**, **A. Li**, S. Stegall, **L. E. Stevens**, **S. E. Stevens**, M. Squires, **L. Sun**, and X. Yin, 2020: Incorporation of the Effects of Future Anthropogenically Forced Climate Change in Intensity-Duration-Frequency Design Values. Final Report., 104 pp., North Carolina Institute for Climate Studies, North Carolina State University.

Kunkel, K. E., S. E. Stevens, L. E. Stevens, and T. R. Karl, 2020: Observed climatological relationships of extreme daily precipitation events with precipitable water and vertical velocity in the contiguous United States. *Geophys. Res. Lett*., **47**, e2019GL086721. Doi.org/10.1029/2019GL086721

Presentations

Kunkel, K., 2021: Extreme Precipitation and Climate Change: Observations and Projections. Virtual. *U.S. Army Corps of Engineers Water Management Implementation Support Team meeting*, February 17, 2021.

Kunkel, K., 2021: Extreme Precipitation: The Merging Streams of Meteorology, Climatology, and Hydrology. Virtual. *2021 AMS Annual Meeting*, January 14, 2021.

Kunkel, K. E., T. R. Karl, D. R. Easterling, X. Yin**, L. Sun**, **J. Biard**, **S. E. Stevens**, **L. E. Stevens**, and **S. M. Champion**, 2020: Incorporating Climate Change into Intensity-Duration-Frequency Value for the United States. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 14, 2020.

Kunkel, K., 2020: The Incorporation of Future Climate into IDF Curves. Virtual. *SERDP & ESTCP Symposium 2020: Enhancing DoD's Missions Effectiveness*, December 1, 2020.

Kunkel, K., 2020: It's All About Water (Vapor). Virtual*. ICNet Global Teaching Climate Change and Civil Infrastructure Workshop*. June 30, 2020.

Stevens, S. E., **K. E. Kunkel**, and **L. E. Stevens**, 2020: More Weather or More Water? What is Driving Increases in Extreme Precipitation. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 8, 2020.

Other

• PI Kenneth Kunkel is PhD graduate advisor for project scientist Sarah Champion (NCSU Department of Marine, Earth, and Atmospheric Sciences)

Synthesis of Observed and Simulated Rain Microphysics to Inform a New Bayesian Statistical Framework for Microphysical Parameterization in Climate Models

Task Leader	Olivier Prat
Task Code	NC-OTH-02-NCICS-OP
Sponsor	Columbia University/US Department of Energy (DOE)

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

Background

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

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

Accomplishments

Final year activities focused on completing manuscripts reflecting the project's innovative research methodology and results. A collaborative review paper (Morrison et al. 2020) was published in May 2020 in the *Journal of Advances in Modeling Earth Systems*. Three additional papers are in various stage of preparation including one paper being finalized on the comparison of the bin- and bulk-microphysical schemes and the dual-polarization signature of microphysical processes (coalescence, breakup, and evaporation). All papers will be submitted by summer 2021.

Planned work

- Complete and publish final project manuscripts.

Publications

Morrison, H., M. van Lier-Walqui, A. M. Fridlind, W. W. Grabowski, J. Y. Harrington, C. Hoose, A. Korolev, M. R. Kumjian, J. A. Milbrandt, H. Pawlowska, D. J. Posselt, **O. P. Prat**, K. J. Reimel, S.-I. Shima, B. van Diedenhoven, and L. Xue, 2020: Confronting the challenge of modeling cloud and precipitation microphysics. *Journal of Advances in Modeling Earth Systems*, **12,** e2019MS001689. http://dx.doi.org/10.1029/2019ms001689

Presentations

Morrison, H., M. van Lier-Walqui, K. J. Reimel, **O. P. Prat**, M. R. Kumjian, S. Lunderman, and M. Morzfeld, 2020: Hierarchical approach to cloud microphysics scheme development using observations, physical models, Bayesian inference, and machine learning. Virtual. *SIAM Conference on Mathematics of Planet Earth (MPE20)*, August 5, 2020.

Reimel, K. J., M. van Lier-Walqui, M. R. Kumjian, H. Morrison, and **O. P. Prat**, 2020: Confronting Microphysical Uncertainty with BOSS. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 15, 2020.

Impact of COVID-19 on Health and Society	
Task Leader	Jennifer Runkle
Task Code	NC-OTH-03-NCICS-JR
Sponsor	multiple

Highlight: Researchers explored the myriad ways in which COVID-19 impacted the health and well-being of vulnerable populations across the United States. A participatory surveillance tool was created to 1) connect residents with needed healthcare and testing resources and 2) provide close to real-time data for situational monitoring in health officials.

Background

The World Health Organization has expressed concern over the significant and largely under-addressed mental health and psycho-social consequences of the pandemic. *The Lancet* recently published an urgent "call to action" for research monitoring and reporting on the pandemic's wide-ranging health, mental, and emotional consequences (Holmes et al., 2020). The objective of this novel population-based surveillance work was to assess the real-time changes in COVID-19 cases at the local level, as well as use an existing partnership with a national text-based service to measure crisis support-seeking at the national level.

Accomplishments

- Working closely with local health officials, a COVID-19 Self-Checker with daily follow-up was created to provide situational awareness for the local health authority in Buncombe County, North Carolina, and to connect vulnerable residents with needed care and testing resources (funded by Buncombe County Health and Human Services).
- Support was obtained for the COVID-19 Working Group from the National Science Foundation [funded by the Social Science Extreme Events Research (SSEER) network and the CONVERGE facility at the Natural Hazards Center at the University of Colorado Boulder (NSF award 1841338)].
- In partnership with the Crisis Text Line, a number of studies were conducted to examine the impact of the COVID-19 pandemic on mental health for vulnerable children and adolescents with a focus on racial/ethnic, non-conforming, and sexual minority groups (funded by the American Foundation of Suicide Prevention SRG-0-200-17).

Planned work

- Research examining crisis response in frontline essential workers and their children will be performed to examine the mental health impacts of the pandemic on these overtaxed workers and their families.

- Another study will apply a popular syndromic surveillance approach to examine bereavement as a significant stressor shouldered by adolescents during the pandemic.
- Extension of the team's early work on the mental health consequences of the pandemic will be extended to look at the effect of compounding events (e.g., 2020 wildfire season).

Products

- Buncombe County Health and Human Services COVID-19 Self-Checker

Publications

Andersen, L. M., S. R. Harden, M. M. Sugg, **J. D. Runkle**, and T. E. Lundquist, 2021: Analyzing the spatial determinants of local Covid-19 transmission in the United States. *Science of The Total Environment*, **754,** 142396. http://dx.doi.org/10.1016/j.scitotenv.2020.142396

Runkle, J. D., M. M. Sugg, **G. Graham**, B. Hodge, T. March, J. Mullendore, F. Tove, M. Salyers, S. Valeika, and E. Vaughan, 2021: Participatory COVID-19 surveillance tool in rural Appalachia: real-time disease monitoring and regional response. *Public Health Report.* http://dx.doi.org/10.1177/0033354921990372

Runkle, J. D., M. M. Sugg, S. McCrory, and C. C. Coulson, 2021: Examining the feasibility of blood pressure self-monitoring: Advancing remote prenatal care for rural Appalachia. *Telemedicine Reports*, **In Press**. http://dx.doi.org/10.1089/tmr.2020.0021

Sugg, M. M., T. J. Spaulding, S. J. Lane, **J. D. Runkle**, S. R. Harden, A. Hege, and L. S. Iyer, 2021: Mapping community-level determinants of COVID-19 transmission in nursing homes: A multi-scale approach. *Science of The Total Environment*, **752,** 141946. http://dx.doi.org/10.1016/j.scitotenv.2020.141946

Sugg, M. M., S. Woolard, M. Lawrimore, K. D. Michael, and **J. D. Runkle**, 2020: Spatial clustering of suicides and neighborhood determinants in North Carolina, 2000 to 2017. *Applied Spatial Analysis and Policy*. http://dx.doi.org/10.1007/s12061-020-09364-1

Other

- PI Runkle supervised graduate students Shrikanth Yadav (NCSU) in the climate/mental health investigations and *Sena McCrory* (Duke University) studying the impacts Climate Change Impacts on reproductive health.

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

Highlight: Metrics developed for the Madden–Julian Oscillation (MJO) monitoring page highlight the most predictable subseasonal to seasonal system signals for NOAA's Climate Prediction Center (CPC) through a new web interface on CPC servers (https://ftp.cpc.ncep.noaa.gov/fews/novella/mjo/).

Background

Subseasonal to seasonal (S2S) forecasting has emerged as one of the frontiers for atmospheric predictability. 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 was 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

The project team successfully transitioned the primary diagnostics from NCICS.org/mjo onto an operational server at CPC. One of the key goals of this project was to apply the same diagnostics to ECMWF forecasts as had been done for CFSv2 at NCICS.org/mjo. The web interface is housed at https://ftp.cpc.ncep.noaa.gov/fews/novella/mjo/, but it is password-protected due to the inclusion of proprietary ECMWF data. Figure 1 shows a screenshot of the website with maps of ECMWF analyses and forecasts of 200-hPa velocity potential. The Fourier-filtered contours are output as shapefiles for easy inclusion into the manual GTH forecasts.

Project activities also identified the need for systematic forecasts of extreme rainfall events based on the MJO. For example, Figure 2 shows the relative number of 2-year rainfall events that happen over the Mediterranean and the Middle East during December–February. These events tend to be more frequent during Phases 7/8/1/2 and less common during phases 3/4/5/6. MJO influences in these subtropical regions were surprising. These results will lay the foundation for future projects.

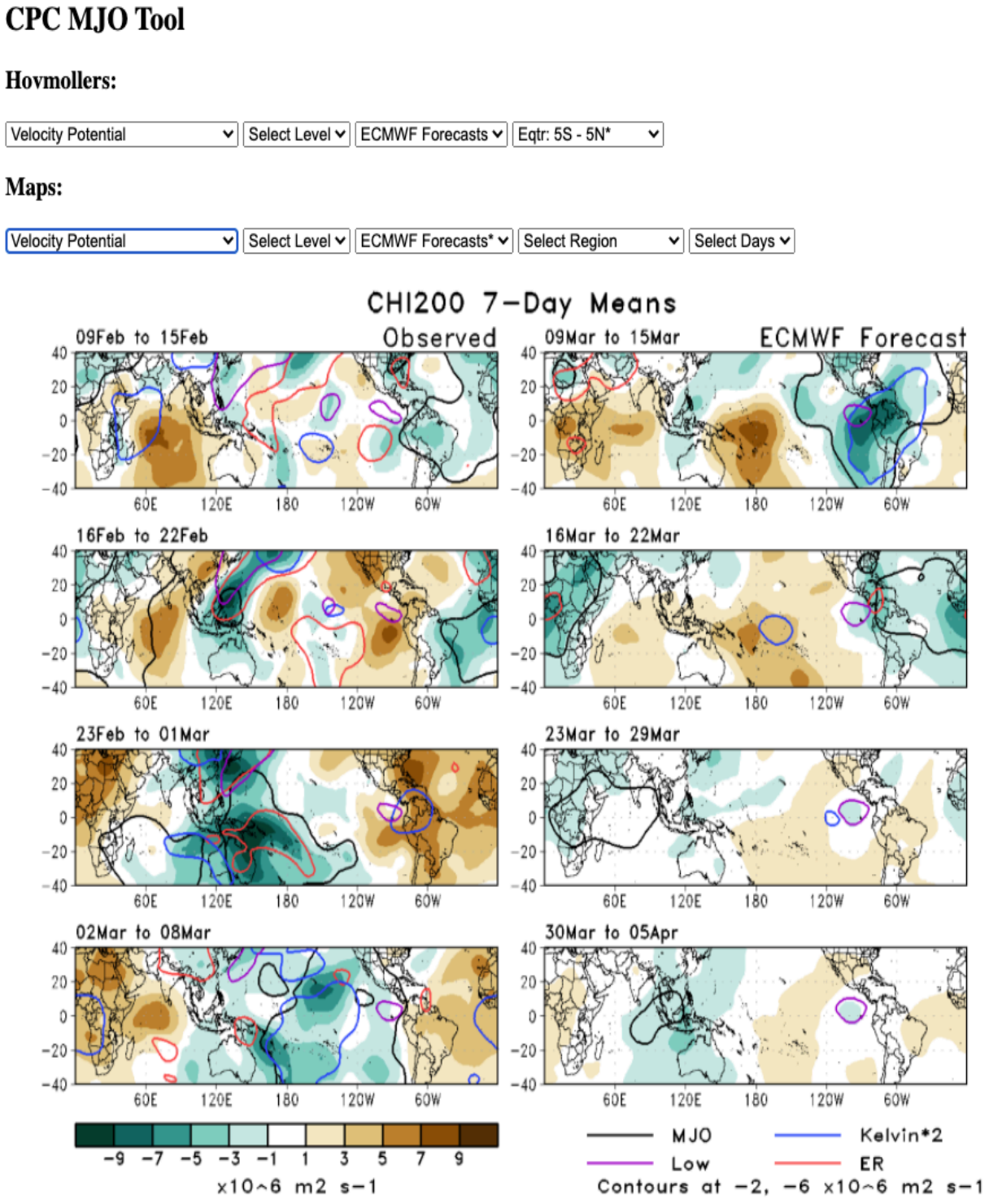

Figure 1. *Difference between HSS for LF+MJO and LF for each region (rows), season (columns), forecast lead, and RMM phase. Red dots indicate LF+MJO is more skillful, blue dots show LF is more skillful. Large dots denote differences that are 95% statistically different from zero. RMM phases are used 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.*

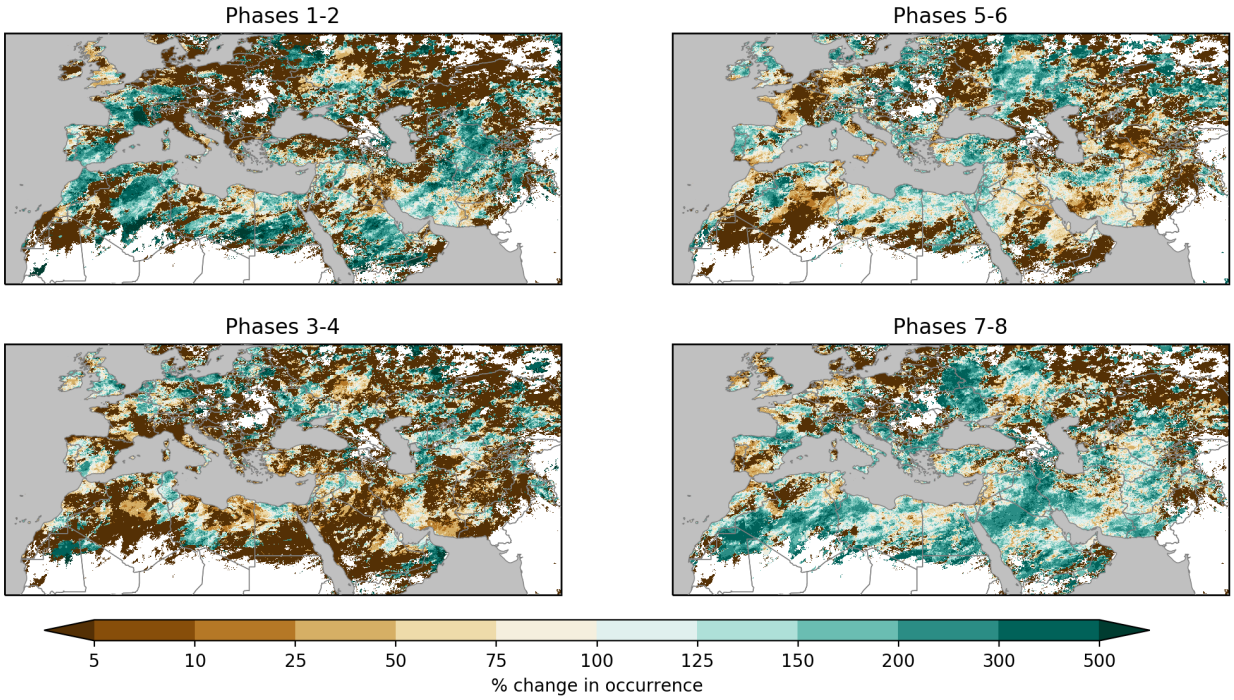

Figure 2. *Percentage changes in the frequency of December–February extreme rainfall events by MJO phase. Green colors mean those events are more likely, brown means less, and white means that they do not occur during those months.*

Products

- CPC MJO tool - web interface on CPC servers (https://ftp.cpc.ncep.noaa.gov/fews/novella/mjo/)

Presentations

Schreck, C. J., 2020: An overview of atmospheric equatorial waves. Virtual. *15th Annual Indonesia-U.S. BMKG-NOAA Workshop*, September 9, 2020.

Schreck, C. J., 2020: How does the MJO affect extreme rainfall around the tropics? Virtual. *NOAA Climate Diagnostics and Prediction Workshop*, October 22, 2020.

Schreck, C. J., 2020: How Does the MJO Affect Extreme Rainfall Around the Tropics. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 16, 2020.

Schreck, C. J., 2020: MJO. Virtual. Tropical Meteorology class, *University of North Carolina Asheville*, September 3, 2020.

Schreck, C. J., 2020: Sources of tropical subseasonal skill in CFSv2. Virtual. *OAR/WPO S2S Program and NWS/OSTI-Modeling* monthly webinar series, November 2, 2020.

Schreck, C. J., 2020: Sources of Tropical Subseasonal Skill in the CFSv2. Virtual. *Unified Forecast System (UFS) Users' Workshop*, July 29, 2020.

Schreck, C. J., 2020: The diagnostics for monitoring and forecasting them on ncics.org/mjo. Virtual. *15th Annual Indonesia-U.S. BMKG-NOAA Workshop*, September 9, 2020.

Schreck, C. J., 2021: How Does the MJO Affect Extreme Rainfall around the Tropics?" *2021 AMS Annual Meeting*, January 14, 2021.

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

Highlight: This project is investigating the interactions between Kelvin Waves and Easterly Waves utilizing NASA CYGNSS data to observe the interactions of their surface winds. 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

Progress was slower than planned this year due to the unanticipated move to full telework in response to the COVID-19 pandemic and the project graduate student's transition from the Ph.D. program to a Master's program. Two of the three project objectives are nearing completion.

The project graduate student successfully completed his graduate research activities and his thesis was submitted for publication in *Monthly Weather Review*. This study completed the first project objective of examining the energetics of interactions between Kelvin waves and African Easterly Waves (AEWs). The key findings were that Kelvin waves modulate the strength and meridional gradient of the African easterly jet over the eastern Atlantic (Fig. 1, left). This modulation strongly affects the southern track of AEWs. A new and unexpected finding was a modulation in the lower-tropospheric temperature gradient on the northern side of the jet (Fig. 1, right). This modulation affects the strength of the northern track AEWs.

Promising results were also produced regarding the vertical heating profiles of both AEWs and Kelvin waves. For Kelvin waves, for example, the heating profile over the Atlantic is similar to that from past studies over the Pacific. That structure becomes strongly distorted as the waves cross the African continent. A second manuscript documenting these findings is planned.

The second project objective was to examine the interactions between Kelvin waves and AEWs in CYGNSS data. This objective has been delayed because primary findings have pointed to mid-level interactions between the waves that would not be observed with CYGNSS. Nonetheless, preliminary results highlight

CYGNSS's ability to identify increases in latent heat fluxes within AEWs before tropical cyclogenesis (Fig. 2). A third manuscript describing these results is planned.

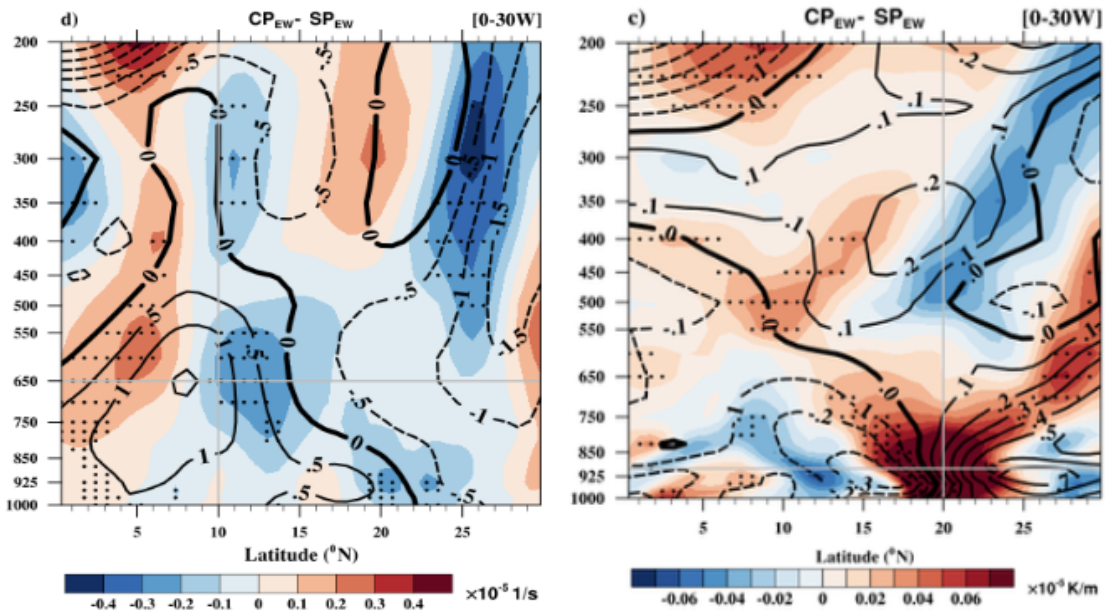

Figure 1. *Composite vertical cross-sections of the difference between AEWs in the convective and suppressed phases of Kelvin waves. Left: Zonal winds (contours) and their meridional gradient (shading) for southern track AEWs. Right: Temperature (contours) and its meridional gradient (shading) for northern track AEWs.*

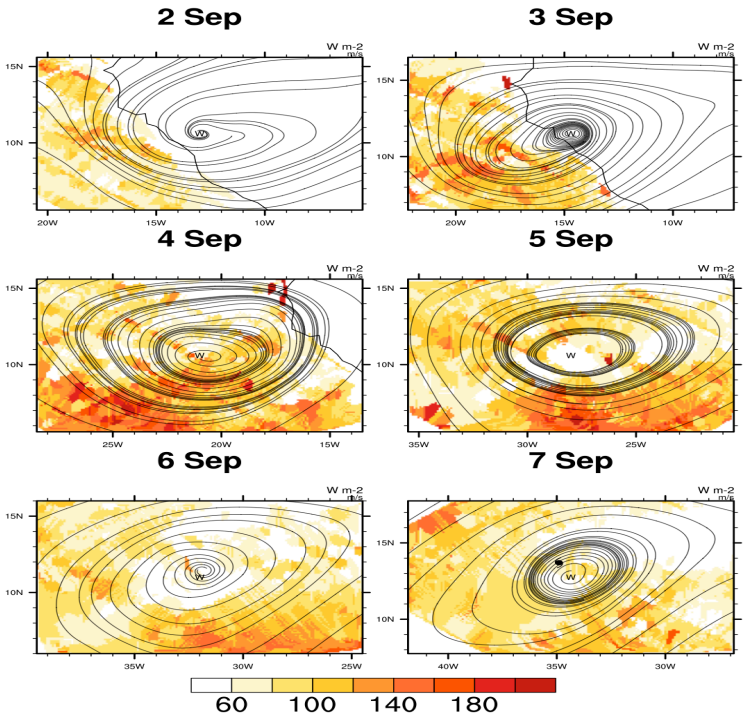

Figure 2. *Maps of 850-hPa streamlines and CYGNSS latent heat fluxes during the tropical cyclogenesis of Hurricane Isaac (2018).*

The third project objective is idealized WRF simulations of the interactions between Kelvin waves and AEWs. Some preliminary model runs were produced, with promising results. However, significant sensitivity testing is required to prepare the results for publication.

Planned work

- Publish budgets of moist static energy and EKE for the Kelvin waves to identify their impacts on the easterly waves (in review).
- Prepare and publish results on variations in latent heating profiles for AEWs and Kelvin waves.
- Prepare and publish results on the representations of Kelvin waves and AEWs in CYGNSS.

Presentations

Aiyyer, A., **C. J. Schreck**, and S. Mantripragada, 2020: Tropical Cyclogenesis from Easterly Waves seen in CYGNSS measurements. Virtual. *CYGNSS Science Team Meeting*, June 11, 2020.

Other

• Project graduate student: Sridhar Mantripragada, NCSU

Appendix 1: CISESS Personnel and Performance Metrics

CISESS Personnel	Numbers*		CISESS Subcontractors	Numbers**
Scientists working ≥ 50% time	**24**		Scientists working ≥ 50% time	**1**
Scientists working < 50% time	**2**		Scientists working < 50% time	**11**
Scientists working at no cost	**1**		Scientists working at no cost	**0**
Total Scientists	**27**		**Total Scientists**	**12**
Administrative/technical staff	**9**		**Administrative/technical staff**	**5**
Graduate Students	**6**		Graduate Students	**2**
Undergraduate Students	**7**		Undergraduate Students	**14**
High School Students	**0**		High School Students	**0**
Total Students	**13**		**Total Students**	**16**
Total Personnel	**49**		**Total Personnel**	**33**

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

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

Performance Metrics	
# of new or improved products developed that became operational	**52**
# of products or techniques submitted to NOAA for consideration in operations use	**10**
# of peer reviewed papers	**32**
# of NOAA technical reports	**0**
# of presentations	**138*****
# of graduate students supported by CISESS task	**8**
# of graduate students formally advised	**11**
# of undergraduate students mentored during the year	**21**

****Presentations: 119 science presentations; 19 outreach and engagement presentations.*

Appendix 2: Publications 2020-2021

CISESS Publications

Abadi, A. M., A. Vander Stoep, K. Foster, S. Clayton, J. E. Bell, and J. Hess, 2020: Mental health in water scarce cities: an unrecognized climate change pressure point. *BMJ* 2020; 371:m2936

Brooks, B.-G. J., D. C. Lee, L. Y. Pomara, and W. W. Hargrove, 2020: Monitoring broadscale vegetational diversity and change across North American landscapes using land surface phenology. *Forests*, **11,** 606. http://dx.doi.org/10.3390/f11060606

Dello, K., W. Robinson, **K. Kunkel**, **J. Dissen**, and **T. Maycock**, 2020: A hotter, wetter, and more humid North Carolina. *North Carolina Medical Journal*, **81,** 307. http://dx.doi.org/10.18043/ncm.81.5.307

Diamond, H. J., and **C. J. Schreck**, 2020: The tropics [in "State of the Climate in 2019"]. *Bulletin of the American Meteorological Society*, **101,** S185–S238. http://dx.doi.org/10.1175/bams-d-20-0077.1

Dong, Q., W. Wang, **K. E. Kunkel**, Q. Shao, W. Xing, and J. Wei, 2020: Heterogeneous response of global precipitation concentration to global warming. *International Journal of Climatology*. http://dx.doi.org/10.1002/joc.6851

Dunn, R., C. Lief, **G. Peng**, W. Wright, O. Baddour, M. Donat, B. Dubuisson, J.-F. Legeais, P. Siegmund, R. Silveira, X. L. Wang, and M. Ziese, 2021: Stewardship Maturity Assessment Tools for Modernization of Climate Data Management. *Data Science Journal*, **20(1),** 7. http://dx.doi.org/10.5334/dsj-2021-007

Gardiner, N., **J. Runkle**, J. Fox, and A. Patel, Eds., 2020: Ch. 5: Vulnerability, risk, and resilience strategies for addressing climate related hazards. *North Carolina Climate Risk Assessment and Resilience Plan: Impacts, Vulnerability, Risks, and Preliminary Actions. A Comprehensive Strategy for Reducing North Carolina's Vulnerability to Climate Change*, State of North Carolina, 5A-1—5N-3. https://files.nc.gov/ncdeq/climate-change/resilience-plan/2020-Climate-Risk-Assessment-and-Resilience-Plan.pdf

Huang, B., C. Liu, V. Banzon, E. Freeman, **G. Graham**, B. Hankins, T. Smith, and H.-M. Zhang, 2021: Improvements of the Daily Optimum Interpolation Sea Surface Temperature (DOISST) Version 2.1. *Journal of Climate*, **34,** 2923-2939. http://dx.doi.org/10.1175/jcli-d-20-0166.1

Hunt, E. D., J. I. Christian, J. B. Basara, L. Lowman, J. A. Otkin, J. E. Bell, K. Jarecke, R. A. Wakefield, and R. M. Randall, 2020: The flash drought of 1936. *J. Appl. Serv. Climatol.*, 2020(4). http://www.doi.org/10.46275/JOASC.2020.11.001

Klotzbach, P. J., **C. J. Schreck, III**, G. P. Compo, S. G. Bowen, E. J. Gibney, E. C. J. Oliver, and M. M. Bell, 2020: The record-breaking 1933 Atlantic hurricane season. *Bulletin of the American Meteorological Society***,** 1–54. http://dx.doi.org/10.1175/BAMS-D-19-0330.1

Knapp, K. R., A. H. Young, H. Semunegus, **A. K. Inamdar**, and W. Hankins, 2021: Adjusting ISCCP cloud detection to increase consistency of cloud amount and reduce artifacts. *Journal of Atmospheric and Oceanic Technology*, **38,** 155-165. http://dx.doi.org/10.1175/jtech-d-20-0045.1

Lawrimore, J. H., D. Wuertz, A. Wilson, **S. Stevens**, M. Menne, B. Korzeniewski, M. A. Palecki, **R. D. Leeper**, and T. Trunk, 2020: Quality control and processing of Cooperative Observer Program hourly precipitation data. *Journal of Hydrometeorology*, **21,** 1811-1825. http://dx.doi.org/10.1175/jhm-d-19-0300.1

Lookadoo, R. E. and J. E. Bell, 2020: Public health policy actions to address health issues associated with drought in a changing climate. *The Journal of Law, Medicine & Ethics*, 48(4), 653-663. https://doi.org/10.1177/1073110520979372

Mekonnen, A., **C. J. Schreck**, and B. D. Enyew, 2020: The Impact of Kelvin wave activity during dry and wet African summer rainfall years. *Atmosphere*, **11,** 568. http://dx.doi.org/10.3390/atmos11060568

Lynch, K. M., Lyles, R. H., Waller, L. A., Abadi, A. M., Bell, J. E., & Gribble, M. O., 2020: Drought severity and all-cause mortality rates among adults in the United States: 1968–2014. *Environ Health,* 19(52), 1-14. https://doi.org/10.1186/s12940-020-00597-8

Nelson, B. R., **O. P. Prat**, and **R. Leeper**, 2021: Using ancillary information from radar-based observations and rain gauges to identify error and bias. *Journal of Hydrometeorology*, **In press**. http://dx.doi.org/10.1175/jhm-d-20-0193.1

Peng, G., C. Lacagnina, R. R. Downs, I. Ivanova, D. F. Moroni, H. Ramapriyan, Y. Wei, and G. Larnicol, 2020: Laying the Groundwork for Developing International Community Guidelines to Effectively Share and Reuse Digital Data Quality Information—Case Statement, Workshop Summary Report, and Path Forward., *Ocean Science Framework*, Version: v03r04-20200828. http://dx.doi.org/10.31219/osf.io/75b92

Rennie, J. J., M. A. Palecki, S. P. Heuser, and H. J. Diamond, 2021: Developing and validating heat exposure products using the US Climate Reference Network. *Journal of Applied Meteorology and Climatology*, **In press**. http://dx.doi.org/10.1175/jamc-d-20-0282.1

Runkle, J. D., K. D. Michael, **S. E. Stevens**, and M. M. Sugg, 2021: Quasi-experimental evaluation of text-based crisis patterns in youth following Hurricane Florence in the Carolinas, 2018. *Science of The Total Environment*, **750,** 141702. http://dx.doi.org/10.1016/j.scitotenv.2020.141702

Runkle, J. D., M. M. Sugg, **R. D. Leeper**, **Y. Rao**, **J. L. Mathews**, and **J. J. Rennie**, 2020: Short-term effects of weather parameters on COVID-19 morbidity in select US cities. *Science of The Total Environment*, **740,** 140093. http://dx.doi.org/10.1016/j.scitotenv.2020.140093

Shen, M., N. Jiang, D. Peng, **Y. Rao**, Y. Huang, Y. H. Fu, W. Yang, X. Zhu, R. Cao, X. Chen, J. Chen, C. Miao, C. Wu, T. Wang, E. Liang, and Y. Tang, 2020: Can changes in autumn phenology facilitate earlier green-up date of northern vegetation? *Agricultural and Forest Meteorology*, **291,** 108077. http://dx.doi.org/10.1016/j.agrformet.2020.108077

Sugg, M., **J. Runkle**, **R. Leeper**, H. Bagli, A. Golden, L. H. Handwerger, T. Magee, C. Moreno, R. Reed-Kelly, M. Taylor, and S. Woolard, 2020: A scoping review of drought impacts on health and society in North America. *Climatic Change*, **162,** 1177–1195. http://dx.doi.org/10.1007/s10584-020-02848-6

Waliser, D., P. J. Gleckler, R. Ferraro, K. E. Taylor, S. Ames, **J. Biard**, M. G. Bosilovich, **O. Brown**, H. Chepfer, L. Cinquini, P. J. Durack, V. Eyring, P. P. Mathieu, T. Lee, S. Pinnock, G. L. Potter, M. Rixen, R. Saunders, J. Schulz, J. N. Thépaut, and M. Tuma, 2020: Observations for Model Intercomparison Project (Obs4MIPs): Status for CMIP6. *Geoscientific Model Development*, **13,** 2945–2958. http://dx.doi.org/10.5194/gmd-13-2945-2020

Wang, S., J. Chen, **Y. Rao**, L. Liu, W. Wang, and Q. Dong, 2020: Response of winter wheat to spring frost from a remote sensing perspective: Damage estimation and influential factors. *ISPRS Journal of Photogrammetry and Remote Sensing*, **168,** 221–235. http://dx.doi.org/10.1016/j.isprsjprs.2020.08.014

Wang, S., **Y. Rao**, J. Chen, L. Liu, and W. Wang, 2021: Adopting "difference-in-differences" method to monitor crop response to agrometeorological hazards with satellite data: A case study of dry-hot wind. *Remote Sensing*, **13**. http://dx.doi.org/10.3390/rs13030482

Wood, K. M., P. J. Klotzbach, J. M. Collins, L.-P. Caron, R. E. Truchelut, and **C. J. Schreck**, 2020: Factors affecting the 2019 Atlantic hurricane season and the role of the Indian Ocean Dipole. *Geophysical Research Letters*, **47,** e2020GL087781. http://dx.doi.org/10.1029/2020gl087781

Worku, L. Y., A. Mekonnen, and **C. J. Schreck**, 2020: The impact of MJO, Kelvin, and equatorial Rossby waves on the diurnal cycle over the Maritime Continent. *Atmosphere*, **11,** 711. http://dx.doi.org/10.3390/atmos11070711

Zhou, J., J. Chen, X. Chen, X. Zhu, Y. Qiu, H. Song, **Y. Rao**, C. Zhang, X. Cao, and X. Cui, 2021: Sensitivity of six typical spatiotemporal fusion methods to different influential factors: A comparative study for a normalized difference vegetation index time series reconstruction. *Remote Sensing of Environment*, **252,** 112130. http://dx.doi.org/10.1016/j.rse.2020.112130

Other Publications

Andersen, L. M., S. R. Harden, M. M. Sugg, **J. D. Runkle**, and T. E. Lundquist, 2021: Analyzing the spatial determinants of local Covid-19 transmission in the United States. *Science of The Total Environment*, **754,** 142396. http://dx.doi.org/10.1016/j.scitotenv.2020.142396

Byrd, B., S. L. Richards, **J. D. Runkle**, and M. M. Sugg, 2020: Vector-borne diseases and climate change: North Carolina's policy should promote regional resilience. *North Carolina Medical Journal*, **81,** 324. http://dx.doi.org/10.18043/ncm.81.5.324

Johnson, K. M., and W. B. Ouimet, 2021: Reconstructing historical forest cover and land use dynamics in the northeastern United States using geospatial analysis and airborne LiDAR. *Annals of the American Association of Geographers*, **In Press**. http://dx.doi.org/10.1080/24694452.2020.1856640

Kunkel, K. E. 2020: Extreme precipitation and climate change: Observations and projections. *ASDSO Journal of Dam Safety*, **17(3)**, 22-28.

Kunkel, K. E., D. R. Easterling, T. R. Karl, **J. C. Biard**, **S. M. Champion**, B. E. Gleason, **K. M. Johnson**, **A. Li**, S. Stegall, **L. E. Stevens**, **S. E. Stevens**, M. Squires, **L. Sun**, and X. Yin, 2020: Incorporation of the Effects of Future Anthropogenically Forced Climate Change in Intensity-Duration-Frequency Design Values. Final Report., 104 pp., North Carolina Institute for Climate Studies, North Carolina State University.

Kunkel, K. E., S. E. Stevens, L. E. Stevens, and T. R. Karl, 2020: Observed climatological relationships of extreme daily precipitation events with precipitable water and vertical velocity in the contiguous United States. *Geophys. Res. Lett*., **47**, e2019GL086721. Doi.org/10.1029/2019GL086721

Morrison, H., M. van Lier-Walqui, A. M. Fridlind, W. W. Grabowski, J. Y. Harrington, C. Hoose, A. Korolev, M. R. Kumjian, J. A. Milbrandt, H. Pawlowska, D. J. Posselt, **O. P. Prat**, K. J. Reimel, S.-I. Shima, B. van Diedenhoven, and L. Xue, 2020: Confronting the challenge of modeling cloud and precipitation microphysics. *Journal of Advances in Modeling Earth Systems*, **12,** e2019MS001689. http://dx.doi.org/10.1029/2019ms001689

Runkle, J. D., M. M. Sugg, **G. Graham**, B. Hodge, T. March, J. Mullendore, F. Tove, M. Salyers, S. Valeika, and E. Vaughan, 2021: Participatory COVID-19 surveillance tool in rural Appalachia: real-time disease

monitoring and regional response. *Public Health Report.* http://dx.doi.org/10.1177/0033354921990372

Runkle, J. D., M. M. Sugg, S. McCrory, and C. C. Coulson, 2021: Examining the feasibility of blood pressure self-monitoring: Advancing remote prenatal care for rural Appalachia. *Telemedicine Reports*, **In Press**. http://dx.doi.org/10.1089/tmr.2020.0021

Sugg, M. M., T. J. Spaulding, S. J. Lane, **J. D. Runkle**, S. R. Harden, A. Hege, and L. S. Iyer, 2021: Mapping community-level determinants of COVID-19 transmission in nursing homes: A multi-scale approach. *Science of The Total Environment*, **752,** 141946. http://dx.doi.org/10.1016/j.scitotenv.2020.141946

Sugg, M. M., S. Woolard, M. Lawrimore, K. D. Michael, and **J. D. Runkle**, 2020: Spatial clustering of suicides and neighborhood determinants in North Carolina, 2000 to 2017. *Applied Spatial Analysis and Policy*. http://dx.doi.org/10.1007/s12061-020-09364-1

Appendix 3: Presentations 2020–2021

Science / Project Presentations

- Aiyyer, A., **C. J. Schreck**, and S. Mantripragada, 2020: Tropical Cyclogenesis from Easterly Waves seen in CYGNSS measurements. Virtual. *CYGNSS Science Team Meeting*, June 11, 2020.
- Bilotta, R., A. M. Courtright, **O. P. Prat**, **R. D. Leeper**, B. R. Nelson, and S. Ansari, 2021: Visualizing Drought Indices Using Remotely Sensed Near-Real Time Monitoring. Poster. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.
- Brewer, M., T. Houston, A. Hollingshead, J. Okrend, and **J., Dissen**, 2021: The Value of Environmental Data from NOAAs National Centers for Environmental Information. Virtual. *2021 AMS Annual Meeting*, January 14, 2021.
- Brewer, M., A. Hollingshead, **J. Dissen**, J., Okrend, 2021: Innovating NCEI Customer Engagement Approaches. Virtual. *2021 AMS Annual Meeting*, January 13, 2021.
- **Brooks, B.**, 2020: A joint private-public citizen science collaboration to 'Fight Forest Fragmentation'. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 18, 2020.
- **Brooks, B.**, 2020: Inventory, Catalog, and Archive administration User Stories and Requirements Project Plan. Virtual. *NCEI Data Stewardship Council Meeting*, August 5, 2020.
- **Brooks, B.**, 2020: Transitioning local to cloud-native data processing, lessons from an environmental dataset. Virtual. *2020 NOAA Environmental Data Management Worksho*p, August 19, 2020.
- **Brown, O.**, 2021: NCICS activities update. Virtual. *CISESS Executive Council* meeting, January 8, 2021.
- Buttigieg, L., ..., **G. Peng**, et al, 2020: Towards a Strategy on Ocean Data and Information Stewardship for the UN Decade of Ocean Science for Sustainable Development. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 17, 2020.
- Carlson, D., K. Elger, J. Klump, **G. Peng**, J. Wagner, 2020: Practical data sharing with tangible rewards through publication in ESSD. Virtual. *EGU General Assembly 2020*, May 4, 2020. https://doi.org/10.5194/egusphere-egu2020-4169
- **Champion, S. M.**, 2020: Information Quality and the National Climate Assessment. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.
- **Champion, S. M.**, 2020: Information Quality and the NCA. Virtual. *Fifth National Climate Assessment (NCA5) Federal Steering Committee* meeting, June 23, 2020.
- **Champion, S. M.**, 2020: Let Them Eat Cake: An Untraditional Guide to Navigating the National Climate Assessment Data Marketplace. Virtual. 6th Annual Climate Adaptive Design Symposium. *American Institute of Architects and CASE Consultants International*, November 6, 2020.
- **Champion, S. M.**, 2020: Quality Climate Data for All: How the National Climate Assessment Connects Users to Actionable Climate Information. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 17, 2020.
- **Copley, L.**, and **T. Maycock**, 2020: Survey of Programs Related to Climate Science Fields at America's HBCUs. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 10, 2020.
- **Dissen, J**., 2020: Artificial Intelligence for Environmental Sustainability. Panel Discussion. Virtual. *Microsoft Federal Research Virtual Summit*, October 20, 2020.
- **Dissen, J.**, 2020: NOAA Big Data Program overview and case study. Virtual. *IEEE Workshop on Interconnections of Renewables & Energy Storage to Electric Grids,* December 4, 2020.

- Elger, K., D. J. Carlson, P. A. Fox, A. L. Hufton, J. Klump, and **G. Peng,** 2020: What do I need to know about data journals? Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 4, 2020. http://doi.org/10.5281/zenodo.4439349
- **Griffin, J.**, **L. E. Stevens**, and **S. M. Champion**, 2020: Using Teamwork as a Tool for Scientific Communication. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.
- **Groisman, P.,** S. Gulev, D. Streletskiy, **G. Peng**, S. Speranskaya, and N, Tchebakova, 2020: Environment changes in the Eurasian Arctic. Poster. Virtual. *The Sixth International Symposium on Arctic Research – Web Conference*, March 18–April 10, 2020.
- **Groisman, P. Y.**, 2020: Environmental, Socioeconomic and Climatic Changes in Northern Eurasia. Convener. Virtual. *JpGU-AGU Joint Meeting 2020*, July 14, 2020.
- **Groisman, P. Y.**, 2020: Environmental, Socioeconomic, and Climatic Changes in Northern Eurasia, Part I. Convener. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.
- **Groisman, P. Y.**, 2020: Environmental, Socioeconomic, and Climatic Changes in Northern Eurasia, Part II. Convener. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.
- **Groisman, P. Y.**, 2020: Northern Eurasia Future Initiative (NEFI), Update. Virtual. *International Conference on Environmental Observations, Modeling, and Information Systems (ENVIROMIS 2020)*, September 11, 2020.
- **Groisman, P. Y.**, 2020: Role of International Collaboration in Restoration of Earth Science Research after the USSR Collapse. Virtual. Science of the Future - Science of the Youth. *5th All-Russia Forum and Competition*, November 30, 2020.
- **Groisman, P. Y.**, and A. Georgiadi, 2020: Long-term Changes of Streamflow and Heat Transport of Two Largest Arctic Rivers of European Russia Severnaya Dvina and Pechora. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.
- **Groisman, P. Y.**, D. A. Streletskiy, E. A. Kukavskaya, and G. M. Henebry, 2020: Northern Eurasia Future Initiative (NEFI), Update. Poster. Virtual. *JpGU-AGU Joint Meeting 2020*, July 12-16, 2020.
- **Groisman, P. Y.**, E. P. Gordov, Y. E. Gordova, and A. A. Ryazanova, 2020: Qualitative Basis for Adaptation of Siberia to Climate Change impact. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.
- **Groisman, P. Y.**, G. M. Henebry, G. R. H. Allington, J. Chen, K. de Beurs, P. Fan, E. A. Mack, H. H. Shugart, A. J. Soja, and M. A. Tomaszewska, 2020: Looking Forward to 30 Years since the Disintegration of the USSR: Environmental and Socio-Economic Consequences of Fundamental Institutional Change amidst Changing Climates. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting.* December 11, 2020.
- **Groisman, P. Y.**, N. M. Tchebakova, E. Parfenova, N. Kuzmina, and S. Kuzmin, 2020: Climate change impacts on seed quality and distribution of light-needled Pinus sylvestris and Larix spp. in Northern Eurasia in a warming climate. Poster. Virtual. *JpGU-AGU Joint Meeting 2020*, July 12-16, 2020.
- **Groisman, P. Y.**, O. N. Bulygina, S. K. Gulev, A. Dufour, **G. Peng**, D. Streletskiy, N. A. Speranskaya, and N. M.Tchebakova, 2020: Environment Changes in the Eurasian Arctic. Poster. Virtual. *JpGU-AGU Joint Meeting 2020*, July 12-16, 2020.
- Hammer, G., **G. Peng,** J. Fulford, T**. Maycock**, A. Anderson, T. Foreman, 2020: In Real Life: How Social Media Propelled One Study. Virtual*. 2020 NOAA Environmental Data Workshop*, August 21, 2020.

- **Inamdar, A.**, and **R. D. Leeper**, 2020: Filling in the Spatio-Temporal Gaps in the GOES-R Land Surface Temperature Product. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 7, 2020.
- **Johnson, K. M.**, 2020: Applications of LiDAR for historical land use studies and archaeology. Virtual. *Robert S. Peabody Museum for Archaeology and Massachusetts Archaeological Society speaker series*, August 5, 2020.
- **Johnson, K. M.**, **S. M. Champion**, **L. B. Copley**, **A. Li**, **L. E. Stevens**, **K. E. Kunkel**, and **J. Griffin**, 2020: From Data to Decisions: Use of NOAA Datasets in the Fourth National Climate Assessment. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.
- Kent, J., J. O'Neil, A. Simonson, P. Keown, P., **J. Dissen**, **O. Brown**, and **J. Brannock**, 2021: NOAA Big Data Program. Virtual. *Coastal Coupling Community of Practice Webinar*. February 22, 2021.
- Keown, P., J. O'Neil, A. Simonson, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Data In The Cloud: What's Next? Virtual. *2020 Environmental Data Management Workshop*, August 21, 2020.
- **Kunkel, K. E.**, 2020: Climate Scenarios and their Use in Decision-making. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.
- **Kunkel, K. E.**, 2020: Climate Science. Virtual. Illinois Climate Assessment author team meeting. *The Nature Conservancy*, April 10, 2020.
- **Kunkel, K. E.**, 2020: Hurricane Florence: Is that our Future? Virtual. *North Carolina Cooperative Extension Webinar*, October 20, 2020.
- **Kunkel, K. E.**, 2020: North Carolina Climate Science Report: An Overview of Climate Change in North Carolina. Virtual. *North Carolina Cooperative Extension Webinar*, September 3, 2020.
- **Kunkel, K. E.**, 2020: North Carolina Climate Science Report. Virtual. *Southeast Climate Monthly Webinar,* April 14, 2020.
- **Kunkel, K. E.**, 2020: North Carolina Climate Science Report. Virtual. *2020 Appalachian Clean Energy CLE workshop*, August 28, 2020.
- **Kunkel, K. E.**, 2020: Our Rapidly Changing Climate. Virtual. Osher Lifelong Learning Institute class, *North Carolina State University*, October 6, 2020.
- **Kunkel, K. E.**, 2020: Probabilities of Extreme Climate Events. Virtual. *Quantitative Analysis of Climate Change Science class, NC State University*, August 18, 2020.
- **Kunkel, K. E.**, 2020: The Future Climate of the Southeast U.S. - Uncharted Waters. Virtual. 45th *Air & Waste Management Association Information Exchange conference*, December 9, 2020.
- **Kunkel, K. E.**, 2020: The Incorporation of Future Climate into IDF Curves. Virtual. *SERDP & ESTCP Symposium 2020: Enhancing DoD's Missions Effectiveness*, December 1, 2020.
- **Kunkel, K. E.**, 2021: Extreme Precipitation: The Merging Streams of Meteorology, Climatology, and Hydrology. Invited *Core Science Keynote* presentation. Virtual. *2021 AMS Annual Meeting*, January 14, 2021.
- **Kunkel, K. E.**, and D. R. Easterling, 2020: Science Needs of the Fifth National Climate Assessment. Virtual. *NOAA Climate Program Office CMIP6 Task Force*, April 21, 2020.
- **Kunkel, K. E.**, and **J. Dissen**, 2020: EPRI Climate Impacts. Virtual. Climate Data for Electric Companies. *Environmental Power Research Institute (EPRI)*, December 3, 2020.
- **Kunkel, K. E.,** T. R. Karl, D. R. Easterling, X. Yin**, L. Sun**, **J. Biard**, **S. E. Stevens**, **L. E. Stevens**, and **S. M. Champion**, 2020: Incorporating Climate Change into Intensity-Duration-Frequency Value for the United States. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 14, 2020.
- **Leeper, R. D.,** 2020: Applications of USCRN's Standardized Soil Moisture Dataset. Virtual. *NCEI Tuesday Seminar Series*. August 11, 2020.

- **Leeper, R. D.**, 2020: Comparisons of In Situ Ground Observations and Satellite Measurements of Soil Moisture Standardizing Using a Consistent Method. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 7, 2020.
- **Leeper, R. D.**, 2020: Exploring the use of Standardized Soil Moisture Datasets as an Indicator of Drought. Virtual. *2020 National Soil Moisture Workshop*, August 9, 2020.
- **Leeper, R. D.**, B. Peterson, and M. A. Palecki, 2021: Exploring the use of Standardized Soil Moisture as a Drought Indicator. Poster. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.
- Li, Q., A. M. Abadi, H. Dai, and J. Bell, 2020: Effects of Climate on Variability in Coccidiomycosis (Valley Fever) Incidence in Arizona and California. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting*, December 2020. https://agu2020fallmeeting-agu.ipostersessions.com/default.aspx?s=BD-38-39-E5-A8-CD-A8-B5-CC-1B-B4-B1-6E-05-6B-8B
- Li, Q., J. Bell, A. M. Abadi, and H. Dai, 2021: Effects of Climate on Variability in Coccidiomycosis (Valley Fever) Incidence in Arizona and California. Virtual. *2021 AMS Annual Meeting*, January 12, 2021. https://ams.confex.com/ams/101ANNUAL/meetingapp.cgi/Paper/383291
- Lief, C., **G. Peng**, O. Baddour, W. Bright, and D. Stuber, 2020: WMO High Quality Global Data Management Framework for Climate (HQ-GDMFC) - A Collaborative Framework for Improving Data Access and Quality. Virtual. *WMO Data Conference*. Nov 18, 2020.
- **Maycock, T.**, **L. E. Stevens**, **K. M. Johnson**, **A. McCarrick**, **J. Allen**, S. Veasey, and **B. C. Stewart**, 2021: Making Climate Change Assessments Accessible. Virtual. *2021 AMS Annual Meeting*, January 13, 2021.
- Miller, D.K., 2020: Water Fight at Cataloochee Creek. Virtual. *JPSS Initiative meeting*, June 22, 2020.
- Moroni, D., H. Ramapriyan, B. Downs, **G. Peng**, and Y. Wei, 2020: Exploring new perspective and formulating best practices for data uncertainty information - Part 1 and 2. Virtual. *ESIP 2020 Summer Meeting*. July 15, 2020.
- Morrison, H., M. van Lier-Walqui, K. J. Reimel, **O. P. Prat**, M. R. Kumjian, S. Lunderman, and M. Morzfeld, 2020: Hierarchical approach to cloud microphysics scheme development using observations, physical models, Bayesian inference, and machine learning. Virtual. *SIAM Conference on Mathematics of Planet Earth (MPE20)*, August 5, 2020.
- Nelson, B. R., and **O. P. Prat**, 2020: An Assessment of a Gridded Gauge-Based Precipitation Estimates (nClimGrid) with National Centers for Environmental Prediction (NCEP) Stage IV Radar-Based Precipitation Estimates. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 15, 2020.
- O'Neil, J., **J. Dissen,** A. Privette, J. Oyler, M. Tribble, V. Lakshmanan, B. Nuno, A. Simonson, P. Keown, J. Kent, **O. Brown,** and **J. Brannock**, 2021: NOAA Big Data Program. Virtual. *2021 AMS Annual Meeting*, January 12, 2021.
- O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Big Data Program --- Transforming Access to NOAA Data. iPoster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting*, December 16, 2020.
- O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Big Data Program --- Transforming Access to NOAA Data. Virtual. *IEEE Workshop on Interconnections of Renewables & Energy Storage to Electric Grids*, December 4, 2020.
- O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: NOAA Big Data Program - Advancing Environmental Sustainability. Virtual. *Microsoft Federal Research Virtual Summit*, October 20, 2020.

- O'Neil, J., A. Simonson, P. Keown, J. Kent, **O. Brown, J. Brannock,** and **J. Dissen**, 2020: Strategies for Advancing Access and End User Interactions of NOAA Data in Collaboration with Cloud Service Providers. Panel Discussion. Virtual. *2020 Environmental Data Management Workshop*, August 26, 2020.
- O'Neil, J., J. Kent, and **J. Dissen**, 2021: NOAA Big Data Program Overview. Focus Forward: Beyond the Cloud. Virtual. *West Virginia Public Education Collaborative*, March 17, 2021.
- **Peng, G.,** 2020: Arctic sea ice coverage: From past to future. Virtual. Changing North: The Arctic in Flux. *Consulate General of Canada in Atlanta*, December 3, 2020.
- **Peng, G.**, 2020: ESIP IQC/BSC Pre-ESIP Workshop Report Out. Lightning Presentation. Virtual. *ESIP 2020 Summer Meeting Highlights Webinar*, August 13, 2020.
- **Peng, G**., 2020: Evaluating the FAIRness of Environmental Data. Virtual. 9th RDA FAIR Data Maturity Model Working Group Workshop, May 20, 2020.
- **Peng, G.**, 2020: Fun facts and preliminary results from the pre-ESIP Workshop. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.
- **Peng, G.**, and **S. M. Champion**, 2020: Towards Developing Community Guidelines for Sharing and Reuse of Digital Data Quality Information. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 8, 2020.
- **Peng, G.**, A. Milan, N. Ritchey, et al, 2020: Providing Structured and Rich Dataset Quality Information. Poster. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 18, 2020.
- **Peng, G.** C. Lacagnina, R. Downs, I. Ivánová, G. Larnicol, D. Moroni, H. Ramapriyan, and Y. Wei, 2020: Challenges of Consistently Curating and Representing FAIR Dataset Quality Information - IQC/BSC Pre-ESIP Workshop Report Out. Virtual. *2020 ESIP Summer Meeting*, July 22, 2020.
- **Peng, G.,** C. Lacagnina, R. Downs, I. Ivánová, G. Larnicol, D. Moroni, H. Ramapriyan, and Y. Wei, 2020: Developing Community Guidelines for Consistently Curating and Representing Dataset Quality Information. Virtual*. Pre-2020 ESIP Summer Meeting Workshop*. July 13, 2020.
- **Peng, G.,** H. Ramapriyan, and D. Moroni, 2020: ESIP Information Quality Cluster and Multi-dimensions of data and information quality. Session. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.
- **Peng, G.**, J. Privette, S. Hausman, E. Kearns, **O. Brown**, and **T. Maycock**, 2020: An Integrated Framework for Supporting Evidence-Based Institutional Research Data Management and Stewardship. Poster. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 19, 2020.
- **Prat, O. P.**, A. M. Courtright, **R. D. Leeper**, B. R. Nelson, R. Bilotta, J. Adams, and S. Ansari, 2020: Operational near-real time drought monitoring using global satellite precipitation estimates. Virtual. *2020 EGU General Assembly, Vienna, Austria*, May 7, 2020.
- **Prat, O. P.**, A. M. Courtright, **R. D. Leeper**, B. R. Nelson, R. Bilotta, J. Adams, and S. Ansari, 2020: Operational Near-real Time Drought Monitoring Using Global Satellite Precipitation Estimates. Poster. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.
- **Prat, O. P.**, B. R. Nelson, and **R. D. Leeper**, 2020: Evaluation of Cold-Season Precipitation Estimates Derived from Gridded Daily Satellite Precipitation Products. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 16, 2020.
- **Rao, Y.**, 2020: A satellite based daily near-surface temperature data records for the Tibetan Plateau. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.
- **Rao, Y.**, 2020: A satellite-station blended daily surface air temperature dataset for the Tibetan Plateau. Virtual. *2nd NOAA Workshop on Leveraging AI in Environmental Sciences*, January 7, 2020.

- **Rao, Y.**, 2020: Creating a blended surface temperature dataset with satellite thermal data and in situ measurements for the Tibetan Plateau. Virtual. *Climate Informatics 2020*, September 23, 2020.
- **Rao, Y.**, 2020: What we wish we learned in grad school: A workshop to develop a mini data management training. Virtual. *ESIP 2020 Summer Meeting*, July 22, 2020.
- **Rao, Y.**, C. Slocum, 2021: A Roadmap of Workforce Development for the NOAA Center for Artificial Intelligence. Virtual. *ESIP 2021 Winter Meeting*, January 29, 2021.
- Reimel, K. J., M. van Lier-Walqui, M. R. Kumjian, H. Morrison, and **O. P. Prat**, 2020: Confronting Microphysical Uncertainty with BOSS. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 15, 2020.
- **Rennie, J. J.**, 2020: Asheville, NC: Climate City. Virtual. *American Meteorological Society Metro Atlanta Chapter*, June 17, 2020.
- **Rennie, J. J.**, 2020: Climate data and the role of NCEI and NCICS in analyzing climate and health data. Virtual. Master of Public Health class, *University of Nebraska Medical Center*, September 1, 2020.
- **Rennie, J. J.**, 2020: North Carolina Heat. Virtual. *North Carolina Cooperative Extension Webinar*, September 25, 2020.
- **Rennie, J. J.**, 2020: ShowYourStripes: Making Climate Information Local with the Use of Simple Visualizations. Virtual. *Esri Ocean, Weather, and Climate GIS Forum*, November 4, 2020.
- **Rennie, J. J.**, and M. A. Palecki, 2021: Using Wet-Bulb Globe Temperature Estimations from the U.S. Climate Reference Network to Generate Standardized Anomalies and Evaluate Extreme Heat Events. Virtual. *2021 AMS Annual Meeting*, January 11, 2021.
- Rogers, K., 2020: Community Resilience Solutions. Virtual. *American Society of Adaptation Professionals/Civic Spark*, May 28, 2020.
- **Runkle, J.**, and M. Sugg, 2020: Exploring the Health Effects of Heat on Populations of Concern. Virtual. *North Carolina Cooperative Extension Webinar*, September 25, 2020.
- **Runkle, J. D.**, M. M. Sugg, **R. D. Leeper, Y. Rao, J. L. Matthews**, and **J. J. Rennie**, 2020: Acute effects of meteorological parameters on COVID-19 morbidity in the US: a case-crossover study with a distributed lag nonlinear model. Virtual. International Symposium on climatological, meteorological, and environmental factors in the COVID-19 pandemic, *World Meteorological Organization,* August 4-6, 2020.
- **Schreck, C. J.**, 2020: An overview of atmospheric equatorial waves. Virtual. *15th Annual Indonesia-U.S. BMKG-NOAA Workshop*, September 9, 2020.
- **Schreck, C. J.**, 2020: How does the MJO affect extreme rainfall around the tropics? Virtual. *NOAA Climate Diagnostics and Prediction Workshop*, October 22, 2020.
- **Schreck, C. J.**, 2020: How Does the MJO Affect Extreme Rainfall Around the Tropics. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 16, 2020.
- **Schreck, C. J.**, 2020: MJO. Virtual. Tropical Meteorology class, *University of North Carolina Asheville*, September 3, 2020.
- **Schreck, C. J.**, 2020: Sources of tropical subseasonal skill in CFSv2. Virtual. *OAR/WPO S2S Program and NWS/OSTI-Modeling* monthly webinar series, November 2, 2020.
- **Schreck, C. J.**, 2020: Sources of Tropical Subseasonal Skill in the CFSv2. Virtual. *Unified Forecast System (UFS) Users' Workshop*, July 29, 2020.
- **Schreck, C. J.**, 2020: The diagnostics for monitoring and forecasting them on ncics.org/mjo. Virtual. *15th Annual Indonesia-U.S. BMKG-NOAA Workshop*, September 9, 2020.
- **Schreck, C. J.**, 2021: How Does the MJO Affect Extreme Rainfall around the Tropics?" *2021 AMS Annual Meeting*, January 14, 2021.

- **Scott, E.**, and L. Shi, 2021: Colocation-Based Calibration of High-Resolution Infrared Radiation Sounder (HIRS) Brightness Temperatures. Poster. Virtual. *2021 AMS Annual Meeting*, January 12, 2021.
- **Scott, E.**, **R. D. Leeper**, and M. A. Palecki, 2021: Extreme Precipitation Event Frequency Observed by the U.S. Climate Reference Network (USCRN). Virtual. *2021 AMS Annual Meeting*, January 11, 2021.
- **Stevens, L. E.**, 2020: From Data to Indicator. Virtual. *USGCRP Forest Related Climate Indicators Development Workshop*, July 30, 2020.
- **Stevens, L. E.** and D. S. Arndt, 2020: Advancing Indicator Science Through Agency Engagement. Virtual. *2020 NOAA Environmental Data Management Workshop*, August 20, 2020.
- **Stevens, L. E.**, D. Arndt, J. Blunden, and D. R. Easterling, 2021: Cultivation, Management, and Value of Interagency Indicators. Poster. Virtual. *2021 AMS Annual Meeting*, January 15, 2021.
- **Stevens, L. E.**, **K. Johnson**, **T. Maycock**, **A. McCarrick**, **J. Griffin**, S. Veasey, and **B. C. Stewart**, 2020: Accessibility Considerations in Climate Communication: Efforts and Lessons Learned from the Fourth National Climate Assessment. Poster. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 11, 2020.
- **Stevens, S. E.**, 2021: The Crosswind Doth Blow. Virtual. *2021 AMS Annual Meeting*, January 15, 2021.
- **Stevens, S. E.**, and **R. D. Leeper**, 2020: Advances in NCEI's U.S. Hourly Precipitation Dataset for Assessing Extremes in Urban Areas. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 14, 2020.
- **Stevens, S. E**., **K. E. Kunkel**, and **L. E. Stevens**, 2020: More Weather or More Water? What is Driving Increases in Extreme Precipitation. Virtual. *2020 American Geophysical Union (AGU) Fall Meeting,* December 8, 2020.
- **Sun, L.**, 2021: Why Climate Change Matters for Seasonal Forecasting? Virtual. *23th Semi-Arid Northeast Brazil Climate Outlook Forum*, January 18, 2021.
- **Sun, L.**, **K. E. Kunkel**, D. R. Easterling, et al, 2021: Dynamical Downscaling Projections of Landfalling Tropical Cyclone Activity over the United States: CMIP5/RCP4.5 Scenarios. Virtual. *2021 AMS Annual Meeting*, January 15, 2021.
- **Sun, L.**, and T. K. Lim, 2020: Seasonal to Decadal Forecasts and Long-Term Trends of Winds over Inner Mongolia: Wind Farm Planning. Virtual. *National Environmental Agency*, December 11, 2020
- **Sun, L.**, 2020: Future Changes of Tropical and Extratropical Cyclones. Virtual. Regional Climate and Climate Impacts class, *Columbia University*, September 22, 2020.
- Wei, Y., Ramapriyan, H., R. Downs, D. Moroni, **G. Peng**, G. Newman, and A. Bower, 2020: Citizen Science Data and Information Quality. Virtual. *2020 ESIP Summer Meeting*, July 22, 2020.
- Wright, W., C. Lief, **G. Peng**, O. Baddour, P. Siegmund, D. Berod, R. Dunn, A. Cazenave, and M. Brunet, 2020: High-Quality Global Data Management Framework for Climate: A Collaboration Framework for Assessing, Validating and Sharing Datasets for Climate Monitoring. Virtual. *EGU General Assembly 2020*, May 5, 2020. https://doi.org/10.5194/egusphere-egu2020-22552

Outreach and Engagement Presentations

- **Brooks, B.**, 2020: Weekly Intern Meeting: career experiences. Virtual. Intern meeting. *NASA DEVELOP* program, July, 7 2020.
- **Brooks, B.**, 2020: Mentoring research project on hemlock decline and landscape change in Cherokee County, NC. Virtual. Intern meetings. *NASA DEVELOP* program, multiple dates, 2020.
- **Brooks, B.**, 2020: Identity and my career in science. Virtual. Skype a Scientist. Middle School class. *Binford Middle School*, Richmond, VA, December 4, 2020.

- **Brooks, B.**, 2021: Identity and my career in science. Virtual. Skype a Scientist. Middle School class. *Binford Middle School*, Richmond, VA, January, 5, 2021.
- **Kunkel, K.**, 2021: Sea Level Rise and Our Coasts. Virtual. Asheville Rotary Club, March 10, 2021.
- **Matthews, J. L.**, 2020: Career and Pathways. Panelist. Virtual. 2020 STRIVE for MORE (Success Through Rewarding and Inclusive Virtual Experience Mathematics – Opportunities in Research and Education Conference. *Virginia Tech* and *Clemson University*, September 26, 2020.
- **Rao, Y.**, 2020: Climate Change. Virtual. High school science class. *TC Roberson High School*, Asheville, NC, October 20, 2020.
- **Rao, Y.**, 2020: Climate Change. Virtual. Meeting. *French Broad River Garden Club*, June 12, 2020.
- **Rao, Y.**, 2021: Birds & Gardens: Observing the changing climate in our neighborhood. Virtual. *Town and Country Garden Club of Asheville,* February 18, 2021.
- **Rao, Y.**, 2021: Region 8 Western Regional Science & Engineering Fair judge. Virtual. *Western Carolina University,* February 18, 2021.
- **Rao, Y.**, 2021: Weather and Climate. Virtual. *Apex Elementary School.* Apex, NC. March 2, 2021.
- **Rennie, J. J.**, 2020: Meteorology, Weather, and Climate. Virtual. Skype a Scientist. 5th Grade class, *Codington Elementary School*, Wilmington, NC, September 17, 2020.
- **Rennie, J. J.**, 2020: Weather and Climate in the U.S. and Canada. Virtual. Skype a Scientist. 4th Grade class, *Chiganois Elementary School*. Debert, Nova Scotia, Canada, October 6, 2020.
- **Rennie, J. J.**, 2020: Working at NCICS. Virtual. Intern meeting. *NASA DEVELOP program*, November 5, 2020.
- **Schreck, C. J.**, 2020: Subseasonal Forecast Contest Discussion. Virtual. *Rutgers University*, September 22, 2020.
- **Schreck, C. J.**, 2021: Cloud types and Solar Energy. Virtual. Skype a Scientist. 4th Grade class, *Riddle Brook School,* Bedford, NH, February 12, 2021.
- **Schreck, C. J.**, 2021: How to become a Meteorologist. Virtual. Skype a Scientist. Kindergarten class, *Graham Elementary and Middle School,* Columbus, OH, February 11, 2021.
- **Schreck, C. J.**, 2021: Hurricanes and Natural Disasters. Virtual. Skype a Scientist. 2nd Grade class, *Dwight School,* New York, NY, March 2, 2021.
- **Stevens, L. E.**, 2020: Careers and working at NCICS. Virtual. Intern meeting. *NASA DEVELOP program*, August 4, 2020.

Appendix 4: Products 2020-2021

CISESS Products

New and/or enhanced datasets now available through NOAA Big Data Program (BDP) cloud service provider partners

- S111
- World Ocean database
- Global Forecast System (GFS)
- GFS Warm Restart Data
- Global Ensemble Forecast System (GEFS)
- GEFSv12 reanalysis and retrospective data
- Severe Weather Data Index (SWDI)
- UFS Prototype 5
- Water Column Sonar Data
- Additional GOES-R data products
    - EXIS Instrument
    - MAG Instrument
    - SEIS Instrument
    - New ABI Level 2 ice products
    - ABI Level 2 Downward Motion Winds Vapor component (DMWV)
- Coastal Lidar data
- CORS
- G-ESTOFS
- National Bathymetric source data
- HRRR (full period of record)
- National Water Model (NWM: GRIB2; ZARR format)
- National Blend of Models (NBM)
- National Digital Forecast Database (NDFD)
- Rapid Refresh (RAP)

GOES-R supported BDP Dashboard

U.S. Climate Resilience Toolkit (https://toolkit.climate.gov) enhancements

- 3 new regional sections
- 4 new case studies
- 36 new tools

U.S. Drought Portal (https://drought.gov) updated website design

Assessment Collaboration Environment (ACE) v1.0 and v1.1

ACE website
https://ace.ncics.org

North Carolina Climate Science Report (NCCSR) accessibility updates

U.S. Global Change Research Program (USGCRP) Indicator Platform

- Annual Greenhouse Gas Index (update) (**link**)
- Arctic Sea Ice Extent (update) (**link**)
- Atmospheric Carbon Dioxide (update) (**link**)
- Billion Dollar Disasters (update) (**link**)
- Frost-Free Season (update) (**link**)
- Global Surface Temperatures (update) (**link**)
- Heating and Cooling Degree Days (update) (**link**)
- Marine Species Distribution (new) (**link**)
- Ocean Chlorophyll Concentrations (update) (**link**)
- Sea Surface Temperatures (update) (**link**)
- Start of Spring (update) (**link**)
- Terrestrial Carbon Storage (update) (**link**)
- U.S. Surface Temperatures (update) (**link**)

Global Historical Climate Network daily (GHCNd) graph database design

NCEI Inventory, Catalog, and Archive Administration User Stories and Requirements

NiFi Unrestricted Mesoscale Analysis (URMA) retrieval stream monitoring improvements

NIFi Pre-ingest system implementation

Integrated System Granule Identification concept

Optimum Interpolation Sea Surface Temperature (OISST) v2.1

GHCNm version 4.0.1 (public, operational version)

CMORPH SPI (operational, near-real-time)
via Interactive Global Drought Information Dashboard https://gdis-noaa.hub.arcgis.com/

Drought index (based on daily soil moisture)

Gridded temperature and precipitation normals (1990-2019)

Sub-monthly U.S. temperature monitoring tool (Python v3 code update)

Hourly and sub-hourly heat exposure indices (HI, AT, and WBGT)
(USCRN derived product)

U.S. Northeast and Mid-Atlantic Coastal Normals (1991–2020)
https://coastal-normals-ncsu.hub.arcgis.com

GOES-R Land Surface Temperature (algorithm to improve product all-weather information)

Global Tropical Cyclones Monthly and Annual State of the Climate Reports
https://www.ncdc.noaa.gov/sotc/tropical-cyclones/

Annual State of the Climate Synoptic Discussion
https://www.ncdc.noaa.gov/sotc/synoptic/202013

Carolinas Drought and Health Virtual Workshop

NCICS/CISESS NC AI training series (14 sessions)

CISESS Science Seminar Series

***Trends* newsletter** (current issue)

Other Products

CPC MJO tool
https://ftp.cpc.ncep.noaa.gov/fews/novella/mjo/ (password protected due to ECMWF data)

SERDP project website

Buncombe County Health and Human Services COVID-19 Self-Checker