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CICS-NC Overview

The operation of the Cooperative Institute for Climate and Satellites-North Carolina (CICS-NC) is the primary activity of the North Carolina Institute for Climate Studies (NCICS), an Inter-Institutional Research Center (IRC) of the University of North Carolina (UNC) System. CICS-NC/NCICS is hosted by North Carolina State University (NCSU) and affiliated with the UNC academic institutions as well as a number of other academic and community partners. CICS-NC is collocated with the NOAA/NESDIS National Centers for Environmental Information (NCEI, formerly known as the National Climatic Data Center) in Asheville, NC, and focuses primarily on collaborative research into the use of satellite and surface observations in climate research and applications that is closely coordinated with NCEI. CICS-NC also engages in collaborative research and other climate activities with other NOAA line offices and units, including the National Weather Service (NWS), Oceanic and Atmospheric Research's (OAR's) Climate Program Office (CPO), and Air Resources Laboratory's (ARL's) Atmospheric Turbulence and Diffusion Division (ATDD) as well as other federal agency collaborators with NOAA/NCEI, including the Federal Emergency Management Agency (FEMA) and the United States Global Climate Research Program (USGCRP).

CICS-NC is led by the Director of the IRC and includes numerous partners from academic institutions with specific expertise in the challenges of utilizing remotely sensed and in situ observations in climate research and applications and other climate science expertise. NCSU provides CICS-NC with access to a strong graduate program in Earth, engineering, and life sciences, and many of the CICS partners offer complementary programs. Other CICS research partners with exceptional strength in scientific computing include the Renaissance Computing Initiative (RENCI) of the UNC System and the Oak Ridge National Laboratory (ORNL). A variety of needed skills and/or information sets have been requested by NOAA that were not originally envisaged in the original CI proposal and additional partners have been added to the CICS Consortium. Additions include: Oak Ridge Associated Universities (ORAU), the Institute for Global Environmental Strategies (IGES), the University of South Carolina, the University of Michigan, the Center for Climate and Energy Solutions (C2ES), the University of Illinois Urbana-Champaign, and the University of Alabama Huntsville. Additional collaboration and support for community engagement and outreach is provided by the North Carolina Arboretum, an affiliate member of the UNC System, the Economic Development Coalition for Asheville-Buncombe County Coalition (Asheville EDC), and Asheville Buncombe Sustainable Community Initiatives (ABSCI), a local non-profit organization with a mission to support and catalyze climate services activities and a shared interest in advancing the capabilities represented by CICS-NC.

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

CICS-NC's mission focuses on collaborative research into the use of in situ and remotely sensed observations in climate research and applications that is led by NCEI; 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 climate science and its applications; engagement with corporate leaders to develop climate-literate citizens and a climate-adaptive society; and the facilitation of regional economic development through its Engagement activities.

CICS-NC activities primarily support NCEI activities and enterprise climate services. Main collaborative activities are currently organized and CICS is structured thematically by the following 8 task streams:

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

These streams are currently supported by the different divisions in NCEI; NOAA Line Offices including the National Environmental Satellite, Data and Information Service (NESDIS), Oceanic and Atmospheric Research (OAR), and the National Weather Service (NWS); and North Carolina State University.

Highlights

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

Administration [NCEI/NCSU]
Information Technology Systems Improvement, Management, and Maintenance: CICS staff require technological infrastructure and resources at a variety of levels and capabilities. This task supports these needs by providing modern approaches to keep CICS-NC at the competitive edge of technology, as well as maintaining core technologies as a stable base for CICS-NC staff operations. Systems range from scientific computing to medium-scale office-oriented services. Significant improvements have been made in CICS-NC's IT infrastructure with the objective of improving system reliability, flexibility and scalability, while supporting cutting-edge technologies that support the communication and computational needs of the administrative and research staff at CICS-NC.

Access and Services Development [CPO/NCEI]
Programming and Applications Development for Climate Portal: UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC)staff assisted with continued development and redesign of the *U.S Climate Resilience Toolkit* (www.toolkit.climate.gov), new Climate Widget design, and the redesign of the *Climate Explorer* application (http://toolkit.climate.gov/climate-explorer). In addition, NEMAC led the implementation of the *Steps to Resilience* in the *Toolkit* redesign and led several workshops in this effort. These products and services support the overall advancement and progression of the NOAA's Climate Services Portal (NCSP) program.

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

Assessment Activities [NCEI/CPO]
Building on the support provided for the Third U.S. National Climate Assessment (NCA3) released in May 2014, the NOAA Assessment Technical Support Unit (TSU), staffed largely by CICS-NC personnel, is providing the same level of scientific, editorial, graphic design, metadata, project management, programming, and web design support for a set of 50 State Summary reports (a NOAA contribution to the National Climate Assessment); the U.S. Global Change Research Program's (USGCRP) Climate Science Special Report (CSSR), scheduled for release in late 2017; and the Fourth National Climate Assessment (NCA4), scheduled for release in late 2018.

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

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

TSU Graphics Support: CICS-NC staff provided editorial, graphics, and production support for the Climate and Health Assessment (released in April 2016), the State Climate Summaries, the Climate Science Special Report (CSSR), and NCA4. Given the intended audience, it is essential that figures and other graphical representations in these reports are designed to be easily understood by a broad audience while maintaining the highest possible standards of accuracy and transparency.

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

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

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

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

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

Climate Data Records and Scientific Data Stewardship [NCEI]

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

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

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

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

NOAA PERSIANN-CDR Support for Hydrologic and Water Resource Planning and Management: The PERSIANN Precipitation Climate Data Record (PERSIANN-CDR) processed precipitation dataset at daily 0.250 lat-long scale covering from 60°S to 60°N and 0° to 360° longitude from 1983 to June 2015. Application of PERSIANN-CDR to hydro-climatological studies was demonstrated.

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

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

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

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

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

Scientific data stewardship for digital environmental data products: This effort focuses on cutting-edge research in and application of scientific stewardship of individual digital environmental data products and promoting scientific data stewardship. The data stewardship maturity matrix (DSMM) has been applied to more than 700 individual NCEI datasets, and 668 of those DSMM assessment ratings are to be integrated into the new NOAA OneStop Search and Discovery portal.

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

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

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

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

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

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

CICS-NC staff participated in K–12 educational outreach events in conjunction with the celebration of the state-wide 2016 and 2017 North Carolina Science Festival at the *Mountain Science Expo* at the North Carolina Arboretum and at Isothermal Community College's *Science and Technology Expo.* CICS-NC also coordinated numerous outreach events in Fall 2016 and Winter 2017. Engagement with higher education institutions is also a CICS-NC focus area being served through mentorship of undergraduate and graduate students, invited speaking engagements with university student and faculty audiences, and through development of a distance education course.

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

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

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

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

Extension of the Great Smoky Mountain Rain Gauge Mesonet and Exploration of the Origins of Extreme Precipitation Events in the Southern Appalachian Mountains and their Signatures as Observed by GOES-R: Completed Fall 2016 maintenance and data collection gauge visits as part of this collaborative research effort to extend the period of observations of the Duke University Great Smoky Mountains National Park Rain Gauge Network (Duke GSMRGN).

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

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

Analysis of hydrological extremes from the U.S. Climate Reference Network (USCRN): Completed a comparison between USCRN and the North American Regional Reanalysis (NARR) soil moisture datasets, which revealed modeled data had similar temporal trends to observed data despite offsets in precipitation and soil moisture conditions. A preliminary analysis evaluating USCRN precipitation extremes for various temporal durations was completed along with the development of an approach to standardized USCRN soil moisture observations.

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

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

Building a Climatology of Extreme Snowfall Events in the United States: A project was completed with both NOAA and FEMA to validate snowfall extremes for every county in the United States. This will help mitigate future snowfall events, and also build better spatial quality algorithms in NCEI weather station data products.

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

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

Workforce Development [NCEI]
CICS-NC actively works to identify and train the next generation of scientifically and technically skilled climate scientists. Junior and/or aspiring scientists, including students and post-doctoral researchers, play an important role in the conduct of research at CICS-NC. High School, Undergraduate, and Graduate level students and recent post-docs support projects across the CICS-NC task streams.

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

Other CICS PI Projects

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

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

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

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

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

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

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

Multiscale Convection and the Maritime Continent: Interactions between the Madden-Julian Oscillation, equatorial waves, and the diurnal cycles of islands in the Maritime Continent can be critical for sub-seasonal-to-seasonal forecasts. **[NASA]**

Relationship between occurrence of precipitation and incidence of traffic fatalities using high-resolution NEXRAD reanalysis: This project used six years of the NEXRAD reanalysis, along with coincident traffic fatality information, to form a quantifiable link between precipitation and an increased risk of traffic fatalities. **[NCEI/CDC]**

Administration

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

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

The CICS-NC Director, in coordination with the Business Manager and University Program Specialist, is responsible for the operations of CICS-NC. Administrative operations are primarily supported by NCSU, with additional support from NOAA via the Task I cooperative agreement. The NOAA Task I allocation provides partial support for the director (2 summer months), a business manager (50%), a university program specialist (10%), IT operations and systems support (20%), and travel funds, primarily for the Director, for administration and research facilitation purposes with the diverse climate science and applications community. NCSU provides support for the 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 telepresence) tools for the Asheville-based staff.

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

Janice Mills, Business Manager
Theresa Stone, Program Specialist
Jonathan Brannock, Network/Systems Analyst
Scott Wilkins, Operations/Systems Specialist

Information Technology Systems Improvement, Management, and Maintenance	
Task Leader	Jonathan Brannock, Scott Wilkins
Task Code	NC-ADM-01-NCICS-JB/SW
NOAA Sponsor	
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 33%; Theme 2: 33%; Theme 3: 33**%**
Contribution to NOAA goals (%)	Goal 1: 33%; Goal 2: 33%; Goal 3: 33%; Goal 4: 0%

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

Background

CICS-NC IT staff support a well-rounded set of IT resources and services as well as maintain the necessary infrastructure required to do so. CICS-NC services can be organized into three areas. A user network, cluster and computing resources, and Network and SAN infrastructure, see *Figure 1*. The user network is made up of wireless network services, Vidyo telecommunications services, and end user software on Apple desktops and laptops. The cluster and computing resources are centered on a high-performance computing cluster and a head node. The head node is a powerful server where users can prototype ideas and perform light work tasks including coding and testing. The head node can queue heavy workloads onto the cluster, where a number of different queues are available to address specific computing requirements. Last, there is the network and storage network (SAN) which supports the former with high-speed access to network resources, high-speed storage, and tape resources.

CICS-NC provides a distributed file system for concurrent system-wide access to high-speed storage. The Quantum Stornext file system is attached to eight Promise SANs providing 1,250 Terabytes of online disk storage. This offers our users high-speed redundant storage for large projects and data sets. 1,210 Terabytes of the total disk storage is managed using Quantum's Storage Manager which makes up to two copies of the data to separate tapes, providing recovery capability for project data.

The high-performance computing cluster supports research tasks for both CICS-NC and NCEI. CICS-NC currently has 3 blade centers with 528 processing cores and 3 terabytes of memory. Each of the processors has access to all of the distributed storage space. The head node provides access to a large variety of software as well as command and control tools to push tasks into the cluster. Users may execute tasks using multiple approaches, including, but not limited to, batch mode processing and OpenMPI.

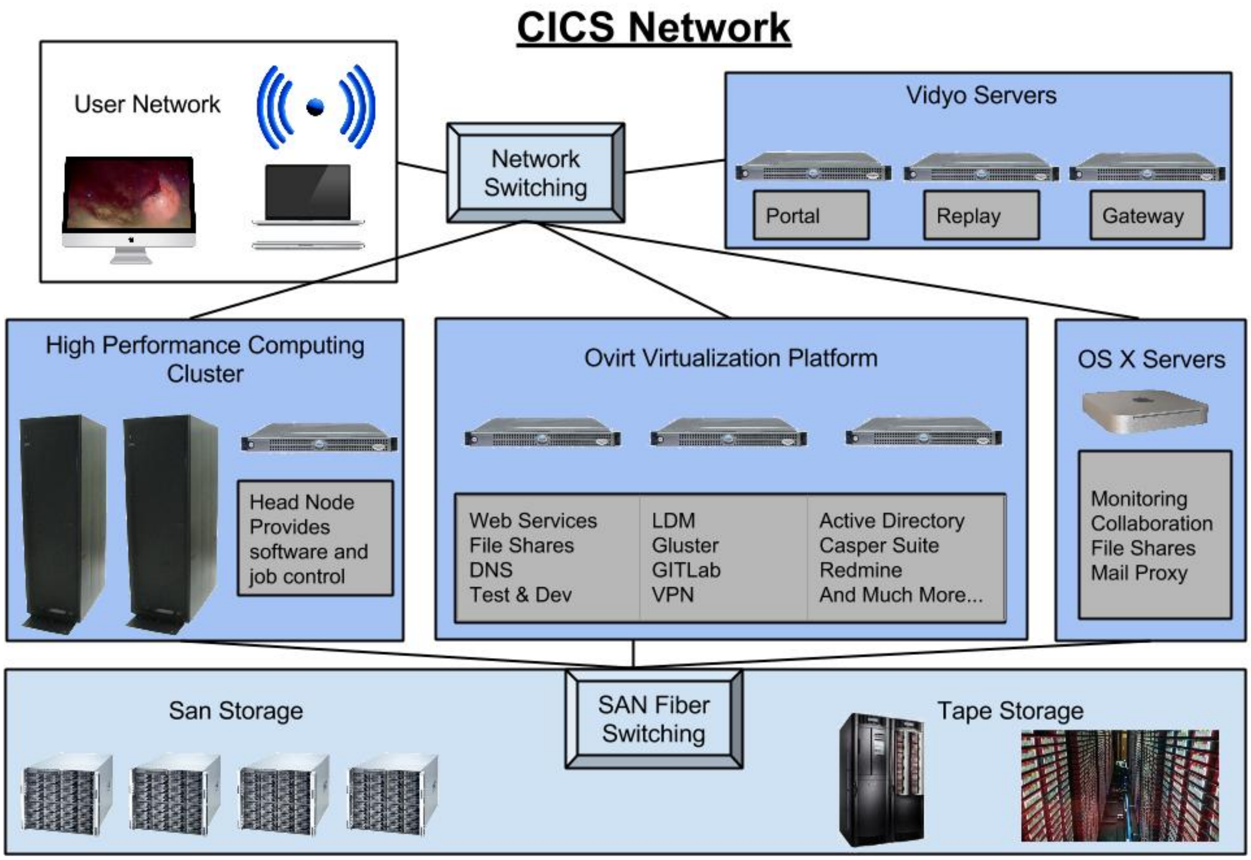


Figure 1. Network, and system diagram.

A building-wide wireless network was created to provide both CICS-NC and its building partners with strong-signal, fast wireless coverage. This allows CICS-NC staff to quickly integrate and work side-by-side with our NCEI partners. There are 32 access points covering areas on the 1st floor through 3rd floors, fitness center, and NCEI archive and full coverage on the 4th and 5th floors. The most populous areas utilize 802.11AC or gigabit WIFI. Heat maps and simulations were used to optimize location of the access points.

The CICS-NC network is simple and fast, providing 10 Gigabit per second connectivity though the core of the network and to our Internet service provider. This allows users to fully take advantage of the high-performance computing cluster as well as the building wireless network. This also gives CICS-NC and our partners an environment where they can quickly perform research tasks as well as testing and development.

A video conferencing solution by Vidyo is available. This provides users with the ability to quickly and easily set up virtual meetings where they can share video, audio, and desktop content. It provides a method to effectively work with offsite employees, teleworkers, and people on travel. It also provides a means to collaborate and attend meetings hosted by other organizations including NCSU and NOAA. The

Vidyo system also provides recording and webcasting services. VidyoVoice allows for integration with existing telephone systems.

CICS-NC IT utilizes oVirt virtualization to enhance security, OS Support, and efficient use of resources. Currently CICS-NC has six host servers that can support more than 120 virtual systems with a variety of operating systems, security, and performance requirements ranging from critical network infrastructure to testing and development systems. This environment supports load balancing, live migration, and service redundancy by placing the virtual systems storage on dual shared LVM SANs. This architecture allows good scalability, resilience, and reduced maintenance overhead to provide systems with better uptime and service reliability.

CICS-NC IT supports a variety of system services required for data, computing, user, and administrative needs. These include: Local Data Manager (LDM) a field standard service for real-time transfer of weather data, Web service for external visibility, and collaborator interfacing, FTP for external data sources, and collaboration tools for administrative and internal office-oriented interaction.

CICS-NC IT staff utilizes a suite of monitoring tools including Casper Suite, Puppet OSE, Nagios, Cacti, Splunk, Ganglia, and Monitis. These and other open source and proprietary tools allow IT staff to quickly address issues and efficiently monitor and maintain systems.

Microsoft Active Directory provides a stable and sustainable infrastructure for centralized authentication services and provides group and role-based access controls to CICS-NC resources. We provide accounts and support to NCEI, NOAA, and all of our partners and associates as needed.

Accomplishments

We conceptualized, designed, engineered, and deployed a software pilot to move data from NOAA to the NOAA Big Data Partnership's CRADA collaborators including Amazon, Microsoft, IBM, Google, and the Open Commons Consortium. The goals of this project are to be portable, platform agnostic, scalable, low latency, preserve data integrity, use a resilient architecture, include monitoring, and to support both traditional POSIX filesystem as well as object file stores. This was accomplished using standard tools as much as possible. The code was written in Python and is executed in Docker containers. The workflow and pipeline is managed by RabbitMQ. Gluster (POSIX), and Ceph (Object) storage systems have been tested. Monitoring and performance analytics are provided by Nagios and the ELK stack, specifically Elasticsearch and Kibana. This architecture as already demonstrated all of the design goals having moved hundreds of thousands of GOES 13, GOES 15, GOES 16, and NEXRAD Level 2 data granules.

The retired metadata controllers/servers were used to replace and retire two servers from the virtualization cluster. This provided a substantial processing power increase and more memory to the cluster. These additional resources have also helped support experimental projects such as the Docker and Ceph implementations.

The CICS-NC network infrastructure has been improved in three ways: new Ethernet floor switches, fiber optics interconnections, and wireless access points. The new Ethernet floor switches provided improved Power Over Ethernet (POE) to support more powerful wireless access points and also allowed our existing Aerohive AP370 units to double their optimal speed. New fiber optics were installed to the floor switches improving the back haul from one gigabit per second to ten gigabits per second, allowing more users to sustain high data throughputs without saturating the uplink connections. New Aerohive AP250 access points are being rolled out. These access points use more efficient silicone and provide 802.11AC Wave 2 support as well as Bluetooth LE beacons.

We have been evaluating new software and approaches to managing IT resources. Two in particular are Docker and Ceph. Docker provides a low overhead ephemeral instantiation of a service. These can be scaled, deployed, versioned, and audited more easily than other approaches. This also eliminates many the dependencies of the underlying systems, as we no longer have to worry about library conflicts or configuration drifts. OS level upgrades are now per container instead of per system. Ceph provides an object storage system. This is a similar approach to what Amazon S3 or Azure and Google's Blob storage. This allows a user to save and recall any blob of data with a URL instead of referencing a mounted file system. Ceph offers a gateway service that implements the Amazon S3 and Open Stack Swift APIs over the Ceph object store. This allows CICS-NC IT to test new approaches to data management and software defined storage. The combination of these two services allows us to create applications and adapt software to an environment that is cloud compatible. This provides the framework to run any combination of on-site and cloud workloads with minimal effort.

This has been an interesting year for everyone with respect to security. CICS-NC IT has worked hard to keep all of our systems up-to-date with the latest security patches and best practices. We have applied many security updates to all aspects of our infrastructure and implemented a monthly security scan to identify vulnerabilities we may not have seen otherwise. In addition, we have implemented two-factor authentication for any administrator (root) level account, including "sudo" access. CICS-NC IT now requires that all mobile systems be encrypted. We are involved in North Carolina State University's new Security Liaisons team, which was formed to create a security community to help guide, inform, and implement the security policies of the university. CICS-NC IT continues to look for ways to improve our security posture without compromising our ability to succeed.

CICS-NC IT has provided ample support to our partners in the federal government and neighbors: we support many low- and high-level meetings and engagements, and regularly provide WIFI, audio visual, and video conferencing support using university resources. CICS-NC IT helped NCEI hold multi-site all-hands meetings bridging various technologies until they were able to implement their own solution. We frequently provide support in both time and equipment to augment existing resources to provide required functionality to facilitate NCEI meetings and events.

We also provide support to interns: Two programs in particular have been supported by CICS-NC, NASA DEVELOP and NOAA Hollings internship programs. CICS-NC IT typically provides workstations, WIFI, video conferencing, virtualization, and high performance computing resources. Due to the shorter nature of these programs, interns have difficulty accessing IT resources until they are half-way through their program. CICS-NC IT equipment and support allows interns to start work immediately, making these programs possible until the interns are able to transition to federal systems.

CICS-NC has been involved in many smaller projects in the last year. We have been working on a continued cost analysis between our on-site tape archive and Amazon Glacier services. We have been laying the ground work for taking advantage of University and Internet2 contracts to make cloud resources available to CICS-NC and potentially our federal partners. We have also been involved in the General Services Administration (GSA) E-Waste Recycle program and recycled several decommissioned resources. We worked to retrofit our conference room with a computer and hardware that can support a variety of conferencing solutions, including Hangouts, Vidyo, Skype, Skype for Business, WebEx, and

Goto Meeting. Since the hardware is general purpose, we can support any software that is available on a computer and make it work in a conference room environment.

The migration to RHEL 7 was a continuing effort over this reporting period. We did a fresh install of RHEL 7 on the servers instead of an upgrade. A fresh install was the Red Hat recommended upgrade path and resulted in a more stable platform. All hardware platforms and most of the virtual machines have been migrated as of this report. Impacts to users and processes have been kept to a minimum. Several functions required extensive effort to transition smoothly, such as the Message Passing Interface (MPI) parallel processing options used on the compute cluster. The newer versions of the OpenMPI and Python software required changes to how our users processed the Localized Constructed Analogs (LOCA) data.

Many of the scientific data processing tools we use were not fully compatible with RHEL 7. The Ultrascale Visualization Climate Data Analysis Tools (UV-CDAT) software required extensive testing and troubleshooting to resolve issues. Ultimately, we used an Anaconda-based installation. Each project running on the compute cluster required testing and installation of new libraries. CICS-NC IT staff worked closely with the project personnel to ensure their software recompiled and processed correctly on RHEL 7 before deactivating the RHEL 6 servers and nodes.

The Stornext Metadata Controllers (MDC) servers were replaced with new hardware to support increasing processing and memory requirements. The old servers were consistently running at 80% capacity, the new servers currently run at 10% capacity. The Stornext software was also updated. These combined upgrades have resulted in much improved and faster filesystem performance.

Planned Work

- Continuous tasks (monitoring and maintenance)
- Planning for expected end of life equipment and associated replacements.
- Improve security scanning regularity and address issues
- Implement two-factor for Google and University accounts.
- Continue migration of RedHat 6 systems to Redhat 7 or Docker.
- Continue to support our federal partners and internship programs.
- Work with NOAA BDP and support the CICS Data Hub.

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

Access and Services Development

Access and services development activities support improvements to access mechanisms for NOAA's National Centers for Environmental Information (NCEI)'s data and product holdings. NCEI has ongoing requirements to improve conveyance of data products and services to its stakeholders and clients. NCEI services include interaction with data users, providing data products to users, and communicating unmet user needs to the science and stewardship components of NCEI. This requires the input and guidance of scientific data management staff, user-interface development, and integration of user-end needs into data products—the goal is to provide tools and information to facilitate improvement of society resilience to climate change. CICS-NC continues to support the enhancement and expansion of NOAA's Climate Services Portal applications. The Climate Resilience Toolkit website (toolkit.climate.gov) was launched in November 2014 and work continues on enhancement of the site as well as other related tasks and climate interactive tools. Capitalizing on this current tool and application development, work was also expanded to identify synergies and integrate products and tools (data visualization capabilities, on-line mapping applications, etc.) across programs including the Climate Services Portal, the National Climate Indicators, and the National Climate Assessment. The new NCEI website, launched in April 2015 following the merger of NOAA's three data centers, offers the opportunity to update and enhance current services to customers with a more user-friendly design and interface to enable current and future users to more easily identify, locate, and access specific data products and services. To meet this demand, CICS-NC provided highly skilled staff in data architecture, management, web services, and user interface design and development. While consistent support remains a challenge, CICS-NC will nevertheless work to identify prospective future skilled practitioners, broaden its software engineering staff and utilize partner expertise as needed, and continue to nurture community interest in climate applications to provide opportunities for improvement of NCEI's user experience.

Programming and Applications Development for Climate Portal	
Task Leader	Jim Fox
Task Code	NC-ASD-01-UNCA
NOAA Sponsor	David Herring/Dan Barrie
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%

Highlight: In support of the overall advancement of the NOAA's Climate Services Portal (NCSP) program, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) staff assisted with the U.S. Climate Resilience Toolkit continued development and redesign, new Climate Widget design (part of Climate Explorer 2 through Habitat Seven), the Climate Explorer (1) application redesign, and update of multiple Climate.gov applications. Additionally, NEMAC led the implementation of the Steps to Resilience in the Toolkit and led several national workshops in this implementation.
https://toolkit.limate.gov

Background

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

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

Supplemental task areas for coordinated development and integration with current task areas include the following:

- Graphics for Indicators and NCA
- GIS/climate projections for NCA
- Regional, state, local products
- Internal management portals
- Decision support

Accomplishments

Drupal Content Management System for Climate.gov

UNC Asheville's NEMAC provided maintenance and development support for the Climate.gov team including Data Snapshots section support and maintenance, assistance in the launch of several new data sources, and providing feedback for the initial stages of the redesign of climate.gov.

U.S Climate Resilience Toolkit
UNC Asheville's NEMAC significantly contributed to the continued development and editorial and content management of the U.S Climate Resilience Toolkit (CRT), which was originally designed and launched in November 2014. NEMAC worked with NOAA personnel to: a) add new content; b) redesign homepage and navigation; c) integrate Climate Explorer 2; and d) develop new sections.

Working with the larger editorial team, NOAA personnel and other federal and academic partners, NEMAC contributed to the content management for several key CRT sections including: a) *Steps to Resilience* user testing, b) the addition of new *Topics* area content (Marine and Built Environment), c) the addition of 18 new *Case Studies* (total of 117 published case studies as of March 2017), and d) 95 additional *Tools* (total of 347 published tools as of March 2017). NEMAC also managed the inclusion of the CRT's Find Experts map, worked with NOAA personnel on the redesign of this map as a Leaflet feature, and managed and facilitated the review, approval, and ingestion of seven new training courses and 185 reports to the CRT.

NEMAC assisted with the completion and implementation of a site design "refresh" for the CRT. NEMAC designed and iterated several prototype site-wide design changes—characterized as a design "refresh"—to the initial CRT design and navigation structure, including mobile responsive layouts.

NEMAC worked with the NOAA editorial team to facilitate and integrate the Climate Explorer 2 tool into the CRT website and to conceptualize and implement the creation of a new Regions section to the website, including the creation of new content types and incorporation into the CRT's navigational structure. NEMAC staff also worked with NOAA's Dr. Edward Gardiner and other NOAA personnel to begin conceptualization and development of new Learning Progressions for the website.

Global Climate Dashboard
Updated the data feed for the individual metrics**;** redesign or redeployment is under discussion.

Climate Explorer and Online Map Viewers
Last year, a decision was made to create a second iteration of the Climate Explorer—dubbed Climate Explorer 2 (CE2)—to support current functionality as well as new climate projection maps. The work of developing CE2 was awarded to Habitat Seven (H7), and NEMAC has collaborated with H7 on the transition. CE2 was deployed and publicly launched on July 27, 2016.

Based on the decision for NEMAC to continue supporting the Climate Explorer 1 (CE1), NEMAC contracted with JMH Consulting to update data feeds into the graphical/temporal part of the application that allow users to explore historical precipitation and temperature readings. These stations are now being fed by ASOS from Cornell University, compared to the GHCN feeds at NCEI. JMH Consulting also provided a working prototype of the Climate Widget in March 2017. The work by NEMAC and JMH Consulting will be completed in April 2017 for final ingest by H7.

Climate Interactive Tools and Maps and Data Section Leadership
John Frimmel has participated in calls relating to the Climate Widget, and has worked with several NOAA personnel to create Drupal code in support of the project. Additionally, John Frimmel maintained a NEMAC-hosted development site that allows developers to work on a site outside of the NOAA firewall for testing and review purposes.

Graphics for Indicators and NCA
NEMAC supported the US Global Change Research Program (USGCRP) team including design, update, and development of static indicator graphics for the USGCRP website. This work included meetings with the USGCRP team, creating a shared data inventory, and developing new versions of the following graphics: AGGI, Annual Sea Surface Temperature, Atmospheric Carbon Dioxide, Frost Free Season, Global Surface Temperature, Heating and Cooling Degree Days, Sea Ice Extent, Start of Spring, and Terrestrial Carbon Storage.

National Climate Assessment (NCA) Regional and State Map Products
NEMAC continued support of NCA mapping needs through the creation of various CONUS and regional maps displaying different climate models, time periods, and variables. This included update of state-specific maps with new model output. These variables included annual and seasonal precipitation maps (RCP8.5) for 2041–2070 and 2071–2099. For each state, a total of two new annual and eight new seasonal maps were produced which resulted in a total of 500 new state-specific maps.

Appropriate hatching/stippling/white-out overlays were added to the maps to represent statistical significance values in the data.

NEMAC also provided support for the Climate Science Special Report with maps created at the North American scale for variables for seasonal and annual surface moisture, total runoff, precipitation and temperature (both RCP8.4 and 4.5) for 2041–2070 and 2071–2099. Mapping these variables produced 16 new maps. The maps were provided in PNG format for incorporation into various reports by NCEI's Graphics Team.

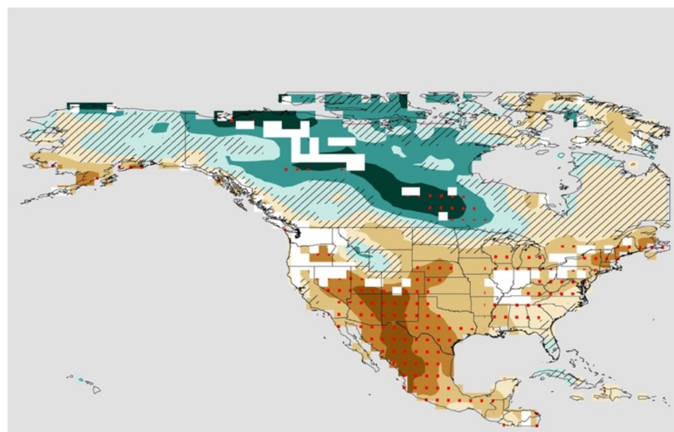


Figure 1. North America: Soil Moisture, RCP8.5, Years 2071 - 2099, Seasonal (DJF)

Internal Management Portals
UNC Asheville's NEMAC supported the CICS-NC TSU and NCEI by creating a new instance of the internal management portal for developing the Extreme Events Report, created containers for all of its chapters, and configured new user accounts.

Decision Support
This work mainly focused on the Steps to Resilience in the CRT and identifying ways of transferring this process to different scales. This included continued work with the Southeast Sustainability Directors Network (SSDN) and working with the cities of Asheville, Huntsville, Charleston, Ft. Lauderdale, Miami, Raleigh, Durham, Cary, and Chapel Hill to update the Steps to Resilience. NEMAC worked with the City of Asheville, NC, on developing a detailed vulnerability analysis and climate resilience plan based on the Steps to Resilience. NEMAC also supported David Herring (CPO) and his team in the creation of multiple presentations for ACCO workshops and other events.

Planned Work

- Work will continue on the Climate Widget, the US Climate Resilience Toolkit, and other interactive tools under Year 4 of the CICS cooperative agreement project.

Publications

- Fox, J., M. Hutchins, N. F. Hall, and K. Rogers. "Resilience Planning in Asheville, North Carolina: A Journey Toward Community Resilience." *Carolina Planning Journal*, in press.
- Lloyd, A., Dougherty, C., Rogers, K., Johnson, I., Fox, J., Janetos, A.C. & Kenney, M.A. Online Resource 3: Recommended National Climate Indicators System Graphic Style Guidance. Electronic Supplementary Material published in: Kenney, M.A., Janetos, A.C. & Lough, G.C. Building an integrated U.S. National Climate Indicators System. Climatic Change (2016)135: 85. doi:10.1007/s10584-016-1609-1

Products

- Data snapshots on Climate.gov (https://www.climate.gov/maps-data/data-snapshots/start)
- US Climate Resilience Toolkit (https://toolkit.climate.gov)
- Climate Explorer 1 (http://climate-explorer.nemac.org)
- Climate Explorer 2 (CE2) (https://toolkit.climate.gov/climate-explorer2/)
- USGCRP Indicator graphics (http://www.globalchange.gov/browse/indicators)
- National Climate Assessment Regional and State Map Products (https://statesummaries.ncics.org/)

Presentations

- Hutchins, M., K. Rogers, and J. Fox. "The Application of the U.S. Climate Resilience Toolkit and its Five Steps to Resilience to Support Municipal Planning." Carolinas Climate Resilience Conference, Charlotte, NC, September 12–14, 2016.
- Dougherty, C., N. F. Hall, J. Frimmel, and J. Fox. "The Emperor's New Clothes: Redressing the U.S. Climate Resilience Toolkit." Carolinas Climate Resilience Conference, Charlotte, NC, September 12–14, 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**7**
# of products or techniques submitted to NOAA for consideration in operations use	**7**
# of peer reviewed papers	**2**
# of NOAA technical reports	**0**
# of presentations	**2**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**3**

Improved and redesigned: the U.S. Climate Resilience Toolkit, the Climate Explorer v2.0 (CE2), and the Climate Widget (3). New products including graphics (static and interactive) for the USGCRP, NCA regional and state products, and internal management portals for the CICS TSU and NCEI (3).

Website Information Architecture Development and User Interface Design for NOAA's National Centers for Environmental Information	
Task Leader	Brian Manning
Task Code	NC-ASD-02-Mediacurrent
NOAA Sponsor	Scott Hausman
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1**:** 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Access and Services Development
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4:0%

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

Background

NOAA's National Centers for Environmental Information (NCEI) is responsible for hosting and providing access to one of the most significant environmental data archives on Earth with comprehensive oceanic, atmospheric and geophysical data. NCEI was established through the 2015 consolidation/merger of NOAA's three former National Data Centers to improve NOAA's ability to meet the demand for its data. While a "merged" NCEI website was launched in Spring 2015 (https://www.ncei.noaa.gov/), all products and datasets remain on the former website of their respective pre-merger data center. The NCEI website thus serves only as an access point to the individual data center sites: https://www.ncdc.noaa.gov, https://www.ngdc.noaa.gov, https://www.nodc.noaa.gov, and https://www.ncddc.noaa.gov.

While this approach minimized the initial level of effort for content migration and the impact to current users and works as a short-term solution, a primary aim is to eliminate the need for maintenance on five separate websites. A team at NCEI initiated an integration plan for merging all content onto the ncei.noaa.gov website and identified three primary needs: to simplify search and discovery of data, enhance usability of the website, and improve the overall user experience.

In 2016, Mediacurrent partnered with CICS-NC to support the NCEI Director's Office and help NCEI achieve their goals for the website. Mediacurrent was tasked with assessing the current website structure and providing the digital strategy and Drupal design expertise necessary to create the foundation for a stream-lined post-merger website integration and an improved user experience on the NCEI website.

Accomplishments

Mediacurrent took a data-driven approach to identifying NCEI's unique advantage and highlighting their opportunity to dramatically improve customer satisfaction and user engagement. The strategic vision put forth in order to unify content from all four data centers into one responsive and powerful site was the result of work completed by Mediacurrent's project team.

After speaking to NCEI about business goals and needs for their website, Mediacurrent defined Key Performance Indicators (KPI's) and the metrics needed to track success of the website. KPI's included increasing the number of primary and secondary conversions, increasing reach and awareness of the website, and increasing user satisfaction and engagement once visitors landed on the site. Current analytics for each individual data center site was documented (where applicable) and will be used as benchmark data for future comparison.

Mediacurrent conducted audience research in order to determine who the current users are, what they like about the site currently, and what frustrates them. Knowing the audience and their desired online experience was the prime driver for all decisions relating to the website. Nine primary user groups were identified in this process, along with three persona lenses which dictated how each user viewed the website. Despite profession and demographics, every user viewed the site through either a novice, expert, or disabled lens.

Following audience research, Mediacurrent conducted a thorough analysis to figure out where NCEI fit in the competitive landscape and to determine their unique advantage. In terms of Search Engine Optimization (SEO), each data center held up against competitors, however NCEI's rank was lacking and an opportunity to target additional user groups in each stage of the sales funnel was documented. In terms of content, we found that NCEI had a lot to learn from competitors, most notably creating an intuitive navigation through the use of a mega menu, creating rich content such as user profiles, using visual patterns and cues that the user can recognize, and creating a more personalized experience for each user. While each pre-merger site is currently mobile friendly, the experience on mobile and tablet devices can be further optimized with an updated design. NCEI offers the most extensive database of environmental information, but it is only useful if users have a good experience on the site and can easily find and interpret the data.

Mediacurrent conducted an audit of 120 pages across all current data center websites with the results contributing to an enhanced user interface design to improve the NCEI site and eliminate frustration around navigation, content, and layout. Components were demonstrated through the creation of style tiles, brand guidelines, hi-res wireframes for primary pages, and a fully designed prototype (delivered with CMS template files). User testing and web accessibility reviews were conducted throughout the design process to ensure an improvement of the user experience.

A Drupal Functional Specification was created to provide the technical requirements for building the proposed Drupal 8 website. This document outlines site requirements, key success factors, and project dependencies. Browser and device compatibility needs, information architecture diagrams, recommended modules, content types, taxonomy, technical sitemap, user roles and permissions, and test plans for QA are all documented along with best practices and recommendations around DevOps, Security and Development Workflows. The Drupal Functional Specification creates a roadmap for the technical implementations to assist NCEI in achieving their website goals.

While this project specifically supported the research and design phases for an enhanced consolidated NCEI website, Mediacurrent and CICS-NC continue to work with the NCEI web team and NCEI to identify implementation stage options based on requirements outlined in the Drupal Functional Specification.

Planned Work

- Provide and update execution options for implementation plan
- Provide Drupal support and/or training as needed
- Meet with related NOAA departments (external to key stakeholders) for input and knowledge sharing

Products

- Strategic Approach for Website
  - -Key Performance Indicators (KPIs)
  - -Assessment of Current Website Analytics
  - -Target Audience Research
  - -Competitive Analysis
  - -Content Audit & Gap Analysis on Top Pages
  - -Search Engine Optimization (SEO) Audit
  - -Recommended Sitemap and Information Architecture
- Enhanced User Interface Design
  - -Style Tiles
  - -KSS Style Guide
  - -High-Fidelity Wireframes for Primary Pages
  - -Fully Designed Prototype
- Functional Specification for a Drupal 8 Build

Presentations

- 8/10/2016 - Mediacurrent Demo 1: Key Performance Indicators and Persona Research
- 9/12/2016 - Mediacurrent Demo 2: Competitive Analysis, Content Audit, SEO Audit
- 10/5/2016 - Mediacurrent Demo 3: Wireframes, Functional Spec Overview
- 11/6/2016 - Mediacurrent Demo 4: Style Guide, Sitemap Update, Wireframes Update
- 11/30/2016 - Phase I Project Summary - NCEI Web Team / IT Managers Presentation
- 12/1/2016 - Phase I Project Summary - NOAA Leadership Presentation

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

Assessment Activities

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

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

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

National Climate Assessment Scientific Support Activities	
Task Leader	Kenneth Kunkel (leader), James Biard, Andrew Buddenberg, Sarah Champion, Laura Stevens, Liqiang Sun
Task Code	NC-CAA-01-NCICS-KK/etal
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%

Highlight: A set of 50 state climate summaries were completed. This is a NOAA contribution to the National Climate Assessment. *http://stateclimatesummaries.globalchange.gov*

Background

NOAA is participating in the high-level, visible, and legally mandated National Climate Assessment (NCA) process, which will be responsive to greater emphasis on user-driven science needs under the auspices of the US 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. NOAA's National Centers for Environmental Information (NCEI) and many other parts of NOAA have provided leadership on climate assessment activities for over a decade. A renewed focus on national and regional climate assessments to support improved decision-making across the country continues to emerge. Decisions related to adaptation at all scales as well as mitigation and other climate-sensitive decisions will be supported through an assessment design that is collaborative, authoritative, responsive, and transparent. NOAA is working through an interagency process and investing in partnerships across many scales to support this comprehensive assessment activity.

To support these activities, CICS-NC has formed a technical support unit (TSU). Within the TSU, a group focused on scientific support has been assembled, consisting of a lead senior scientist (Kenneth Kunkel), a deputy scientist (Liqiang Sun), support scientist (Laura Stevens), data lead (Sarah Champion), and two software engineers (Andrew Buddenberg and James Biard). The Lead Senior Scientist provides scientific oversight for the development of NOAA's assessment services, focusing on a contribution to the National Climate Assessment and, in support of the National Climate Assessment and in conjunction with NOAA and other agency expertise, providing scientific oversight and guidance to coordinate and implement distributed and centralized high-resolution modeling capabilities. As part of an ongoing effort to satisfy Information Quality Act (IQA) compliance, and as part of the Sustained Assessment process, the design and capabilities of a metadata documentation, archive, and delivery end-to-end process are being improved.

Accomplishments

The development of "NOAA's State Climate Summaries for the United States" was completed and released on January 6, 2017. This project was led by Kunkel and coordinated by Champion. Each state summary is four pages in length and summarizes historical climate trends as well as Coupled Model Inter-comparison Project, Phase 5 (CMIP5) projections of temperature and precipitation for each state.

The project included extensive development, editing, and informal/formal review of climate text, graphics, metadata, and web development for all 50 U.S. states. TSU staff also coordinated with state climatologists and climate experts at regional climate centers in all states. Express interest in these summaries already exists for future updated versions and dissemination at climate-related conferences.

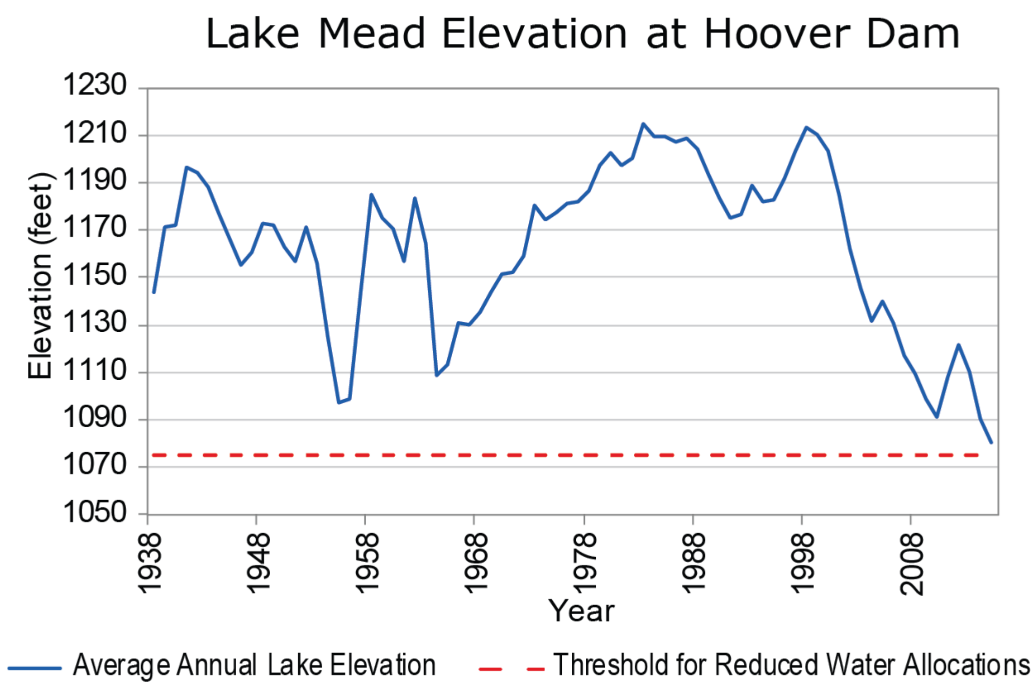


Figure 1. Time series (1938–September 2016) of the annual average water level of Lake Mead at Hoover Dam. Water levels in Lake Mead have varied widely over the years. Low levels in the 1950s and 1960s were due to drought and the filling of Lake Powell, respectively. Recent years have seen the lowest recorded levels since the original filling of Lake Mead. The red-dashed line indicates the threshold (1075 feet) below which a federal shortage will be declared, resulting in reduced water allocations for Nevada and Arizona. Source: USBR.

In support of the upcoming Climate Science Special Report and the Fourth National Climate Assessment, processing of the Localized Constructed Analogs (LOCA) data set has continued in order to produce new climate scenarios as the basis of physical climate and impacts analyses. This is a new statistically downscaled daily data set based on CMIP5 simulations at 1/16-degree spatial resolution for the conterminous United States Computer programs to process these data were developed and in addition to the initial set of 23 derived climate variables, another 10 extremes metrics have been calculated. A comprehensive set of graphics have also been produced depicting both historical and future climate simulations for all 33 variables under both higher and lower emissions.

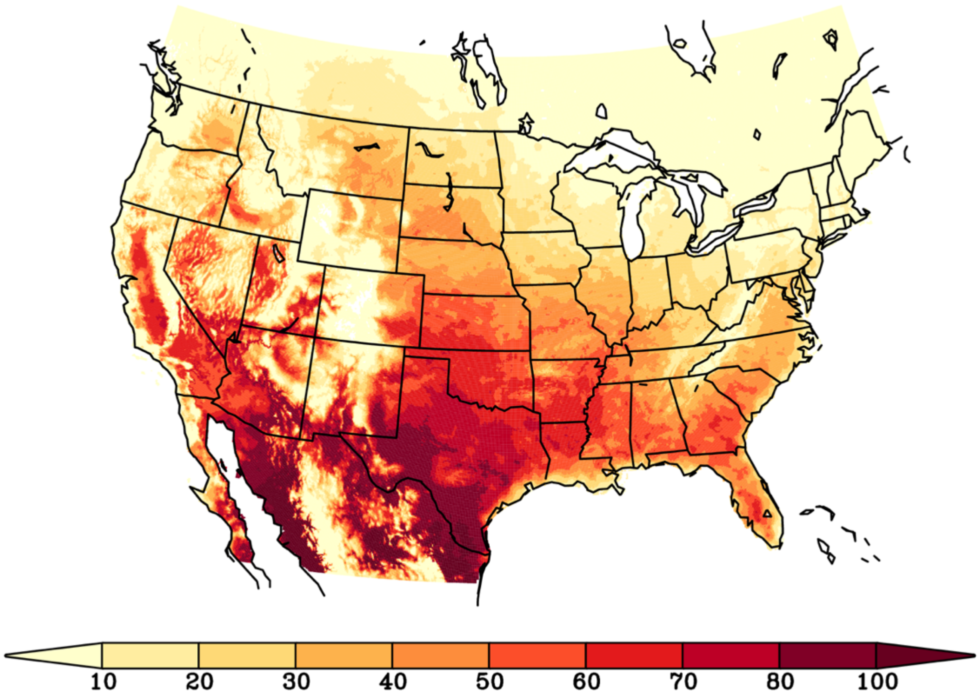


Figure 2. Change in the number of days with the maximum temperature exceeding 100°F for 2070–2099 relative to 1976-2005 under a high emissions scenario. This is derived from the Localized Constructed Analogs (LOCA) dataset and is an example of a product being made available to the authors of the Fourth National Climate Assessment.

Adhering to the federal agency documentation standard of ISO-19115, team staff contributed to the improved functionality of a web-based metadata survey in support of the Climate Science Special Report and forthcoming Fourth National Climate Assessment. A streamlined, advanced technological solution to collect metadata for all Assessment product figures, their associated datasets, analysis methods, and tools was completed.

All project deliverables (documentation and software) and milestones have been accomplished as planned.

Planned Work

- Complete scientific and metadata support toward the completion and rollout of the Climate Science Special Report.
- Complete scientific and metadata support for the public review draft of the Fourth National Climate Assessment.
- Continue to enhance of features and capabilities of the metadata survey system, based on feedback from various Assessment product contributors.
- Complete papers on the effect of the changeover to MMTS on extreme temperature trends, use of CoCoRaHS data, and descriptions the state summaries.

Publications

- Crimmins, A., J. Balbus, J.L. Gamble, D.R. Easterling, K.L. Ebi, J. Hess, K.E. Kunkel, D.M. Mills, and M.C. Sarofim, 2016: Appendix 1: Technical Support Document: Modeling Future Climate Impacts on Human Health. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.* U.S. Global Change Research Program, Washington, DC, 287–300. http://dx.doi.org/10.7930/J0KH0K83.
- Balbus, J., A. Crimmins, J.L. Gamble, D.R. Easterling, K.E. Kunkel, S. Saha, and M.C. Sarofim, 2016: Ch. 1: Introduction: Climate Change and Human Health. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment.* U.S. Global Change Research Program, Washington, DC, 25–42. http://dx.doi.org/10.7930/J0VX0DFW.
- Hallar, A.G., N. Molotch, J. Hand, B. Livneh, I. McCubbin, R. Petersen, J. Michalsky, D. Lowenthal, and K. Kunkel, 2016: Impacts of increasing aridity and wildfires on aerosol loading in the intermountain Western U.S. *Environmental Research Letters*, in press.
- Janssen, E., R.L. Shriver, D.J. Wuebbles, and K.E. Kunkel, 2016: Seasonal and regional variations in extreme precipitation event frequency using CMIP5. *Geophys. Res. Lett*., 43, 5385-5393, doi: 10.1002/2016GL069151
- Kunkel, K.E., D.A. Robinson, S. Champion, X. Yin, T. Estilow, and R.M. Frankson, 2016: Trends and extremes in Northern Hemisphere snow characteristics. *Current Climate Change Reports*, **2**, 65–73, doi:10.1007/s40641-016-0036-8.
- Kunkel, K., R. Frankson, J. Runkle, S. Champion, L. Stevens, D. Easterling, and B. Stewart (Eds.), 2017: State Climate Summaries for the United States. *NOAA Technical Report NESDIS 149.*
- Runkle, J., K. Kunkel, L. Stevens, and R. Frankson, 2017: Alabama State Summary. *NOAA Technical Report NESDIS 149-AL*, 4 pp.
- Stewart, B., K. Kunkel, S. Champion, R. Frankson, L. Stevens, and G. Wendler, 2017: Alaska State Summary. *NOAA Technical Report NESDIS 149-AK*, 4 pp.
- Frankson, R., K. Kunkel, L. Stevens, D. Easterling, T. Brown, and N. Selover, 2017: Arizona State Summary. *NOAA Technical Report NESDIS 149-AZ*, 4 pp.
- Runkle, J., K. Kunkel, S. Champion, B. Stewart, and D. Easterling, 2017: Arkansas State Summary. *NOAA Technical Report NESDIS 149-AR,* 4 pp.
- Frankson, R., L. Stevens, K. Kunkel, S. Champion, D. Easterling, and W. Sweet, 2017: California State Summary. *NOAA Technical Report NESDIS 149-CA,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens, and D. Easterling, 2017: Colorado State Summary. *NOAA Technical Report NESDIS 149-CO,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, D. Easterling, B. Stewart, R. Frankson, and W. Sweet, 2017: Connecticut State Summary. *NOAA Technical Report NESDIS 149-CT,* 4 pp.
- Runkle, J., K. Kunkel, D. Easterling, R. Frankson, S. Champion, B. Stewart, W. Sweet, D. Leathers, and A.T. DeGaetano, 2017: Delaware State Summary. *NOAA Technical Report NESDIS 149-DE,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, R. Frankson, B. Stewart, and W. Sweet, 2017: Florida State Summary. *NOAA Technical Report NESDIS 149-FL,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens, B. Stewart, W. Sweet, and B. Murphey, 2017: Georgia State Summary. *NOAA Technical Report NESDIS 149-GA,* 4 pp.
- Stevens, L., R. Frankson, K. Kunkel, P-S. Shin, and W. Sweet, 2017: Hawaii State Summary. *NOAA Technical Report NESDIS 149-HI,* 4 pp.

- Runkle, J., K. Kunkel, R. Frankson, S. Champion, and L. Stevens, 2017: Idaho State Summary. *NOAA Technical Report NESDIS 149-ID,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, B. Stewart, D. Easterling, B. Hall, and J. R. Angel, 2017: Illinois State Summary. *NOAA Technical Report NESDIS 149-IL,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, B. Stewart, and J. Runkle, 2017: Indiana State Summary. *NOAA Technical Report NESDIS 149-IN,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, and J. Runkle, 2017: Iowa State Summary. *NOAA Technical Report NESDIS 149-IA,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens, D. Easterling, X. Lin, and M. Shulski, 2017: Kansas State Summary. *NOAA Technical Report NESDIS 149-KS,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, R. Frankson, and B. Stewart, 2017: Kentucky State Summary. *NOAA Technical Report NESDIS 149-KY,* 4 pp.
- Frankson, R., K. Kunkel, and S. Champion, 2017: Louisiana State Summary. *NOAA Technical Report NESDIS 149-LA,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, R. Frankson, B. Stewart, and A.T. DeGaetano, 2017: Maine State Summary. *NOAA Technical Report NESDIS 149-ME,* 4 pp.
- Runkle, J., K. Kunkel, D. Easterling, B. Stewart, S. Champion, R. Frankson, and W. Sweet, 2017: Maryland State Summary. *NOAA Technical Report NESDIS 149-MD,* 4 pp.
- Runkle, J., K. Kunkel, R. Frankson, D. Easterling, A.T. DeGaetano, B. Stewart, and W. Sweet, 2017: Massachusetts State Summary. *NOAA Technical Report NESDIS 149-MA*, 4 pp.
- Frankson, R., K. Kunkel, S. Champion, and J. Runkle, 2017: Michigan State Summary. *NOAA Technical Report NESDIS 149-MI,* 4 pp.
- Runkle, J., K. Kunkel, R. Frankson, D. Easterling, and S. Champion, 2017: Minnesota State Summary. *NOAA Technical Report NESDIS 149-MN,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, R. Frankson, and B. Stewart, 2017: Mississippi State Summary. *NOAA Technical Report NESDIS 149-MS,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion and B. Stewart, 2017: Missouri State Summary. *NOAA Technical Report NESDIS 149-MO,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, and D. Easterling, 2017: Montana State Summary. *NOAA Technical Report NESDIS 149-MT,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens and M. Shulski, 2017: Nebraska State Summary. *NOAA Technical Report NESDIS 149-NE,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, and D. Easterling, 2017: Nevada State Summary. *NOAA Technical Report NESDIS 149-NV,* 4 pp.
- Runkle, J., K. Kunkel, D. Easterling, R. Frankson, and B. Stewart, 2017: New Hampshire State Summary. *NOAA Technical Report NESDIS 149-NH,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, R. Frankson, B. Stewart, and W. Sweet, 2017: New Jersey State Summary. *NOAA Technical Report NESDIS 149-NJ,* 4 pp.
- R. Frankson, K. Kunkel, L. Stevens, and D. Easterling, 2017: New Mexico State Summary. *NOAA Technical Report NESDIS 149-NM,* 4 pp.
- R. Frankson, K. Kunkel, S. Champion, B. Stewart, W. Sweet, and A. T. DeGaetano, 2017: New York State Summary. *NOAA Technical Report NESDIS 149-NY,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens, D. Easterling, W. Sweet, A. Wootten, and R. Boyles, 2017: North Carolina State Summary. *NOAA Technical Report NESDIS 149-NC,*3 pp.
- Frankson, R., K. Kunkel, L. Stevens, D. Easterling, M. Shulski, and A. Akyuz, 2017: North Dakota State Summary. *NOAA Technical Report NESDIS 149-ND,* 4 pp.

- Frankson, R., K. Kunkel, S. Champion and D. Easterling, 2017: Ohio State Summary. *NOAA Technical Report NESDIS 149-OH,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens, S. Champion, and B. Stewart, 2017: Oklahoma State Summary. *NOAA Technical Report NESDIS 149-OK,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, L. Stevens, D. Easterling, K. Dello, M. Dalton, and D. Sharp, 2017: Oregon State Summary. *NOAA Technical Report NESDIS 149-OR,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, B. Stewart, A.T. DeGaetano, and W. Sweet, 2017: Pennsylvania State Summary. *NOAA Technical Report NESDIS 149-PA,* 4 pp.
- Runkle, J., K. Kunkel, D. Easterling, B. Stewart, S. Champion, L. Stevens, R. Frankson, and W. Sweet, 2017: Rhode Island State Summary. *NOAA Technical Report NESDIS 149-RI,* 4 pp.
- Runkle, J., K. Kunkel, L. Stevens, R. Frankson, B. Stewart, and W. Sweet, 2017: South Carolina State Summary. *NOAA Technical Report NESDIS 149-SC,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, and D. Easterling, 2017: South Dakota State Summary. *NOAA Technical Report NESDIS 149-SD,* 4 pp.
- Runkle, J., K. Kunkel, D. Easterling, L. Stevens, B. Stewart, R. Frankson, and L. Romolo, 2017: Tennessee State Summary. *NOAA Technical Report NESDIS 149-TN,* 4 pp.
- Runkle, J., K. Kunkel, J. Nielsen-Gammon, R. Frankson, S. Champion, B. Stewart, L. Romolo, and W. Sweet, 2017: Texas State Summary. *NOAA Technical Report NESDIS 149-TX,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens and D. Easterling, 2017: Utah State Summary. *NOAA Technical Report NESDIS 149-UT,* 4 pp.
- Runkle, J., K. Kunkel, S. Champion, and L-A. Dupigny-Giroux, 2017: Vermont State Summary. *NOAA Technical Report NESDIS 149-VT,* 4 pp.
- Runkle, J., K. Kunkel, L. Stevens, S. Champion, B. Stewart, R. Frankson, and W. Sweet, 2017: Virginia State Summary. *NOAA Technical Report NESDIS 149-VA,* 4 pp.
- Frankson, R., K. Kunkel, S. Champion, D. Easterling, L. Stevens, K. Bumbaco, N. Bond, J. Casola, and W. Sweet, 2017: Washington State Summary. *NOAA Technical Report NESDIS 149-WA,* 4 pp.
- Runkle, J., K. Kunkel, R. Frankson, and B. Stewart, 2017: West Virginia State Summary. *NOAA Technical Report NESDIS 149-WV,* 4 pp.
- Frankson, R., K. Kunkel, and S. Champion, 2017: Wisconsin State Summary. *NOAA Technical Report NESDIS 149-WI,* 4 pp.
- Frankson, R., K. Kunkel, L. Stevens, D. Easterling, and B. Stewart, 2017: Wyoming State Summary. *NOAA Technical Report NESDIS 149-WY,* 4 pp.

Products

- A new metadata survey was completed and deployed for use in collection of information for the Climate Science Special Report.
- A set of climate metrics was computed from the Localized Constructed Analogs (LOCA) statistically-downscaled dataset and deployed for use by authors of the Fourth National Climate Assessment.

Presentations

- Kunkel, K.E., 2017: An Introduction to Downscaling Methods", U.S.-India Partnership for Climate Resilience Workshop on Development and Application of Downscaling Climate Projections, Indian Institute for Tropical Meteorology, Pune, India (March 7).
- Kunkel, K.E., 2017: Effects of MMTS on Long-Term Extreme Temperature Trends", Annual Meeting of the American Meteorological Society, Seattle, WA (January 24).

- Kunkel, K.E., 2017: NOAA's State Climate Summaries for the National Climate Assessment: A Resource for Decision Makers, Annual Meeting of the American Meteorological Society, Seattle, WA (January 24).
- Stevens, L.E., 2017: NOAA's State Climate Summaries for the National Climate Assessment: State Level Trends in Temperature and Precipitation, Annual Meeting of the American Meteorological Society, Seattle, WA (January 24).
- Kunkel, K.E., 2016: Climate Scenarios for the Fourth National Climate Assessment and the Sustained Assessment Process, Fall Meeting of the American Geophysical Union, San Francisco, CA (December 14).
- Kunkel, K.E., 2016: NOAA's State Climate Summaries for the National Climate Assessment: A Sustained Assessment Product", Fall Meeting of the American Geophysical Union, San Francisco, CA (December 14).
- Champion, S., 2016: NOAA's State Climate Summaries for the National Climate Assessment: A Resource for Decision Makers, CICS Science Conference, Greenbelt, MD (November 29).
- Sun, L., 2016: Analysis of Climate Extremes over the Contiguous United States, CICS Science Conference, Greenbelt, MD (November 29).
- Champion, S. and L. Sun, 2016: NCA Technical Support Unit, CICS Science Conference, Greenbelt, MD (November 29).
- Kunkel, K.E. and S. Champion, 2016: Metadata requirements and system demonstration, invited talk, Climate Science Special Report 2nd Lead Authors Meeting, Boulder, CO (November 3).
- Kunkel, K.E., 2016: The NOAA State Summaries, invited talk, Fourth National Climate Assessment Federal Coordinating Lead Authors Meeting, Washington, DC (October 26)
- Sun, L., 2016: Analysis of U.S. Regional Conditions Using LOCA Downscaling Data, invited talk, Risk Analysis and Environmental Disasters, Rio de Janeiro, Brazil (September 27).
- Stevens, L.E., 2016: NOAA's State Summaries for the National Climate Assessment, 2016 Carolinas Climate Resilience Conference, September 13, 2016, Charlotte, NC (September 13).
- Kunkel, K.E., 2016: The National Climate Assessment, invited talk, Journalists Workshop, Asheville, NC (August 16).
- Kunkel, K.E. and D.R. Easterling, 2016: The India National Climate Assessment, invited talk, NCEI Science Council, Asheville, NC (July 14).
- Kunkel, K.E., 2016: Extreme Weather Events: Ice Storms, invited talk (remote), National Academy of Sciences Panel on Enhancing the Resiliency of the Nation's Electric Power Transmission and Distribution System (July 11).
- Kunkel, K.E., 2016: NOAA State Summaries for the National Climate Assessment, Annual Meeting of the American Association of State Climatologists, Santa Fe, New Mexico (July 1).
- Kunkel, K.E., 2016: Extreme Rainfall and Resilient Building Codes, invited talk, White House Conference on Resilient Building Codes, Washington, DC (May 10).
- Kunkel, K.E., 2016: Laudato Si and Climate Science, invited talk, Laudato Si Interdisciplinary Symposium, Franciscan University of Steubenville, Steubenville, Ohio (April 28).
- Kunkel, K.E., 2016: Climate Scenarios for the U.S. National Climate Assessment, Scoping Workshop for the U.S.-India Partnership for Climate Resilience, Indian Institute for Tropical Meteorology, Pune, India (April 11).

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**5**
# of NOAA technical reports	**51**
# of presentations	**20**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Two products became available:

1. A new metadata survey was completed and deployed for use in collection of information for the Climate Science Special Report.
2. A set of climate metrics was computed from the Localized Constructed Analogs (LOCA) statistically-downscaled dataset and deployed for use by authors of the Fourth National Climate Assessment.

Peer-reviewed papers included 4 journal articles and two chapters of the Climate and Health Assessment.
The 50 technical reports are the 50-part series of NOAA's State Climate Summaries.
One Ph.D. student (Brooke Stewart) is being advised by Kenneth Kunkel.

TSU Software Support	
Task Leader	Andrew Buddenberg
Task Code	NC-CAA-02-NCICS-AB
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	Climate Research and Modeling
Contribution to NOAA goals (%)	Goal 1:0%; Goal 2: 100%, Goal 3: 0%; Goal 4:0%

Highlight: This task focuses on ensuring the integrity and portability of the programs developed for the NCA and assisting the lead scientist in their creation and development of analyses.

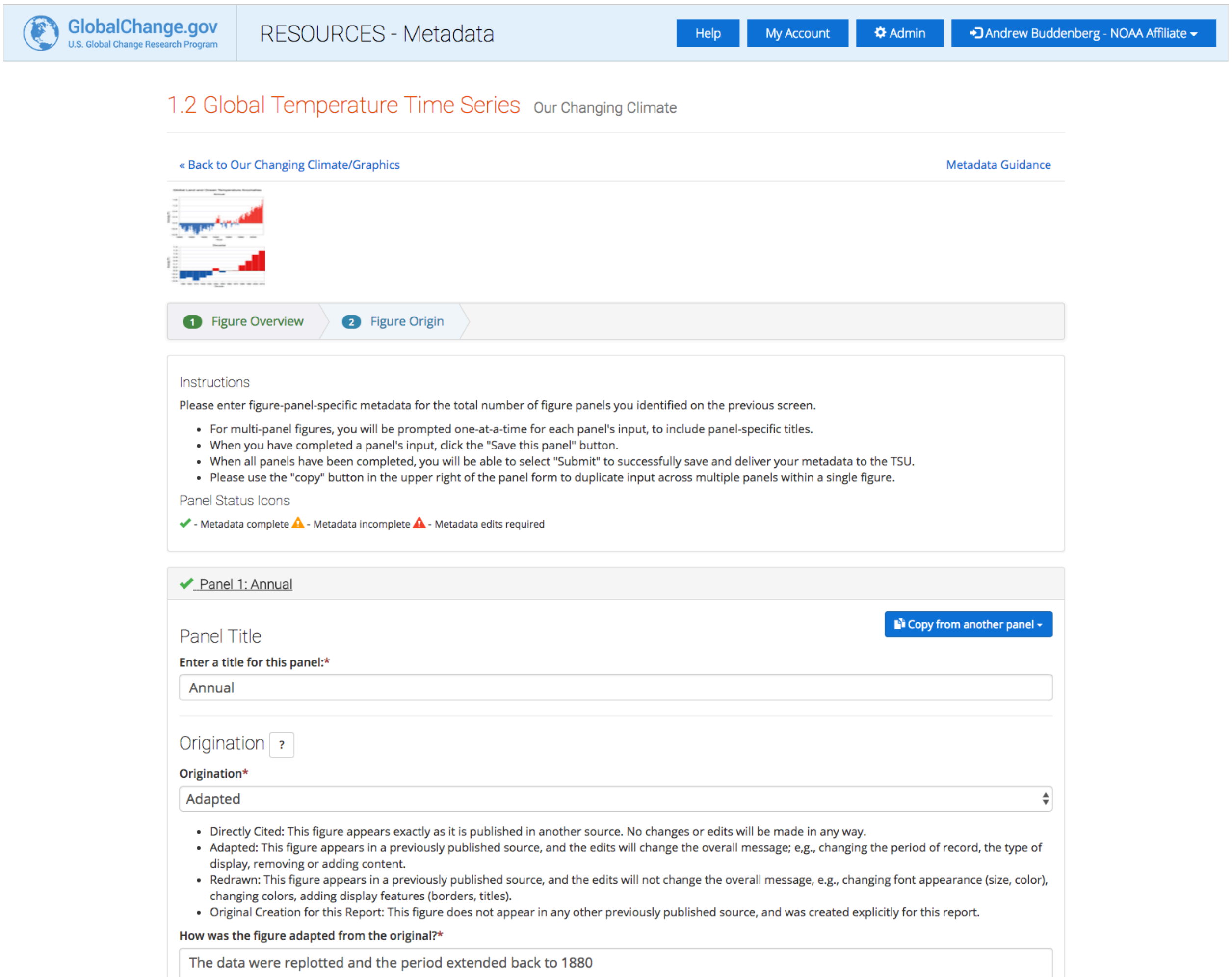
Background

The National Climate Assessment integrates, evaluates, and interprets the findings of the U.S. Global Change Research Program (USGCRP) into a single cohesive report for policymakers and private entities to inform their decision-making and planning for the future. The far-reaching effects of this report demand the highest levels of traceability and reproducibility of the datasets and scientific analyses that operate upon them.

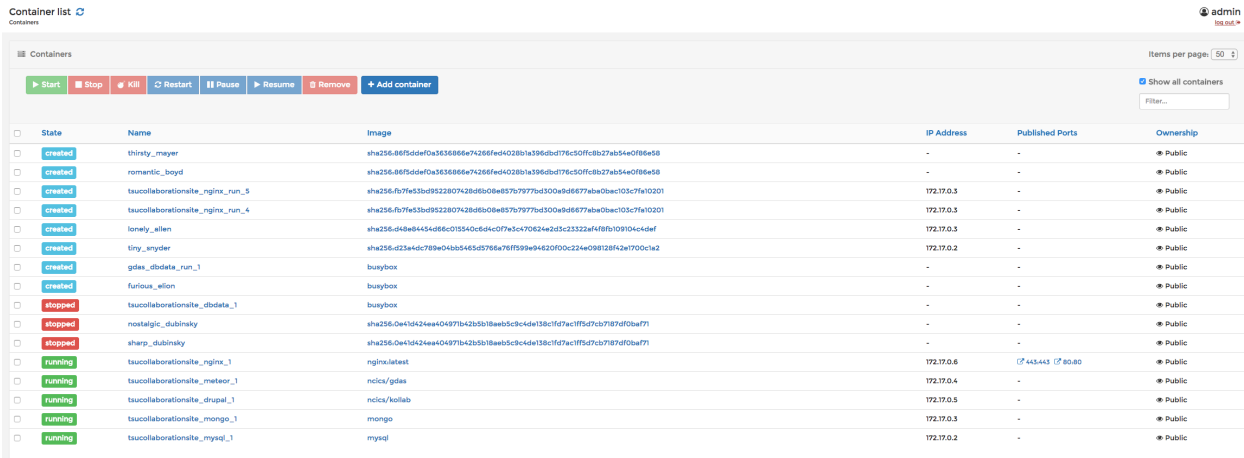
Given that these analyses are implemented with computer software, this task focuses on ensuring the integrity and portability of the programs developed for the NCA and assisting the lead scientist in their creation and development. In addition, to facilitate the overall business of the NCA and its integrity, ancillary software tools must be created and continue to be developed as part of the continuing assessment process.

Accomplishments

Continued development of TSU's software portfolio supporting the USGCRP Climate and Human Health Assessment, NOAA 50 State Summaries, and the forthcoming USGCRP Climate Science Special Report, as well as commencement of the Fourth National Climate Assessment. Improvements to these tools greatly enhance our ability to gather, process, and disseminate climate science metadata to ensure the highest levels of traceability and reproducibility. *Figure 1* below depicts our next-generation, real-time metadata collaboration tool:



The growing utility and cost savings offered by Cloud Computing has become obvious and widely known. To streamline development-to-operations processes, reduce overhead, and enable a seamless transition to these lower-cost Cloud-based solutions, state of the art container infrastructure has been deployed. With this technology, new or legacy products from web applications to data processing can enjoy the stability and scalability this new frontier promise.



Planned Work

- Continue development of metadata collection system and supporting technologies.
- Continue TSU web team leadership and project management.
- Continue performance analysis and enhancement of Big Data processing.
- Continue assisting lead scientist and associates with scientific programming tasks.

Products

- GCIS Data Acquisition System v3.3.2: real-time metadata collaboration and management tool.
- Enhanced, interactive surveys to ease collection of NOAA-IQA-required climate science metadata.
- Integrated a suite of web applications into Docker containers to streamline their operation and management.
- loca-proc: flexible, scalable processing framework for LOCA dataset.
- gcis-py-client 1.2.1: latest iteration of Global Change Information System tools.

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

National Climate Assessment Technical Support Unit Graphical Services	
Task Leader	Jessicca Griffin
Task Code	NC-CAA-03-NCICS-JG
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: CICS-NC staff provided editorial, graphics, and production support for the Climate and Health Assessment.	

Background

The National Climate Assessment (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. Given the intended audience, it is essential that the report is written and graphically represented in clear language that is easily understood by a broad audience while maintaining the highest possible standards of accuracy and transparency.

Accomplishments

Graphic design support services were provided for the final stages of the Climate and Health Assessment, which was released in April 2016, the development of the NOAA National Centers for Environmental Information State Climate Summary Fact Sheets (released in January 2017), and the forthcoming Climate Science Special Report. Tasks included basic image editing, as well as more extensive editing and new creations to improve readability and ensure accuracy, and layout design of the report. Production services included preparing graphics for various pre-release drafts, templates for PDF products, and production of final PDFs for the Climate and Health Assessment and the State Climate Summaries. With tight deadlines and short turnaround times, delivery of these products required successful integration of the functions of multiple staff members within the TSU and effective coordination between the TSU staff and state and regional climatologists.

Planned Work

- Continued figure development and layout of the Climate Science Special Report expected in October 2017
- Begin development of graphics of the Fourth National Climate Assessment expected in 2018
- Continue providing graphical support as a Visual Communications team member in the Communications and Outreach Branch of NCEI.
    - BAMS State of the Climate
    - Explaining Extreme Events
    - Conference posters and briefings

Products

- Climate and Health Assessment Report (April 2016)
- BAMS State of the Climate (August 2016)

- Explaining Extreme Events (November 2016)
- NOAA National Centers for Environmental Information State Summary Fact Sheets (January 2017)

Presentations

- "Tell the Story–Communicating Technical Science to the Public", Brevard High School Science Club, Brevard, NC, June 12, 2016.
- "NOAA's State Climate Summaries for the National Climate Assessment: A Resource for Decision Makers", Annual Meeting of the American Meteorological Society, Seattle, WA, January 24, 2017.
- "NOAA's State Climate Summaries for the National Climate Assessment: State Level Trends in Temperature and Precipitation", Annual Meeting of the American Meteorological Society, Seattle, WA, January 24, 2017.
- "NOAA's State Climate Summaries for the National Climate Assessment: A Sustained Assessment Product", Fall Meeting of the American Geophysical Union, San Francisco, CA, December 14, 2016.
- "NOAA's State Climate Summaries for the National Climate Assessment: A Resource for Decision Makers", CICS Science Conference, College Park, MD, December 1, 2016.

Other

Nominated for NOAA National Centers for Environmental Information 2015 Employee's Choice Awards:

- Team Excellence (Visual Communications Team in the Communications and Outreach Branch)
- Team Excellence (National Climate Assessment Technical Support Unit)

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

U.S. – India Partnership for Climate Resilience (PCR) Workshop Support	
Task Leader	Katharine Hayhoe
Task Code	NC-CAA-04-TTU
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI (DOS)
Contribution to CICS themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: Development of state-of-the-art climate products and analysis tools for resilience planning and sustainable development and provision to U.S. – India Partnership for Climate Resilience (PCR) collaborators including practitioners and researchers.	

Background

In September 2014, U.S. President Obama and Indian Prime Minister Modi agreed to a new and enhanced strategic partnership on energy security, clean energy, and climate change. The resulting U.S.-India Partnership for Climate Resilience (PCR) aims to advance capacity for climate adaptation planning by supporting climate resilience tool development. Joint activities include downscaling global climate models for the Indian sub-continent to a much higher resolution than currently available, assessing climate risks at the sub-national level, working with local technical institutes on capacity building, and engaging local decision-makers in the process of addressing climate information needs and informing planning and climate resilient sustainable development, including for India's State Action Plans.

With their previous leadership and scientific and technical support in the Third National Climate Assessment process, the NOAA National Centers for Environmental Information (NCEI) and the NOAA Cooperative Institute for Climate and Satellites–North Carolina (CICS-NC) are now providing key technical support for the PCR bilateral activities in collaboration with the U.S. State Department. Included in the planned activities are several specific topical workshops presented and/or facilitated by U.S. scientists and subject matter experts. This project supports the engagement of Katharine Hayhoe, a lead author for the National Climate Assessments since 2007, and Texas Tech Climate Science Center researchers Anne Stoner and Ranjini Swaminathan, in a workshop and associated research activities aimed at equipping the Indian Institutes with the ability to generate and analyze high-resolution climate projections and apply these to quantify the impacts of climate change at the local to regional scale.

Accomplishments

The team made significant progress toward its anticipated project outcomes. Specifically, we have: (a) developed and provided state-of-the-art climate products and analysis tools to PCR collaborators; (b) contributed to the design and implementation of a workshop to disseminate these datasets and tools to academic, federal, and non-profit experts in India who can use these products to inform sustainable development and hazard mitigation, including leading a hands-on exercise to train attendees in using these products; and (c) begun to build long-term collaborations with Indian practitioners, researchers, and other experts to expand on these initial products. Each of these steps is described in more detail below.

Climate Data and Analysis Tools: To generate climate information for resilience planning and sustainable development, we assembled long-term daily temperature and precipitation observations from available Global Historical Climatology Network stations and from additional stations provided by Indian Institute colleagues (*Figure 1*). We quality-controlled the data to remove any potentially erroneous entries, then downscaled daily simulations from six CMIP5 (Climate Model Intercomparison Project, Phase 5) global climate models (GCMs) for the 20th century based on natural and anthropogenic forcings and corresponding simulations for the 21st century based on the higher 8.5 and lower 4.5 Representative Concentration Pathways (RCPs) to individual weather station locations. The downscaling was accomplished using the Asynchronous Regional Regression Model version 2 (ARRM2). ARMM2 is a non-parametric and significantly improved version of the original ARRM model that was used in the Second and Third U.S. National Climate Assessments. It is specifically designed to improve analyses at the tails of the distribution of climate variables, enhancing model ability to simulate potential extreme and hazardous weather events by incorporating real-world observations into the modeling framework. The high-resolution information was complemented by development of a user-friendly analysis package, written in R, that allowed participants without any knowledge of R or climate data to calculate a broad range of user-defined indicators relevant to impacts in their region. For example, they could calculate seasonal average temperature or precipitation based on any combination of months they preferred; they could also calculate exceedances, such as the number of days per year above or below a certain temperature or precipitation threshold, as well as records, such as the hottest day or wettest week of the year, and cooling degree-days, a proxy for energy use during the warm season. The goal of this analysis package was to allow users to identify which climate indicators were most directly relevant to their information needs at the local to regional scale, including for India's State Action Plans, and to calculate these indicators and analyze the results for the weather station(s) closest to their locations of interest

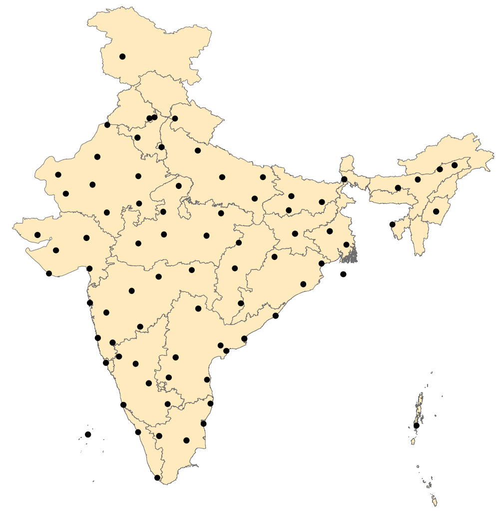


Figure 1. Location of long-term weather stations for which daily projections were generated.

Workshop Design and Implementation: To assist users in the application of this analysis package, we created a series of presentations and videos explaining the data and code, complemented by a detailed hands-on, multi-day exercise in the afternoons of Days 1 and 2 of the workshop that enabled researchers and state policy makers to use the downscaled climate data, perform analysis, and even generate usable products, including plots and presentations. As part of the workshop activity, we designed Excel and Powerpoint templates that allowed the users to create time series, bar charts, and maps of both the historical and projected future climate indicators they had selected (*Figure 2*), and then put those figures into a presentation that they could take home with them and use to share with others.

Long-Term Collaborations: Finally, through engagement with workshop participants, we are already establishing collaborations for future work with experts who have access to additional data and applications for this data. These include Nitin Bassi (IRAP), Sandhya Rao (INRM), Ashwini Kulkarni (ITTM), and many others. More information on future plans is provided below.

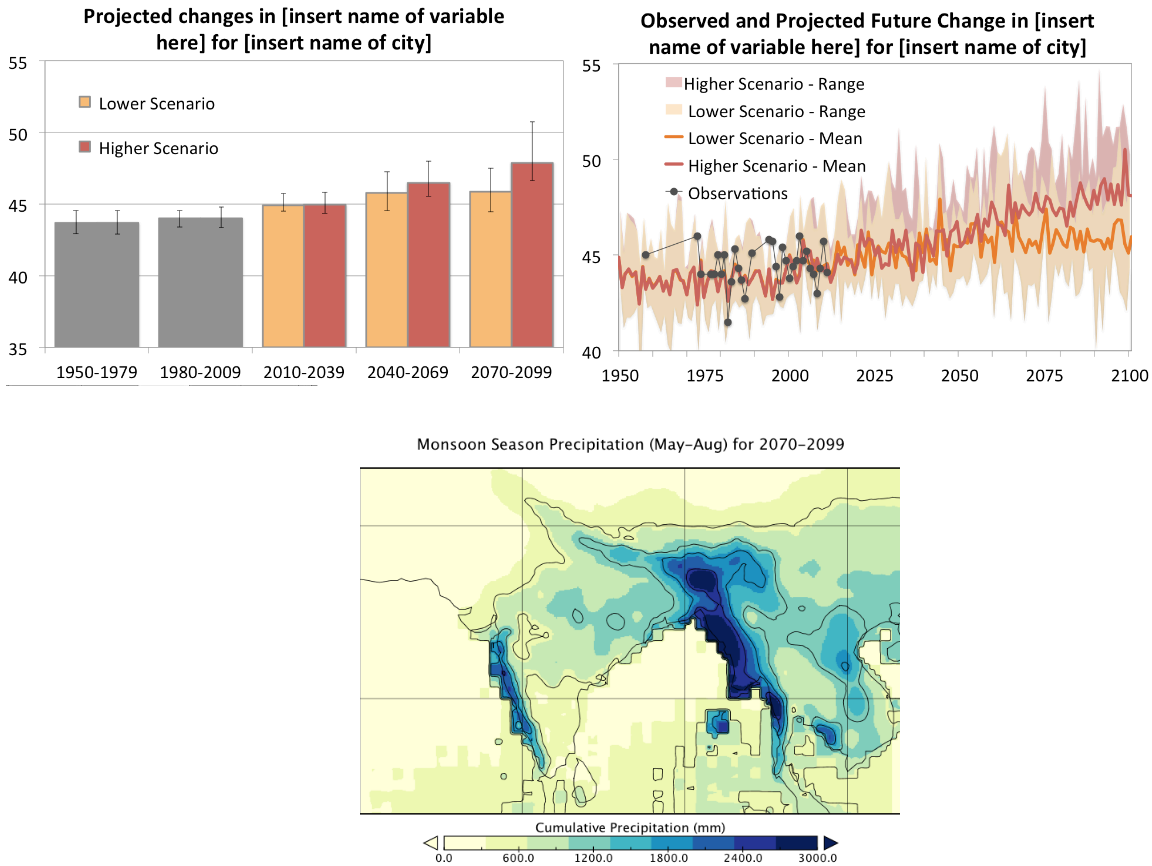


Figure 3. Sample (top left) bar charts, (top right) time series, and (bottom) maps users were able to create with the analysis code and plotting templates generated under this project.

Planned Work

Over the remainder of this project, we propose to continue to expand the products that have been developed to date, based on input and additional resources that are being supplied by new collaborators and contacts. Specifically, we plan to:

- Create several additional videos to accompany the product archive, providing further information on data availability and best practices for its use and application (in progress)
- Obtain and quality control additional weather station records supplied by collaborators (in progress with data obtained from Nitin Bassi from Institute for Resource Analysis and Policy in New Delhi)
- Generate future projections for new weather station records and incorporate these stations into the analysis code (in progress)
- Obtain shape files for Indian states; regrid NEX output to generate monthly maximum and minimum temperature and precipitation time series for individual states
- Obtain "block"-level observational data and downscale daily temperature and precipitation to those records, based on data availability through new collaborations with the Watershed Organization Trust (WOTR), Pune

- Automate the QC process in the form of a stand-alone software package for collaborators and stakeholders to use to quality-control new datasets (as per specific request for the soon to be established network of automated weather stations in the State of Maharashtra through the Project on Climate Resilient Agriculture or PoCRA)
- Provide documentation in the form of a publication or report to be released with the QC software.

Products

The products generated during this period of performance consist of:

- Quality controlled daily temperature and precipitation data for approximately 80 weather stations across India
- ARRMv1 statistically downscaled daily precipitation to station level for 6 GCMs (CCSM4, GFDL-ESM2G, IPSL-CM5A-LR, MIROC5, MPI-ESM-LR, MRI-CGCM3) and 2 RCPs (RCP4.5, RCP8.5)
- ARRMv2 statistically downscaled daily minimum and maximum temperature for 6 GCMs (CCSM4, GFDL-ESM2G, IPSL-CM5A-LR, MIROC5, MPI-ESM-LR, MRI-CGCM3) and 2 RCPs (RCP4.5, RCP8.5)
- User-friendly climate analysis R package
- Excel sample spreadsheet to make time series plots and bar graphs
- Powerpoint sample presentation to make a presentation with analysis output
- Detailed documentation on the generation, application, and use of climate information relevant to quantifying the potential impacts of climate change at the local to regional scale across India

Presentations

Project presentations during this period of performance all took place at the *U.S.–India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections* held in Pune, India, March 7-9, 2017. They include:

- “Comparing the performance of multiple statistical downscaling approaches using a perfect model framework” by Anne Stoner, Katharine Hayhoe, Keith Dixon, John Lanzante, and Ian Scott-Fleming.
- “Automated Quality Control of Observed Weather Station Data” by Ranjini Swaminathan, Katharine Hayhoe
- “Climate Exercise – Day 1 and Day 2” by Katharine Hayhoe
- “Application Examples of Downscaled Output” by Anne Stoner

Other

We have identified multiple collaborative research opportunities for new projects with scientists at the Indian Institute of Tropical Meteorology that we look forward to pursuing in future work.

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

New products consist of: (1) quality-controlled station observations; (2) downscaled climate projections for each station; (3) an analysis package that allows the user to select, define and calculate their own impact-relevant indicators for the location(s) of their choice, and (4) detailed templates and documentation to allow them to easily & accurately interpret and communicate the results of their analysis.
One postdoctoral research fellow was supported by this task (Anne Stoner).

Web Development for Assessments	
Task Leader	Angel Li
Task Code	NC-CAA-05-NCICS-AL
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1:100%; Goal 2:0%; Goal 3:0%; Goal 4:0

Highlight: Launched the Climate and Health 2016 website, designed, and implemented the 50 states climate summaries web site, designed, and implemented a new NCICS website.

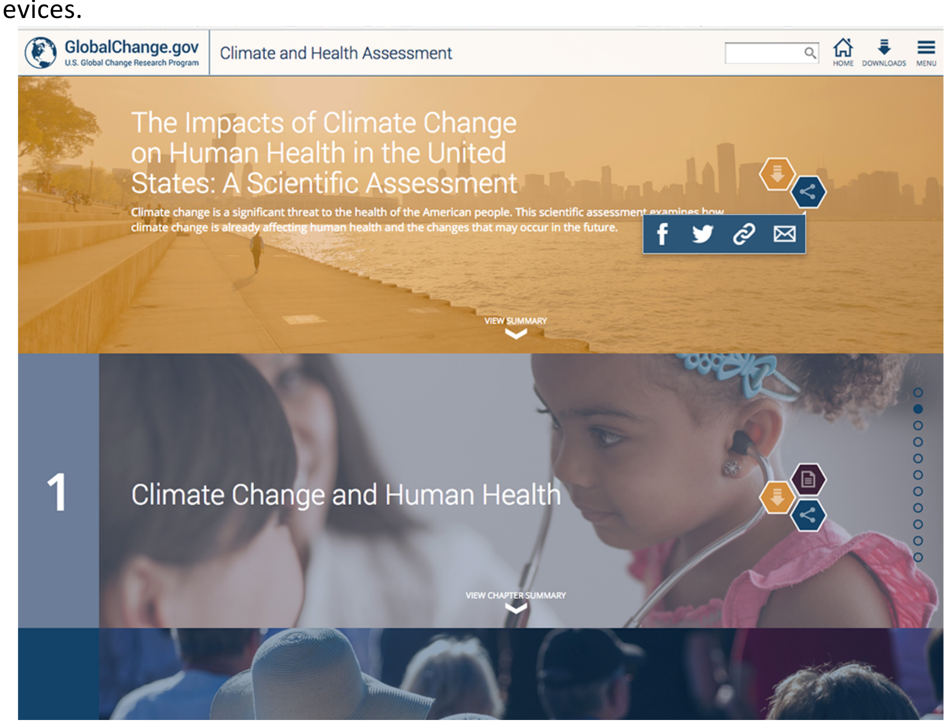
https://ncics.org

Background

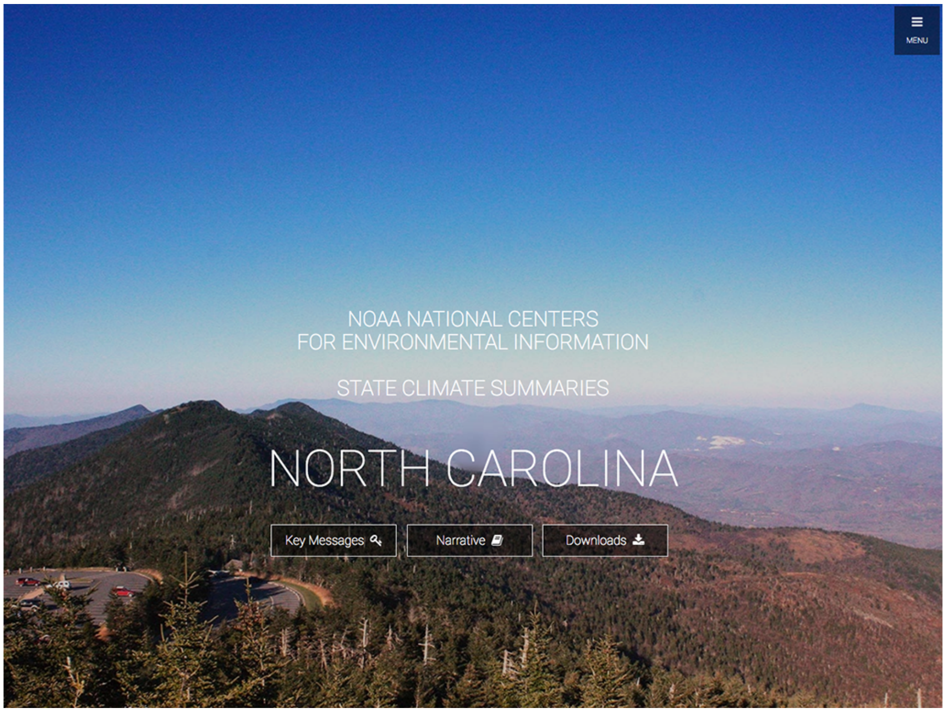
The web is now the expected way to read reports. Mobile (tablets and phones) usage continues to rise and for many, mobile is their sole access to the internet. With the loss of our lead Drupal developer, there is more of an emphasis on using lighter-weight technologies for content management.

Accomplishments

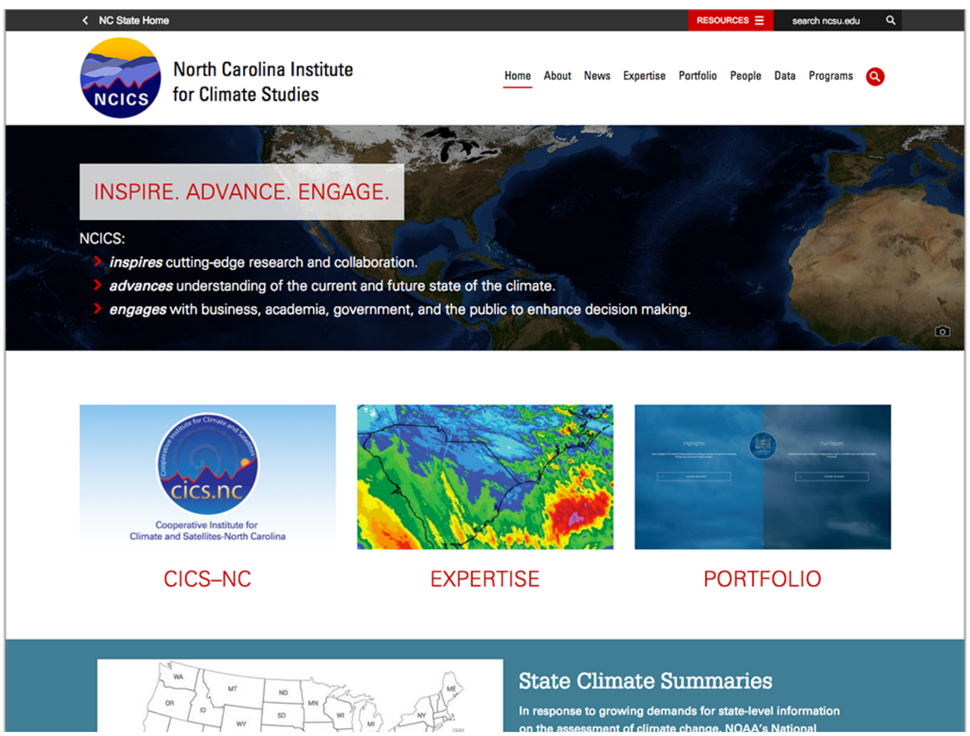
2016 was an extremely busy year for the CICS-NC web team. The year started with the launch of the Climate and Human Health Assessment website, a Drupal website designed in-house. The site showcases the use of Javascript for many animation effects. Much time was spent on optimizing the site for mobile devices.



Later in the year, the 50 State Climate Summaries Drupal website, also designed in-house, launched. The site uses full-screen high-resolution photos for visual appeal and it reused technology developed for the *Climate and Human Health* site.



A new NCICS website was designed and launched in 2016. All the content from the previous CICS-NC site was migrated along with the integration of the monitor.cicsnc.org experimental data site. This site conforms to the NC State branding and is very mobile-friendly.



The team is still supporting the suite of Drupal USGCRP sites. Most were developed by the TSU and it has been a challenge extending the Drupal knowledge needed to enhance these sites.

Planned work

- Launch a new Scenarios website geared to NCA4
- Design and implement the CSSR web site
- Start design process for the 4th National Climate Assessment website
- Implement a new metadata display
- Continue support of USGCRP sites

Products

- http://health2016.globalchange.gov
- http://stateclimatesummaries.globalchange.gov
- https://ncics.org

Other

- Attended Drupalcon New Orleans
- Attended Drupal Camp in Asheville
- Attended Wordpress Camp in Asheville

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

http://health2016.globalchange.gov, http://stateclimatesummaries.globalchange.gov, https://ncics.org

TSU Support	
Task Leader	Tom Maycock
Task Code	NC-CAA-06-NCICS-TM
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: Provided project management and editorial and technical support for USGCRP Climate and Health Assessment and the Climate Science Special Report.	
health2016.globalchange.gov	

Background

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the sustained National Climate Assessment (NCA) process, a premier activity of the U.S. Global Change Research Program. The NCA is conducted under the auspices of the Global Change Research Act of 1990, which calls for a report to the President and Congress that evaluates, integrates, and interprets the findings of the federal research program on global change (USGCRP) every four years. As the USGCRP agencies seek to establish an ongoing, sustainable assessment process, NCEI's TSU and the staff at USGCRP work in concert to provide coordination and technical support to a wide network of interagency and external groups and individuals.

Efforts this year focused on the release of, and follow-up support for, the USGCRP assessment report entitled "The Impacts of Climate Change on Human Health: A Scientific Assessment," editorial support for the Climate Science Special Report currently under development, and input into the early development of the Fourth National Climate Assessment.

Accomplishments

Maycock served as the TSU's project coordinator and lead editor for the Climate and Health Assessment (CHA), which was released by the White House on April 4, 2016. Ongoing support included delivering minor errata updates, and coordinating with staff from EPA and NOAA NCEI to deliver a Spanish-language translation of the CHA Executive Summary. He also supervised development and implementation of a survey of CHA participants to assess the development and production process. A 24-page report on the survey results was delivered in early 2017, and it is hoped that the results will help facilitate and improve ongoing assessment activities.

Maycock served as interim TSU editorial lead for the preparation and delivery of the Third Order Draft of the Climate Science Special Report, which was released for public comment and review by the National Academy of Sciences in December of 2016. Activities included science editing of multiple chapters, coordinating work on updates to figures and citations, and interaction with authors to finalize chapter drafts.

In his role as the CICS-NC Science Public Information Officer, Maycock coordinated with NOAA NCEI communications and the U.S. Global Change Research Program on the rollout of the NOAA State Climate Summaries, release in January 2017.

Planned Work

- Continued editorial and production support for the Climate Science Special Report and Fourth National Climate Assessment

Publications

- Peng, G., N. A. Ritchey, K. S. Casey, E. J. Kearns, J. L. Privette, D. Saunders, P. Jones, T. Maycock, and S. Ansari, 2016: Scientific stewardship in the Open Data and Big Data era - Roles and responsibilities of stewards and other major product stakeholders. *D.-Lib Magazine*, **22**. http://dx.doi.org/10.1045/may2016-peng

Products

- Spanish-language translation of the Executive Summary of the Climate and Health Assessment
- Report presenting results from survey of Climate and Health Assessments
- Errata updates to PDF and web versions of Climate and Health Assessment and the Third National Climate Assessment.
- Draft of Climate Science Special Report for public comment and NAS review

Presentations

- Maycock, T. and J. Runkle, 2016: Climate and Health. *Asheville Museum of Science Beer City Science Pub Series*, October 28, 2016*,* The Collider, Asheville, NC.

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

Science Editor for the Climate and Human Health Assessment and State Summaries Documents / Project Lead for Climate Science Special Report / Project Coordination for Fourth National Climate Assessment	
Task Leader	Brooke Stewart
Task Code	NC-CAA-07-NCICS-BS
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: %; Theme 3: 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%;
Highlight: CICS-NC staff provided editorial, graphics, and production support for NOAA's Technical Support Unit to the National Climate Assessment, making significant contributions to the development of the full report and accompanying Highlights document.	

Background

The Climate Science Special Report (CSSR) is being undertaken as part of the sustained National Climate Assessment process. This report will serve as the climate science foundation for the upcoming Fourth National Climate Assessment (NCA4). The report will focus more on physical climate science and less on impacts, as compared to the Third National Climate Assessment's Climate Science chapter. The purpose of completing this special report separately from and ahead of the NCA4 is to provide a consistent scientific foundation for the various regional and sectoral chapters of the quadrennial report.

The CSSR will cover topics such as observed and projected national and global changes in climate, scientific basis for climate change, attribution, feedbacks, extremes, natural climate variability, physical indicators of climate change, and mitigation pathways, among others.

The draft report is slated for release for public and peer review in December 2016, with the final report scheduled for release in October 2017.

The NCA4, which again is being undertaken due to congressional mandate by the U.S. Global Change Research Act of 1990, is already underway. The Steering Committee has been formed, author groups have been chosen, and a timeline has been formulated. The writing of the report is underway. Public and Peer review are slated for September 2017, with the final report scheduled for release in December 2018.

Accomplishments

Stewart led the TSU's editorial team through several rounds of extensive editing to help ensure scientific accuracy and consistency throughout the Climate Science Special Report (CSSR). Stewart assisted USGCRP leadership with planning and execution of two additional author meetings, as well as continued planning of production and timelines for CSSR.

Stewart assisted TSU management and USGCRP leadership with further development of NCA4 timeline, author guidance, and production planning. Stewart worked with USGCRP staff to provide guidance for NCA4 authors regarding formulation of key messages and traceable accounts. Stewart worked with USGCRP and TSU staff to design a plan for graphics production and tracking for NCA4. Stewart also provided numerous training webinars for NCA4 and SOCCR2 authors as well as USGCRP staff on how to use web tools provided by the TSU.

Planned Work

- Continue to serve as the Technical Support Unit's (TSU) Project Lead for USGCRP's Climate Science Special Report. In this role, Stewart will be responsible for keeping TSU management updated on the progress of the report and ensuring the team has adequate resources to meet expectations and deliverables in a timely manner.
- Continue to serve as Editorial Team Lead. In this role, Stewart will be responsible for ensuring scientific consistency and accuracy across various TSU projects and that deadlines are met by the editorial team.
- Continue to work with TSU management and USGCRP leadership on guidance and planning for NCA4.
- Begin editorial work on NCA4. In this role, Stewart will coordinate work by editorial team and serve as a science editor/writer for NCA4 author teams in an effort to help them clearly communicate their science while maintaining consistency and accuracy.

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

Analytical Support for the Fourth National Climate Assessment	
Task Leader	Terence R. Thompson
Task Code	NC-CAA-08-LMI
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%
Highlight: LMI's proprietary ClimateIQ toolkit is being used and tailored to develop climate scenario products for the Fourth National Climate Assessment regional and sectoral chapter authors.	

Background

LMI developed a proprietary ClimateIQ toolkit as part of its climate analytics capability. ClimateIQ accesses and analyzes climate-related data from climate models, re-analyses, and observational sources and its outputs include statistical characterizations of local and regional climate variables, as well as selected impact metrics and/or surrogates for such metrics. LMI is working with CICS-NC and the NCEI National Climate Assessment Technical Support Unit's Assessment Science Team (hereafter referred to as the TSU-ST) to develop products for use in the Fourth National Climate Assessment (NCA4). Specifically, LMI uses and adapts elements of the LMI ClimateIQ toolkit for specific NCA4 needs. The primary application is to meet the climate scenarios needs of the NCA4 authors for regional and sectoral chapters. LMI coordinates closely with the TSU-ST to insure integrity, traceability, and reproducibility of products provided to NCA4 authors. This is necessary to meet the requirements of the Information Quality Act (IQA).

Accomplishments

We have developed the following major capabilities:

- Determine LOCA grid-cell centers that lie within a defined region.
- Extract time-ordered annual values for these grid cells for each derived variable, model, and scenario. Also calculate averages over defined periods for each grid cell, variable, model, and scenario.
- Calculate ensemble averages for each grid cell from these single-model averages using a vector of model weights. Also calculate a spatial average of these values across all grid cells in the region, and an associated range across models.
- Display region-specific evolution of the ensemble averages and single-model ranges across all 33 LOCA derived variables.

We show below results from this capability for two specific regions, the Chicago Metropolitan Statistical Area and Los Angeles County.

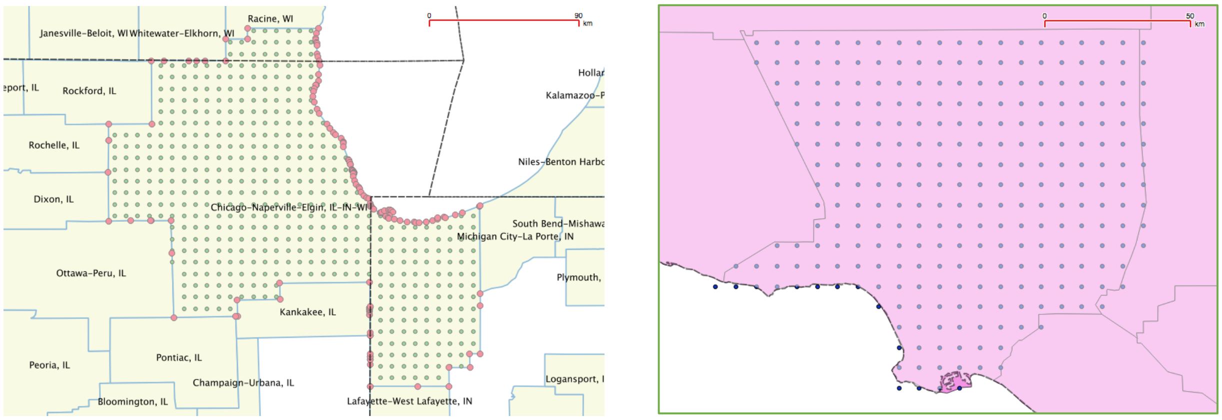


Figure 1. LOCA grid locations within the Chicago-Naperville-Elgin Metropolitan Statistical Area (left) and Los Angeles County (right).

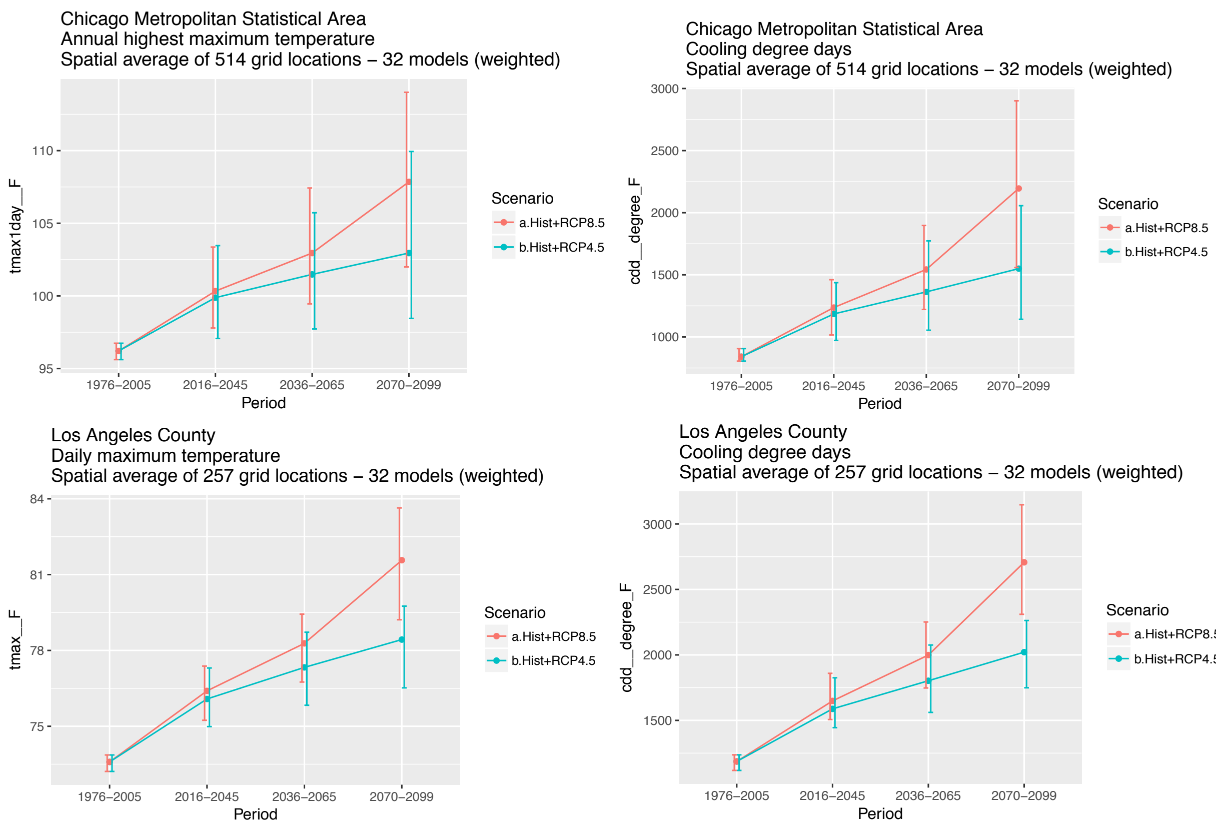


Figure 2. Representative outputs from the regional selection and spatial averaging process for the Chicago Metropolitan Statistical Area (top panels) and Los Angeles County (bottom panels).

Planned Work

- Complete all 34 displays for each of approximately 10 Metropolitan Statistical Areas and review these with the CICS-NC Assessment Science Team.
- Respond to comments and any additional requests from NCA4 chapter lead authors in coordination with the CICS-NC Assessment Science Team.
- Develop insights into additional derived variables that may be useful for sector-specific climate impacts (e.g., built environment).
- Develop accelerated extraction and processing techniques.

Publications

- Thompson, Terence R. Kenneth E. Kunkel, Laura E. Stevens, David R. Easterling, James C. Biard, and Liqiang Sun, "Localized Trend Analysis of Multi-Model Extremes Metrics for the Fourth National Climate Assessment," AMS Applied Climatology Conference 2017 (submitted)

Products

- Algorithm development and data-set generation for regional projections of derived climate variables.

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

The general nature of this work (not specific results) has been discussed in presentations to GSA and DoD.

An investigation into current and future trends in severe thunderstorms and their environments	
Task Leader	Robert J. Trapp
Task Code	NC-CAA-09-UIUC
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

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

Background

Historically, climate-scale studies of severe hail have been limited due to inherent biases within report-based databases (Schaefer and Edwards 1999; Schaefer et al. 2004; Doswell et al. 2005; Allen and Tippett 2015). Little information can be obtained regarding the size or path of hail swaths, given that reports are limited to single observers, separated by a minimum of 16 km or 15 minutes (Schaefer et al. 2004). This limits the study of "severe hail outbreaks," which are challenging to identify given that reports are "point based" where actual events will cover a larger area, for a longer time (Doswell et al. 2005). The NEXRAD/in situ gauge Climate Data Record (CDR) data set provides an opportunity to greatly expand upon the understanding of severe hail events in the United States.

Brooks et al. (2014) found that the frequency of tornado outbreaks could be increasing. Because a considerable fraction of severe hail events coincides with tornado events (Brooks et al. 2003), a similar trend in severe hail outbreaks is likely. A traditional way of locally parameterizing the occurrence of severe thunderstorms is through a combination of convective available potential energy (CAPE) and vertical wind shear (VWS) (Brooks et al. 2003, 2009). Trapp et al. (2007, 2009) developed the Ndsev (number of severe thunderstorm days) parameter using CAPE and 0-6 km VWS in order to estimate the number of days with potential for severe thunderstorms. This method of analyzing environments could also be utilized to study historical severe hail and tornado outbreak events.

Our objective is to investigate changes in historical severe convective weather, specifically the spatial extent and frequency of severe hail and tornado outbreaks over the United States using reanalysis and NEXRAD/in situ gauge Climate Data Record (CDR) data.

Accomplishments

The 12-year MESH climatology was created by recording daily severe MESH counts for every grid point over the United States. The daily MESH counts were saved by month for 29 mm ≤ MESH < 100 mm. This threshold constitutes our "severe hail" criteria, based on Cintineo et al. (2012). We set a max MESH size threshold to remove erroneous values much larger than realistic severe hail sizes.

Quality Control of the Data:

Erroneous signatures were apparent on yearly composite maps of severe MESH counts. Generally, such signals show up for anywhere from an hour to a few hours to even a single five-minute file in various locations. In many cases these MESH error signatures correspond to composite reflectivity (CREF) values larger than accepted for severe hail existence. We filtered out many of these errors by restricting severe MESH counts to points where CREF < 80 dbz. Any point not meeting this criterion, and 40 points in any direction, were flagged with -999.0 for the entire day. The 40-point radius and entire day criterion removes error signals that fall within the range of acceptable CREF values for the general area of the error producing radar. This ensures that the complete error signal is removed from the dataset.

Very apparent errors still remained in the dataset, even with the CREF constraint. We discovered that some 5-minute MESH files have excessively large severe MESH counts, higher than could physically fall within a 5-minute window, cumulative over the United States. For example, in November of 2005, during one 5-minute file, 67287 severe MESH counts were recorded. There were 52 instances of 5-minute severe MESH counts exceeding 3000. That is 0.000035% of the total number of 5-minute files. The 99th percentile of 5-minute file counts is 280 and the 99.99th percentile is 1327.3282 counts. With examination of individual days, it was determined to be unlikely that any excessively large counts are the result of a real hail event. However, several days with 5-minute file counts between 1000 and 3000 reflected real hail signatures. Setting a threshold of MESH counts ≤ 3000, for any 5-minute file, was determined appropriate to further quality control the data. If a 5-minute file crossed the threshold, it was not included in the climatology.

Several apparent errors signals can be seen over the U.S. in *Figure 1*. *Figure 2* shows a composite map of the severe MESH counts for the same year, but with the quality control measures applied. At least 3 very apparent error signatures are successfully removed from the data set, while keeping real signatures intact.

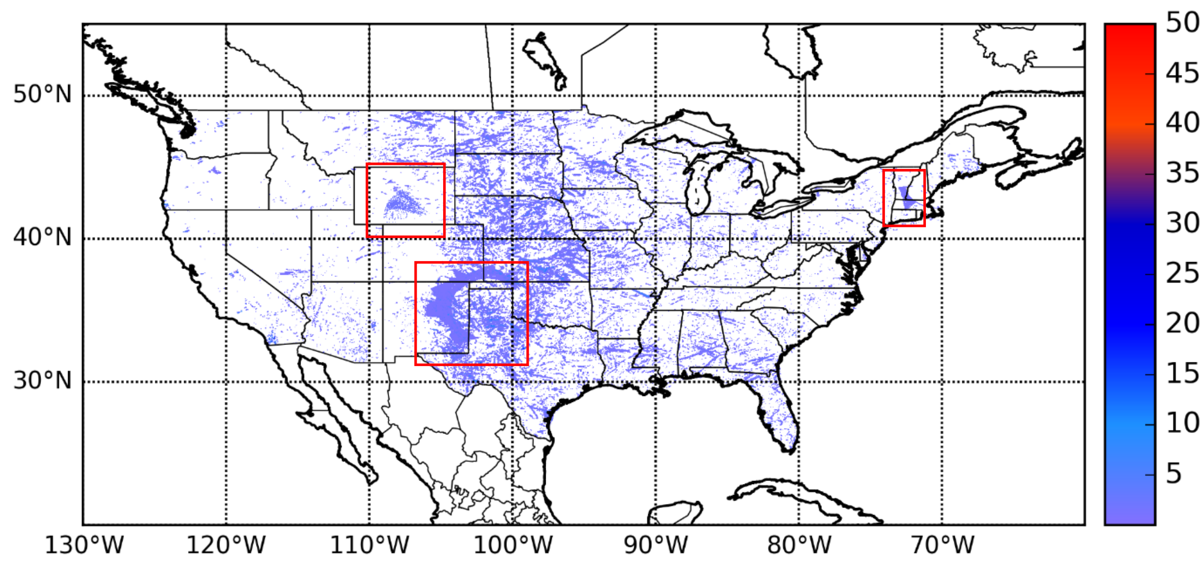


Figure 2. A composite of all Severe MESH counts for 2005 with no applied quality control. Red boxes highlight a few large error signatures within the data.

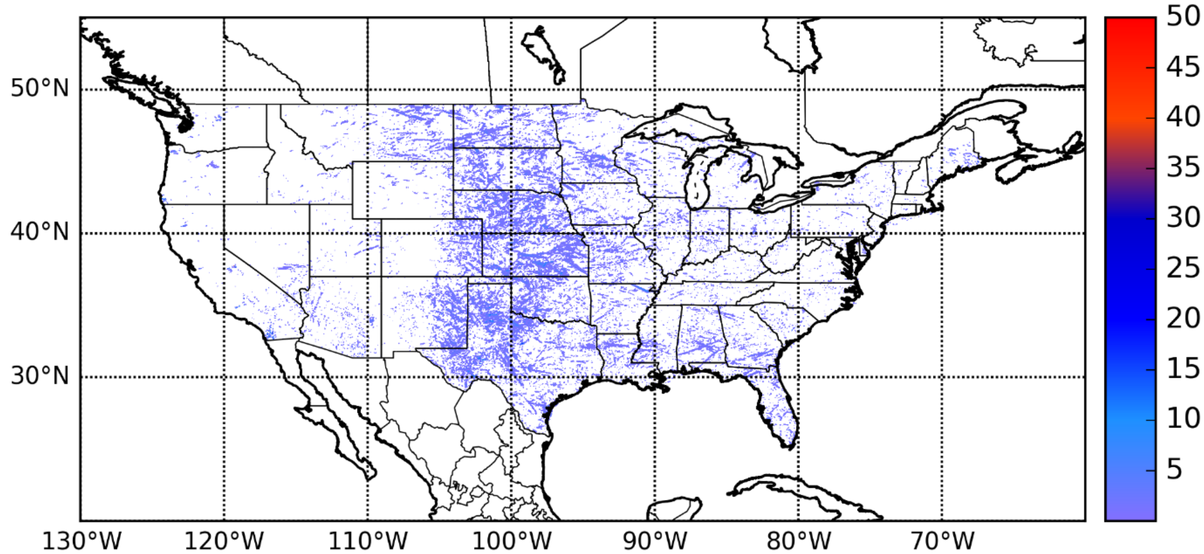


Figure 3. A composite of all Severe MESH counts for 2005 with the quality control measures applied.

Defining a Severe Hail Outbreak Event:
We examined MESH counts and MESH density (number of grid points with MESH count > 0) for four cases (March 26th 2000, May 18th 2000, April 18th 2002, April 28th 2002) that would commonly be accepted as "severe hail outbreaks", and two null cases (June 8th 2001, April 6th 2002) that would not be considered outbreaks. Only days with 200 or more severe hail reports, from the NOAA/NCDC Storm Data database, were considered. To determine acceptable thresholds signifying a severe hail outbreak we looked for: total MESH counts for a given period over which an outbreak event occurred, how the total MESH counts for the period of interest and the entire day compared to the number of SPC hail reports, how the MESH density compared to reports for the day, and the spatial extent of the outbreak event.

All of the cases examined had MESH counts and density greater than 5000. It is logical to expect report totals to be significantly smaller than MESH totals because a single hail report generally represents a large area where more hail likely occurred. MESH counts exceeded 10000 in some outbreak cases. The lowest MESH count total was 8415 and the lowest MESH density was 5915. For the null cases, both had SPC severe hail report totals well below 200. The largest MESH count total for null cases was 1583 and the largest MESH density was 1133. Based on these cases it appears an acceptable MESH threshold would be MESH counts ≥ 5000 and MESH density ≥ 5000. This meets approximately at the halfway point between a more significant null case and a less significant outbreak case. While MESH density was consistently smaller than total MESH counts, across all cases, they were close enough that the same threshold should be acceptable.

Given the stark difference in MESH counts for some severe hail outbreak events, a separate threshold will be applied to determine "significant severe hail outbreak days" where the MESH count and MESH density meet or exceed 10,000. These more significant events will still be counted as regular "severe hail outbreak days" but by having an independent threshold for the most severe of outbreaks we can look for additional trends in the most severe of events.

Planned Work

- Analyze short-term trends in recent severe hail outbreaks using the severe MESH climatology and the definition of "severe hail outbreak" defined here.
- Investigate historical trends in the spatial extent of environments supportive of tornadoes and severe hail outbreaks using reanalysis data.
    - Determine a "severe hail" criteria using parameters signifying environments supportive of severe hail within the North American Regional Reanalysis dataset
        - Create a severe hail environment climatology for the NARR
    - Define a "severe hail outbreak" day for the NARR by using the MESH severe hail outbreak record as ground truth
        - Analyze historical trends in spatial extent and frequency of severe hail outbreak environments
        - Include statistics on the false alarm, hit and miss rates for the NARR severe hail and outbreak records
- Apply the same methodology used to determine severe hail outbreak environments within NARR to tornado outbreak environments within NARR
    - Analyze spatial trends within tornado outbreak environments

Publications

We expect 2 publications to result from this research. The first publication will focus on detailing the creation of the MESH and NARR severe hail climatologies and results from the short and long term trends in severe hail outbreaks. The second publication will cover the analysis of spatial and temporal trends in environments supportive or tornado outbreaks using the NARR.

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

While this project has yet to produce a peer reviewed paper, the graduate student supported by this CICS task is set to present her work at the 2nd European Hail Workshop at the University of Bern, Switzerland on April 19, 2017. She will also be giving several seminars within the next couple of months at the Earth System Science Interdisciplinary Center in Maryland, as well as at the University of Illinois and hopefully at CICS-NC as well.

Climate Data Records and Science Data Stewardship

Climate Data Records (CDRs), also known as Reference Environmental Data Records (REDRs), provide climate-quality satellite and in situ observing datasets that document the Earth's climate and are part of the vast data holdings of the National Centers for Environmental Information (NCEI). NCEI is also responsible for preserving, stew26arding, and maximizing the utility of the Federal government's billion-dollar investment in high-quality environmental data. Key objectives include ensuring the scientific quality, integrity and long-term utility of existing datasets and products and ensuring that all new datasets and any major changes meet internal standards for traceability, lineage, and provenance.

CICS-NC supports efforts at NCEI for the development and transition from research to operations (R2O) of CDRs. While some of this effort is in-house, a significant part of it is accomplished by CICS partner institutions, which include some of the leading climate science practitioners in the nation working in basic and applied research endeavors.

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

CDR Name Here

maturity level as of mm/dd/yyyy

Climate Data Record (CDR) Maturity Matrix

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

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

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

Figure 1: *Updated Bates, et. al. CDR Maturity Matrix*

CDR's primary aim is to develop and sustain as complete and consistent a climate record as possible from remotely sensed and in situ measurements in order to provide users with climate-quality data and information products. Support of these activities requires the highly specialized scientific and technical experience that is currently assembled in CICS-NC.

CICS-NC's climate and instrument researchers and scientific support staff at the senior, mid-career, and junior levels, as well as post-doctoral and graduate students in climate science and related areas, work under the direction of the CICS Director and in coordination with the NCEI project leader and staff, providing necessary skills in the following areas:

- Expertise needed to coordinate the development of calibration and validation activities and approaches for high-quality baseline climate data sets from satellite and in situ observations relevant to documentation and detection of climate change in the land, ocean, and atmosphere.
- Expertise needed to develop, refine, and implement algorithms for daily, global, multi-sensor, optimally interpolated Climate Data Records (CDRs); to characterize the sources and magnitudes of errors and biases in the CDRs; and to develop methodologies for the reduction of these errors and biases.
- Expertise needed to develop high-quality baseline climate data sets from satellite and in situ climate data and develop the relationship(s) between the observed tropospheric and stratospheric trends from the ground-based network with those observed from satellite.
- Software engineering expertise to support coding, code refactoring, code review, database development, and the transition of scientific codes into operationally executable and maintainable processes.
- Development of scientifically-based quality control algorithms for in situ climate data of various time scales (hourly, daily, monthly, annually), methods to detect and adjust for inhomogeneities due to issues such as instrumentation changes or observing station relocations, and scientific analyses of structural uncertainty due to these methods.
- Expertise needed to ensure that research to operation transitions occur between data set development activities and the operational use of these data sets in activities such as climate monitoring and climate research, as well as performing research documenting climate variability and change using the observed record and climate model simulations.
- Expertise to provide "transitions management" of various externally developed CDRs to NCEI.
- Expertise to develop and implement interim CDRs for early use of climate-relevant observations.
- Expertise needed to support the stewardship of archival and current climate observations.
- Expertise needed to provide scientific programming and computer processing support including computing resource access and use and relevant specific project support.
- Data stewardship skills to enhance data curation, standards-based data management, metadata and other data documentation.
- Technical and scientific skills to enhance all aspects of NCEI data discovery and access services, including data interoperability, semantic technologies, no-SQL and graph database technologies, linked open data standards, and other related technologies and standards.
- Operations analysis to explore methods for more effective data ingest, quality assurance, product processing and data archival.

Scientific Subject Matter Expertise Support	
Task Leader	Anand Inamdar, Jessica Matthews, Ge Peng, Olivier Prat
Task Code	NC-CDR/SDS-01-NCICS-AI/etal
NOAA Sponsor	Jay Lawrimore / Russell Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

Highlight: Several CICS-NC scientists have served as subject matter experts on multiple CDR IPTs. Further, they are acting as Product Leads and Portfolio Area Leads for a number of NOAA-NCEI products and portfolios. *https://www.ncdc.noaa.gov/cdr*

Background

Climate Data Record (CDR) IPTs are multidisciplinary teams comprised of members from offices and organizations supporting the transition of research-grade CDRs into an initial operational capability (IOC) status. IPTs are formed to enable efficient and effective collaboration, coordination, and execution and reporting of member's office/organization tasks required to transition the CDR to an IOC state.

The science management practices at NOAA's NCEI are evolving towards a new product portfolio planning approach that borrows from the best practices used widely in both public and private sectors. The objective of this approach is to ensure the focus on stakeholder priorities and to align with today's government environment and expectations. To support this initiative, CICS-NC staff have been enlisted to act as Product Leads for 18 of 173 products, and as Portfolio Area Leads for 2 of 16 portfolios.

Accomplishments

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

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

Subject Matter Expert IPT responsibilities include:

- leading and scheduling IPT meetings needed for resolving technical issues on the products with PIs,
- 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 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 CR and route for signatures
- attending Change Control Board meetings, when needed,

- reviewing PI-submitted documents delivered as part of the WA (C-ATBD, Maturity Matrix, Data Flow Diagram, Implementation Plan) and providing feedback,
- reviewing PI-submitted documents delivered as part of the WA (QA procedure, QA results, VDD, annual reports) for information only, and
- deliver presentation to the NCEI User Engagement Branch on the CDR.

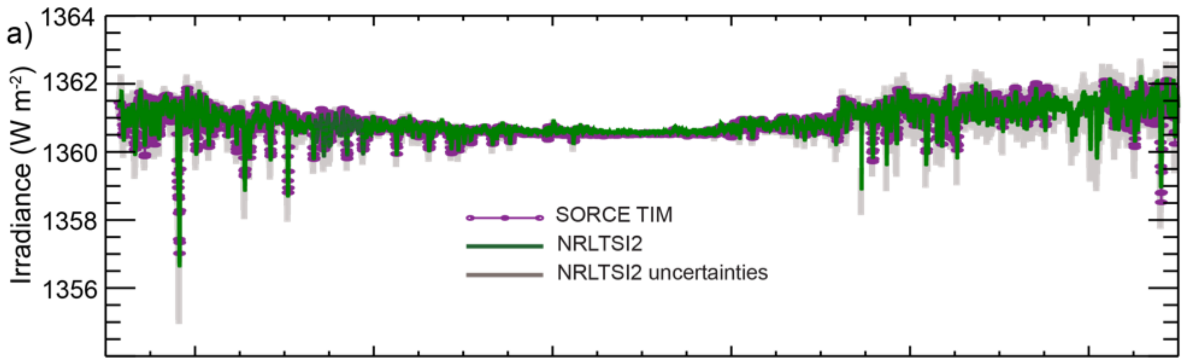


Figure 1: *Comparison of NRLTSI2 modeled output with SORCE TIM observations (v17) between 2003-2014. The NRLTSI2 uncertainties (grey shading) do not include the uncertainty due to the TSI absolute scale, which is approximately 350 ppm.*

Product Lead:

- Land Surface Data Sets / USCRN Science: Drought indices (Bell, Leeper)
- Land Surface Data Sets / USCRN Science: Soil moisture (Bell)
- AVHRR Surface Reflectance CDR (Matthews)
- Normalized Difference Vegetation Index CDR (Matthews)
- Leaf Area Index and FAPAR CDR (Matthews)
- GOES Albedo CDR (Matthews)
- Land Surface Data Sets / USCRN Science: Precipitation Extremes (Leeper)
- Precipitation – CMORPH (Prat)
- Outgoing Longwave Radiation – Monthly CDR (Schreck)
- Outgoing Longwave Radiation – Daily CDR (Schreck)
- Total Solar Irradiance CDR (Inamdar)
- Solar Spectral Irradiance CDR (Inamdar)
- Ocean Heat Fluxes – CDR (Peng)
- Sea Surface Temperature – WHOI CDR (Peng)
- Land Surface Data Sets / Extreme Snowfall (Rennie)
- Sea Ice Concentration CDR (Peng)
- Land Surface Data Sets / ISTI (Rennie)
- Ocean Near Surface Atmospheric Properties CDR (Peng)

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

- Coordinating the following product phases (as appropriate)
    - Development
    - Assessment of maturity
    - Transition to operations
    - Sustainment in operations
    - Upgrades, succession, and retirement

- For operational products, sustaining the product if internally generated or serving as the liaison to external providers.
- Maintaining technical knowledge of the product including characteristics, status, algorithmic approach, dependencies, limitations, sustainment activities, and uses and user requirements, as appropriate.
- Drafting annual work agreements or SOWs, as appropriate, for non-Federal product development, transition and/or sustainment activities.
- Providing regular status reports and participating in technical meetings.

Portfolio Area Lead:
- Land surface properties (Matthews)
- Radiative fluxes (Schreck)

The objective of a Portfolio Area Lead is strategic and coherent planning and management of the product portfolio, this includes:
- Maintain a coherent strategic portfolio vision and plan, including potential new work activities, responsive to evolving user needs.
- Maintain a life cycle management plan for portfolio products, and maintain a high-level schedule to accomplish plans.
- Maintain status and priority ranking of each product in portfolio.
- Review and provide input on product change requests.
- Review and recommend 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 Portfolio Area Leads to support the NOAA NCEI product inventory

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

Total Solar Irradiance and Solar Spectral Irradiance CDRs transitioned to IOC status.

Expansion of CDR User Base through the obs4MIPs Program	
Task Leader	Jim Biard, Jessica Matthews, Olivier Prat, Scott Stevens
Task Code	NC-CDR/SDS-02-NCICS-JB/etal
NOAA Sponsor	Jay Lawrimore / Russell Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

Highlight: Several CICS-NC scientists have worked on a project to make observational products more accessible for climate model inter-comparisons.
https://ncics.org/data/obs4mips/

Background

The aim of this project is to make NOAA Climate Data Records (CDRs) from observational platforms (e.g. satellite, in situ datasets) easily available for evaluating climate model outputs produced for the Coupled Model Inter-comparison Project (CMIP) Phases 5 (CMIP5) and 6 (CMIP6), which are managed by the Program for Climate Model Diagnosis and Inter-comparison (PCMDI) at Lawrence Livermore National Laboratory (LLNL). Results from CMIP5 analyses were used for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, and the CMIP6 results will be used in the sixth report. In order for NOAA CDRs to be used for comparison with CMIP model output, there are some key requirements that need to be met, such as format, temporal/spatial resolution, documentation, and data access support.

CMIP model outputs allow the international climate modeling community to project simulated climate when adjusted to changes in climate forcings (e.g., increase in carbon dioxide for the next several decades). PCMDI's Observations for Model Intercomparison Projects (obs4MIPs) program is an effort to obtain observational datasets that have been reformatted into the standard form used by the CMIP community for their model outputs, allowing the model outputs over historical time frames to be easily compared with actual observations. NOAA CDRs feature observational data that have a "time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change." Unlike most observational datasets, CDRs address the challenges of using data from multiple instruments and provide systematic, comprehensive and sustainable long-term records of several essential climate variables. The international community would benefit greatly from using CDR data together with the CMIP model outputs for addressing critical climate questions.

Accomplishments

The pilot study portion of this project, which involved conversion of three operational CDRs to obs4MIPs form, was completed by March 2015, and these products were submitted to the obs4MIPs data access system. A key accomplishment of the pilot study was development of a configurable software tool for this purpose. Given the success of the pilot study, conversion to obs4MIPs form was begun for another six CDRs (see Table 1).

Table 1. Summary of input NOAA CDRs from the current phase of this project.

Input CDR (temporal resolution, spatial resolution)
Extended Reconstructed Sea Surface Temperature (monthly, 2°)
Fraction of absorbed photosynthetically active radiation (daily, 0.05°)
Leaf Area Index (daily, 0.05°)
Normalized Difference Vegetation Index (daily, 0.05°)
Brightness temperature - GridSat (monthly, 0.25°)
Precipitation - PERSIANN (daily, 0.25°)

Good initial progress was made on producing obs4MIPs datasets for these six products. The team interacted with NCEI Subject Matter Experts (SMEs) to determine the best approach for converting each product, and to determine appropriate values for metadata elements that are stored in each dataset. Sample and full datasets matching the CMIP5 file format were produced for each product, and were provided to the SMEs for validation. These datasets were incomplete, in that certain required metadata elements were filled with placeholders, but the rest of their contents could be evaluated for correctness.

In addition to validating the datasets, the SMEs wrote Technical Notes for them. Each dataset that is submitted to PCMDI must be accompanied by a Technical Note describing the dataset and its use at a graduate student level.

PCMDI is the source for a number of metadata elements required for each dataset, and the needed elements for some of the datasets being converted were not yet defined at project onset. PCMDI decided that the necessary metadata elements would only be defined for the CMIP6 format, and they requested that the new datasets be produced to match the CMIP6 format. Waiting for the metadata elements to be defined and modifying software to produce outputs matching the CMIP6 format limited the amount of progress that could be made in the latter part of 2016 towards making final versions of the six datasets and submitting them. These issues have been resolved in March 2017, paving the way to complete and submit the six datasets.

An additional dataset has been identified for conversion to obs4MIPs format in 2017. Conversion of the Blended Sea Winds dataset will commence once the current six datasets are submitted.

Planned Work

- Finish software changes to produce CMIP6-compatible datasets.
- Finalize the metadata content for each dataset.
- Convert a subset of each CDR dataset to obs4MIPs form using the software tool.
- Verify subset outputs from the tool against the original CDRs.
- Validate the metadata contained in the obs4MIPs datasets that were produced.
- Convert full periods of record for the CDRs to obs4MIPs form using the software tool.
- Verify the full outputs from the tool against the original CDRs.
- Work with the SMEs to get a full set of Technical Notes.
- Submit the completed dataset packages to PCMDI.

Publications

- Matthews, J.L. Obs4MIPs Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) CDR Technical Note. 9 pp., August 2016.
- Matthews, J.L. Obs4MIPs Leaf Area Index (LAI) CDR Technical Note. 7 pp., August 2016.
- Matthews, J.L. Obs4MIPs Normalized Difference Vegetation Index (NDVI) CDR Technical Note. 8 pp.,
  August 2016.
- Prat, O.P. Obs4MIPs PERSIANN-CDR Technical Note. 10 pp., July 2016.

Other

- Jim Biard spent three days in September 2016 with PCMDI personnel at Lawrence Livermore National Laboratory to update the obs4MIPs conversion effort to using the CMIP6 format.

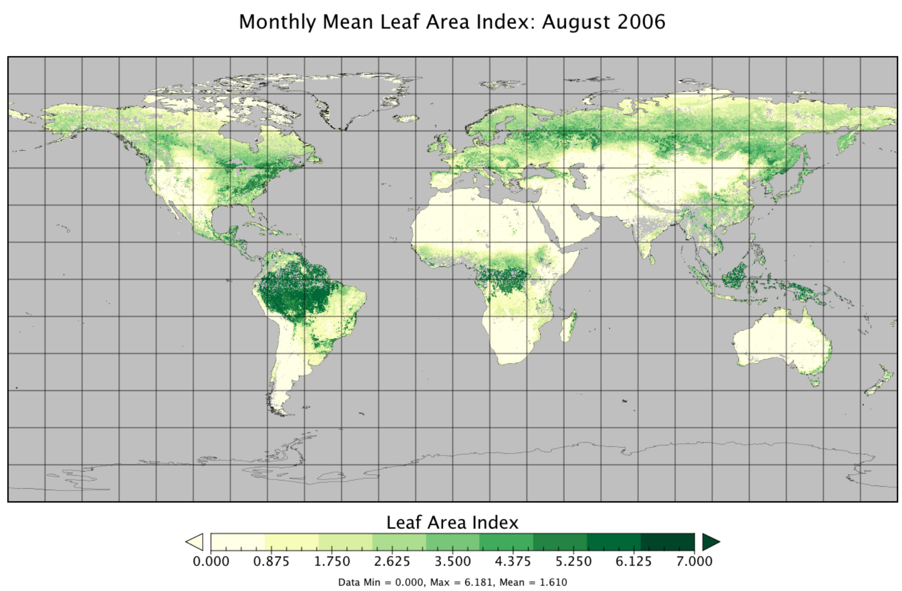


Figure 1. A sample image from the obs4MIPs Monthly Mean Leaf Area Index dataset.

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

Optimum Interpolation Sea Surface Temperature (OISST) Transition to Operations	
Task Leader	Jim Biard
Task Code	NC-CDR/SDS-03-NCICS-JB
NOAA Sponsor	Jeff Privette
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%, Theme 2: 100%, Theme 3: 0%
Main CICS Research Topic	Climate and Satellite Observations and Monitoring
Contribution to NOAA goals (%)	Goal 1: 100%, Goal 2: 0%, Goal 3: 0%, Goal 4: 0%
Highlight: The OISST production software was refactored to meet Climate Data Record Program requirements for operation readiness.	
https://www.ncdc.noaa.gov/cdr/oceanic/sea-surface-temperature-optimum-interpolation	

Background

A primary requirement in bringing Climate Data Records (CDRs) to operational readiness within NCEI is that the software is stable, reproducible, portable, and efficient. The CDR Program works with the Principal Investigator to ensure that incoming CDR software meets these goals for long-term stewardship and transparency. To that end, the Optimum Interpolation Sea Surface Temperature (OISST) product was selected as a pilot case for investigating the feasibility of refactoring scientific software to meet CDR program requirements while keeping costs manageable.

The OISST software was originally written by CICS staff scientist Dr. Richard Reynolds, and currently runs operationally within the NCEI. OISST is a high-quality product with many end users in the scientific and business communities. While the software runs efficiently, its source code contains a large amount of redundancies, difficult to follow “spaghetti” code, and incomprehensible variables. In addition, it is written in a proprietary language package, has many hardcoded paths, and requires data inputs retrieved via ftp from permission-based sources, all of which affect the portability of the OISST software.

The OISST refactor project has consisted of several scheduled phases conducted by three to four part-time to full-time NCEI staff. These phases included a Technical Assessment Review, source code refactoring, control script refactoring, operational framework integration, Test Readiness Review/system testing, and Operational Readiness Review, as well as writing an Operational Algorithm Document (OAD), which is necessary for ongoing sustainment by NCEI personnel and for CDR customers wishing to reproduce OISST results.

In the course of the work done during FY 2015, discrepancies between the results from the production code running on a 32-bit server and the refactored code running on a 64-bit server with a newer operating system and compiler were traced to a bug in the older compiler used to compile the production applications. The production applications were compiled with optimizations enabled, and the optimizations were introducing small but significant errors in the results from all transcendental functions (sine, cosine, log, etc.). Compiling with optimizations enabled using the newer compiler on the 64-bit system introduced no errors. Many of the activities for FY 2016 revolved around characterizing these errors which, for consistency, must be left in place in the production system.

Accomplishments

FY 2016 planned work included:

- Compile the production software on the 32-bit server with optimizations disabled (the source of the introduced errors) and compare the outputs from a run using the fixed input dataset with the outputs from the refactored software compiled on the 64-bit server.
- Determine if any changes to the refactored software are mandated by the analysis results. If there are, make the changes and redo the analysis.
- Assist NCEI personnel as needed with reprocessing the entire period of record for the OISST dataset.
- Assist NCEI personnel as needed with final testing and review of the refactored software.
- Assist NCEI personnel with preparing presentations and journal articles that will explain the differences between the current version of the OISST dataset and the version that will be released when the refactored code goes into production.

Analysis of the results from the comparative runs between the non-optimized production and refactored applications uncovered what amounted to a bug in the refactored code. Code had been changed in the refactored software source in an attempt to remove differences seen between the faulty optimized production software output and the refactored code output. This code change was removed from the refactored software, producing a much better match to the non-optimized production output. No other code changes were identified during this effort. The difference in the comparisons can be seen in *Figures 1 and 2*.

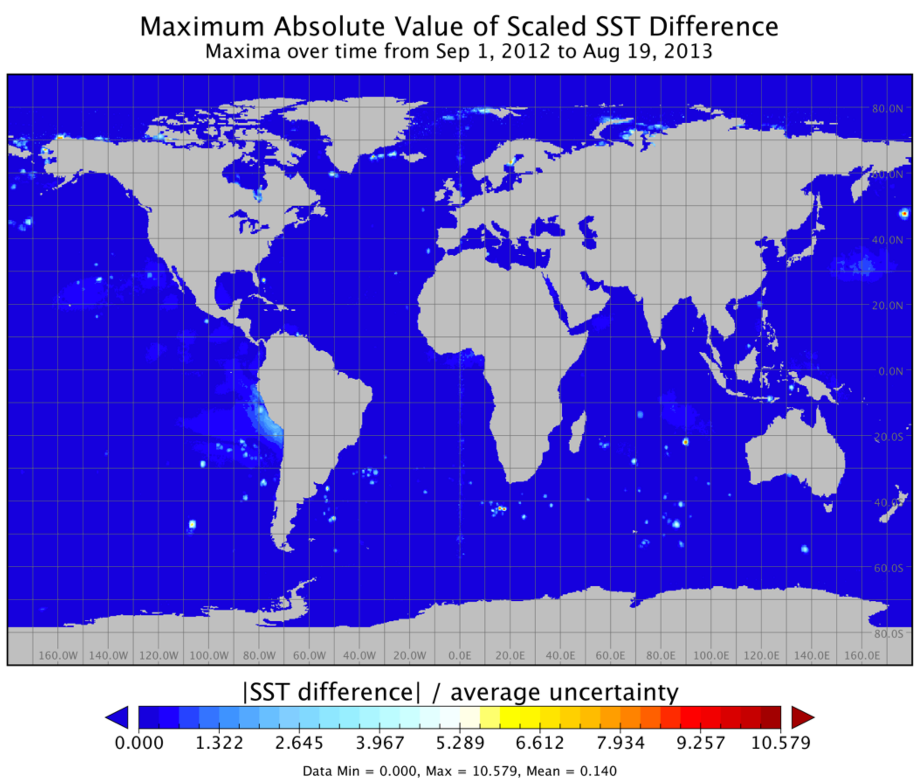


Figure 1. The maximum over time of the absolute value of the difference between the 32-bit production and 64-bit refactored OISST outputs scaled by the mean uncertainties optimization and code errors present.

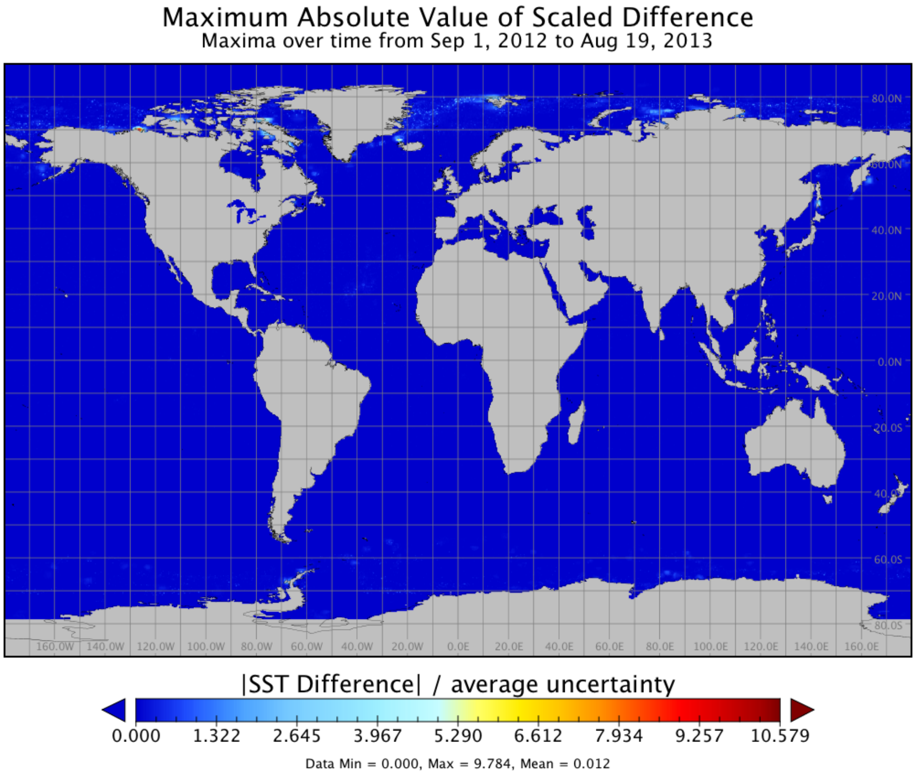


Figure 2. The maximum over time of the absolute value of the difference between the 32-bit production and 64-bit refactored OISST outputs scaled by the mean uncertainties optimization and code errors removed.

A problem developed in the real-time production software output while these analyses were being performed. OISST production depends on sea surface temperature (SST) measurements from buoys and ships, and one buoy had started to report erroneous values. The changes in the values were slow enough that existing filtering algorithms failed to exclude them, and they ended up producing a significant skewing of temperatures in the Indian Ocean. This problem was resolved by developing a "bad buoy" exclusion step in the processing workflow. A script was written that filtered the buoy and ship SST inputs, excluding all measurements from given buoys and ships over specified time ranges. This script was incorporated into the production workflow and added to the refactored workflow.

The refactored software scripting, which provides the framework for running the applications involved in OISST production, was also modified to make it easier to use, making sure that inputs and outputs could be set to be stored on different file systems, and making it easier for users to run the software.

NCEI personnel were assisted with various smaller tasks as they continued with the testing and review of the refactored software.

Planned Work

- CICS-NC planned work for this activity has come to an end. Low-level advisory help will continue as needed.

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

Common Ingest Agile Development Team	
Task Leader	Linda Copley
Task Code	NC-CDR/SDS-04-NCICS-LC
NOAA Sponsor	Scott Hausman
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 25%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%

Highlight: Enhanced NCEI Common Ingest system with data security scanning, streaming aggregation, dynamic FTPS feeding, NCEI archive, and shell aliasing processors. Worked with NCEI operations to secure, drive, engineer, and support deployment of system.

Background

The system used at NCEI-NC for ingest and archive of weather and climate data archives up to 6.7 terabytes per day, packaged into as many as 39,000 archive information packages, yet its technical capacity is at risk of being outpaced by the growth in data sets being submitted for archive at NCEI-NC. The effort targeted at evolving the IAS to a new software architecture have been overcome by a constant barrage of operational issues and bug-fixes.

The NCEI-CO Common Ingest (CI) system has recently undergone a redesign to provide a generic, workflow-driven common ingest system that is independent of dataset-specific requirements. The system implements a modern software architecture and provides a browser-based interface for configuration and monitoring. Rather than crafting our own solution, the merging of the teams at NCEI-NC and NCEI-CO provided us with the opportunity to leverage the NCEI-CO Common Ingest system to fulfill the ingest needs at NCEI-NC.

Accomplishments

As members of an agile software development team, we worked in concert with Federal employees and contractors to modify the Common Ingest system for use at NCEI-NC. The initial phase of the project had the goal of implementing an initial dataset at NCEI-NC. The follow-on phase of the project involves replacing all of the functionality of the outdated system currently in use.

Security Enhancements: Based on input from the NCEI-NC IT Security team, we completed software security enhancements to implement the Open Web Application Security Project (OWASP) Top 10 web application security best practices. Security enhancements for the Common Ingest system included the addition of user authentication and authorization, password encryption and enabling https. Various security remediations were performed to prevent cross-site scripting (XSS), cross-site request forwarding (CSRF), SQL injection, and the addition of whitelists to restrict the movement of files outside of the Common Ingest system. This security remediation also included upgrading the underlying software stack to the latest versions, including Grails 3 and Java 8. The implementation of these security best practices allows us to provide to NCEI an application that minimizes the IT security risk.

File Aggregation: To support the dynamic streaming model of data ingest used at NCEI-NC, we made significant modifications to the processing engine which aggregates files based on time period (e.g.

hour, day, month). Since files can arrive over the course of a month, for example, the processor needs to be able to group files into "buckets" for later aggregation, and then wait for the time period to expire prior to creating the aggregation (i.e. "tar" file).

File Archive: Individual processors were created for the archive of data to each of the NCEI-NC archives—an HPSS archiver for the local High-Performance Storage System, and the CLASS archiver for submissions to NOAA's Comprehensive Large-Array Stewardship System. Both archivers send files to the indicated archive, and also create the manifest as required by the specific archive.

Security Scanning: In order to facilitate the scanning of each file that is ingested at NCEI, we created a security scanner engine which will implement the security scanning software as chosen and controlled by NCEI IT Security. We also modified the system to use the RabbitMQ Shovel plug-in to allow secure passing of messages on specific queues across the firewall. This allows us to run required components in the non-secure landing zone to retrieve files, while managing the system and performing the bulk of the processing on the secure system inside the NCEI firewall.

Additional Modifications: Additional modifications to Common Ingest included UI enhancements, a shell command alias feature to support complex shell command processing from Common Ingest, a toggle to turn the REST API off, FTPS ingest capability, and enhancement of the data stream restart capability to support the dynamic stream processing paradigm and for the multi-step HPSS archiving process.

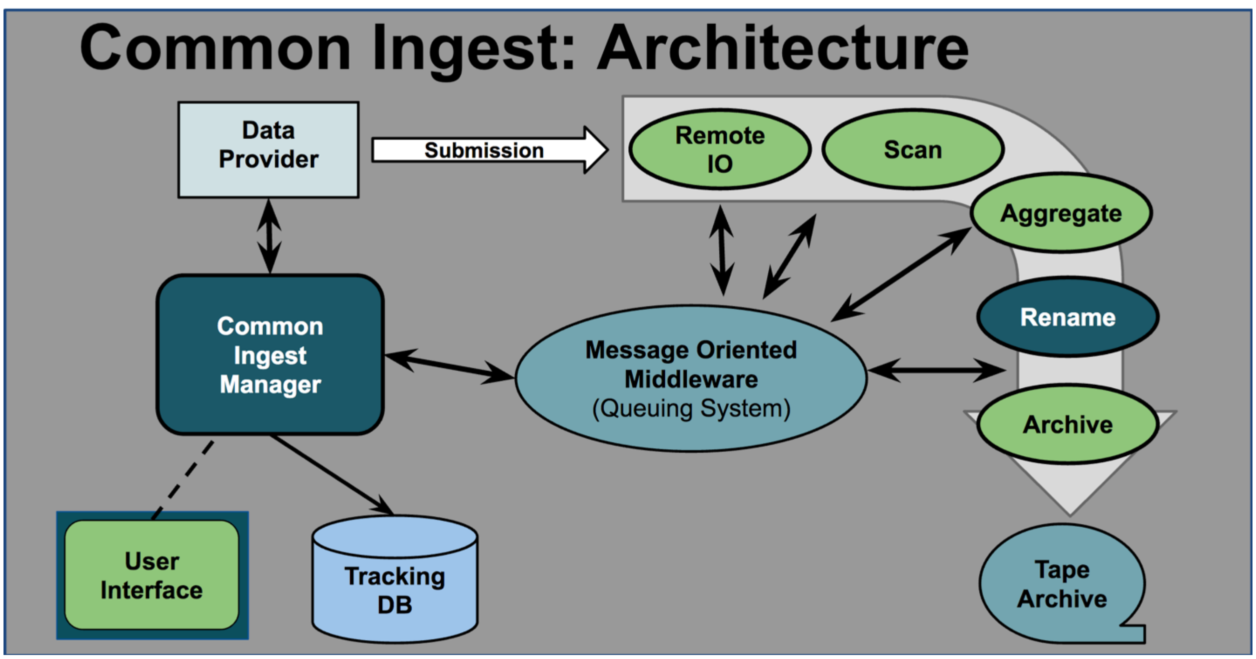


Figure 4. Common Ingest Architecture (green highlights: components with significant upgrades)

Deployment to Operations: After working with NCEI-NC IT to specify and build a 3-tier environment for Common Ingest at NCEI, the Common Ingest system was deployed to NCEI in the development, test and production environments. A successful test of data ingest was performed in the NCEI-NC production environment. To prepare for the transition to operations in the NCEI environment we coordinated with the NCEI-NC IT department to create an automated deployment environment for the three tiers. To enable the deployment of Common Ingest in multiple NCEI locations, we modified the software to allow differing software configurations to be loaded based on the operational location.

Operations Support: In support of the transition to operations of the Common Ingest system, we created specific detailed documentation that represents Common Ingest usage at NCEI-NC. We provided several training classes for the Common Ingest operators, and have supported the operators as they have configured and tested over 170 data streams in the NCEI-NC test environment.

Planned Work

- Implement functionality for NEXRAD processing flow
- Implement processing engine to open a tar file and continue processing on un-tarred files
- Enhance Common Ingest User Interface to improve user experience
- Provide monitoring of Common Ingest system components
- Create automated backup for Data Stream configurations
- Continue to drive operational deployment of system at NCEI
- Investigate and plan upgrade to state of the art stream processing solutions.

Products

- Common Ingest components deployed in NCEI production
- Ingest-manager v1.2.0
- Ingest-engines v1.2.0 cleanup
- Ingest-engines v1.2.0 dynamic-feeder
- Ingest-engines v1.2.0 hpss-archiver
- Ingest-engines v1.2.0 path-transformer
- Ingest-engines v1.2.0 remote-io
- Ingest-engines v1.2.0 restart-processor
- Ingest-engines v1.2.0 shell-processor
- Ingest-engines v1.2.0 time-aggregator
- Common Ingest components complete; awaiting NCEI deployment
- Ingest-engines v1.2.0 class-archiver
- Ingest-engines v1.2.0 move-file-processor
- Ingest-engines v1.2.0 security-scanner

Presentations

- L. Copley: Common Ingest, NCEI Seminar Series, April 18, 2017

Other

- NOAA NCEI 2016 People's Choice Award for Team Excellence – Linda Copley
- NOAA NCEI 2016 People's Choice Award for Team Excellence – Louis Vasquez

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**9**
# of products or techniques submitted to NOAA for consideration in operations use	**3**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**1**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Delivered 9 Common Ingest components (see 'Products') that are deployed in the NCEI production environment. Delivered 3 Common Ingest components (see 'Products') that are awaiting deployment in the NCEI production environment. L. Copley made a presentation for the NCEI Seminar Series.

NOAA PERSIANN-CDR Support for Hydrologic and Water Resource Planning and Management	
Task Leader	Kuolin Hsu
Task Code	NC-CDR/SDS-05-UCI
NOAA Sponsor	Jeff Privette
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 75%; Goal 2: 25%; Goal 3: 0%; Goal 4:0%

Highlight: The PERSIANN Precipitation Climate Data Record (PERSIANN-CDR) processed precipitation datasets at daily 0.25^0 lat-long scale covering from 60°S to 60°N and 0° to 360° longitude from 1983 to August 2016. Application of PERSIANN-CDR to hydro-climatological studies is demonstrated.

Background

PERSIANN-CDR is a daily near-global precipitation product for the period of 1983 to near current time. The data covers from 60°S to 60°N and 0° to 360° longitude at 0.25-degree spatial resolution. This relatively long record of high-resolution, near-global precipitation estimates is particularly useful for climate studies.

The PERSIANN-CDR product is generated for each time step by estimating precipitation for each GridSat-B1 Infrared Window (IRWIN) file using the PERSIANN algorithm. Each month of PERSIANN estimates is then bias corrected with monthly GPCP precipitation data and the final PERSIANN-CDR product results when those bias-corrected precipitation estimates are accumulated to daily. The PERSIANN-CDR data flow chart is listed in *Figure 1*.

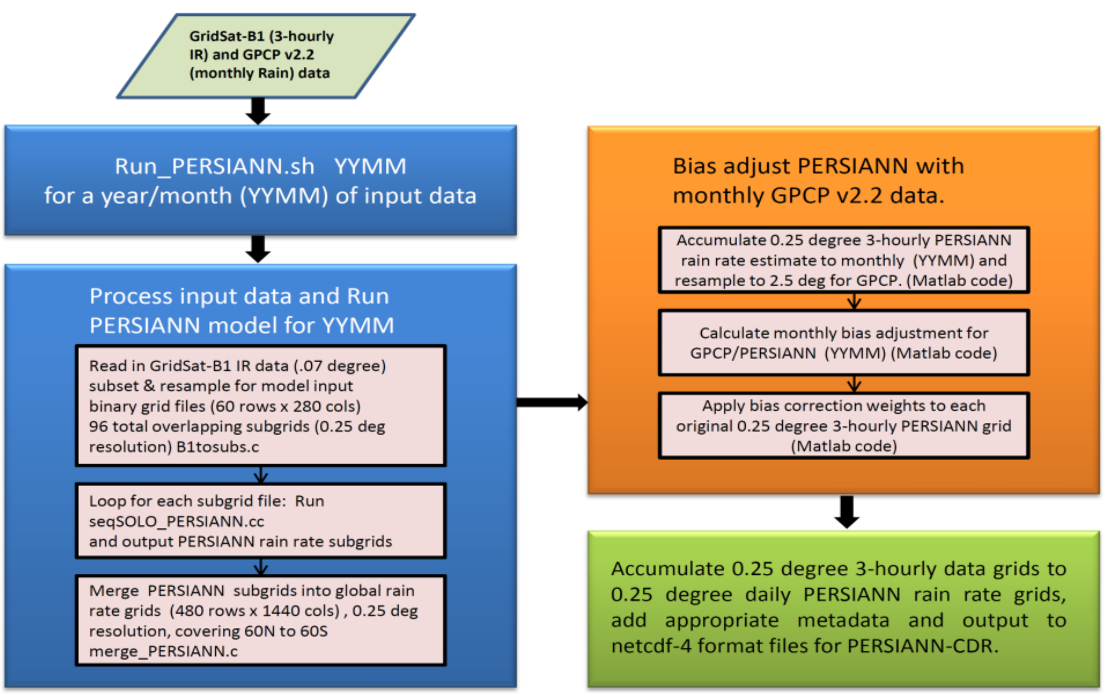


Figure 1. The PERSIANN-CDR flowchart

Accomplishments

This final report reflects work from April 1, 2016 through project end in 2016. During this report period, we continued processing PERSIANN-CDR data for public use and demonstrated the usefulness of the data for hydroclimate studies.

1. *CDR Data Processing and Archive:* PERSIANN-CDR daily data was processed up to August 2016.

2. *CDR Data Application: PERSIANN-CDR data was applied* to the streamflow simulation over experimental watersheds. The runoff simulation from other high-resolution precipitation products (Stage IV & TMPA-V7), and the USGS streamflow gauge observation were included in the evaluation. The experimental results were published in the Journal of Hydrometeorology (see Ashouri et al., 2016.)

Products

- Update of PERSIANN-CDR software and data product for the daily precipitation analysis at 0.25-degree resolution
- Documentation for software and data product
- Demonstration of PERSIANN-CDR data in hydrologic applications

Publications

- Ashouri, H., P. Nguyen, A. Thorstensen, K. Hsu, S. Sorooshian, and D. Braithwaite, Accessing efficacy of high-resolution satellite-based PERSIANN-CDR precipitation product in simulating streamflow, *Journal of Hydrometeorology*, 17, 2061-2076. 2016. doi: 10.1175/JHM-D-15-0192.1

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

Spatial-Temporal Reconstruction of Geostationary Land Surface Temperature for Multi-Sensor Data Fusion	
Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-06-NCICS-AI
NOAA Sponsor	RussellVose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3:0%; Goal 4: 0%

Highlight: Geostationary Earth Orbit thermal infrared data combined estimates of net surface solar radiation (or surface solar absorption) derived from the visible channel is used in reconstructing the temporal evolution of LST even under partially cloud-contaminated conditions.

Background

Land surface temperature (LST) is a key parameter in the initialization of climate models, in many environmental studies, and in applications related to water resources management over agricultural sites. Conventionally remote sensing data from infrared sensors aboard polar orbiting and geostationary satellites have been used in the retrieval of LST. But the bulk, if not all, of the retrieval techniques are limited to clear sky conditions, and accuracy of the retrieved LST depends upon the effectiveness of the cloud-clearing scheme. Missing LST values due to the presence of clouds constrains the potential application of the available satellite LST products. Diurnal evolution of the LST is strongly correlated with the diurnal pattern of surface absorbed solar radiation. Results from a companion study on the diurnal variation of net surface solar radiation (Inamdar & Guillevic, 2015) provides a promising option to fill in the spatial and temporal gaps in LST values even under partially cloud-contaminated conditions.

Accomplishments

One month of recently reprocessed gridded GOES data (Knapp & Matthews 2016), MODIS level 2 data of LST and land surface emissivity, corresponding results of net surface solar radiation (Inamdar & Guillevic 2015), along with a host of ancillary data have been employed in producing hourly LST values over the CONUS for the month of April 2007. The gridded GOES data available at NCEI represent remapped and calibrated GOES brightness temperatures, and reflectance provided in CF-compliant netCDF format in collaboration with sustained and coordinated processing of Environmental Satellite data for Climate Monitoring (SCOPE-CM). Retrieved LST values have been validated with in situ measurements available from the NOAA’s surface radiation measurement network (SURFRAD) stations.

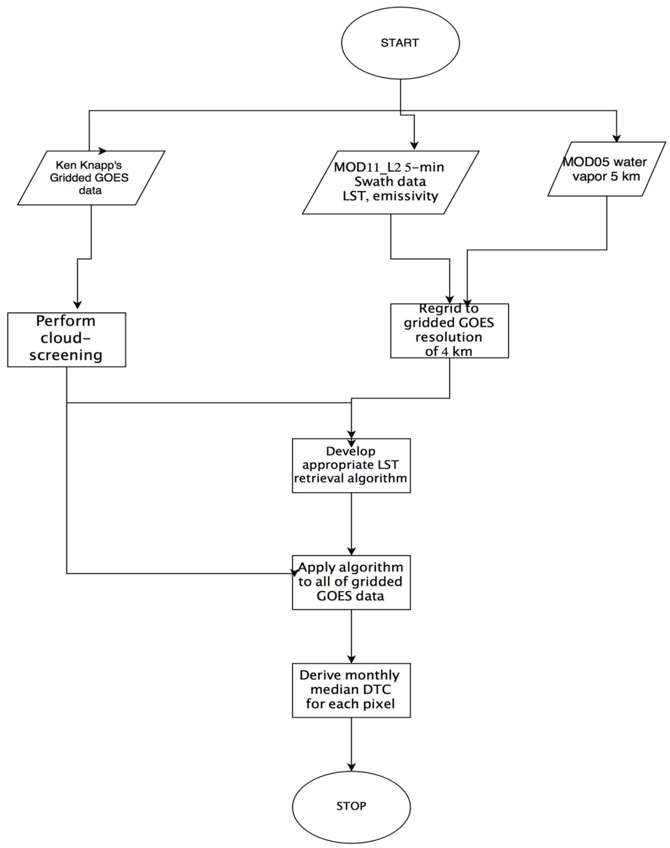


Fig. 1. Schematic of LST retrieval from geostationary satellite imagery.

Planned Work:

- Extension of the LST retrieval for extended time spans (at least 2 years);
- Develop scheme to estimate the thermal inertia of surface and link with the measured soil moisture at USCRN sites;
- Investigate the relationship between soil moisture/thermal inertia and LST analyzing data from the USCRN sites.

Presentations:

- Anand Inamdar & Ken Knapp, 2016: Estimation of land surface temperature under all-sky conditions. Presented at the AGU Fall Meeting, San Francisco, Dec 2016.

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

Calibration of the Visible Channel of the ISCCP B1 Data for the Extended Period (2010-2015)	
Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-07-NCICS-AI
NOAA Sponsor	RussellVose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 70%; Theme 3: 30%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3:0%; Goal 4: 0%

Highlight: Calibration of the Geostationary Earth Orbit (GEO) visible channel in the ISCCP B1 data stream, based on the AVHRR PATMOSx data, completed for all meteorological satellites for the period 1979-2009, has been performed for the GOES series of satellites beyond 2009, and now being extended to other geostationary satellites in the series.

Background

The ISCCP (International Satellite Cloud Climatology Project) B1 data represents geostationary imagery at 3 hourly and 10 km spatial resolution retrieved from the suite of geostationary meteorological satellites all over the world. It is currently being employed in the reprocessing of the ISCCP Cloud Climatology H-series products, surface radiation budget and aerosol retrieval at higher spatial resolution. The present calibration has been performed for data provided by each individual Satellite Processing Center (SPC), without constraining for the space constant. However, for use in the GSA project, calibrations will be performed for the entire time series of each satellite irrespective of the source SPC and constrained to the prescribed space constant.

Accomplishments

Calibration for the METEOSAT, GMSm and INS series for the extended period of 2010–2015 (see attached figure) using AVHRR PATMOSx data as reference has been completed. Calibration for all the GEOs has been performed separately through implementing the ISCCP calibration procedure (in a separate effort under “ISCCP Transition to NCEI” task) and provides an independent source of comparison. Comparisons reveal a systematic higher bias for the ISCCP which is being investigated.

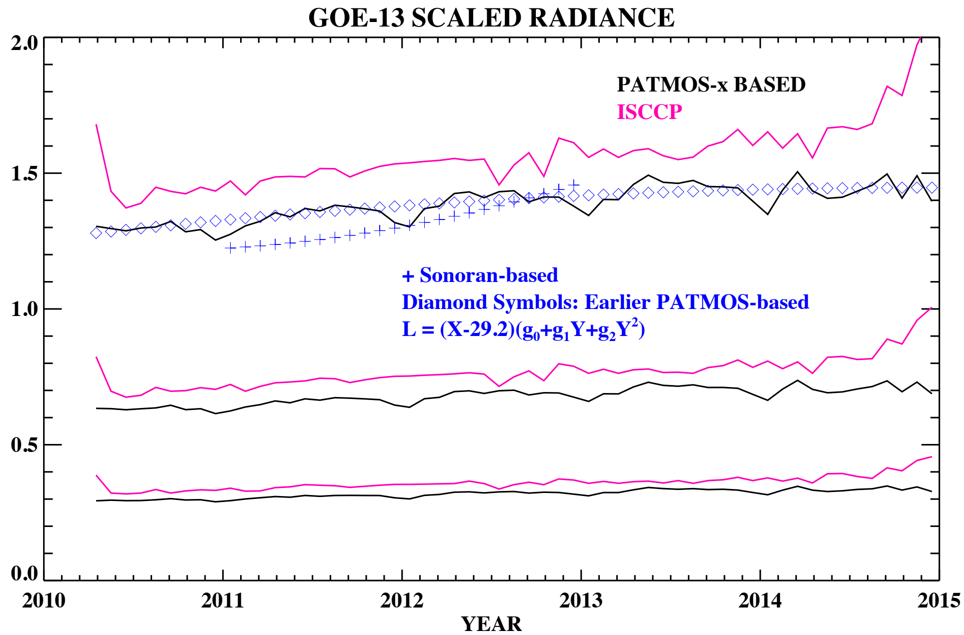


Fig. 1. Time variation of the scaled radiance for 8-bit count values of 64 (bottom pair of curves), 128 (middle pair of curves) and 254 (top pair of curves) derived from ISCCP (magenta) and PATMOSx (dark) using the monthly slope and intercepts. The blue-colored diamond symbols represent the count value of X = 254, monthly slope, and intercept fit into the standard form of scaled radiance, $L = (X - X_0)(g_0 + g_1 Y + g_2 Y^2)$*, with Y representing number of years since launch. The + symbols refers to independent calibration based on the views of the Sonoran Desert target.*

Planned Work

- Continue processing of calibration with PATMOS-x reference for all GEOs;
- Perform independent calibration with desert targets over other regions for the extended period and compare results.

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

The improved product is the set of calibration coefficients for the extended period.

Transitioning of ISCCP processing to NCEI-NC	
Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-08-NCICS-AI
NOAA Sponsor	RussellVose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: %; Theme 2:70%; Theme 3:30%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3:0%; Goal 4: 0%
Highlight: https://www.ncdc.noaa.gov/isccp	

Background

The International Satellite Cloud Climatology Project (ISCCP) began in 1983 under the leadership of Dr. William Rossow (CCNY and GISS) with the objective of pooling the radiance from the suite of meteorological satellites around the globe and the polar orbiting AVHRR sensors to derive a cloud climatology of the Earth. It is one of the longest-lived and most widely used satellite climate datasets in existence. It has been extensively cited in the peer-reviewed literature. An example of its widespread application is the ISCCP simulator, an algorithm developed to mimic ISCCP observations from Global Climate Models (GCMs) in order to evaluate model simulation of current environment. This simulator is in widespread use today. Furthermore, ISCCP data (and its derivative datasets) have been used to study and understand a wide array of weather and climate phenomena, including: clouds, Earth's radiation budget, aerosols, surface radiation budgets, renewable energy, hurricanes, tropical cyclone genesis, climate modeling, stratospheric moisture, weather states, cloud forcing, cloud feedbacks, and the relationship of clouds with numerous other phenomena.

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

Accomplishments

The latest version of the ISCCP processing code, Build 5, following its initial implementation in 2015, and additional upgrades has been successfully deployed in H-series production for the baseline period (1983–2009). Post-production review of results both by the internal NCEI team and Bill Rossow (PI) continues. These activities have unearthed several issues related to the input data resulting in some code updates and quarantining of bad B1U and GAC data. Where possible, data gaps have been filled and some bad data files have been corrected. Currently, production for the full baseline period has been completed and years 1989–2009 have been reviewed and approved for transition into the archive by the PI. Archival of the full baseline period data is on the verge of completion and an ORR (Operational Readiness Review) is scheduled for May 2017, accompanied by a presentation to the NCEI Science Council. Following implementation of an additional package for adding new satellites and calibration monitoring Cal Add-on software, calibration of AVHRR GAC data for NOAA-18 polar orbiter and B1U data has been processed and is being analyzed. The ISCCP-implemented B1U calibrations for the VIS channel compare favorably for the METEOSAT and GMS series with the PATMOSx-based calibrations for the visible channel. Some differences noted for the GOES-13 and GOES-15 satellites are being investigated.

ISCCP H-series product updates have been presented at the GEWEX Data and Assessments Panel (GDAP) meeting Nov 30-Dec 1. GDAP is being added as an advisory board for the H-series data based upon their request. The ISCCP team has received and responded to more than 15 data requests from users in the last six months. One of the major users has been Dr. Paul Stackhouse of the NASA Langley Atmospheric and Radiation Sciences branch representing the GEWEX. A stripped-down version of the full ISCCP data product (called ISCCP- BASIC) with fewer variables is also being simultaneously produced and scheduled for archival. This version will also accommodate a few additional variables needed in a cloud inter-comparison studies by GDAP.

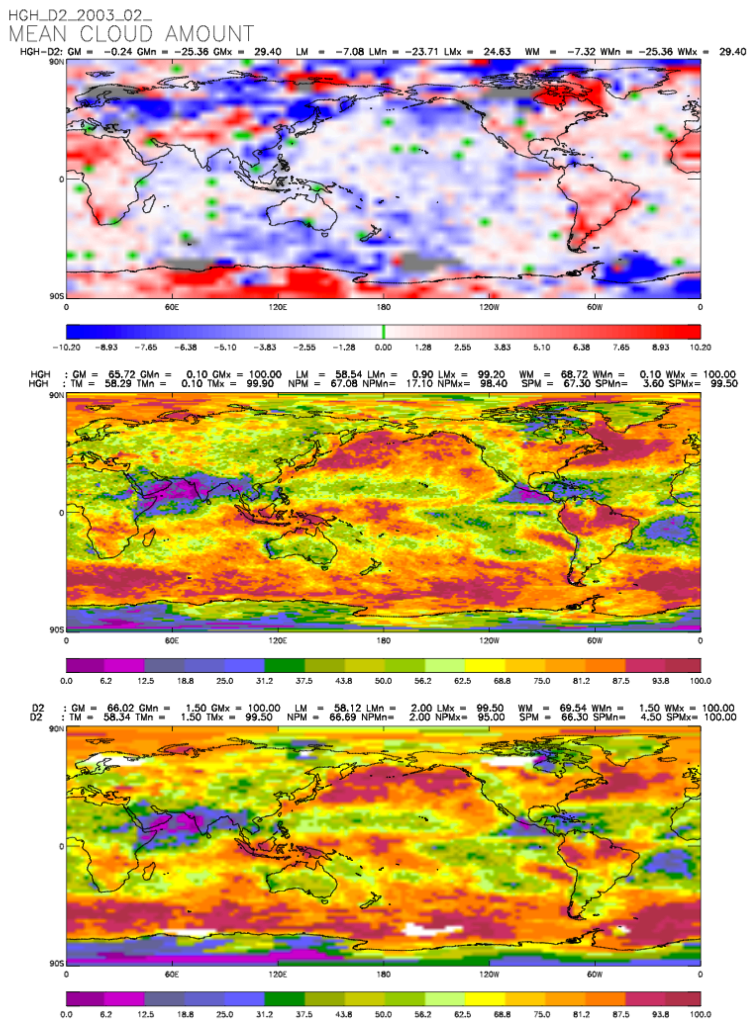


Fig. 1. H-series global hourly cloud mean amounts (middle panel) for 2003 Feb 1500 hrs vs the corresponding D-series product (bottom panel), showing improvements attained in the H-series. The top panel shows the difference plot.

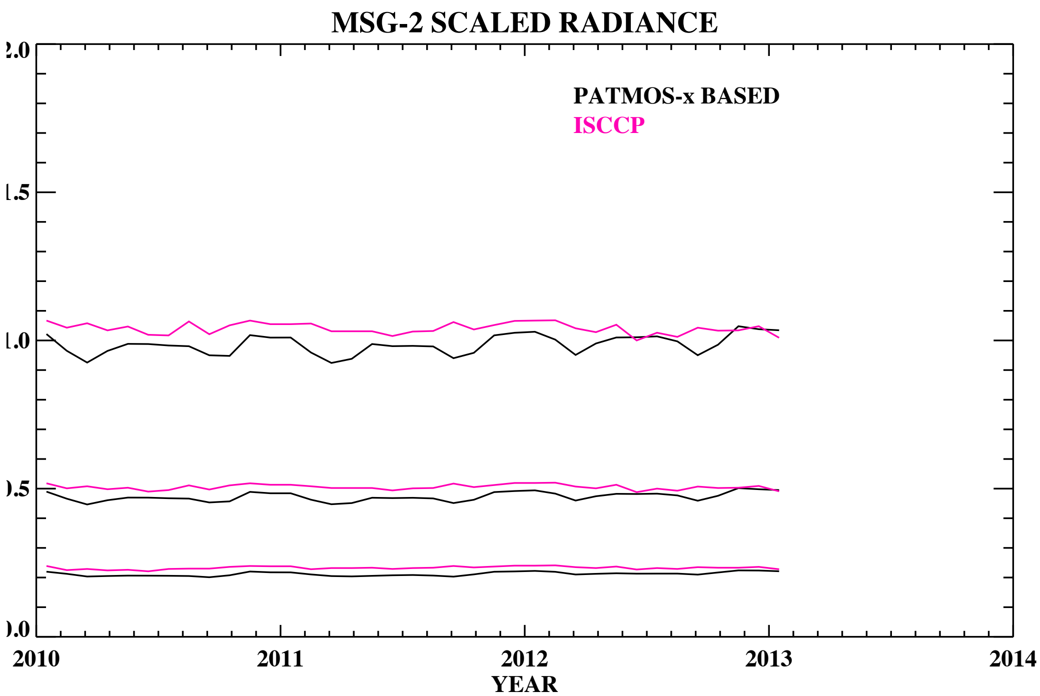


Fig. 2. Comparison of ISCCP-implemented and PATMOSx-based calibration of the VIS channel for MSG-2 satellite for the extended period. The 3 curves represent (bottom to top order), time series of scaled radiance for count values of 64, 128 and 256 (8-bit) respectively.

Planned Work:

- Resolve differences of ISCCP calibration for GEO Visible channel with PATMOSx;
- Finalize and prepare HBT tables for all GEOs for the extended period production runs
- Provide support in the sharing of ISCCP H-series cloud products among the diverse scientific community and receive feedback;
- Assist the team in the evaluation of cloud products for the extended period;
- Provide support in disseminating ISCCP H-series results through conference, symposia and journal publications.

Presentations:

- Anand K. Inamdar, K. R. Knapp, A. H. Young, W. Hankins, and W. B. Rossow. Calibration of Historical Visible Geostationary Data for ISCCP and Other Applications, Poster presented at the 21st Conference on Satellite Meteorology, Madison WI Aug 17 2016.
- Alisa Holley Young, W. B. Rossow, K. R. Knapp, W. Hankins, and A. K. Inamdar, ISCCP H-Series data production at NCEI: Updating the iconic ISCCP data. Poster presented at the 21st Conference on Satellite Meteorology, Madison WI Aug 17 2016.
- William Hankins, K. R. Knapp, A. H. Young, A. K. Inamdar, and W. B. Rossow, ISCCP Data QC and Processing: Transitioning Production Between Institutions. Poster presented at the 21st Conference on Satellite Meteorology, Madison WI Aug 17 2016.

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

The H-series cloud products for the base period (1983-2009); the HBT calibration tables for the extended period.

Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES data	
Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-09-NCICS-JM
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: The GSA algorithm is being implemented as the American contribution of an international collaboration between Europe, Japan, and the US to produce a joint climate data record. **http://www.scope-cm.org/projects/scm-03/**	

Background

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

Previously, as part of the SCOPE-CM agreement, the GSA algorithm was run with GOES data for a pilot period of 2000–2003. A project charter was developed in July 2014 describing the implementation of a related land surface albedo product, the so-called Albedo of the Americas (AOTA). This product will be focused on the Americas, which is the primary user base of the CDRP, and will provide greater temporal resolution and historical extent than other available albedo data sets. In short, the scope of the plan is to process 1995–2015 GOES-GVAR data (GOES-8 through 15) using the SCOPE-CM algorithm with a unified approach to calibration and handling of NWP inputs.

Accomplishments

This project is one of only 10 selected by the SCOPE-CM Executive Panel from open competition. We proposed to extend the international collaboration into Phase 2, which is planned to last 5 years and includes activities such as: a common cloud mask approach, a common inter-calibration method, exploration of different temporal resolutions and formats of output, and validation of Level 2 products. We are now in year 4 (2017) of this 5-year plan.

Initial processing of the 1995-2015 GOES-GVAR data was completed.
This included:

- Obtaining ancillary ECMWF data
- Updating acceptor code to handle 5 additional satellites
- Implementing a new calibration approach
- Devising a methodology to handle duplicate GOES imagery in an automated way

Planned Work

- Implement and test cloud mask as developed by the Satellite Application Facility on Climate Monitoring
- Re-process GOES-E and GOES-W data for all of 1995-2015 with this cloud mask
- Perform validation of GSA products with MODIS and in situ observational data
- Begin transition to Initial Operating Capability within NOAA's Climate Data Records Program

Presentations

- Knapp, K.R., and J.L. Matthews. Reprocessing GOES GVAR data. *AMS 21st Conference on Satellite Meteorology*, 14-19 August 2016, Madison, WI.

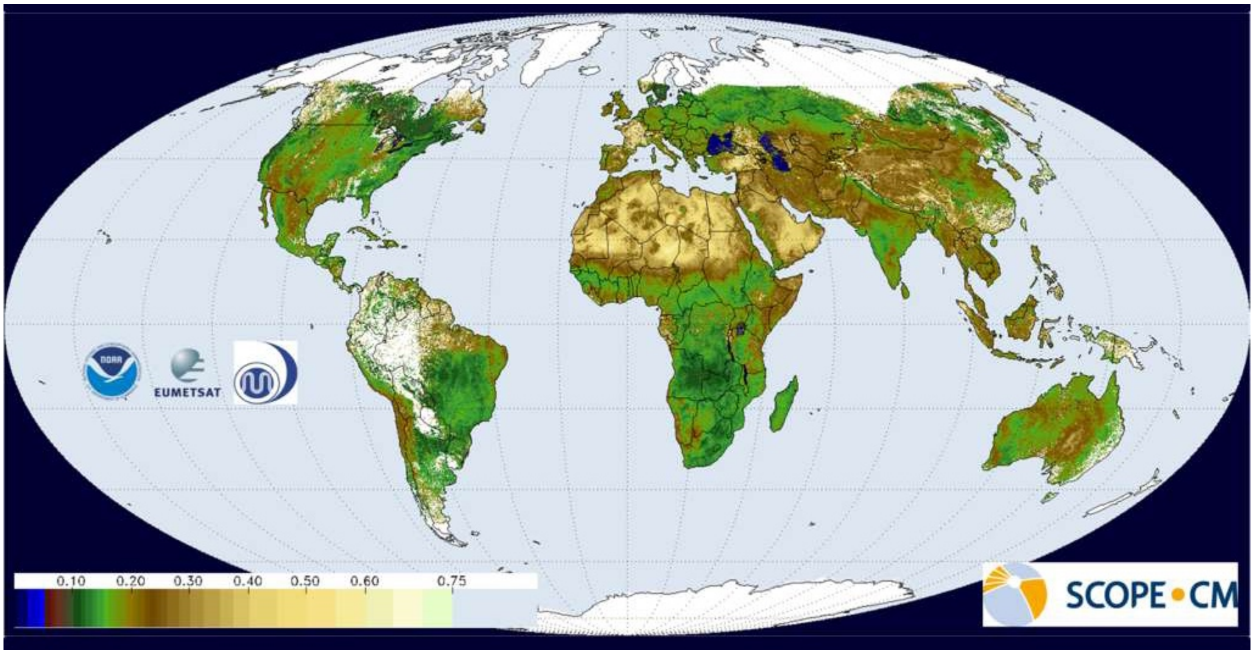


Figure 1. Broadband black sky albedo spatial composite product for the period 1-10 May 2001.

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

HIRS Temperature and Humidity Profiles	
Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-10-NCICS-JM
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

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

Background

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

For the temperature profiles HIRS Channels 2–12 were used, while for the humidity profiles HIRS Channels 4–8 and 10–12 were used as inputs. 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 were three different neural nets, one each for: surface pressures less than 700 mb, greater than 850 mb, and those in between 700 and 850 mb. Radiative Transfer for Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) (RTTOV) data were used as inputs of profile data for calibration purposes.

The resultant neural networks were applied to produce global temperature and humidity profiles using a series of 13 satellites during the 1978–2015 time period. When processing the data, USGS topography information on a 1 degree grid was used to define topography (and thus surface pressure) to select which of the three neural nets to apply. Additionally, monthly CO2 inputs (assumed to be global) were obtained from the Scripps CO_2 program.

Accomplishments

Competed processing of v2015 of HIRS temperature and humidity profiles, described in detail in the *Remote Sensing* article.

The evolution of the versions of this data is summarized below:
v2010:
First version using neural network, no bias corrections applied.
v2014:

- Optimized to find thresholds for AVHRR Reflectance - PATMOS-x CDR parameters cloud_prob and cloud_frac to indicate clear/cloudy conditions (indicated with QC flags).
- Bias correction with Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC).
- Bias correction determined for northern and southern hemispheres separately.

- Bias correction globally applied to temperature and humidity data for P <= 850mb.
- Set nonphysical negative humidity values to 0.
- Humidity values forced to have monotonic decrease with altitude, using value closest to surface as truth.
- No bias correction for skin and 2m values.

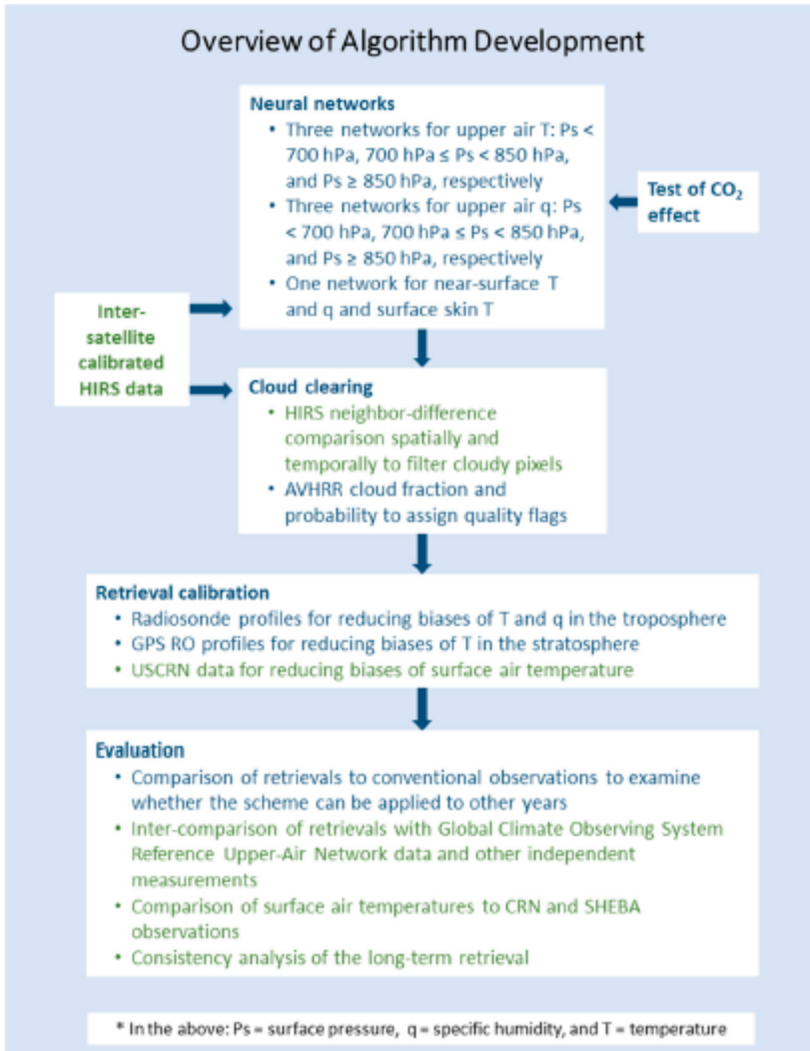


Figure 1. Overview of v2015 algorithm development. New developments for this version are listed in blue, related developments outside the study in Shi and Matthews (2016) are in green.

v2015:

- Same QC flags as v2014.
- Bias correction determined by for northern and southern hemispheres separately.
- Temperature bias correction determined by RS92 for 1000mb <= P <= 400mb, by COSMIC2013 for 300mb <= P <= 50mb.
- Humidity bias correction determined by RS92 for 1000mb <= P <= 300mb (all pressure levels).
- Bias correction globally applied to temperature and humidity data for P <= 1000mb.

- Smoothing applied across equator (because of different correction applied on each hemisphere).
- No bias correction for temperatures between −90 and −60 latitude for 1000mb <= P <= 400mb.
- No bias correction for humidity between −90 and −60 latitude.
- Set nonphysical negative humidity values to 0.
- Humidity values forced to have monotonic decrease with altitude, using 1000mb value (or profile value closest to surface) as truth.
- Bias correction based on US Climate Reference Network (USCRN) applied to skin and 2m values.

A v2016 is currently under development. Key updates are to remove the HIRS channel 10 dependencies from the neural networks, incorporate emissivity data for all channels, and convert output to netCDF.

Planned Work

- Continue development of v2016
- Continue validation work to assess the performance of the algorithms
- Implement conversion to netCDF format
- Explore implementing bootstrap methodology to provide associated uncertainty estimates
- Submit manuscripts on validation of full time series and initial analysis

Publications

- Shi, L., J.L. Matthews, S.-P. Ho, Q. Yang, J. J. Bates, 2016: Algorithm development of temperature and humidity profile retrievals for long-term HIRS observations. *Remote Sensing*, 8:280.

Products

- HIRS Temperature and Humidity Profiles, v2015

Presentations

- Matthews, J.L. and L. Shi. “Long-term HIRS-based temperature and humidity proles." Poster presented at CICS Science Conference, College Park, MD, November 29-December 1, 2016.

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

v2015 data processed through 2015.

Scientific data stewardship for digital environmental data products	
Task Leader	Ge Peng
Task Code	NC-CDR/SDS-11-NCICS-GP
NOAA Sponsor	Scott Hausman
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 80%; Goal 2: 0%; Goal 3: 0%; Goal 4: 20%

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

Background

U.S. Laws (Information Quality Act of 2001 and Federal Information Security Management Act of 2002) require, and expert bodies recommend, that environmental data be:

- Preserved and sustainable
- Secure and accessible
- Transparent and traceable
- Assessed, improved, and scientifically defensible

Any improvement process requires the knowledge of the current stage and what needs to be done to improve. In collaboration with the NOAA OneStop program, NCEI's Data Stewardship Division, and NCEI's Center for Weather and Climate, a consistent framework, namely, DSMM, has been applied to over 700 individual datasets (*Figure 1*) to assess the quality of stewardship practices applied to digital environmental datasets to provide consistent information, such as the state of data integrity and usability to users and stakeholders.

Accomplishments

- Led the application of DSMM and coordinated development of a data use/service maturity matrix.
- Provided DSMM training and guidance to NOAA OneStop metadata content editors, who have assessed about 668 datasets archived by NCEI during OneStop Phase I.
- Reviewed selected DSMM assessments and provided feedback to the editors to ensure or improve DSMM assessments.
- Worked with OneStop metadata SMEs and NOAA Metadata Working Group to develop a DSMM ISO collection-level metadata model.
- Worked with OneStop developers to develop tools and processes to improve the workflow of curating DSMM assessment reports and integrating DSMM assessment results.
- Communicated with dataset POCs to improve DSMM assessments.
- Lead-authored a manuscript published by a peer-review journal on roles and responsibilities of product key players for ensuring quality and usability of digital environmental data products (Peng et al., 2016a).

- Lead-authored a manuscript published by a peer-review journal on lessons learned of assessing the stewardship maturity of a highly utilized NCEI dataset (Peng et al., 2016b). The stewardship maturity rating diagram for this dataset is shown in *Figure 2*.
- Organized/co-chaired several conference sessions, and led/co-authored several conference presentations on systematically curating and presenting data quality information to users.

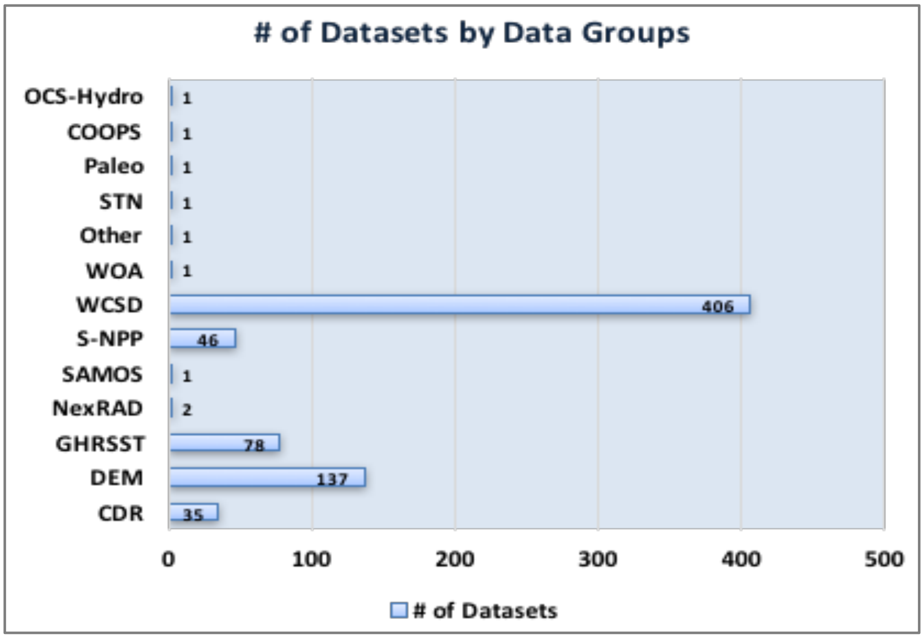


Figure 1. Bar diagram of NCEI datasets by data groups that have DSMM assessments.

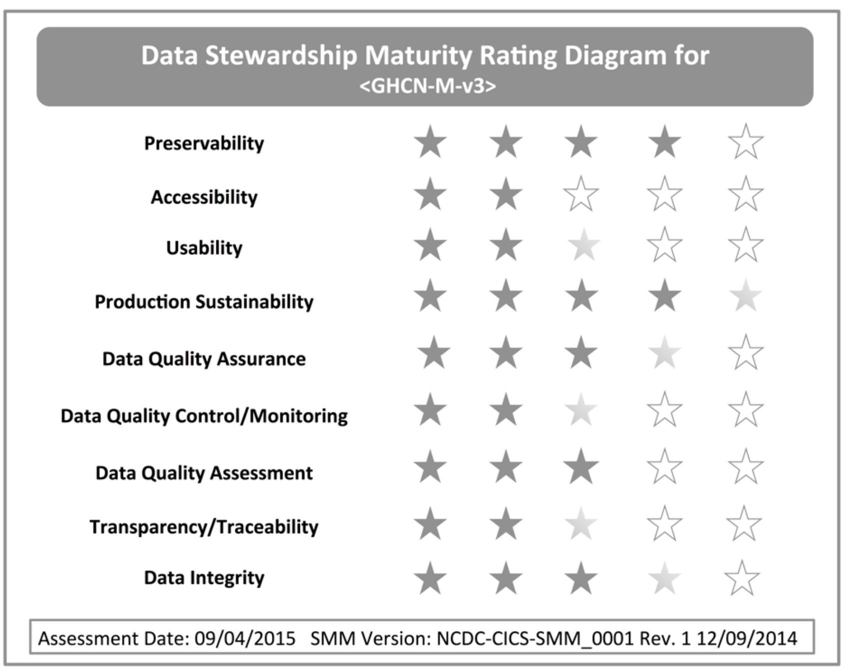


Figure 2. Data stewardship maturity rating diagram of a monthly monthly-land-surface-temperature dataset derived from the Global Historical Climatology Network (GHCN-M), v3. The dark filled stars indicate that all the practices are completely satisfied. The light filled ones indicate that not all practices are satisfied. The non-filled ones indicated that the practices are not satisfied. Adapted from Peng et al., 2016b.

Planned Work

- Continue to support NOAA OneStop Program as the DSMM SME and coordinate application of reference frameworks for measuring maturity of NOAA datasets, pending the availability of OneStop funding or NCEI task allocation.
- Continue to engage stakeholders and Earth Science community by participating in NOAA and ESIP working Groups and attending relevant conferences.

Publications

- Peng, G., N. A. Ritchey, K. S. Casey, E. J. Kearns, J. L. Privette, D. Saunders, P. Jones, T. Maycock, and S. Ansari, 2016a: Scientific stewardship in the Open Data and Big Data era - Roles and responsibilities of stewards and other major product stakeholders. D.-Lib Magazine. 22, doi:10.1045/may2016-peng.
- Peng, G., J. Lawrimore, V. Toner, C. Lief, R. Baldwin, N. Ritchey, and D. Bringar, 2016b: Assessment of Stewardship Maturity of the Global Historical Climatology Network-Monthly (GHCN-M) Dataset and Lessons Learned. *D.-Lib Magazine,*22, doi:10.1045/nov2016-peng.
- Ramapriyan, H., G. Peng, D. Moroni, C.-L. Shie, 2016: Ensuring and Improving Information Quality for Earth Science Data and Products – Role of the ESIP Information Quality Cluster. *Resubmitted to the Data Science Journal.*
- Peng, G., 2016: A Quick Startup Guide for Utilizing the NCEI/CICS-NC Scientific Data Stewardship Maturity Matrix. Version: v01r01 20160624. NOAA/NCEI internal release.
- Peng, G., 2016: Stewards – Knowledge and Communication Hub. Version: v01r02 20160519. *Figshare*, doi: https://dx.doi.org/10.6084/m9.figshare.3189724.

Presentations

- Peng, G., 2016: Challenges and potential approach in search relevance ranking from a dataset maturity perspective. Talk. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC, USA.
- Ritchey, N. and G. Peng, 2016: Data stewardship maturity matrix (DSMM) – NCEI use case and application update. Talk. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC, USA.
- Ramapriyan, H., G. Peng, D. Moroni, C.-L. Shie, 2016: Ensuring and Improving Information Quality for Earth Science Data and Products – Role of the ESIP Information Quality Cluster. Talk. SciDataCon, 11-16 September 2016, Denver, Colorado, USA.
- Ritchey, N., A. Milan, P. Jones, Y.Li, G. Peng, and D. Collins, 2016: Advances in Earth Science metadata for NOAA's OneStop Project. Talk. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC, USA.
- Peng, G., N. Ritchey, and H. Ramapriyan, 2016: A Holistic and Systematic Approach and Panel Discussion. Session. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC, USA.
- Peng, G., R. Duerr, S. Hou, and R. Downs, 2016: Maturity Models Use Case Study Updates and Training/Working Session. Session. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC, USA.

- Ritchey, N.A., G. Peng, A. Milan, P. Lemieux, R. Partee, R. Lonin, and K.S. Casey, 2016: Practical Application of the Data Stewardship Maturity Model for NOAA's OneStop Project. IN42D-08. Talk. AGU 2016 Fall Meeting, 12 – 16 December 2016, San Francisco, CA, USA.
- Ramapriyan, H., D. Moroni, G. Peng, and S. J. Worley, 2016: Managing Earth Science Data Quality Information for the Benefit of Users I Posters. Session IN41C. 12 – 16 December 2016, San Francisco, CA, USA.
- Ramapriyan, H., D. Moroni, G. Peng, and S. J. Worley, 2016: Managing Earth Science Data Quality Information for the Benefit of Users II. Session IN43D. 12 – 16 December 2016, San Francisco, CA, USA.
- Peng, G., H. Ramapriyan, and D. F. Moroni, 2016: The State of Building a Consistent Framework for Curation and Presentation of Earth Science Data Quality. Poster: IN41C.1666, AGU 2016 Fall Meeting, 12 – 16 December 2016, San Francisco, CA, USA.
- Moroni, D., H. Ramapriyan, G. Peng, and C.-L. Shie, 2016: Ensuring and Improving Information Quality for Earth Science Data and Products – Role of the ESIP Information Quality Cluster. Poster. ESIP 2017 Winter Meeting, 11 – 13 January 2017, Bethesda, MD, USA.
- Peng, G., C. Lief, and S. Ansari, 2017: Improving Stewardship of Scientific Data Through the Use of a Maturity Matrix – A Success Story. Talk. 2016 NOAA Enterprise Data Management Workshop. 9 – 10 January 2017, Bethesda, MD, USA.
- Peng, G., N. Ritchey, and S. Gordon, 2017: Towards Systematically Curating and Integrating Data Product Descriptive Information for Data Users. Session. ESIP 2017 Winter Meeting. 11 – 13 January 2017, Bethesda, MD, USA.
- Peng, G., H. Ramapriyan, and D. F. Moroni, 2016: The State of Building a Consistent Framework for Curation and Presentation of Earth Science Data Quality. Poster. ESIP 2017 Winter Meeting, 11 – 13 January 2017, Bethesda, MD, USA.
- Zinn, S., J. Relph, G. Peng, A. Milan, and A. Rosenberg, 2017: Design and implementation of automation tools for DSMM diagrams and reports. Invited Talk. ESIP 2017 Winter Meeting, 11 – 13 January 2017, Bethesda, MD, USA.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of NOAA technical reports	**0**
# of presentations	**10**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

1) The Data Stewardship Maturity Matrix (DSMM) is now a part of NOAA OneStop-ready process.
2) Two papers are published and one is revised.
3) Not included in the presentations are 5 conference sessions that I have organized or served as a co-convener or co-chair.

Regional Variability of Sea Ice Coverage	
Task Leader	Ge Peng
Task Code	NC-CDR/SDS-12-NCICS-GP
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 75%; Goal 2: 0%; Goal 3: 0%; Goal 4: 25%

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

Background

Since the late 1970s, about 49% sea ice reduction in extent and 80% in volume were observed. With rapid Arctic sea ice coverage depletion, it is critical to examine the historical change and continue monitoring the current stage to understand the vulnerability, and to provide reliable projection for climate adaptation and risk mitigation. To help put the changes in the historical perspective, it is useful to baseline long-term sea ice state from a consistent, inter-calibrated, long-term time series of sea ice.

Not all sea ice changes are uniform in both space and time. Spatial sea ice variability may lead to large spread in climate model sea ice projections and therefore induces high uncertainty on regional scales. Thus, it is beneficial to baseline the regional temporal and spatial variability.

In this task, regional temporal variability of Arctic sea ice coverage and its decadal trends are examined for 15 sub-regions (see *Figure 1a*) with the implication of spatial variability, using a passive microwave sea ice concentration climate data record (CDR) dataset for the period of 1979-2015.

Accomplishments

The sea ice coverage, i.e., area and extent, are computed for the whole Arctic and 15 sub-regions using monthly sea ice concentration CDR data files. The temporal variability is demonstrated using temporal distribution of sea ice extent (see *Figure 1b-e*). The decadal sea ice coverage trends are also computed for the whole Arctic (*Figure 2a*) and all 15 sub-regions (only 3 selected regions shown in *Figure 2b-d*). The sensitivity analysis of trends to average windows and methods has been carried to examine the robustness of Arctic sea ice trends and ice-free projections (*Figure 3*).

Algorithms for generating monthly sea ice climate normal products have been developed.

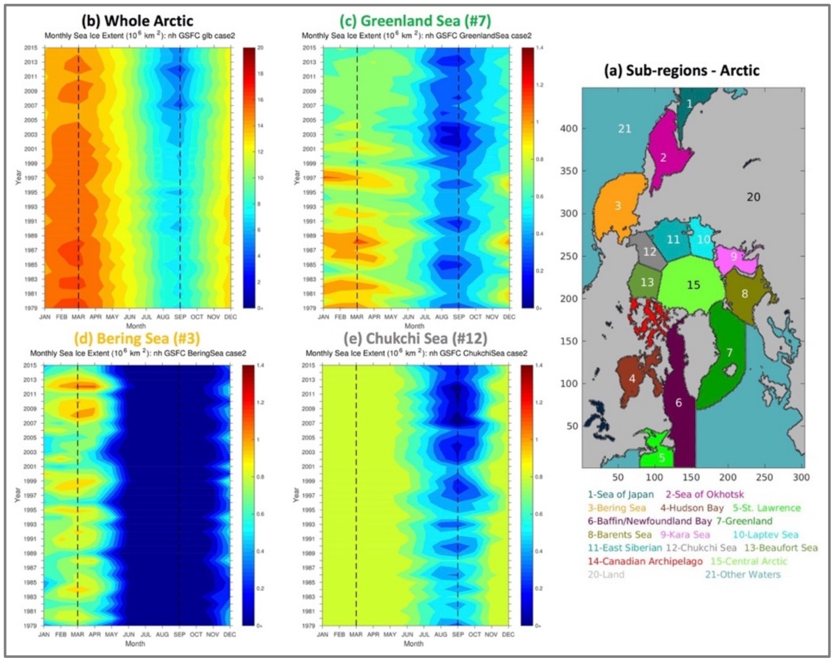


Figure 1. a) Location map of sub-regions in Arctic.Temporal distributions of monthly sea ice extent for the period of 1979–2015 for the region of (b) whole Arctic, (c) Greenland Sea, (d) Bering Sea, and (e) Chukchi Sea. 0+ in the color scale denotes the state when there is zero cell in the region with SIC greater than 15%.

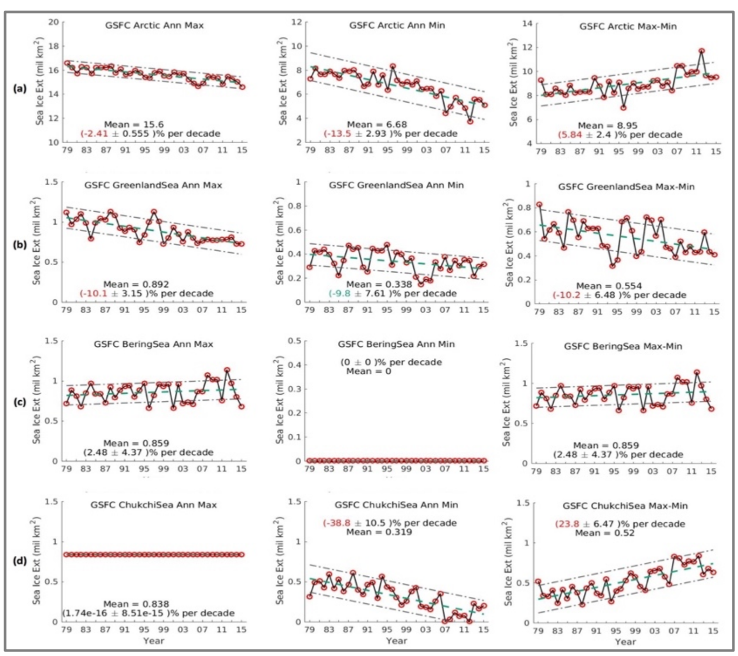


Figure 2. Time series of sea ice extent (red circles with solid black line), its linear regression (thick green dashed line) for the annual maximum (left), minimum (middle) and the difference between the two (right) for (a) Whole Arctic, (b) Greenland Sea, (c) Bering Sea, and (d) Chukchi Sea. The dot-dashed lines are one standard deviation from its linear regression.

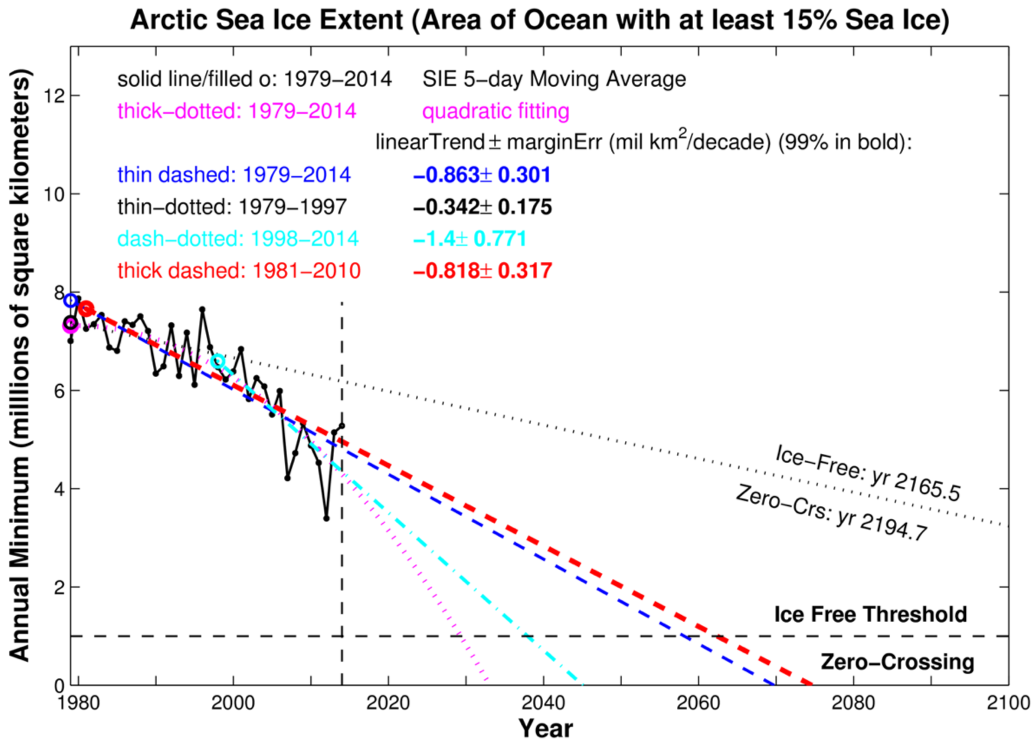


Figure 3. Sensitivity of sea ice extent trend and projection with different curve fitting.

Planned Work

- Analysis of temporal and spatial variability of Arctic sea ice coverage has been summarized in a paper to be submitted to a peer-review journal such as the Annals of Glaciology.
- Sensitivity analysis of Arctic sea ice coverage trends will be finished and summarized in a paper to be submitted to a peer-reviewed journal.
- Sea ice climate normal products will be validated using other existing products such as those generated by NSIDC to establish and improve their accuracy and precision. A manuscript will be prepared for submission to a peer-reviewed journal.

Publications

- Peng, G. and W. N. Meier, 2017: Temporal and Spatial Variability of Arctic Sea Ice Coverage from Satellite Data. *To be submitted to Annals of Glaciology.*
- Peng, G., J. Matthews., W. N. Meier, and J. Yu, 2017: Another Look at Sensitivity Analysis of Trend and Projection of Arctic Sea Ice Coverage. *In Prep.*

Products

- Algorithm for generating monthly sea ice climate normal products has been created.

Presentations

- Peng, G., W.N. Meier, J.T. Yu, and A. Arguez, 2016: Climate Normals and Variability of Arctic Sea Ice. Poster. 2016 CLIVAR Open Science Conference, 19 – 23 September 2016, Qingdao, Shangdong, China.
- Shi, L., J.L. Matthews, S. Stegall, and G. Peng, 2016: A long-term global dataset of temperature and humidity profiles from HIRS. Poster. 2016 CLIVAR Open Science Conference, 19 – 23 September 2016, Qingdao, Shangdong, China.

Other

- Served as NCEI co-Focal Point for NOAA/CMA JWG-19 Activity 2.3:
    - visited CMA/NMIC (National Meteorological Information Center) and,
    - facilitated the NMIC's visit by NCEI expert to contact technical in-person exchange.
- Served as a CWC POC in the NCEI Arctic Action Team.
- Served as external reviewer for Remote Sensing and Atmosphere journals.

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

Toward the Development of Reference Environmental Data Records (REDRs) for Precipitation: Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs)	
Task Leader	Olivier Prat
Task Code	NC-CDR/SDS-13-NCICS-OP
NOAA Sponsor	RussellVose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 20%; Theme 2: 75%; Theme 3: 5%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: The project team conducted a long-term assessment of the different Satellite based precipitation products from the Reference Environmental Data Records (PERSIANN-CDR; GPCP; CMORPH-CDR; AMSU A-B Hydro-bundle) and derived long-term global precipitation characteristics at fine spatial and temporal resolution. This work is part of a broader effort to evaluate long-term multi-sensor QPEs and to develop Reference Environmental Data Records (REDRs) for precipitation.	

Background

Four satellite-based precipitation Reference Environmental Data Records (REDRs: previously Climate Data Records) are or will be transitioned to the REDR program (PERSIANN-CDR; GPCP; CMORPH; AMSU-A, B Hydrologic 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 17-year record of daily-adjusted global precipitation. CMORPH is a 17-year record of daily and sub-daily adjusted global precipitation. AMSU-A, B Hydro-bundle is an 11-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 QPEs are evaluated over the concurrent period. The product inter-comparisons are performed at various temporal (annual, seasonal, daily, or sub-daily when possible) and spatial scales (global, overland and over ocean, tropics or higher latitudes, high elevation). The evaluation of the different products includes trend analysis and comparison with in situ data sets from the Global Historical Climatology Network (GHCN-Daily), the Global Precipitation Climatology Centre (GPCC) gridded full data daily product (GPCC), and the Climate Reference Network (CRN).

Accomplishments

The inter-comparison of the different precipitation REDRs was completed for the globe over the full period of record of each product. The inter-comparison was performed for different areas (land, ocean, high elevation) and various temporal scales (annual, seasonal, monthly, daily). *Figure 1* displays the annual precipitation derived from the operational REDR PERSIANN and the two REDRs in transition CMORPH and GPCP. PERSIANN-CDR and GPCP are close due to the fact that PERSIANN-CDR uses GPCP for monthly adjustment, while CMORPH generally displays lower averages. All products are very close over ocean since GPCP is used as calibration for the two others. While long-term daily averages and variability are relatively similar between the three REDRs, seasonal differences are more pronounced between products and are a function of the location and geography. Globally, PERSIANN-CDR matches GPCP, which is not surprising, but differences exist when considering sub-domains such as the Northern and Southern hemispheres (not shown).

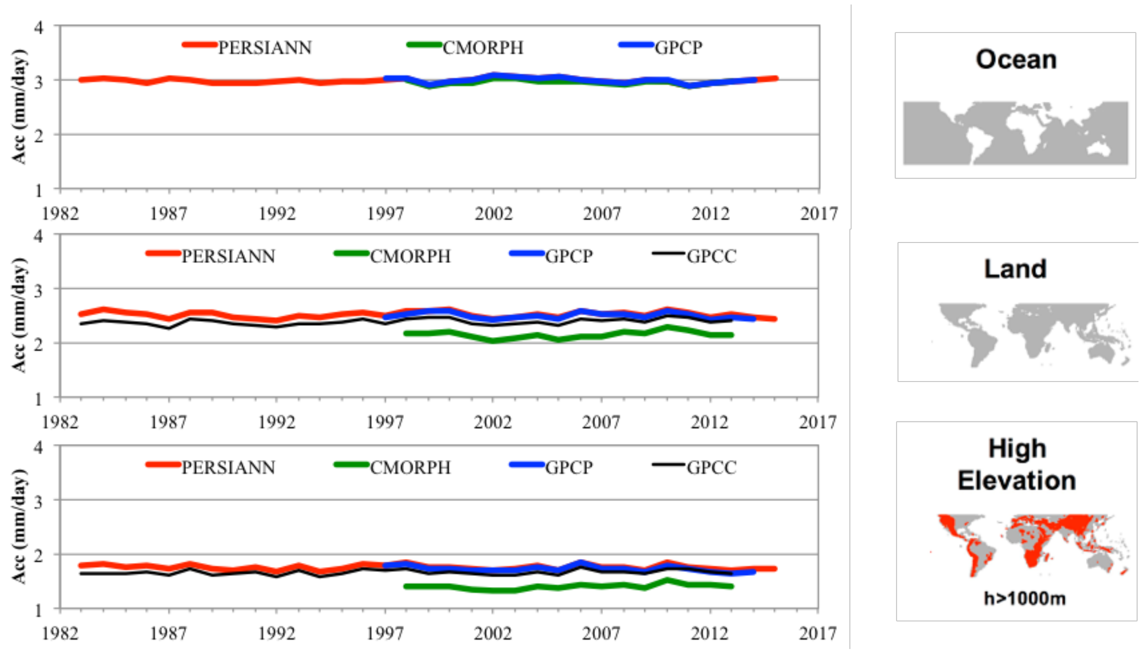


Figure 1. Annual rainfall derived from current or in-transition Reference Environmental Data Records (REDRs) PERSIANN, CMORPH, and GPCP for each product period of record over ocean (upper row), over land (median row), and for high elevation (lower row). Comparisons between satellite QPE and gridded in-situ GPCC over land and for high elevation.

Over land, the comparison with precipitation estimates from the Global Precipitation Climatology Centre (GPCC: Full Data Reanalysis Product at 1 deg. resolution) shows that the satellite based REDRs present similar long-term daily averages with in-situ GPCC data (Fig. 1).

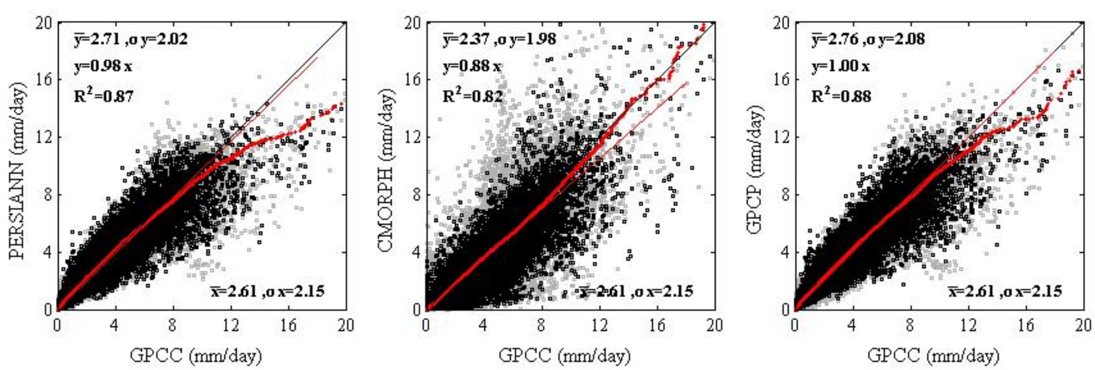


Figure 2. Comparison (Quantile-Quantile plot) of PERSIANN-CDR, CMORPH, and GPCP with surface observations from GPCC for the annual precipitation over land for 1998–2012. GPCP and PERSIANN, which is monthly adjusted with GPCP, present a comparable agreement with in situ GPCC. Both present a slightly higher average rainfall than surface observations from GPCC. CMORPH presents a lower average rainfall than in-situ GPCC.

Figure 2 provides a closer look at the comparison with in situ GPCC data. Similar performances are observed for PERSIANN-CDR and GPCP with an average daily precipitation close to GPCC. However, while CMORPH presents a lower daily average when compared to in situ GPCC, the quantile-quantile plot (red dotted line) displays a better agreement for CMORPH with in situ data for higher rain rates. Conversely, PERSIANN-CDR and GPCP present a significant underestimation at higher accumulation (>10 mm/day). A conditional analysis performed over CONUS using in situ data from the Climate Reference Network (CRN) confirms that CMORPH tends to perform better for higher daily rainfall and for precipitation extremes greater than 50 mm/day (not shown).

Current work consists of extending the comparison to the other CDR in transition AMSU-A,B-Hydrologic bundle. A comparison with other gridded with other multi-sensor satellite precipitation products (IMERG, TMPA) is also considered.

Planned Work

- Summarize the finding of the satellite precipitation REDRs (PERSIANN, CMORPH, GPCP) evaluation into a publication. This includes the inter-comparison of the different satellite precipitation REDRs at global and local scales and for various time scales, and a comparison of the different products with in-situ observations (GHCN-D, GPCC, CRN).
- Extend the analysis to daily (sub-daily when possible) precipitation extremes. Evaluate precipitation extremes in relation with tropical and extra-tropical cyclonic activity.
- Extend this work by including the other REDR in transition (AMSU-A,B-Hydrologic bundle).
- Extend this work by including other satellite precipitation QPEs (IMERG, TMPA).

Publications

- Prat, O.P., and B.R. Nelson, 2016. On the link between tropical cyclones and daily rainfall extremes derived from global satellite quantitative precipitation estimates. *Journal of Climate.* 29, 6127-6135.
- Kim, B., D.-J. Seo, S.-J Noh, O.P. Prat, and B.R. Nelson, 2017. Improving multi-sensor estimation of heavy-to-extreme precipitation via conditional bias-penalized optimal estimation. *Journal of Hydrology.* In press.
- Prat, O.P., B.R. Nelson, E. Nick, and R. Leeper, 2017. Global evaluation of satellite based Quantitative Precipitation Estimates (QPEs) from the Reference Environmental Data Records (REDRs). *Journal of Hydrometeorology. In preparation.*

Products

- Global evaluation of the different satellite precipitation REDRs. Comparison with in-situ data (GHCN-D, GPCC, CRN) for the entire period of record at the annual, seasonal, and daily scale;
- Manuscript summarizing the results of this comparison effort at the global scale.

Presentations

- Prat, O.P., B.R. Nelson, E. Nickl, R. Adler, R. Ferraro, S. Sorooshian, and P. Xie, 2016. Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs) from the Reference Environmental Data Records (REDRs). *2016 EGU general assembly*, April 17-22 2016, Vienna, Austria.
- Prat, O.P., R.D. Leeper, S.E. Stevens, B.R. Nelson, D.R. Easterling, and K.E. Kunkel, 2016. Long-term quantification of extreme precipitation in relation with tropical and extra-tropical cyclonic activity over the Carolinas. *Carolinas Climate Resilience Conference*. September 12-14 2016, Charlotte, NC, USA.

- Prat, O.P., B.R. Nelson, and R.R. Ferraro, 2016. Evaluation of satellite Quantitative Precipitation Estimates (QPEs) products. *CICS Science Conference*, November 29-December 1 2016, College Park, MD, USA.
- Nelson, B.R., O.P. Prat, and S.E. Stevens, 2016. Assessment of NOAA's NEXRAD reanalysis. *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA, USA.
- Prat, O.P., and B.R. Nelson, 2016. Evaluation of satellite Quantitative Precipitation Estimates (QPEs) products. *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA, USA.
- Prat, O.P., and B.R. Nelson. Evaluation of extreme precipitation derived from long-term global satellite Quantitative Precipitation Estimates (QPEs). *2017 EGU general assembly*, April 23-28 2017, Vienna, Austria.
- Prat, O.P., and B.R. Nelson, and R. Ferraro, 2017. Evaluation of the AMSU-A, B Hydro-Bundle suite of products for hydrological and climate applications. *23rd AMS Conference on Applied Climatology*, June 26-28 2017, Asheville, NC, USA.
- Nelson, B.R., O.P. Prat, S.E. Stevens, J. Zhang, K. Howard, and Y. Qi, 2017. NOAA's NEXRAD reanalysis – Use case and applications. *23rd AMS Conference on Applied Climatology*, June 26-28 2017, Asheville, NC, USA.

Performance Metrics	
# of new or improved products developed that became operational	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of NOAA technical reports	**0**
# of presentations	**8**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

One journal article on the evaluation of the different satellite precipitation REDRs is in preparation and will be submitted in Spring 2017 (1). One manuscript on the contribution of tropical cyclones to extreme rainfall was published in September 2016 (1). Although not directly related to satellite precipitation but yet relevant in the context of the improvement of multi-sensor precipitation estimates, a paper accepted for publication in October 2016 was coauthored (1). Four presentations were given on the topic (4) and one presentation was coauthored at the AGU Fall Meeting (1). One presentation has been accepted for the EGU General Assembly in April 2017 (1). Two abstract were submitted for the AMS Conference on Applied Climatology in June 2017 (2).

Identifying Tropical Variability with CDRs	
Task Leader	Carl Schreck
Task Code	NC-CDR/SDS-14-NCICS-CS
NOAA Sponsor	RussellVose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 50%; Theme 3: 50%.
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 25%; Goal 2: 75%; Goal 3: 0%; Goal 4: 0%

Highlight: Climate data records can inform, validate, and improve subseasonal-to-seasonal forecasts of tropical variability for numerous users.
https://ncics.org/mjo/

Background

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

Accomplishments

Tropical convection varies on a variety of time scales, each with unique impacts. Separating these modes and their impacts has long been a critical need for improving subseasonal-to-seasonal forecasts. Commonly used climate information records (CIRs) exist for tracking and predicting low-frequency modes like El Niño–Southern Oscillation (ENSO) and the intraseasonal MJO. However, these CIRs do not cleanly separate these two modes, nor do they necessarily separate the contributions from equatorial waves.

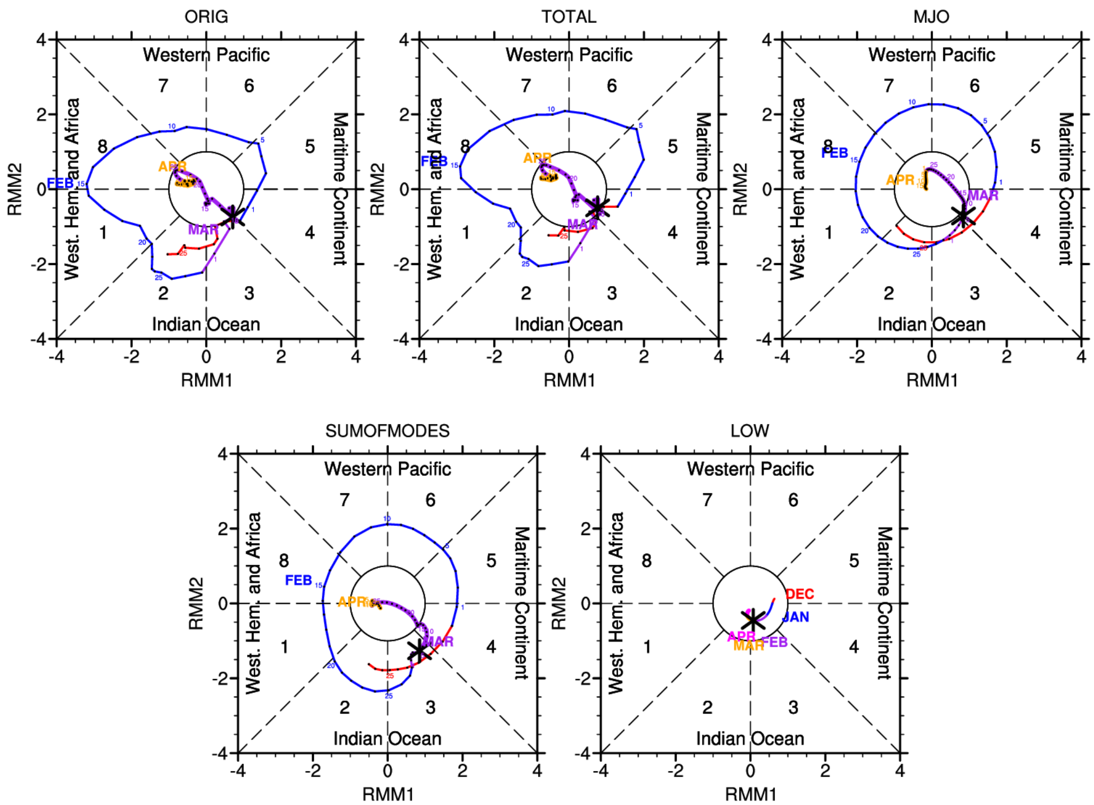


Figure 1. Newly developed variations of the Wheeler–Hendon Real-time Multivariate MJO (RMM) CIR available on [*https://ncics.org/mjo/rmm*](https://ncics.org/mjo/rmm)*.*

Figure 1 shows an example of several variations on the traditional Wheeler–Hendon Real-time Multivariate MJO (RMM) CIR that have been developed to address this need. The upper-left panel ("ORIG") is the traditional RMM, which subtracts a 120-day running mean to reduce the influence of ENSO. It shows a high-amplitude event in Phase 8/1 during February.

The top-middle panel ("TOTAL") shows a variant in which the 120-mean is not removed. The differences between this and the ORIG give some indication of the contribution of the low-frequency modes (explicitly shown in the lower right, "LOW"). The upper-right ("MJO") version applies a Fourier filter to the CDR of outgoing longwave radiation (OLR) and forecasts from NOAA's Climate Forecast System (CFS). This eliminates contributions from non-MJO features.

The lower-right ("SUMOFMODES") combines the contributions for the MJO along with equatorial Rossby waves and Kelvin waves, both of which are known to contribute to the traditional RMM. Both ORIG and SUMOFMODES show a high-amplitude event, consistent with ORIG. However, their amplitudes in phase 8/1 are not quite as large, indicating that some other synoptic variability must have been at play.

Work is ongoing to determine how best to apply these indices to improve forecasts and to develop better ways of tracking equatorial Rossby and Kelvin waves. In the meantime, diagnostics like *Fig. 1* are being produced routinely on https://ncics.org/mjo/rmm where they are served to > 300 unique users per month.

Tropical variability as identified by CDRs also plays a pivotal role in understanding the recent climate. Three specific examples from this past year:

1) Several sections of the NCEI/BAMS annual State of the Climate report use CDRs to monitor tropical variability. Notably OLR, optimum interpolated sea surface temperatures (OI SST), and the International Best Track Archive for Climate Stewardship (IBTrACS) figure prominently.
2) Under the advisement of Dr. Schreck, Hilawe Semunegus used CDRs of convective cloud types as part of his Ph.D. dissertation at the NC Agricultural and Technical University to examine the evolution of convection in African easterly waves.
3) Schreck and coauthors are using OLR, OI SST, and IBTrACS to document the environmental conditions for tropical cyclone activity for a review article submitted to *Monthly Weather Review.*

Planned Work

Continue developing CIRs similar to Fig. 1 to better meet user needs for subseasonal-to-seasonal forecasting. Particular emphasis will be on improving the monitoring and tracking of equatorial Rossby and Kelvin waves.

Publications

- Diamond, H. J., and C. J. Schreck, eds., 2016: The tropics [in “State of the Climate in 2015”]. *Bull. Amer. Meteor. Soc.*, 97, S93–S130, doi:10.1175/2016BAMSStateoftheClimate.1.
- Semunegus, H., A. A. Mekonnen, and C. J. Schreck: 2017. Characterization of Convective Systems and Their Association with African Easterly Waves. *Int. J. Clim.*, In Press.

Products

- New MJO indices on https://ncics.org/mjo/rmm

Presentations

- Subseasonal Variability of Tropical Cyclones: The MJO and Kelvin Waves. *Fourth Santa Fe Conference on Global & Regional Climate Change*, 6-10 February 2017, Santa Fe, NM.
- Schreck, C. J., 2016: Cluster analysis of tropical modes. *NOAA’s 41st Climate Diagnostics and Prediction Workshop*, 3-6 October 2016, Orono, ME.
- Schreck, C. J., K. R. Knapp, J. P. Kossin, and C. Velden, 2016: Comparing CI-number/Pressure Relationships in the Western Pacific using HURSAT-ADT and Historical Reconnaissance. *32nd Conference on Hurricanes and Tropical Meteorology*, 17-22 April 2016, San Juan, PR.

Other

- Hilawe Semunegus successfully defended his Ph.D. thesis in Fall 2016 under the co-advisement of Dr. Schreck.

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

New MJO indices on https://ncics.org/mjo/rmm

Hourly Precipitation Dataset (HPD) Quality Analysis	
Task Leader	Scott Stevens
Task Code	NC-CDR/SDS-15-NCICS-SS
NOAA Sponsor	RussellVose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: Quality analysis of hourly precipitation dataset in preparation for release.	

Background

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

Accomplishments

Performed several quality assessments on the dataset prior to its beta release, including:

- Quantification of quality flags
- Analysis of rain rate distributions to find abnormalities
- Comparison against USCRN hourly precipitation totals
- Comparison against GHCN-D daily totals to find indications of false precipitation values

Planned work

- Continue to support this dataset as it is prepared for full release

Products

- Beta release of Hourly Precipitation Dataset (HPD)

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

Obs4MIPs Processing	
Task Leader	Scott Stevens
Task Code	NC-CDR/SDS-16-NCICS-SS
NOAA Sponsor	Russell Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: Reformatting gridded observations to a standardized form for the modelling community.	

Background

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

Accomplishments

Code written by Jim Biard is running successfully on the CICS-NC computing cluster and several datasets are being run through this process.

Planned Work

- Process several more datasets through this method
    - Extended Reconstructed Sea Surface Temperature (ERSST)
    - Gridded Satellite Data (GridSat)
    - Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)
    - Leaf Area Index (LAI)
    - Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
    - Normalized Difference Vegetation Index (NDVI)

Products

- Reformatted datasets for modeling use

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

Climate Literacy, Outreach, Engagement and Communications

CICS-NC climate literacy, outreach, engagement, and communication efforts are focused on improving the public's knowledge and understanding of climate information. CICS-NC supports NCEI's engagement strategic plan to foster a climate-literate public that understands climate risks, vulnerabilities to a changing climate, opportunities for innovation, and makes informed decisions using climate data.

Over the last decade, understanding changes in our climate has emerged as one of the most important areas of scientific endeavor. There is an increasing realization that profound changes in the Earth climate system are already occurring and the consequent impacts are already being experienced. It is well recognized globally that there is a need to mitigate the effects of climate change by reducing greenhouse emissions. The magnitude and scale of climate change and its impacts are unpredictable, arguably underestimated, and certain to intensify as past emission levels impact weather patterns today and into the future. As the discussion on reducing emissions shifts into mainstream awareness, questions still remain about understanding the inevitable impacts that are already occurring and how we can strategically adapt to adverse conditions.

Anticipated climatic changes, which vary by regions, can include more intense precipitation events, warmer temperatures, shorter snow seasons, and changes in growing seasons, among many others. Collecting and processing the fundamental data on climatic conditions, developing the models and algorithms to simulate natural cycles, assessing the possible projections, and communicating the information are critical activities in building resiliency.

CICS-NC supports NOAA's commitment to the development of a society that is environmentally responsible, climate resilient and adaptive, and utilizes effective, science-based problem-solving skills in building climate literacy. Working collaboratively with partners, stakeholders, and the private sector, CICS-NC supports and engages in various educational, engagement, and outreach-related activities that:

- Advance the development engagement, education, and outreach activities about climate, oceanic, and atmospheric sciences with the intent to:
    - Increase awareness of climate science and changes in the climate system
    - Grow the understanding of how climate data is collected, observed, analyzed, and used in research purposes
    - Increase awareness of NCEI climate datasets and products, and how various stakeholders can make use of climate data products for their respective purposes
- Advance climate literacy for private sector partnerships through interdisciplinary activities, including engagement with select business solution providers and industry leaders on uses and applications of climate data for climate risk management or innovative opportunities
- Provide operational support to activities in NOAA organizations like NCEI in advancing their engagement activities with customers
- Support outreach and engagement activities on climate applications to local economic development groups and non-profits

Climate Literacy, Outreach, Engagement, and Communications	
Task Leader	Jenny Dissen
Task Code	NC-CLOEC-01-NCICS-JD
NOAA Sponsor	Tim Owen
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Climate Literacy, Outreach, Engagement, and Communications
Contribution to NOAA goals (%)	Goal 1: 40%; Goal 2: 40%; Goal 3: 0%; Goal 4: 20%

Highlight: CICS-NC conducts activities in outreach, engagement, and communications to reach various types of stakeholders on environmental information, climate change and variability, adaptation and mitigation, and uses and applications of climate data for decision-making.
https://www.cicsnc.org/events/; https://ncics.org/expertise/engagement/

Background

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

The various engagement and outreach activities require developing frameworks, delivering presentations, engaging in relationship-building and capacity-building activities, enabling catalytic support of innovation in uses of climate data, engaging in individual and executive-level roundtable discussions, and providing ongoing operational support to NOAA NCEI to advance their science and services capabilities.

Accomplishments

Key highlights of accomplishments in this past year are framed under these areas:

- Providing operational support to the Information Services Division at NOAA NCEI for advancing their strategy, operations, sectoral engagement, and outreach as well as building process capabilities for a sustainable management of customer information.
- Engaging in meaningful dialogue on uses, applications, and requirements of environmental information across various user groups.
- With support from CICS-NC staff, conducting interdisciplinary outreach activities to reach academia and the general public

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

Engagement Activities with the NCEI Climatic Information Services Branch:
CICS-NC led and advised in the design and development of a customer relationship management solution (CRM), which would identify, track, and store customer information gathered by engagement personnel at NCEI. It included an analysis and requirements phase and the design and deployment of a Phase I Google form solution that tracked and analyzed 15,000+ entries. Phase II of the solution involved analyzing CRM vendor solution providers, development of the decision process, and the procurement of the Salesforce CRM tool. CICS-NC was involved in the detailed implementation of the Salesforce solution, ranging from technical integration needs to training needs for the NCEI users. The Salesforce solution is expected to go live in April 2017 and will provide NCEI a customer database, insights into uses and applications of NCEI data, and requirements from users. The previous year's efforts in sectoral analysis using the US Census Bureau of Economic Analysis sectors (NAICS codes) is being implemented in the cataloguing and categorization of the data.

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

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

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

Engaging with Business and Industry Sectors:
CICS-NC continued engagement with the Research Triangle Foundation (RTF) and held a second webinar in September 2016 that facilitated executive-level engagement on environmental information with corporate leaders from companies located at RTP. Speakers included Johanna Jobin, Global Sustainability Director of Biogen; Andrew Hoffman, University of Michigan; Scott Shuford, Planning and

Code Enforcement Services Director, City of Fayetteville; and Amanda Rycerz from Acclimatise. Kenneth Kunkel and Jenny Dissen, both from CICS-NC, NC State University, and NOAA NCEI, also presented.

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

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

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

Outreach Activities in Education and General Public:
CICS-NC conducts outreach activities across K–12, higher education, and the general public to advance environmental information and increase climate literacy. This year's outreach activities included:

- 4/9/2016: Mountain Science Expo, Asheville, NC. Theresa Stone, Laura Stevens and Scott Stevens, represented CICS-NC at a booth with NCEI as part of the larger NC Science Festival events. This event was open to the public, with ~1500 attendees. The booth showcased the Cyclone Center, the National Climate Assessment, and NOAA educational materials.

- 4/15/2016: ICC Science and Technology Expo, Isothermal Community College, Spindale, NC. Theresa Stone gave a 20 minute presentations on the NCA, climate change, and the Cyclone Center to 8 groups of 6th graders (~160 students) from Polk County.
- 4/21/2016: Climate and Weather at NCEI/CICS, Asheville, NC. Theresa Stone, Scott Stevens, Paula Hennon, and Jared Rennie, partnered with NCEI to provide an overview of NCEI activities, and give presentations on "What is Climate Change and How do we know it's real", the Cyclone Center website, and "Coding in Climate Science" to 30 students and their parents.
- 4/23/2016: "Celebrate STEM" Buncombe County Schools, Nesbitt Discovery Academy (STEM HS), Asheville, NC. Theresa Stone hosted a CICS-NC booth with ~500 K-5 students and their parents. Participants received NOAA climate materials, info on the Cyclone Center, and climate literacy and built rain gauges as a hands-on activity.
- 4/27/2016: East Yancey Middle School, Burnsville, NC. Scott Stevens gave a presentation on climate change to all 7th grade science classes.
- 05/20/2016: Environmental Educators of North Carolina (EENC) Western Section, NCEI/CICS, Asheville, NC. Theresa Stone and Tom Maycock coordinated presentations by Jake Crouch (NCEI) on the Climate Monitoring branch and their activities, Greg Hammer (NCEI) gave a tour of building with focus on IT capabilities and the archive, and Jeff Robel (NCEI) gave a presentation on the customer service branch activities to 12 EENC participants.
- 6/16/2016: Brevard HS, Brevard, NC. Scott Stevens, Jenn Runkle, and Jessicca Griffin gave presentations to 15-20 high school science students participating in an intensive year-long program that allowed them to conduct original research into their own questions.
- 06/20/2016: St. Mark's Lutheran Church Vacation Bible School, Asheville, NC. Carl Schreck taught science lessons, made anemometers, and provided weather related handouts.
- 10/11/2016-10/13/2016: Asheville Middle School, Asheville, NC. Scott Stevens, Laura Stevens, and Jared Rennie each took a day of classes (four 7th grade classes each day), speaking about what NCEI does, and how we safeguard all of the nation's weather and climate observations.
- 11/22/2016: North Buncombe Elementary School Career Day, Asheville, NC. Carl Schreck presented on hurricanes and rain gauges to the special needs classrooms (K-4).
- 12/9/2016: Isaac Dickson Elementary School, Asheville, NC. Linda Copley and Jared Rennie supported the Hour of Code outreach event on Dec. 9th for Kindergarten, 1st, 2nd, and 3rd grades.
- 12/9/2016: Ira B. Jones Elementary, Asheville, NC. Jared Rennie gave a presentation to ~75 5th graders on "Weather, Climate, and Code.”.
- 02/14/2017: Imagine Collegiate Invest (charter school), Asheville, NC. Scott Stevens gave three presentations centered on the value of keeping 150 years of weather data to ~50 7th grade science classes.
- 02/17/2017: Etowah Elementary School Career Day, Etowah, NC. Scott Stevens gave three presentations to ~40 students ranging from 3rd to 5th grade about meteorology as a career.
- 03/24/2017: UNC-Charlotte Weatherfest, Charlotte, NC. Theresa Stone manned a CICS-NC booth giving out weather activity handouts and demonstrating the Cyclone Center.
- 03/29/2017: Franklin School of Innovation Career Day, Asheville, NC. Laura Stevens was a presenter to ~60 6th to 11th grade students.
- 03/31/2017: Isothermal Community College STEM Expo, Spindale, NC. Theresa Stone gave presentations to ~160 6th graders on the use of satellites and radar in climate science and used NCEI’s Magic Planet to show satellite tracking and images of hurricanes around the globe.

Planned Work

- Hold energy forum portraying use of NCEI supplemental normals data, role of environmental information for grid resilience, and the investment in renewables
- Develop plans for continued engagement with Indian Institute of Tropical Meteorology and collaborative research projects
- Host engagement discussions on climate downscaling at The Collider
- Support and advance implementation activities of Salesforce and capability building within NCEI; develop analytics and reports on customer information using Salesforce
    - Host training on the Census Bureau NAICS code
- Continue to increase K-12 outreach engagement and events

Presentations

- Dissen, J., 2016: EHS, Sustainability and Climate Resilience – What's the Connection., Research Triangle Park Foundation webinar (8 September 2016).
- Dissen, J., T. Owen, M. Brewer, E. Mecray, T. Houston, 2016: Engagement with the Energy Sector - Our Experience., 2016 Carolinas Climate Resilience Conference. September 2016, Charlotte.
- Thompson, T., O. Brown, J. Dissen., 2016: Applying NOAA Big Data to Utilities – An Example., Utility Analytics Week (31 October 2016).

Other

- CICS-NC continues engagement and involvement in the Asheville Museum of Science development activities. The geodome panorama was installed and in part supported through engagement by NC State University and NCEI. It reaches thousands of children per month.
- Supported outreach and identification of journalists for the National Association Science Writers conference using the NCEI customer database Google form analytics
- Partnered with UNC Asheville NEMAC in a proposal to New Hanover County "New Hanover County Water Supply: A Climate Risk and Resilience Assessment"
- Supported Tim Owen in the development of the NCEI FY2017 Implementation Framework for the Regional Climate Services meeting held at NCEI in August 2016
- Continuing engagement and support activities at the Collider, Asheville's climate innovation center.

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

Outreach to Higher Education Institutions	
Task Leader	Jessica Matthews
Task Code	NC-CLOEC-02-NCICS-JM
NOAA Sponsor	Tim Owen
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Climate Literacy and Outreach
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

Highlight: Engagement with academic institutions is a CICS-NC focus area being served through mentorship of undergraduate and graduate students, invited speaking engagements with university student and faculty audiences, and through development of a distance education course.

Accomplishments

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

Figure 1. SAMSI's Workshop for Women in Math Sciences, April 6-8, 2016.

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

Figure 2. Dr. Matthews presenting on her research applications at the US EPA in July 2016.

"Mathematics of Climate Science" is a new course to satisfy the need for training graduate-level researchers in how mathematics contributes to the study of the Earth's climate. We will teach this course remotely from a key climate research hub, NOAA's National Centers for Environmental Information in Asheville, NC, through NCSU's North Carolina Institute for Climate Studies. This will be the first graduate-level mathematics course offered in an online environment. Students can be located in the Asheville location, on main campus, or participate via distance education. This course is being developed by Dr. Matthews in collaboration with NCSU Distance Education and Learning Technology Application (DELTA) staff as supported by the award of a competitive grant in August 2016.

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

Planned Work

- Teach first offering of "Mathematics of Climate Science" distance education course at the graduate level available to students at NCSU, Duke, and UNC-CH for the Fall 2017 semester.
- Continue to engage with academic institutions as invited to speak and as opportunities arise for mentorship of undergraduate and graduate students.

Presentations

- Hartman, T., Matthews, J.L., Bell, J.E. "Monitoring Drought with Vegetation and Soil Moisture Data". Poster presentation, 97th AMS Annual Meeting, Seattle, WA, 22-26 January, 2017.
- Matthews, J.L. "Research applications at the National Centers for Environmental Information." Invited speaker, Clemson University Mathematical Sciences Department Colloquia, Clemson, SC, September 16, 2016.
- Matthews, J.L. "Research applications at the National Centers for Environmental Information." Invited speaker, Environmental Protection Agency, Research Triangle Park, NC, July 20, 2016.
- Matthews, J.L. "What to expect in a non-academic career." Invited speaker, SAMSI's Workshop for Women in Math Sciences, Durham, NC, April 6-8, 2016.

Other

- Received an $8,000 award and yearlong DELTA staff assistance for the design and development of a new graduate-level mathematics distance education course.

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

Dr. Matthews mentored Theodore Hartman, a NOAA Hollings Scholar from Iowa State University, during summer 2016.

CICS-NC Communications	
Task Leader	Tom Maycock
Task Code	NC-CLOEC-03-NCICS-TM
NOAA Sponsor	Tim Owen
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Climate Literacy, Outreach, Engagement, and Communications
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

Highlight: This task promotes the Cooperative Institute for Climate and Satellites (CICS-NC) to its stakeholders and advances the external and internal communications efforts of NOAA's National Centers for Environmental Information.
https://ncics.org/

Background

CICS-NC communication activities serve to raise awareness and highlight the accomplishments of the Institute and its staff, including research findings of CICS-NC scientists and their NOAA NCEI colleagues. Other activities include working to improve the science communication capabilities of CICS-NC staff, expanding the social media reach of the institute, and providing editorial and communications support to NCEI.

Accomplishments

- Led development and release of a completely redesigned institute website. The new site (https://ncics.org/) offers an engaging interface designed to highlight our capabilities, expertise, and accomplishments and provides a more unified view of the Institute's activities. The look and feel of the site more closely aligns our identity with NC State and uses approved NC State branding standards.
- Helped coordinate "Measure Locally, Respond Globally"—an engagement workshop for science and environmental journalists and writers held in Asheville on August 15-16. The workshop included an afternoon session hosted at NCEI, including a building tour and presentations from CICS-NC and NCEI staff. The event attracted approximately 25 journalists from around the Southeast and has resulted in a number of stories in regional and national outlets, including several featuring NCEI data and/or research.
- Provided scientific copyediting services in support of the *Explaining Extreme Events of 2015* and *State of the Climate 2015* reports, produced by NCEI and published in the *Bulletin of the American Meteorological Society* in 2016.
- Wrote and posted 20 web stories highlighting peer-reviewed research produced by institute staff and 10 news stories highlighting other activities.
- Institute social media reach remains modest but continued to grow again this year. Facebook activities included more than 65 posts and an increase in likes from 424 to 529. More than 90 Tweets were sent, and followers increased followers from 154 to 257.

Planned Work

- Produce two issues of *Trends* newsletter
- Continue to highlight and promote work done by CICS-NC and the Institute as a whole

- Continue to build reach of Facebook and Twitter accounts
- Provide scientific editorial and communications support to CICS-NC staff and to NCEI's Communications and Outreach Branch.

Publications

- Peng, G., N. A. Ritchey, K. S. Casey, E. J. Kearns, J. L. Privette, D. Saunders, P. Jones, T. Maycock, and S. Ansari, 2016: Scientific stewardship in the Open Data and Big Data era - Roles and responsibilities of stewards and other major product stakeholders. *D.-Lib Magazine*, 22. http://dx.doi.org/10.1045/may2016-peng

Products

- Redesigned institute website
- ~ 30 web stories
- Editorial support for two BAMS reports

Presentations

- Maycock, T. and J. Runkle, 2016: Climate and Health. *Asheville Museum of Science Beer City Science Pub Series*, October 28, 2016*,* The Collider, Asheville, NC.

Other

- Mentoring Andrew Dundas, a high-school intern who is writing web stories on research articles, interviews with staff, and participating in other communications projects.

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

Products count includes the new website, all web stories (counted as one product), and contribution to the *State of the Climate* and *Explaining Extreme Events* reports published as special issues of the *Bulletin of the American Meteorological Society*.

“Spot the Rip”: Rip Current Documentation for Education and Research	
Task Leader	John McCord
Task Code	NC-CLOEC-04-ECU/CSI
NOAA Sponsor	Nicole Kurkowski
NOAA Office	NWS/STI
Contribution to CICS Research Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3:0%
Main CICS Research Topic	*Climate Literacy, Outreach, Engagement, and Communications*
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2:0%; Goal 3:0%; Goal; 4:0%

Highlight: The project team documented and captured imagery for two rip current events and worked closely with NOAA's NOS production group “Oceans Today” to produce three short videos:
Rip Current Survival Guide: http://oceantoday.noaa.gov/ripcurrentfeature/
Rip Current Science: http://oceantoday.noaa.gov/ripcurrentscience/
Break the Grip of the Rip: http://oceantoday.noaa.gov/ripcurrent/

Background

Rip currents are among the leading causes of beach injuries along coastal United States waters. While there have been significant outreach efforts (e.g., “Break the Grip of the Rip”) related to informing the public on methods for self-rescue and survival once in a rip, relatively little effort has been placed on educating the public to identify rips in advance of getting into the water. A proactive, preventative approach could limit the number of instances of beach-goers entering the water in dangerous conditions and subsequently result in fewer injuries and rescues by lifeguards.

Identification of rip currents can be a difficult task for the untrained eye. Subtle differences in water texture and color, wave formation and shape are just a few of the telltale signs that are difficult to identify from ground level. A comprehensive documentation of rip current events with high definition video and photography from a variety of typical visitor views and aerial views could then be used as educational collateral as part of a nationwide educational campaign to “Spot the Rip” and prevent instances in which beach visitors get themselves into potentially dangerous swimming conditions.

Accomplishments

The Advanced Media and Visualization Lab at the UNC Coastal Studies Institute (UNC CSI), in partnership with NOAA's National Ocean Service (NOS) and Kill Devil Hills (KDH) Ocean Rescue, documented and captured imagery of rip current events on the northern beaches of the Outer Banks of North Carolina. In an effort to capture a variety of different rip current conditions, the team from UNC CSI documented two rip current events from a variety of land based and aerial perspectives, using multiple cameras simultaneously. Pre-production location scouting, “dress rehearsal” dry run filming and tests of multiple locations was completed prior to filming the first rip current event. Once the locations were determined, the team worked with KDH Ocean Rescue to respond to opportunistic rip current events as they happened. Camera angles included the following:

- Aerial videography from a variety of heights and angles (10m, 30m)
- Beach, Dune line angle
- Beach, Mid-beach angle
- Beach, waterfront level angle
- In water first person view angle

Figure 5. Mid-beach viewing angle of rip current. This angle is typical of what a beach visitor in a beach chair would observe and identification of the rip current is difficult for the untrained eye.

In addition to documenting rip currents from multiple camera angles, the team used fluorescein dye to illustrate and track the flow of the rip. The dye provided a visual cue that can be used to easily locate rip currents. By filming with and without the dye, it is easier for viewers to identify the rip current indicators.

Figure 2. Aerial image of rip current featured in Figure 1 with flourescein dye illustrating current path.

Aerial footage was shot using a DJI Inspire 1 UAV system with a DJI X5 micro 4:3 camera capturing video in 4k resolution. Ground level footage and imaging documentation was shot using Red Epic cameras for shooting in 6k resolution, providing the highest level of detail and significant latitude for grading and post production of imagery. 205 GB of graded footage of rip currents shot from multiple perspectives was delivered to NOAA's NOS team for use in research and education programming.

In addition, the team from UNC CSI worked closely with NOAA's NOS production group "Oceans Today" to produce outreach content, educational videos and collateral on rip current identification and safety. In all, three short features were created in partnership with the production team. The video features are as follows:

- Rip Current Survival Guide: http://oceantoday.noaa.gov/ripcurrentfeature/
- Rip Current Science: http://oceantoday.noaa.gov/ripcurrentscience/
- Break the Grip of the Rip: http://oceantoday.noaa.gov/ripcurrent/

Planned Work

During the last phase of the project in Spring of 2017, the Advanced Media and Visualization team at UNC CSI plan to capture additional rip current events with and without fluorescein dye. The team will work closely with KDH Ocean Rescue to respond to rip current events in a variety of conditions. This additional footage will be used in future educational programming and research. Shots planned include:

- Mid-beach angle
- Mid beach oblique angle
- Aerial straight down 30m altitude
- Water front standing angle
- Dune/beach access angle
- Aerial 30m altitude down the beach angle
- Aerial 30m altitude beach facing angle
- Aerial 10m altitude oblique angle
- Aerial 10m altitude straight out to sea angle
- Waterfront beach chair oblique angle

Products

Three outreach videos were produced in partnership with NOAA's "Oceans Today" production team.

- Rip Current Survival Guide: http://oceantoday.noaa.gov/ripcurrentfeature/
- Rip Current Science: http://oceantoday.noaa.gov/ripcurrentscience/
- Break the Grip of the Rip: http://oceantoday.noaa.gov/ripcurrent/

Other

The work performed in this project received considerable attention in local media outlets including print, web media, and local television coverage.

- North Beach Sun article: http://www.northbeachsun.com/let-it-rip-re-writing-rip-current-science-with-green-dye/
- Outer Banks Sentinel article: http://www.obsentinel.com/news/kill_devil_hills/rip-current-project-aims-to-raise-awareness-save-lives/article_4b31637a-273c-11e6-8ebd-5faa310255cb.html

- East Carolina University News Services article: http://www.ecu.edu/cs-admin/news/Rip-Current-project.cfm

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

Three educational videos on rip current science and safety were produced in partnership with NOAA's "Oceans Today" production team. Over 205 GB worth of ultra-high definition footage documenting rip currents to be used in research and education programming was delivered to NOAA's NOS.

Surface Observing Networks

Surface observing network activities address sustaining and improving the quality of in situ climate observations and observing networks.

The National Centers for Environmental Information (NCEI) along with NOAA partner institutions lead two national climate-observing programs, the U.S. Climate Reference Network (USCRN) and the U.S. Historical Climatology Network-Modernized (USHCN-M). NOAA's U.S. Climate Reference Network (USCRN) consists of 114 stations across the continental United States collecting sustainable observational climate data to provide a 50-year picture of climate change. Deployment of additional stations in Hawaiʻi and Alaska to provide for the detection of regional climate change signals is ongoing under the management of NCEI, in partnership with NOAA's Atmospheric Turbulence and Diffusion Division.

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

To support these activities, CICS-NC has built a group of research scientists supporting various climate observing network initiatives and providing relevant scientific expertise.

Support of NOAA- and NCEI-led climate observing network activities requires collaboration with the best climate science practitioners in the nation as well as the hiring of outstanding scientific staff with unique skills and backgrounds in Earth System Science and the use of observations for defining climate and its impacts. CICS-NC staff, under the CICS-NC Director and in coordination with NCEI project leaders and their respective staff, will continue to provide necessary expertise in the following areas:

- Expertise in the integration of surface, model, and satellite fields focusing on surface temperature dataset construction to pull through methodological lessons from a decade of research into radiosonde temperatures and supporting legacy projects on quality control of synoptic land data.
- Expertise in Quality Assurance in the USCRN program through comparison of USCRN observations with those from other surface observing networks (*e.g.*, COOP, ASOS, *etc.*) for the purpose of developing transfer functions and integrating networks for climate change studies; application of statistical techniques to examine uncertainties in operational USCRN measurements, QC techniques, and missing data treatments; development of methods for the automated production of USCRN-derived data products, map graphics, and time series for climate monitoring; and preparation of research data sets in various formats for internal and external use.
- Expertise in drought data monitoring and establishing drought monitoring products for the USCRN network through comparison of drought monitoring products developed using the combined USHCN-M/USCRN instrument suite to objective SCAN soil moisture data and

subjective U.S. Drought Monitor assessments; contribution to the scientific analysis of USCRN soil moisture/temperature data for the purposes of improving data quality and advancing the understanding of soil climate behavior as a function of the ensemble of USCRN observations; and providing access to the USCRN/USHCN-M observations and drought tools through the U.S. Drought Portal.

- Software engineering expertise in support of the maintenance and streamlining of the GHCN-M and HPD datasets through the following activities: review and analysis of the entire dataset processing function, including ingest, quality control, and homogeneity adjustments; daily processing oversight and troubleshooting; and initial development of a suite of quality control procedures through advanced statistics.
- Technical/scientific expertise to provide support for the Global Temperature Portfolio, targeting specific activities in ocean (sea surface temperature) and land temperature fields and products.

Analysis of USCRN Soil Observations	
Task Leader	Jesse E. Bell
Task Code	NC-SON-01-NCICS-JB
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCEI/USCRN
Contribution to CICS Research Themes (%)	Theme 1: 25%; Theme 2: 50%; Theme 3: 25%
Main CICS Research Topic	*Surface Observing Networks*
Contribution to NOAA goals (%)	Goal 1: 75%; Goal 2: 25%; Goal 3: 0%; Goal 4: 0%

Highlight: This research is an analysis of USCRN soil observations for developing an understanding of spatial and temporal variability of soil moisture and temperature. The goal of this work is to determine the changes in soil conditions to improve USCRN for drought monitoring and satellite calibration.

Background

The US Climate Reference Network is a series of climate monitoring stations maintained and operated by NOAA. To increase the network's capability for monitoring soil processes and accurately estimating drought, it was decided to add soil observations to the list of USCRN instrumentation. In the summer of 2011, the USCRN team completed the installation of all soil observational probes in the contiguous US. Each station, along with traditional measurements of surface air temperature, precipitation, infrared ground surface temperature, wind speed, and solar radiation, now also transmits relative humidity, soil temperature, and soil moisture measurements every hour. The data is maintained and stored at NOAA's National Centers for Environmental Information, while installation and maintenance is performed by NOAA's Atmospheric Turbulence and Diffusion Division (ATDD). In order to improve the ability of the network, multiple projects were started to analyze soil moisture variability and change.

Accomplishments

Surface soil moisture is a critical parameter for understanding the energy flux at the land–atmosphere boundary. Weather modeling, climate prediction, and remote sensing validation are some of the applications for surface soil moisture information. The most common in situ measurement for these purposes are sensors that are installed at depths of approximately 5 cm. There are, however, sensor technologies and network designs that do not provide an estimate at this depth. Extrapolating soil moisture estimates at deeper depths to the near-surface values would enhance the value of in situ networks providing estimates at other depths . Soil moisture sensors from the U.S. Climate Reference Network (USCRN) were used to generate models of 5 cm soil moisture, with 10 cm soil moisture measurements and antecedent precipitation as inputs, via machine learning techniques. Validation was conducted with the available, in situ, 5 cm resources. It was shown that a 5-cm estimate extrapolated from a 10-cm sensor and antecedent local precipitation produced a root-mean-squared-error (RMSE) of 0.0215 m^3/m^3. Next, these machine-learning-generated 5-cm estimates were also compared to AMSR-E estimates at these locations. These results were then compared with the performance of the actual in situ readings against the AMSR-E data. The machine learning estimates at 5-cm produced an RMSE of approximately 0.03 m^3/m^3 when optimized gain and offset values were applied. This is necessary considering the performance of AMSR-E in locations characterized by high vegetation water contents, which are present across North Carolina. Lastly, the application of this extrapolation technique is applied to the ECONet in North Carolina, which provides a 10-cm depth measurement as its shallowest soil moisture estimate. A raw RMSE of 0.028 m^3/m^3 was achieved and, with a linear gain and offset applied at each ECONet site, an RMSE of 0.013 m^3/m^3 was possible.

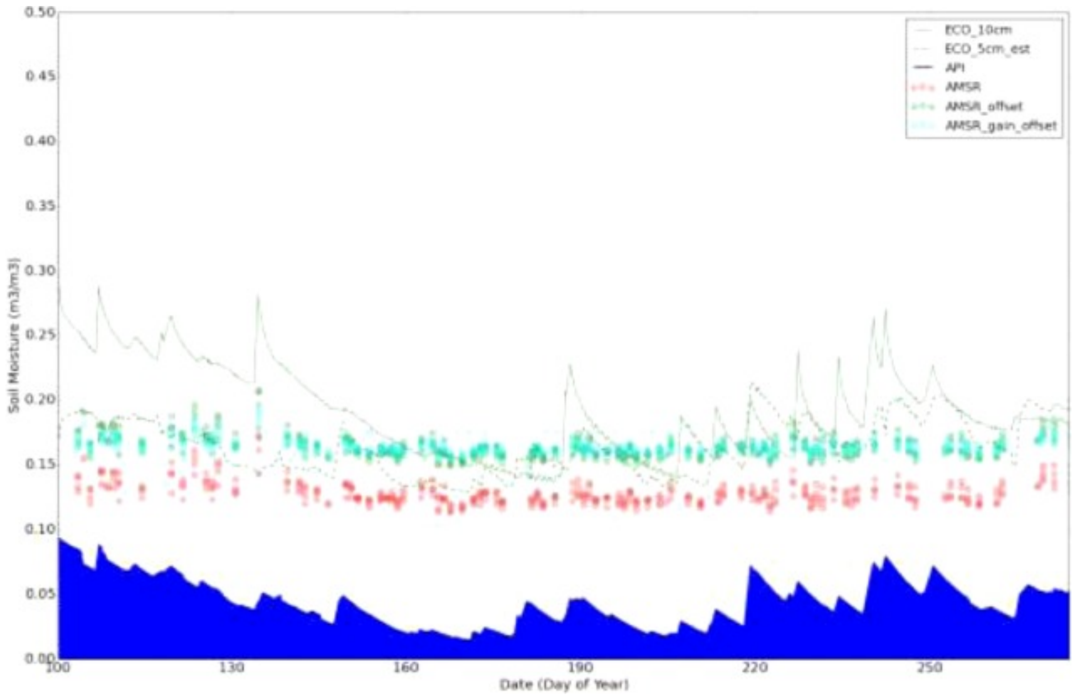


Figure 1. ECONet estimates at the Clayton station during 2011. The antecedent precipitation index (dark blue, filled) precipitation events to which the in situ soil moisture series and model respond (green and dashed-green lines), but the AMSR-E data from Ascending (A) Series do not.

Soil observations networks at the national scale play an integral role in hydrologic modeling, drought assessment, agricultural decision support, and our ability to understand climate change. Understanding soil moisture variability is necessary to apply these measurements to model calibration, business and consumer applications, or even human health issues. The installation of soil moisture sensors as sparse, national networks is necessitated by limited financial resources. However, this results in the incomplete sampling of the local heterogeneity of soil type, vegetation cover, topography, and the fine spatial distribution of precipitation events. To this end, temporary networks can be installed in the areas surrounding a permanent installation within a sparse network. The temporary networks deployed in this study provide a more representative average at the 3 km and 9 km scales, localized about the permanent gauge. The value of such temporary networks is demonstrated at test sites in Millbrook, New York, and Crossville, Tennessee. The capacity of a single U.S. Climate Reference Network (USCRN) sensor set to approximate the average of a temporary network at the 3 km and 9 km scales using a simple linear scaling function is tested. The capacity of a temporary network to provide reliable estimates with diminishing numbers of sensors, the temporal stability of those networks, and, ultimately, the relationship of the variability of those networks to soil moisture conditions at the permanent sensor are investigated. In this manner, this work demonstrates the single-season installation of a temporary network as a mechanism to characterize the soil moisture variability at a permanent gauge within a sparse network.

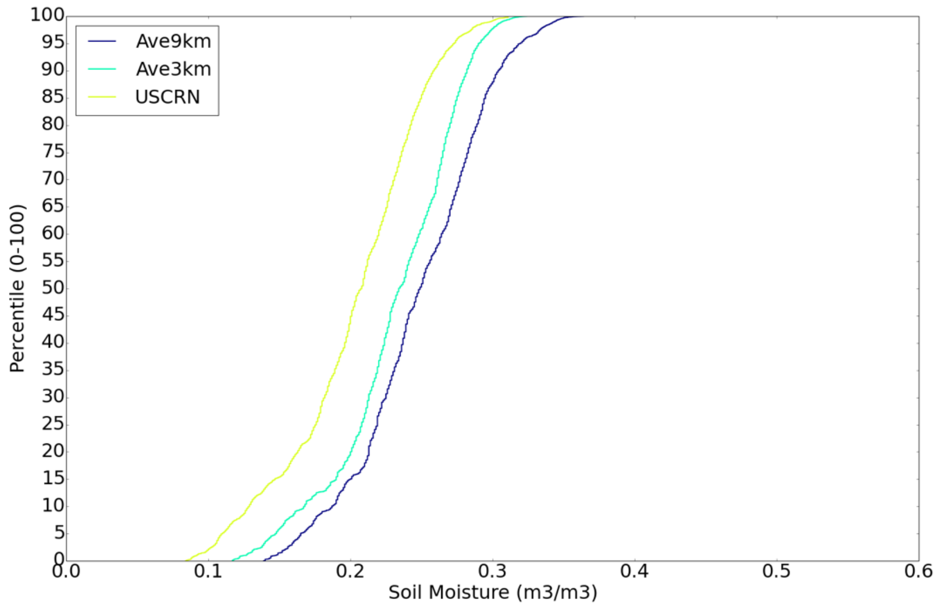


Figure 2. Cumulative distribution frequency plots were constructed to evaluate the population of USCRN values and compare them to 9 km and 3 km grid average value populations. The cumulative distribution frequency plots show that the three-time series at Millbrook display similar patterns of soil moisture for the period of record. Again, as expected, USCRN values were consistently drier than the 9 km values. The 3 km values were wetter than the USCRN values in the lower soil moisture percentages but were more similar to the USCRN values in the higher soil moisture conditions.

Planned Work

- Continue to evaluate drought indices for metric for USCRN
- Continue to improve USCRN soil observation quality control.
- Extend the soil moisture for the other depths with modeling
- Evaluate new soil moisture probes technology for USCRN

Publications

- Leeper, R. D., Bell, J. E., Vines, C., & Palecki, M. (2017). An Evaluation of the North American Regional Reanalysis Simulated Soil Moisture Conditions during the 2011 to 2013 Drought Period. Journal of Hydrometeorology, (available online).
- Coopersmith, E. J., Cosh, M. H., Bell, J. E., & Boyles, R. (2016). Using machine learning to produce near surface soil moisture estimates from deeper in situ records at US Climate Reference Network (USCRN) locations: Analysis and applications to AMSR-E satellite validation. Advances in Water Resources, 98, 122-131.
- Wilson, T.B., Baker, C.B., Meyers, T.P., Kochendorfer, J., Hall, M., Bell, J.E., Diamond, H.J. and Palecki, M.A., 2016. Site-Specific Soil Properties of the US Climate Reference Network Soil Moisture. Vadose Zone Journal, 15(11).
- Coopersmith, E. J., Cosh, M. H., Bell, J. E., Kelly, V., Hall, M., Palecki, M. A., & Temimi, M. (2016). Deploying temporary networks for upscaling of sparse network stations. International Journal of Applied Earth Observation and Geoinformation, 52, 433-444.

Products

- Improved USCRN soil moisture and temperature record.

Presentations

- Theodore M.I. Hartman, Jessica L. Matthews and Jesse E. Bell. Monitoring Drought with Vegetation and Soil Moisture Data. Annual AMS Meeting 2017

Other

- Theodore Hartman was a NOAA Hollings Scholar during the summer of 2016. He was advised by Jessica Matthews and co-advised by Jesse Bell.

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

Climate Monitoring and Research Support to the Atmospheric Turbulence and Diffusion Division of NOAA's Air Resources Laboratory	
Task Leader	Mark Hall
Task Code	NC-SON-02-ORAU
NOAA Sponsor	Howard Diamond / Bruce Baker
NOAA Office	NESDIS/NCEI/USCRN/ATDD
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: ORAU/ATDD performed annual maintenance at 12 Alaskan USCRN sites and completed one additional Alaska site installation in Yakutat bringing the current Alaska site total to 19. http://www.atdd.noaa.gov/research/	

Background

NOAA's Air Resources Laboratory (ARL) Atmospheric Turbulence and Diffusion Division (ATDD) plays a vital role in support of the United States Climate Reference Network (USCRN) and the United States Climate Reference Network-Alaska (USCRN-AK). These networks contribute to improved understanding of U.S. national climate variability and change by providing high-quality in situ observations. The installation, commissioning, and ongoing maintenance and support of these climate-observing systems are essential to scientific climate research and provide national- and regional-scale data required by several sectors of the economy, in particular the water and energy resources management industries. NOAA's ATDD and Oak Ridge Associated Universities (ORAU) are primarily responsible for installing, maintaining, and designing these observing systems for NOAA. In addition to these projects, the ATDD/ORAU partnership conducts research on urban climatology, renewable energy, satellite calibration/validation, and fluxes of meteorological parameters and chemical species and their impact on land surface changes and climate.

ORAU contractor personnel are co-located with ATDD federal civil service employees, and they work closely with NOAA to conduct research to advance atmospheric science and technology and provide the highest quality atmospheric, meteorological, and climate products and services to NOAA, the research community, and society to protect human health and our environment.

ATDD's research and infrastructure and instrument support is aligned with NOAA's objectives to build and maintain a Weather Ready Nation, enhance our nation's abilities in Climate Adaptation and Mitigation, and promote a holistic understanding of the Earth system through research and the development of an integrated environmental modeling system.

Accomplishments

A new Alaskan site was installed in August 2016 bringing the total sites in Alaska to 19. Yakutat is located in the lowlands along the Gulf of Alaska and at the mouth of the Yakutat Bay. It is a single system, A/C powered site with battery backup.

CRN site at Yakutat, Alaska

Annual Maintenance was performed at 12 Alaskan CRN sites.

Planned Work

Two more sites are scheduled to be installed in Alaska during summer and early fall.

Publications

- Buisan S.T., J.I. López-Moreno, M.A. Saz, J. Kochendorfer (2016). Impact of weather type variability on winter precipitation, temperature and annual snowpack in the Spanish Pyrenees. Climate Research 69:79-92. doi:10.3354/cr01391
- Graham, S. L., John Kochendorfer, Andrew M.S. McMillan, Maurice J. Duncan, M.S. Srinivasan, and Gladys Hertzog (2016). Effects of agricultural management on measurements, prediction, and partitioning of evapotranspiration in irrigated grasslands. Agricultural Water Management 177: 340-347. http://dx.doi.org/10.1016/j.agwa t.2016.08 .015
- Graham, S. L., John Kochendorfer, Andrew M.S. McMillan, Maurice J. Duncan, M.S. Srinivasan, and Gladys Hertzog (2016). Effects of agricultural management on measurements, prediction, and partitioning of evapotranspiration in irrigated grasslands. Agricultural Water Management 177: 340-347. http://dx.doi.org/10.1016/j.agwa t.2016.08 .015
- Wilson, Timothy B., C. Bruce Baker, Tilden P. Meyers, John Kochendorfer, Mark Hall, Jesse E. Bell, Howard J. Diamond, and Michael A. Palecki, (2016) Site-Specific Soil Properties of the US

Climate Reference Network Soil Moisture, Vadose Zone Journal, 15 (11), 10.2136/vzj2016.05.0047

- Coopersmith, E. J., M. H. Cosh, J. E. Bell, V. Kelly, M. Hall, M. A. Palecki, and M. Temimi (2016). Deploying temporary networks for upscaling of sparse network stations. International Journal of Applied Earth Observation and Geoinformation, 52, 433-444. doi: 10.1016/j.jag.2016.07.013

Presentations

- Scientists from ATDD had a significant presence at the 97th Annual Meeting of the American Meteorological Society at the Washington State Convention Center in Seattle, Washington, on January 22-26, 2017. Among the scientific presentations made at the conference by ATDD researchers was one entitled “The WMO Solid Precipitation Intercomparison and the determination of universal wind speed corrections” by John Kochendorfer.
- Bruce Baker organized and served as Program Chair for the “Special Symposium on Meteorological Observations and Instrumentation”. In this Symposium, several ATDD scientists served as session chairs. John Kochendorfer chaired a session titled “Boundary Layer Studies Including Important Flux Measurements" and Bruce Baker chaired the “New Observations from Field Programs".
- Bruce Baker also Co-chaired a Joint Session between the 18th Conference on Aviation, Range and Aerospace Meteorology and the Special Symposium on Meteorological Observations and Instrumentation entitled “Unmanned Aerial Systems: Environmental Monitoring and Impacts on Operations”

Other

- Dr. LaToya Myles was selected to receive the 2016 Technology All-Stars Award at the Technological Recognition Luncheon during the 21st Women of Color STEM Conference in Detroit, MI on October 14, 2016.
- ATDD scientists hosted three student interns from the 2016-2017 NOAA Hollings Scholar class during the summer of 2016.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**5**
# of NOAA technical reports	**0**
# of presentations	**3**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**3**

Extension of the Great Smoky Mountain Rain Gauge Mesonet and Exploration of the Origins of Extreme Precipitation Events in the Southern Appalachian Mountains and their Signatures as Observed by GOES-R

Task Leader	Douglas Miller
Task Code	NC-SON-03-UNCA
NOAA Sponsor	Steven Goodman
NOAA Office	NESDIS/GOESPO
Contribution to CICS Research Themes (%)	Theme 1: 20%; Theme 2: 80%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%

Highlight: Completed Fall 2016 maintenance and data collection gauge visits as part of this collaborative research effort to extend the period of observations of the Duke University Great Smoky Mountains National Park Rain Gauge Network (Duke GSMRGN). Details of every gauge visit along with precipitation raw and CSV files: https://drive.google.com/open?id=0B9P8oUaRiBOweG5VcU9wMVE3TDg

Background

The Duke University Great Smoky Mountains National Park Rain Gauge Network (Duke GSMRGN), funded by NASA to measure rainfall accumulation at 32 mid (~3400 feet) and high (~6600 feet) elevation locations in the Pigeon River basin (Figure 1 of Duan et al. 2015), has been collecting observations since the first gauges were installed in 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 rainrate retrieval algorithms. Although analysis of the nine-year record of precipitation observations continues, significant findings have emerged and been publicized (e.g., Wilson and Barros 2014, Duan et al. 2015, Miller et al. 2016).

NASA funding for the Duke GSMRGN ended with calendar year 2014 and has been supported in an ad hoc fashion since then via internal research grants at Duke University that ended in calendar year 2015. This project represents a collaborative research effort to extend the period of observations of the Duke GSMRGN for three years beyond 1 July 2016, with funding provided by UNC Asheville, the Center for Western Weather and Water Extremes located at the Scripps Institution of Oceanography, and NOAA-NESDIS.

Accomplishments

Table 1. Gauge visits during the autumn 2016. Comments: DD=gauge data download, MN=general gauge maintenance (cleaning, re-level), CA= rain gauge calibration, and BR = data logger battery replacement.

Date	Gauges Visited	Technicians	Comments
10/2/2016	1; 3	Doug, Carly, Ben	DD, MN, CA, BR
10/7/2016	2; 5; 8*	Doug, Jackie	DD, MN, CA, BR
10/15/2016	100T, 105, 104	Doug, Kyle	DD, MN, CA, BR
10/16/2016	300, 308	Doug, Samuel, William	DD, MN, CA, BR
10/21/2016	106, 10	Doug	DD, MN, CA, BR
10/22/2016	304, 307	Doug, Carly, Samuel	DD, MN, CA, BR
10/28/2016	4, 108, 109	Doug, Ben	DD, MN, CA, BR

11/4/2016	311, 110	Doug	DD, MN, CA, BR
11/5/2016	111, 112, 107	Doug, Kyle	DD, MN, CA, BR
11/6/2016	303s, 306	Doug, Rachel, Carly	DD, MN, CA, BR
11/11/2016	101, 102, 103	Doug	DD, MN, CA, BR
11/13/2016	305, 309, 310	Doug, William, Samuel	DD, MN, CA, BR
12/7/2016	109, 110	Doug	CA, MN
12/21/2016	301, 302	Doug, Daniel	DD, MN, CA, BR

2 October – 21 December 2016

Gauge visitation in support of the Duke Great Smoky Mountain Rain Gauge Network (GSMRGN) during the autumn 2016 occurred over 14 days spanning a period of 12 weeks from October–December 2016. The primary purpose of the visits in the autumn 2016 was [1] to perform downloads of gauge tip observations since the previous gauge visits in the summer 2016, [2] to complete maintenance tasks, [3] to replace the data logger lithium or HOBO battery and [4] to calibrate every rain gauge with three trials using the 50, 100, and 300 mm nozzles. Ten technicians and volunteers made the visits and performed the required work. It is important to note that the volunteers were NOT directly involved in any of the gauge visit tasks, but were volunteering to assist with personal safety should someone get injured during a particular series of gauge visits.

The general tasks completed at every gauge visit consisted of (1) gauge data download from the data loggers [DD in Table 1], (2) general gauge maintenance and ML1 logger condition monitoring [MN in Table 1], (3) replacement of lithium data logger or HOBO batteries [BR in Table 1], and (4) three calibration trials [CA in Table 1]. Specialized tasks were to re-install a gauge that had been pushed over (evidence of a bear) at the southernmost gauge on Cataloochee Divide (g110), re-install a gauge cover that had been torn off (evidence of a bear) at the northernmost gauge on Lickstone Ridge (g010), remove insect cocoons that had incapacitated the tipping mechanism of the gauge buckets (g104 and g107), and re-visit a gauge (g109) that had registered missing tips during its initial calibration visit. Task (1) merely required a serial port link between the field study laptop and the gauge data logger and consisted of pulling the data (often in files having raw [*.txt] and CSV formats) onto a desktop folder on the laptop, checking for completeness of the data, and comparing the data logger time and date to the actual GPS time and date (making a screen capture of the time comparison). The standard that has been chosen for this study is to maintain the clocks on Eastern Daylight Time, since most of the "warm" precipitation will be occurring during the season when EDT is in effect. Most ML1-FL data logger times have been adjusted (using "TA" command) during previous gauge visits to coincide with the EDT given by the GPS locator. Most new ML1-420 loggers installed during the summer 2013 campaign were keeping much better time than did the older generation ML1-FL loggers and only required minimal adjustment. However, the lithium battery life of the ML1-420 loggers (one logger had a dead battery since the previous visit in the summer 2016; g301) is much less predictable than the ML1-FL loggers. Task (2) required the cleaning of debris from the funnel filter, cleaning the tipping buckets of debris (if necessary), cleaning the gauge drain ports and siphon, re-leveling the gauge if it has come unleveled, and fixing or replacing the gauge mesh if it had been damaged. Task (3) consisted of replacing data logger lithium or HOBO batteries at ALL gauges during the autumn visit campaign. The Hydrological Services of America (HSA) logger draws power from the laptop while connected, so it is unknown if the voltage shown during a WinComLog (HSA software) session is accurate. Task (4) involved running three trials using the 50, 100, and 300 mm nozzles using the Duke #2 calibration tube. Calibration trials required the packing of water (one gallon per gauge) and slowed each gauge visit (1.25 extra hours) so that the total gauge visit campaign was spread out over a much greater period than usual.

The challenges encountered during some of the gauge visits in the autumn 2016 were the result of unusual weather; remnants of hurricane Matthew, northwest flow snow, severe drought, wildfires, and the windstorm of 28 November 2016. Since calibration trials require a lack of precipitation and relatively calm wind speeds, gauge visits had to be re-scheduled until favorable weather conditions could return. At least one gauge (g008) will need to have the calibration trials completed during the spring 2017 visit campaign as a return visit to the Waynesville Watershed was unable to be scheduled during the autumn 2016. A windstorm on 28 November 2016 resulted in the downing of numerous trees and the spreading of a significant wildfire in the Gatlinburg, TN region. As a result, entrance to the Cosby, TN campground in the GSMNP was closed until 15 December 2016. Visits to gauges #301 and 302 were delayed until 21 December 2016, the shortest day of the year.

Details of every gauge visit along with precipitation raw and CSV files can be found via Google Drive at https://drive.google.com/open?id=0B9P8oUaRiBOweG5VcU9wMVE3TDg which contains sub-folders for each gauge that consist of the 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 a MS Word document that mirrors the notes made in the field journal during the visit.500-700 words; up to two figures with figure caption.

Planned Work

25 March – 6 May 2017
Gauge visitation in support of the Duke GSMRGN during the spring 2017 will occur over at least eight days spanning a period of six weeks in March - April 2017. The primary purpose of the visits will be to download precipitation observations that were made since the previous gauge visits in October – December 2016 [DD in Table 2], perform maintenance and check if the ML1 logger times have drifted between visits and make the corresponding needed adjustments [MN in Table 2], clear vegetation (and tree branches) from overhanging gauges [CV in Table 2], and replace ML1 or HOBO batteries at the needed rain gauge location [BR in Table 2].

Details of every gauge visit along with each gauge precipitation and calibration data record will be posted online and shall contain sub-folders for each gauge that consist of the 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 a MS Word document that mirrors the notes made in the field journal during the visit.

New undergraduate research students at UNC Asheville will be recruited as field technicians for the Duke GSMRGN project during an informational meeting to be held in the ATMS Department early in the fall 2017 semester. The current technician roster during the academic year consists of William Clark, Rachel Dunn, Ben House, Jackie Hoyle, Carly Narotsky, Kyle Noel, Samuel O'Donnell, Zachary Tuggle, and Ethan Wright. Students William Clark, Ben House, Kyle Noel, and Ethan Wright will be graduating from UNC Asheville in May 2017.

Publications

- Miller, D.K., D. Hotz, J. Winton, and L. Stewart, 2017: Investigation of atmospheric rivers impacting the Pigeon River Basin of the southern Appalachian Mountains. Soon to be submitted to Wea. Forecasting.

Products

Ralph Ferraro's group has used observations of the Duke GSMRGN from three case studies in August, September, and October 2016 for NESDIS validation activities related to the following precipitation products:

- NOAA's Multi-Radar/Multi-Sensor (MRMS) system,
- NOAA's Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR),
- NOAA's Hydro Estimator (HYDROE), and
- NASA's Integrated Multi-SatellitE Retrievals for GPM (IMERG).

Presentations

- Miller, D., L. Stewart, D. Hotz, J. Winton, A. Barros, J. Forsythe, A. P. Biazar, and G. Wick, 2016: Investigation of Atmospheric Rivers Impacting the Pigeon River Basin of the Southern Appalachians. Oral presentation given at the 2016 International Atmospheric Rivers Conference, San Diego, CA.

References

- Barros, A. P., Petersen, W., Schwaller, M., Cifelli, R., Mahoney, K., Peters-Liddard, C., Shepherd, M., Nesbitt, S., Wolff, D., Heymsfield, G., Starr, D., Anognostou, E., Gourley, J. J., Kim, E., Krajewski, W., Lackman, G., Lang, T., Miller, D., Mace, G., Petters, M., Smith, J., Tao, W.-K., Tsay, S.-C., and Zipser, E.: NASA GPM-Ground Validation: Integrated Precipitation and Hydrology Experiment 2014 Science Plan, Duke University, Durham, NC, 64 pp., doi:10.7924/G8CC0XMR, 2014.
- Duan, Y., Wilson, A. M., Barros, A. P.: Scoping a field experiment: error diagnostics of TRMM precipitation radar estimates in complex terrain as a basis for IPHEx2014, Hydrology and Earth System Sciences, 19, 1501- 1520, doi:10.5194/hess-19-1501-2015, 2015.
- Miller, D., L. Stewart, D. Hotz, J. Winton, A. Barros, J. Forsythe, A. P. Biazar, and G. Wick, 2016: Investigation of Atmospheric Rivers Impacting the Pigeon River Basin of the Southern Appalachians. Oral presentation given at the 2016 International Atmospheric Rivers Conference, San Diego, CA.
- Wilson, A. M. and Barros, A. P.: An investigation of warm rainfall microphysics in the southern Appalachians: Orographic enhancement via low-level seeder–feeder interactions, J. Atmos. Sci., 71, 1783–1805, doi:10.1175/jas-d-13-0228.1, 2014.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**1**
# of graduate students supported by your CICS task	**1**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**10**

A presentation was made at the 2016 International Atmospheric Rivers Conference in San Diego, California, including results based partly on observations of the Duke GSMRGN. Continuation of the high-elevation gauge network was publicized during the presentation as supported by this study.
Graduate student Ryan Smith, of the University of Maryland, is working with Ralph Ferraro of NESDIS to validate NOAA and NASA precipitation products using observations of the Duke GSMRGN.
Nine undergraduate students of the University of North Carolina Asheville received field research credit based on their assisting PI Miller with the activities described in the Accomplishments section. One undergraduate student utilized observations of the Duke GSMRGN to assist PI Miller in the analysis and generation of results described in the manuscript soon to be submitted to the Weather and Forecasting Journal of the American Meteorological Society.

Development and verification of U.S. Climate Reference Network (USCRN) Quality Assurance Methods	
Task Leader	Ronald D. Leeper
Task Code	NC-SON-04-NCICS-RL
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCEI/USCRN
Contribution to CICS Research Themes (%)	Theme 1: 5%. Theme 2: 80%, Theme 3: 15%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 95%; Goal 2:5%; Goal 3:0%; Goal 4:0%

Highlight: Completed the adoption work of USCRN precipitation algorithm with colleagues at the National Ecological Observatory Network (NEON). In addition, the precipitation algorithm was used in the World Meteorological Organization (WMO) Solid Precipitation Inter-Comparison Experiment (SPICE) study. This task also developed a methodology to capture spurious precipitation estimates from USCRN stations, which led to the flagging of over 248,000 observation hours. Many of these flagged hours only impacted one of the three redundant sensors in the Geonor gauge, allowing precipitation to still be calculated from the remaining two sensors.

Background

The US Climate Reference Network (USCRN) monitors the U.S. climate from over 124 representative locations across the United States. Climate variables (e.g., temperature, precipitation, and soil moisture) are observed redundantly with sensors in triplicate to ensure data quality and continuity. Network quality control (QC) methods are responsible for both identifying suspicious sensor activity and combining redundant measurements into a single observation. The QC methods provide the foundation for the network to achieve its mission of monitoring the Nation's climate and serve as a valuable resource of current weather and climate information.

Accomplishments

Manual quality control efforts for precipitation were streamlined using a semi-automated system that reported suspicious precipitation estimates. This led to the network's first large scale manual QC endeavor for precipitation, which identified over 248,000 hours of suspicious gauge depths (*Figure 1*). Over half (~63%) of the documented Geonor gauge issues was due to intermittent sensor failure, which generally only impacts a single sensor at a time as it slowly degrades. This task further improves the quality of USCRN's precipitation data products, which promotes it's use in verification and hydrological based studies. For instance, USCRN precipitation dataset was used as a reference to verify the Hourly Precipitation Dataset's (HPD) revised QC algorithm in addition to ongoing efforts to verify satellite and radar precipitation products.

A collaborative effort with Derek Smith of the National Ecological Observatory Network (NEON) to implement a variant of USCRN's precipitation algorithm for their system was completed this year. In addition, a version of USCRN's precipitation algorithm was applied to U.S. based Geonor gauges used in a World Meteorological Organization's (WMO) study investigating precipitation gauge biases during freezing conditions.

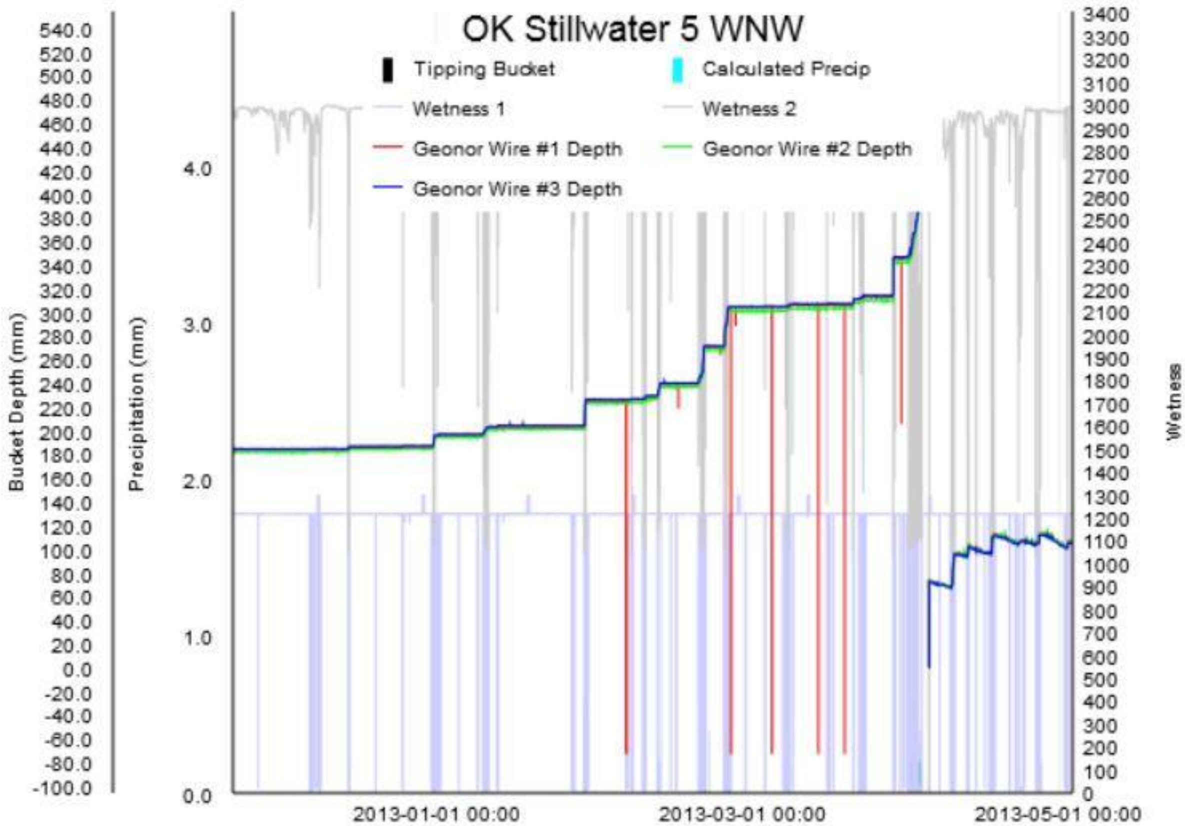


Figure 1. Redundant Geonor gauge depth measurements for the sensor wires 1 (red), 2 (green), and 3 (blue) with observed wetness channels 1 (purple) and 2 (gray) at the Stillwater 5 WNW, Oklahoma, station, which shows the intermittent failure (reporting of -60 mm) of depth sensor wire 1 prior to the sensor's replacement in April 2013.

As a continuation of previous efforts to analyze observation biases, Leeper mentored a student from the North Carolina State's Climate office who evaluated the impacts of land use on station observations. One of the key results was that minimum daily temperatures were more sensitive to urban warming than maximum temperatures.

Planned Work

- Continue to document and implement manual QC of suspicious gauge and other station observations as they are discovered.
- Complete analysis of the land-use study results and publish results
- Explore and evaluate techniques to expand the implementation range of the new precipitation algorithm to include the 15-minute data stream; post 2005 for most stations. The current version of the precipitation algorithm has not been applied to this period of the data record.

Publications

- Kochendorfer, J., Rasmussen, R., Wolff, M., Baker, B., Hall, M. E., Meyers, T., Landolt, S., Jachcik, A., Isaksen, K., Brækkan, R. and Leeper, R. 2017, The quantification and correction of wind-induced precipitation measurement errors, In Press

Products

The implementation of manual QC on USCRN precipitation data directly improves the quality of the Network's precipitation products from sub-hourly to monthly. The enhancement of data quality indirectly promotes other hydrological assessments using USCRN's precipitation data:

- Satellite and radar calibration and verification studies
- Verification of the Hourly Precipitation Dataset (HPD) QC algorithm
- USCRN precipitation extremes
- Efforts to estimate USCRN soil moisture using gauge data

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

- Improved USCRN's precipitation related ftp products: sub-hourly, hourly, and monthly.
- Provided expertise to colleagues using USCRN precipitation data to verify the Hourly Precipitation Dataset's (HPD) new QC algorithm; the revised HPD dataset was released in beta.

Development of an Extra-Tropical Cyclone Track Datasets	
Task Leader	Ronald D. Leeper
Task Code	NC-SON-05-NCICS-RL
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 30%. Theme 2: 5%, Theme 3: 65%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals (%)	Goal 1: 75%; Goal 2: 20%; Goal 3: 0%; Goal 4: 5%

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

Background

This project is a part of a Strategic Environmental Research and Development Program (SERDP) grant that, among other things, aims to quantify changes in precipitation patterns with climate. While this grant focuses on precipitation from a variety of sources (e.g., atmospheric rivers, mesoscale convective complexes, hurricanes), this task concentrates on precipitation along frontal boundaries. To evaluate changes in precipitation patterns along fronts, frontal-based precipitation will be evaluated both historically and in the future using climate projections.

Accomplishments

Software has been developed that associates low pressure centers with frontal boundaries to describe an ETC system at any given point in time. This is accomplished using geographic information systems (GIS), which links ETC centers and nearby fronts based on distance criteria and the juxtaposition of lows, fronts, and front type (i.e., occluded, cold, warm). This process is currently being evaluated using surface bulletins from the National Weather Service (NWS).

Initial efforts to quantify frontal based precipitation observed at GHCN-D stations is nearly complete. The GHCN-D station observations have been paired with the respective metadata (i.e., latitude, longitude) in time, and observation times have been converted from local standard time to UTC to allow temporal alignment with NWS fronts. In addition, a few GHCN-D station observations have been assigned nearest front distances to allow for the identification of frontal days—days that have a nearby front within some critical distance. Preliminary results showing the percent of GHCN-D precipitation observed at 12UTC associated to fronts by distance criteria is shown in *Figure 1.*

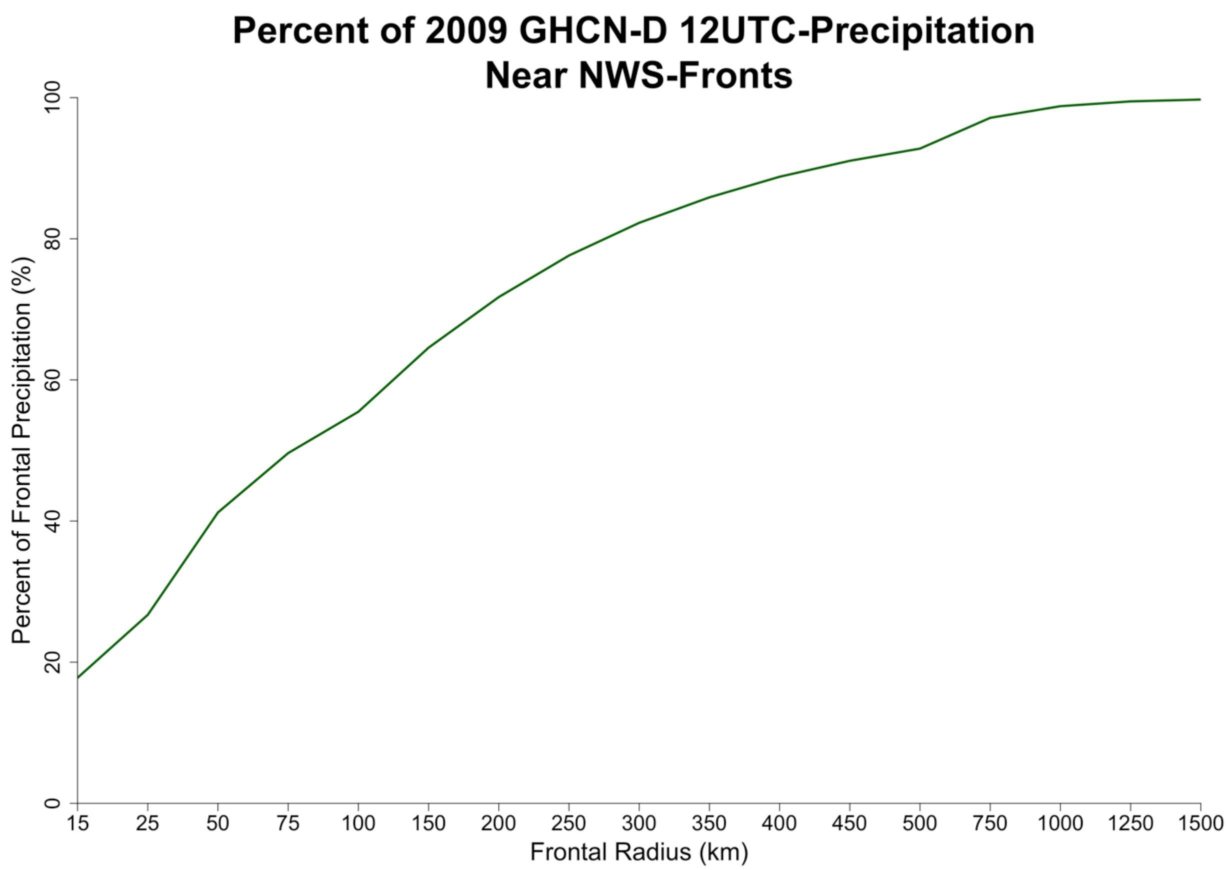


Figure 1. The percent of frontal precipitation (green line) by NWS front distance for 2009 GHCN-D stations with reporting times between 10:00 and 12:00 UTC.

Planned Work

- Complete front distance calculations for all GHCN-D station observations as well as other networks and observing platforms (i.e. radar and satellite).
- Finish evaluating the association of ETC pressure centers and frontal boundaries and apply the approach to available NWS data

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

Analysis of hydrological extremes from the U.S. Climate Reference Network (USCRN)	
Task Leader	Ronald D. Leeper
Task Code	NC-SON-06-NCICS-RL
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCEI/USCRN
Contribution to CICS Research Themes (%)	Theme 1: 0%. Theme 2: 75%, Theme 3: 25%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA goals (%)	Goal 1: 85%; Goal 2: 15%; Goal 3: 0%; Goal 4: 0%

Highlight: Completed a comparison between USCRN and the North American Regional Reanalysis (NARR) soil moisture datasets, which revealed that despite offsets in precipitation and soil moisture conditions, modeled data had similar temporal trends to observed data. In addition, a preliminary analysis evaluating USCRN precipitation extremes for various temporal durations was completed along with the development of an approach to standardized USCRN soil moisture observations. It has been proposed to NCEI that these two latter projects be operational products.

Background

The United States Climate Reference Network (USCRN) monitors precipitation and soil moisture conditions redundantly, which greatly enhances the quality and continuity of the data record. These variables provide a unique opportunity to evaluate hydrological conditions (droughts and flooding) in addition to extreme events.

Accomplishments

Hollings Scholar Emma Scott evaluated USCRN's precipitation extremes for various durations corresponding to the National Oceanic Atmospheric Administration's (NOAA) Atlas-14 durations (*Fig. 1*). The USCRN precipitation extreme results (frequency of exceedance) were compared with NOAA-Atlas 14, which showed sharp contrasts for the short durations (i.e., sub-daily). It was unclear if the differences were caused by recent trends in precipitation data over the last 10 years observed at USCRN stations that could differ from the longer period of record used in NOAA Atlas 14 stations or from assumptions and data used to estimate sub-daily frequency of exceedance.

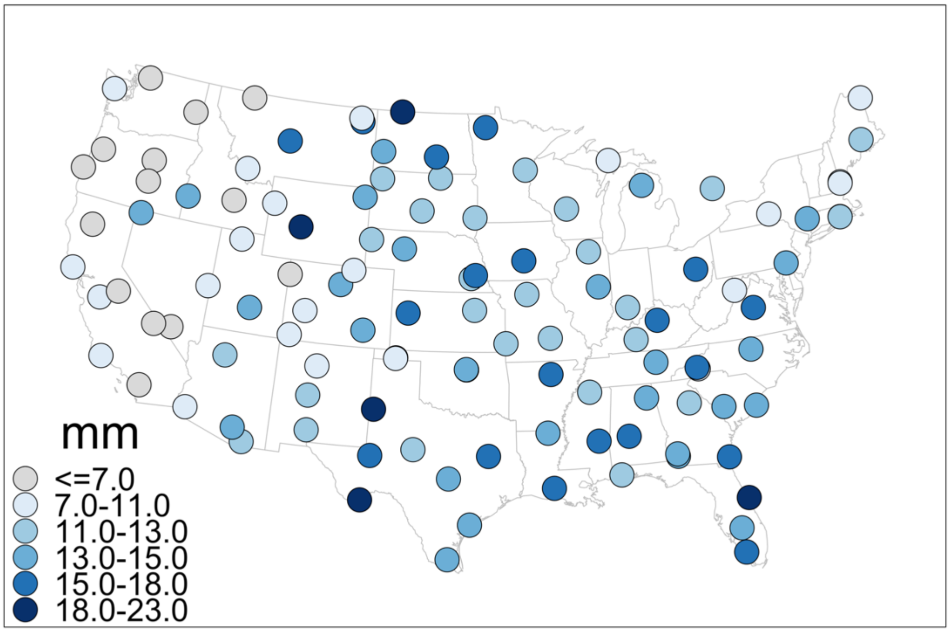


Figure 1. USCRN station period of record 5-minute precipitation extremes, showing lower extreme totals generally occur along the West due a reduced likelihood of convective type of precipitation events.

Several methodologies to standardized USCRN soil moisture observations were explored, which is necessary given the difficulty of interpreting volumetric soil moisture data. *Figure 2* shows how standardizing volumetric soil moisture data improves the identification of drier-than-typical regions as a result of the 2012 drought. Based upon the literature and analysis, it was decided that the most appropriate standardization approach for USCRN is an empirical method, which does not require assumptions about the distribution of the soil moisture data. This is important because soil moisture distributions will vary with station location and possibly observation depth, requiring a family of discrete distributions for each station that could evolve over time.

One of the main challenges of using an empirical approach is the short-term monitoring record: six years for most USCRN stations. The project group is currently investigating ways to sample the dataset in such a way that increases the sample size, which will improve the robustness of the empirically based approach.

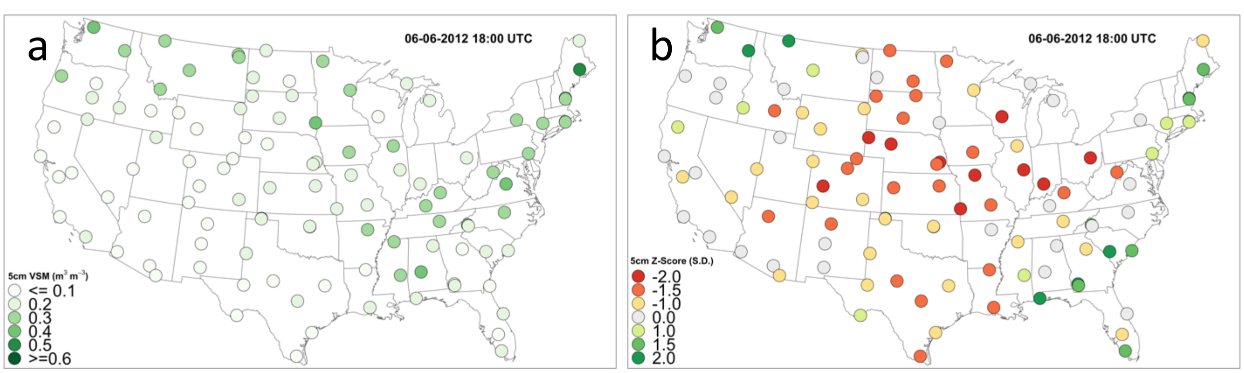


Figure 2. Maps of weekly averaged USCRN (a) volumetric soil moisture and (b) standardized volumetric soil moisture ending June 6th 2012 18:00 UTC, during the peak of the 2012 extreme drought.

Planned Work

- Recalculate USCRN precipitation extremes once ongoing manual QC efforts are completed
- Reanalyze USCRN precipitation extremes with NOAA-Atlas 14
- Further evaluate sampling methods to increase the sample size
- Operationalize USCRN soil moisture standardization processes and release a beta product
- Evaluate the effectiveness of the soil moisture percentiles to monitor drought and flood conditions

Publications

- Leeper, R. D., Bell, J. E., Vines, C., Palecki, M. 2017. An evaluation of the North American Regional Reanalysis simulated soil moisture conditions during the 2011-13 drought period. *Journal of Hydrometeorology*, 18, 515-527. http://dx.doi.org/10.1175/JHM-D-16-0132.1

Products

- Two new products are being proposed for USCRN. The first is a monthly updated precipitation extremes product that will report precipitation extreme metrics for each USCRN station. The second product is hourly standardized soil moisture data that will provide access to near-real time soil condition information to improve hydrological monitoring.

Presentations

- Leeper, R. D. Evaluation of In-Situ Soil Moisture Metrics to Monitoring Hydrological Extremes. Oral presentation at the American Meteorological Society Annual Meeting in Seattle, WA on January 23rd 2017
- Scott, E., Leeper, R. D., Palecki, M. Evaluating Precipitation Extremes from a Sparse Network: the NOAA U.S. Climate Reference Network. Oral presentation at the American Meteorological Society Annual Meeting in Seattle, WA on January 23rd 2017.
- Leeper, R. D., Palecki, M., Bell, J. E., Analysis of Soil Moisture Metrics to Assess Societal Risks to Hydrological Extremes. Poster presentation at the biannual Carolinas Climate Resilience Conference in Charlotte, NC, September 2016.
- Leeper, R. D. Evaluation of In Situ Soil Moisture Metrics to Monitor Hydrological Conditions. Poster presentation at the CICS Science Conference in Greenbelt, MD November, 2016.
- Leeper, R. D. Monitoring hydrological conditions using soil moisture observations at NCEI Science Council meeting, Asheville, NC, January 2017.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	0
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	1
# of NOAA technical reports	0
# of presentations	5
# of graduate students supported by your CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

Maintenance and Streamlining of the Global Historical Climatology Network – Monthly (GHCN-M) Dataset	
Task Leader	Jared Rennie
Task Code	NC-SON-07-NCICS-JR
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: Using an open and transparent databank of land surface stations, the next iteration of NOAA's global temperature product has been developed and released as a public beta. This new version includes more stations, along with enhancements to the data quality and homogenization algorithms.	
www.surfacetemperatures.org | https://www.ncdc.noaa.gov/ghcnm/	

Background

Since the early 1990s, the Global Historical Climatology Network-Monthly (GHCN-M) dataset has been an internationally recognized source of data for the study of observed variability and change in land surface temperature. The third version of this product has undergone many updates since its initial release in 2011. Updates include incorporating monthly maximum and minimum temperature, improving processing run time, and providing user-driven products. Currently the product is at version 3.3.0 and includes 7,280 stations globally.

Recently, there has been a need to address gaps in data coverage, along with proper documentation of data provenance. The International Surface Temperature Initiative (ISTI), developed in 2010, has taken on this issue by developing a state of the art databank of global surface temperature. Released in 2014, the first version of the databank contains over 30,000 surface temperature stations and triumphs in its openness and transparency, documenting the product all the back to the original source data. Many international organizations have heralded the product and have provided feedback that has gone into subsequent updates. All versions are available online, and the current operational version stands at v1.1.0, released in late 2015.

Because of the increase of number of stations, along with its transparency, this databank serves as the starting point for the next version of GHCN-M (version 4). In order to accommodate this, a new end-to-end processing system is set up to accommodate the new data. This system includes an update to ingest and quality control procedures. In addition, the algorithm to remove non-climatic influences in the data needs to be updated to incorporate the addition of stations, as well as adhere to NCEI coding standards.

Accomplishments

Version 1.1.0 of the databank serves as the starting point for version 4.0.0 of GHCN-Monthly. Because of this, the GHCN-M team has worked on setting up a new end-to-end process on an internal server. A three-tiered system has been set up, including a development, test, and production environment. Processing is done nightly and is performed in multiple steps (see *Figure 1*). The first step incorporates the latest Databank data that has near real time updates, including GHCN-Daily, as well as stations sent as climatic summary data, known as CLIMAT data. This data is compiled into ISTI format and then appended to version 1.1.0 of the databank. Afterwards, they are converted into a format that is similar to the GHCN-M format. From there, data is run through a suite of quality control algorithms and then finally through the Pairwise Homogeneity Algorithm (PHA) to remove non-climatic influences, such as station moves and instrument changes. Recently, the PHA has been refactored to improve cyclomatic complexity, reduce bugs, and adhere to new coding and configuration management standards set at NCEI.

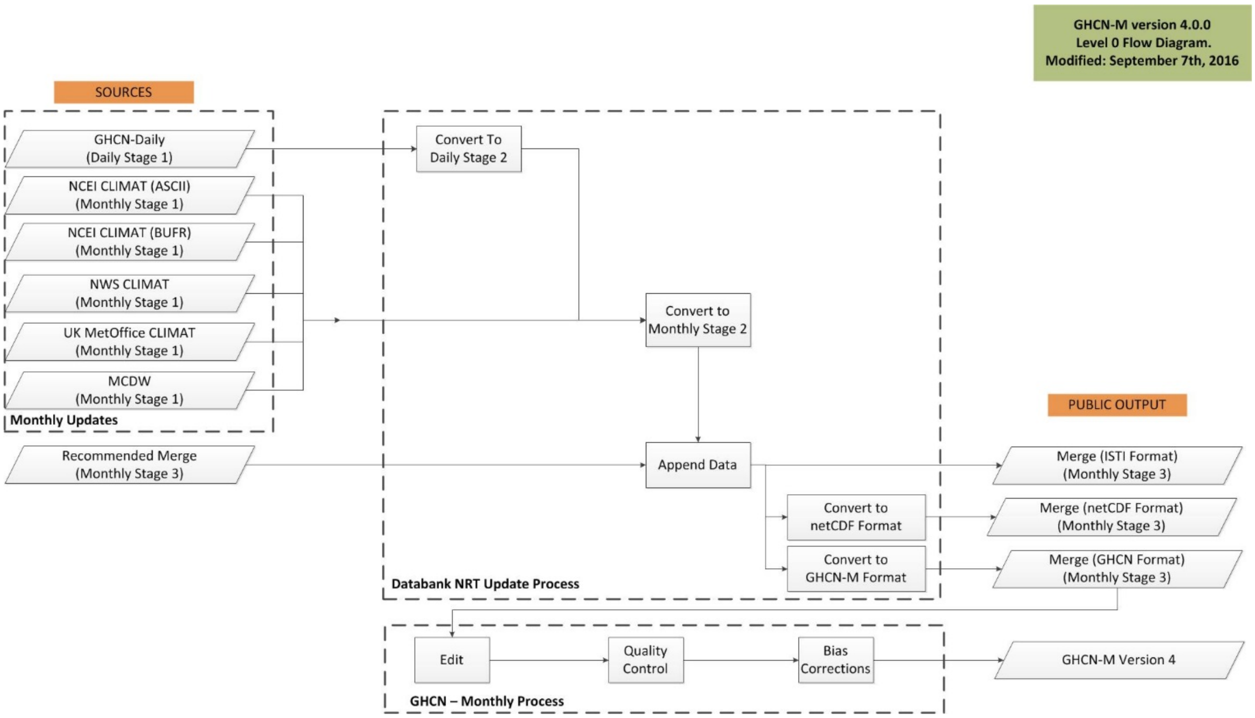


Figure 1. Level 0 Diagram of the GHCN-Monthly version 4 process, run each night.

GHCN-Monthly version 4 has been in a public beta (known as v4.b.1) since October 2015. Since then, feedback has been given by members of the public and by other organizations who use this data, including NASA and the United Kingdom's MetOffice. Changes based on user comments have been incorporated in the daily update system as needed. Documentation has been generated and presented at an Operational Readiness Review (ORR), given on December 8, 2016. The dataset has been approved for release by the NCEI Science Council, contingent upon publication of a journal article. The journal article is being drafted and incorporates uncertainty estimates, including spatial and temporal uncertainties. A preliminary example of spatial uncertainty in the global temperature mean is provided in *Figure 2*. Once the manuscript has been accepted for publication, GHCN-M version 4 will become operational. It will be applied to monthly State of the Climate reports a few months after that.

Planned Work

- Continue to engage with public on feedback regarding both the ISTI Databank version 1.1.0 and GHCN-M version 4.b.1. Provide updates to processing as needed.
- Finalize journal article, submit for internal and external review
- Release GHCN-M version 4 as an operational product. Engage with user community on any constructive feedback.

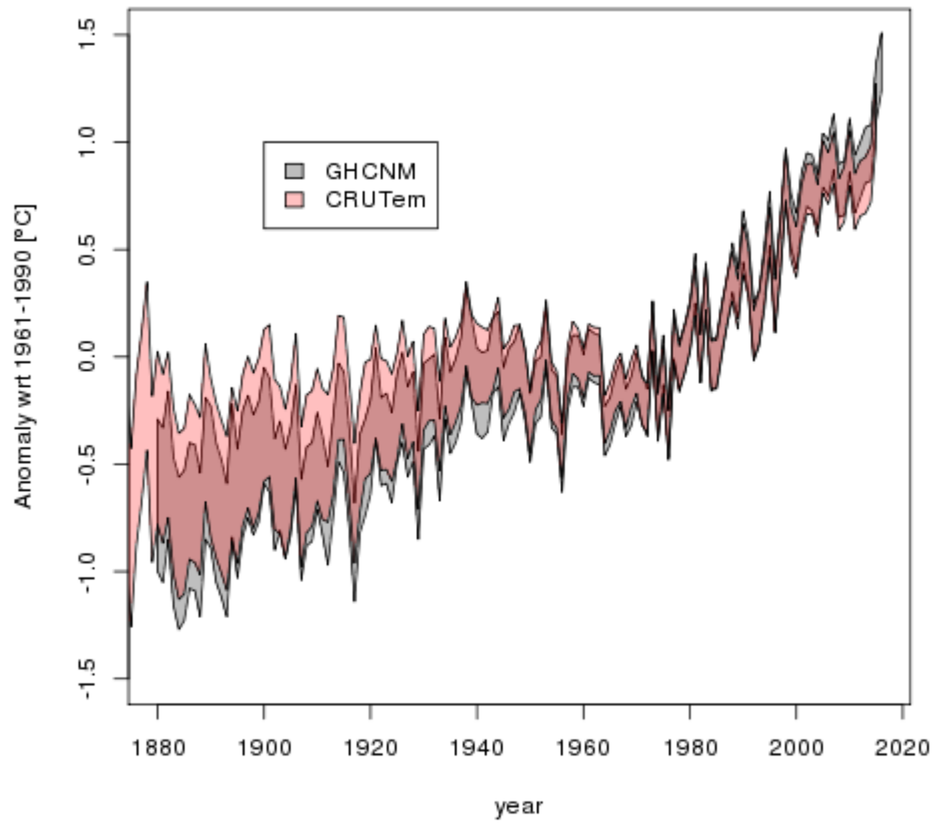


Figure 2. Global temperature time series from 1880–2016, along with a spatial uncertainty estimate, based upon a 100 multi-member ensemble assessment of the PHA. Plotted is the beta version of GHCN-Monthly (version 4) and the public version of the UK Met Office's CRUTEM product (version 4.5).

Publications

- An Overview of the Global Historical Climatology Network- Monthly Mean Temperature Data Set, version 4, in preparation.

Products

- Updates to both ISTI Databank (v1.1.0) and GHCN-M (v4.b.1) after addressing feedback from user community.
- Public version of GHCN-M version 4.0.0, upon acceptance of journal article.

Other

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

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

GHCN-Monthly version 4, based on the International Surface Temperature Initiative's Databank version 1.1.0, is under consideration for operational use. It passed the Operational Readiness Review (ORR) in December 2016, and we are finalizing the product for operational release. A technical report was developed for the ORR, and a journal article is currently in progress.

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool	
Task Leader	Jared Rennie, Kenneth Kunkel, and Jesse Bell
Task Code	NC-SON-08-NCICS-JR/KK/JB
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

Highlight: Steps have been made to create a sub-monthly tool for monitoring impacts of temperature extremes in the United States. Using products already distributed in house, station data is aggregated on the state, NCA region, and contiguous US levels to analyze current temperatures against its period of record. A dataset has been produced and has plans to undergo research to operation status.
https://ncics.org/portfolio/monitor/sub-monthly-temperatures/

Background

Land surface air temperature products have been essential for monitoring the evolution of the climate system. Before a temperature dataset is included in such reports, it is important that non-climatic influences be removed or changed so the dataset is considered homogenous. These inhomogeneities include changes in station location, instrumentation, and observing practices. Very few datasets are free of these influences and therefore most require homogenization schemes. 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). Since there is a demand for sub-monthly monitoring tools, there is a need to address these issues.

The Global Historical Climatology Network–Daily (GHCN-D) dataset provides a strong foundation for measuring 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 standards, no daily adjustments are applied. However, this dataset lays the groundwork for other products distributed at the National Centers for Environmental Information, including the climate divisional dataset (nClimDiv), the North American monthly homogenized product (Northam), and the 1981–2010 Normals. Since these downstream products already provide homogenization and base-period schemes, it makes sense to combine these datasets to provide a sub-monthly monitoring tool for the United States.

Accomplishments

A system has been set up on CICS-NC servers to grab the latest version of the following datasets: 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 is then aggregated through to the state level and then to the regional level using the regions defined by the National Climate Assessment (NCA). Plots are made for each day to analyze the state of the U.S. temperature values and anomalies. Once daily averages for each defined state and NCA region are made, probability distribution functions are generated to provide ranks on different time scales. These ranks are useful for understanding recent extremes in a changing climate. The process runs every morning, to incorporate the latest data from GHCN-D. Older versions are archived for future analysis. In addition, the analysis has been updated to incorporate three temperature elements (maximum, minimum, and average temperature). The website used to display the data has been upgraded and moved here: https://ncics.org/portfolio/monitor/sub-monthly-temperatures/. An example of an upgraded map is shown in *Figure 1.*

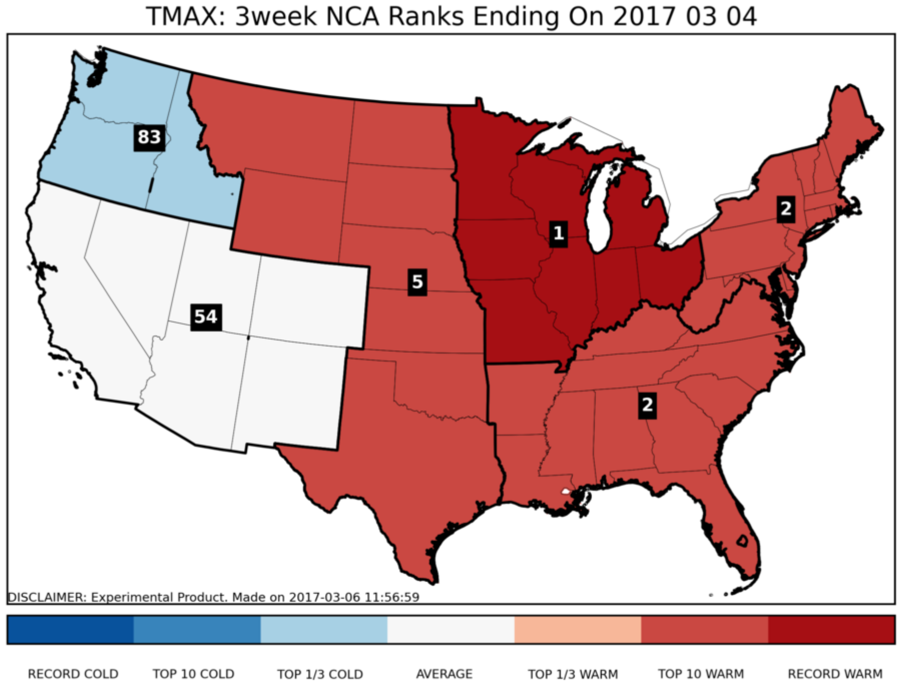


Figure 1. NCA averaged ranks of surface temperature, aggregated to a 3-week period ending on March 4, 2017. Maps have been updated to highlight regions of the National Climate Assessment, as well as maximum and minimum temperature (maximum shown here).

Currently, this dataset serves as the baseline for determining heat wave events in a project with both the Centers for Disease Control and Prevention (CDC) and the Society of Actuaries (SOA). Using state aggregated data for both Kansas and North Carolina. Heat events are being identified in their respective areas and compared to available health data to find any correlations. Work is also underway to draft a journal article describing the methodology and show results for events that occurred in 2016. In addition, a paper has been published describing a new daily homogenization algorithm, and it is hoped it will be applied to this dataset.

Planned Work

- Continue to engage with users on the product.
- Work with CDC and SOA to identify heat events with available health data.
- Publish journal article on processing and results.
- Incorporate new daily homogenization algorithm developed by Clemson University.

Publications

- Hewaarachchi, A.P., Y. Li, R. Lund, and J. Rennie, 2017: Homogenization of Daily Temperature Data. Journal of Climate, 30,985-999. doi: 10.1175/JCLI-D-16-0139.1

Products

- A new, state of the art monitoring tool for sub-monthly data for the lower 48 states.
- Public facing website to display updated maps and ranks.

Presentations

- Rennie, J.J., (2016), Shaken or Stirred: How Do You Want Your Climate Data? *Ask the Audience Session*, 2nd Carolinas Climate Resilience Conference, Charlotte, NC, 13 Sep 2016.

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

The product is considered operational and is running daily on CICS-NC servers. Two peer reviewed papers indirectly involve this dataset. The first is a daily homogenization technique that is hoped to be applied to this dataset, and the other is a manuscript in draft for the BAMS 2016 Climate Perspectives Report. A presentation was given at the Carolinas Climate Resilience Conference in September 2016, which showed off this data.

Building a Climatology of Extreme Snowfall Events in the United States	
Task Leader	Jared Rennie
Task Code	NC-SON-09-NCICS-JR
NOAA Sponsor	Jay Lawrimore, Derek Arndt
NOAA Office	NESDIS/NCEI (FEMA)
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%

Highlight: A project has been completed with both NOAA and FEMA to validate snowfall extremes for every county in the United States. This will help mitigate future snowfall events, and also build better spatial quality algorithms in our weather station data products.
https://www.ncdc.noaa.gov/snow-and-ice/snowfall-extremes/

Background

Understanding snowfall extremes is important for several reasons, including their disruptive effect on transportation in the United States, including roadways, air, and rail. In addition, businesses and schools can have impacts on their operations during periods of heavy, intense snowfall. The National Oceanic and Atmospheric Administration (NOAA), in coordination with the Federal Emergency Management Agency (FEMA), has maintained climatologies of 1-day, 2-day, and 3-day snowfall events for every United States County using NOAA's cooperative observer program (COOP). This network has been in existence since the late 1800s and includes volunteers who manually measure snowfall every day. Over the past few decades, there have been efforts to collect these measurements through additional networks, including the Automated Surface Observing System (ASOS) and the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network. In addition, improvements have been made to consolidate and archive these data through the Global Historical Climatology Network–Daily (GHCN-D) dataset, which includes an automated suite of quality assurance to ensure data integrity.

Because of the recent technological advancements, there is a need to update this climatology in order to not only use the latest and most complete data but also evaluate the importance of these indices in a changing climate. CICS-NC is leading this project and has worked to gather valid data, update climatologies for US counties, and verify through observing the historical data archive.

Accomplishments

Using station data from GHCN-D, snowfall data in the US has been gathered and aggregated to 1-day, 2-day, and 3-day totals. The stations are then organized by U.S. county using the Historical Observing Metadata Repository (HOMR), and the top 20 values (for each of the three totals) are ranked. County values ranked as number one are inspected to determine their validity. For observations that fail these validity checks, subsequent values are inspected until a valid event is confirmed. Bad data are logged so they can be processed as such later and also kept for future verification schemes of updated quality control processes.

There are two validation methods. The first is by looking up the original paper record where available. If a paper record is hard to read or unavailable, a spatial eye-ball test is performed using neighboring stations. Data for all 50 states and the District of Columbia have been confirmed through the latest winter season (2015/2016). A preliminary version of results was sent to local National Weather Service (NWS) Offices in September of 2016 for vetting. This vetting has been completed, and a website has been generated displaying the results: https://www.ncdc.noaa.gov/snow-and-ice/snowfall-extremes/. An example for the state of North Carolina is provided in *Figure 1.* While updates will be required to incorporate the latest winter seasons, the scope of this project for CICS-NC has been completed.

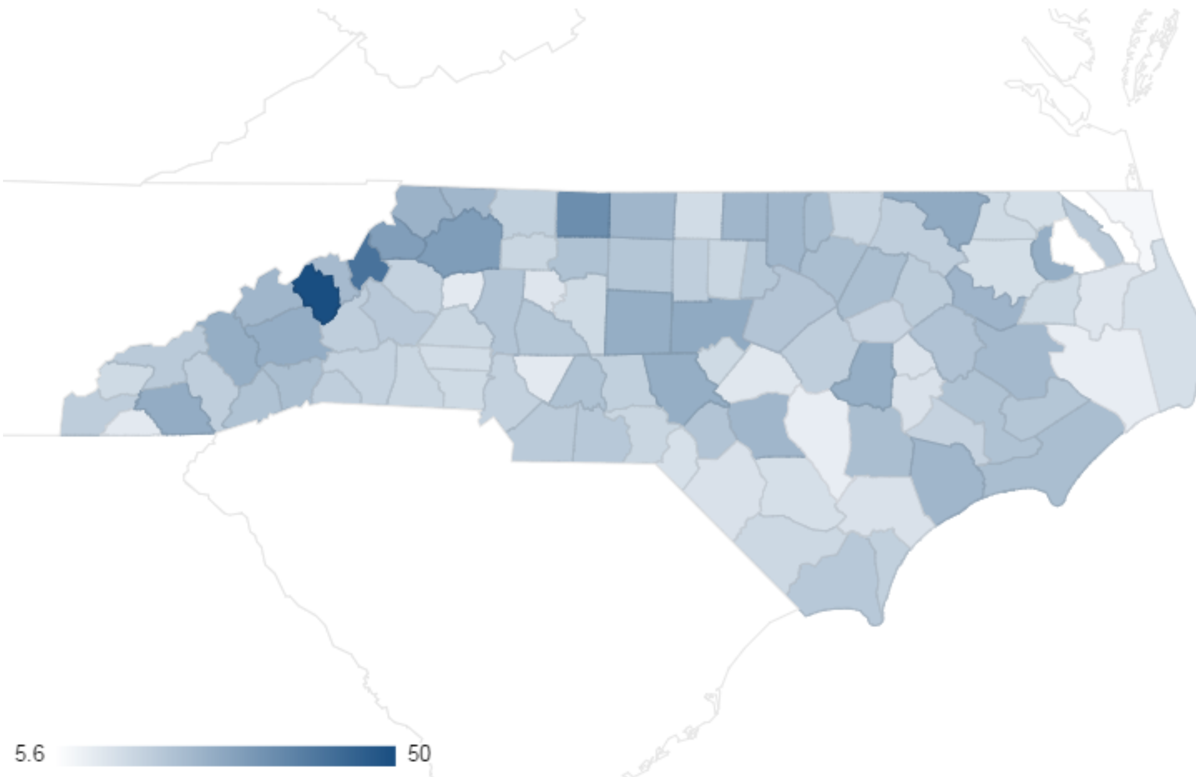


Figure 1. Map of 3-day snowfall extremes for North Carolina, organized by county. The highest total occurred in Yancey County, where Mt. Mitchell saw 50 inches of snowfall between March 12th and 14th of 1993.

Planned Work

- Update as needed for future winter seasons.

Products

- An update to 1-day, 2-day, and 3-day snowfall climatologies for every county in the US.
- Website displaying results

Presentations

- Rennie, J.J., and D.S. Arndt (2017) Updating a Climatology of Extreme Snowfall Events in the United States, POSTER, 29th Conference on Climate Variability and Change, AMS Annual Meeting, Seattle, WA, 24 Jan 2017.

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

The product has been completed, and is considered operational by NOAA. A poster presentation was given at the AMS Annual Meeting in Seattle, Washington in January 2017.

Simplified and Optimal Analysis of NOAA Global Temperature Data: Data Validation, New Insights, Climate Dynamics and Uncertainty Quantification	
Task Leader	Samuel Shen
Task Code	NC-SON-10-SDSURF
NOAA Sponsor	Russell Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%
Highlight: Developed a suite of modern big data and computing tools for delivering NOAA environmental data to schools, households, and the general public. **http://climate.mrsharky.com/**	

Background

Modern climate data have helped deepen the understanding of climate dynamics that operate in the background of global temperature increase and has also called for more careful, transparent, and independent analyses of relevant climate datasets, including the blended NOAAGlobalTemp. The general public has enormous interest in climate variation, wants to have an easy access to climate data, and needs the quantitative description of the climate data accuracy. These give rise to many research questions on climate data delivery, climate data accuracy quantification, and the climate dynamics that can reasonably explain the climate data. The purpose of this project is to provide partial answers to these questions. The project has four primary tasks:

1. R programming for NOAAGlobalTemp data and fast delivery of data from climate and satellite observations and monitoring to both the science community and the general public: Develop R codes for analyzing NOAA datasets, conduct a short course at CICS-NC/NCEI about R using the NOAAGlobalTemp data, and deliver NOAA datasets to school classrooms using big data technology.
2. Construction of independent datasets to verify bias adjustments: Make global temperature extrapolations from-ocean-to-land and from-land-to-ocean, and compare the results with NOAAGlobalTemp data to verify bias adjustments for observed data.
3. Use climate dynamics and forcings to explain the NOAAGLobalTemp data: Explore various climate dynamics indices and explain the staircase increase of the global temperature since 1880, particularly since 2000.
4. Evaluation of alternative approaches for creating area-averaged time series: Explore various kinds of optimization methods to compute the global average of surface air temperature anomalies.

Accomplishments

Research has progressed as planned and we have made five major accomplishments during this report period. Our most important achievement is the fast delivery of big environmental data. Accomplishments below include: #1 and #2 in support of project Task 1 above, #3 in support of project Task 2, #4 in support of project Task 3 and #5 in support of project Task 4.

1. 4-dimensional visual delivery (4DVD) of big climate data: We have developed a remarkably fast visual delivery system as a distributed file service application based on web browser, database, server and Hadoop technology. The 4DVD can be accessed in a limited way at http://climate.mrsharky.com/, before a full operational version is installed at CICS-NC/NCEI, or another big data provider contracted with NOAA. See *Figure 1* for January 1983 NOAAGlobalTemp. This is a map on a globe, but can also be displayed in a 2D lat-lon map.

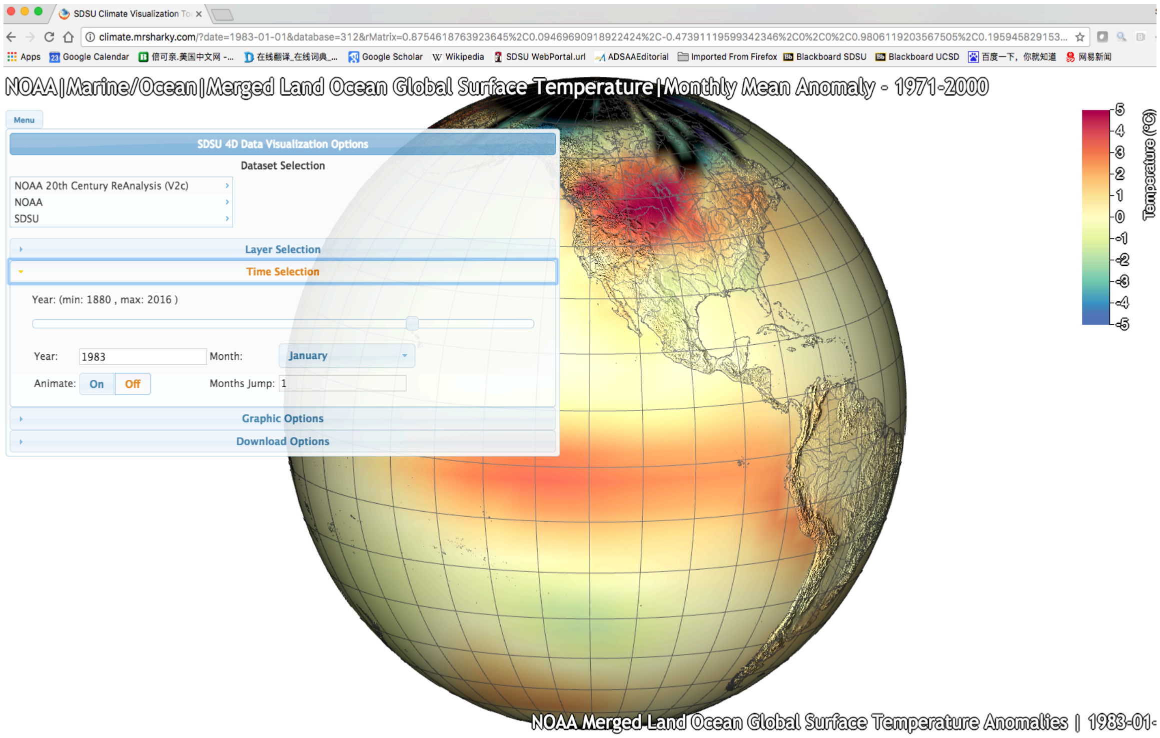


Figure 1. 4DVD display of NOAAGlobalTemp data: January 1983 temperature anomalies

4DVD delivers data in a 4D space-time box and allows users to visualize the climate data as maps (e.g., *Figure 1*) or time series for a point on a map (see *Figure 2* next page). Data can be downloaded for maps or time series, after the maps and time series are found useful. Our 4DVD system is scalable to any data size. The 4DVD's fast speed and beautiful maps are attractive to students and can help with NOAA climate literacy and outreach. These make 4DVD very different from the traditional data downloads and the existing online plotting system at NOAA and NASA, such as NOAA's Climate at a Glance, climate.gov, Explorer, and NASA's Giovanni. See Pierret and Shen (2017) for 4DVD's details.

2. R programming for climate data and R course: We have written a suite of R codes to read NOAA climate data in different formats (e.g., asc, and nc). These R codes can be incorporated with the current readme files associated with the NOAA climate datasets, such as NOAAGlobalTemp. Users can easily use our R codes to read the data, compute their statistics, and plot maps or time series. The free R and our easy-to-use R codes in the readme files should attract many more NOAA data users.

   A 52-page instruction manual has been written for the planned CICS/NCEI short course on R programming. NOAA climate data scientists will be trained use the developed R codes, but also to create new R codes for NOAA datasets, such as NOAAGlobalTemp.

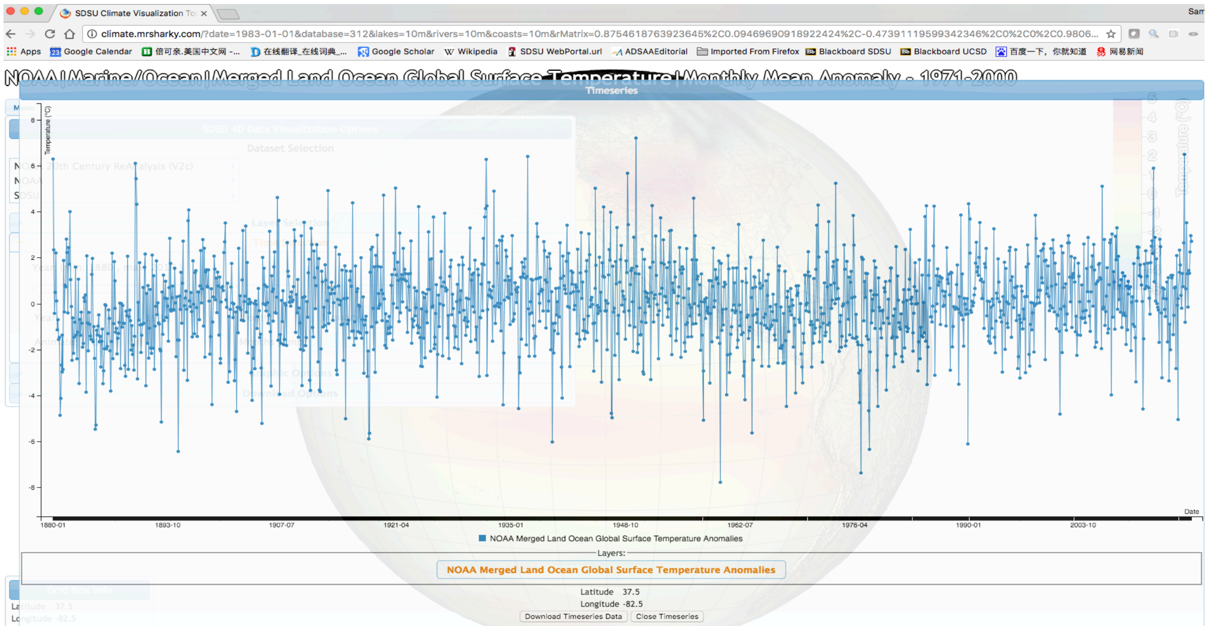


Figure 2. 4DVD display of the temperature anomaly history of the Asheville, NC grid box.

3. Global temperature extrapolations from-ocean-to-land and from-land-to-ocean: We have used multivariate regression to make spatial predictions for the entire globe from the bias-corrected land only GHCN data. Similarly, we have made the global extrapolation from only the SST data. Our results show that the extrapolation can accurately predict both the global temperature trend and the large-scale spatial patterns, such as El Nino. An MS thesis has been written on this research. A paper will be written to include results on verification of bias adjustments for observed data, and the climate assessment from independent datasets.
4. Cumulative weighted climate dynamics indices: We used the singular value decomposition (SVD) for the Tahiti and Darwin standardized sea level pressure data to produce a weighted Southern Oscillation Index (WSOI) which gives Darwin station 30% more weight than Tahiti station (0.79 vs -0.61), while the conventional SOI puts the equal-size weights (i.e., -1 vs 1). We have found that the cumulative WSOI (CWSOI) and the cumulative Arctic Oscillation Index (CAOI) can help explain the temperature variation phases in the periods of 1950-1975, 1976-1998, and 1999-2016. The mathematical theory of this SVD work is included in Shen et al. (2017). CWSOI, CAOI and their climate dynamics implications are in a paper under preparation.
5. Mathematical theories on evaluation of alternative approaches to spatial average: We have examined the three alternative methods in the project goals: BLUE (Best Linear Unbiased Estimates), B-SHADE (Biased Sentinal Hospitals Areal Disease Estimation), and MSN (Means of Stratified Nonhomogeneous Surface). Our test on BLUE is described in the accomplishment Item 3 above as a multivariate regression. We have proved that the spectral optimal averaging (SOA) method developed by my group in 1994 and 1998 share the same estimation theory as B-SHADE and MSN.

Planned Work

- Numerical implementations on alternative approaches for creating area-averaged time series: Comprehensive numerical tests will be made with different station densities on the global averages by SOA, B-SHADE and MSN. The results will be compared with the current area-weighted average.
- Product development and publication: Write a technical report for CICS and NCEI on the mathematical theory, R codes, and test results on the relevant averaging methods.

Publications

- Shen, S.S.P., G. Behm, T.Y. Song, and T.D. Qu, 2017: A multivariate regression reconstruction for ocean temperature using both ocean model and in situ data. *Journal of Atmospheric and Oceanic Technology*, 34, DOI: 10.1175/JTECH-D-16-0133.1.
- Pierret, J., and S.S.P. Shen, 2017: 4D visual delivery of big climate data: A fast web database application system. *Advances in Data Science and Adaptive Analysis*, accepted publication.
- Ehard, S., 2017: *Statistical Spatial Predictions of Monthly Global Surface Air Temperature Anomalies from 1880 to 2015*. MS Thesis, San Diego State University, California, USA, 59pp.
- Shen S.S.P., 2017: *R Programming for Climate Data Analysis*. An instruction manual for a short course at NCEI, San Diego State University, California, USA, 52pp.

Products

- 4DVD (4Dimensional visual delivery) visual delivery system for big climate data: The software product can temporarily be accessed in a limited way through the website http://climate.mrsharky.com/, before a full version is installed at CICS/NCEI or other big data platforms which signed the 2015 big data contract with NOAA. 4DVD is a web and database application developed by our group to make space-time visualization and delivery of big climate data. The delivery system with cloud computing technology shows climate data in a 4D space-time box and allows users to visualize the data before downloading. Users can zoom in or out to help identify desired information for particular a location and time. Data can then be downloaded for the spatial maps of a given time or historical climate time series of a clicked location, after particular maps and time series are identified to be useful. These functions enable users to quickly reach the core features without downloading the entire dataset in advance, which not only saves enormous amount of time, but also increases efficiency and accuracy of signal identification. The 4DVD system has many graphical display options such as displaying data on a round globe or on a 2D map with detailed background topographic images, rivers, lakes, and coastal lines. It can animate maps and show multiple time series for comparisons. The 4DVD's numerous visualization features make the system a convenient and attractive multimedia tool for classrooms, museums, and households, school teachers, and students, in addition to its service to NOAA professionals, climate research scientists, business applicants, and policy makers. San Diego State University plans to file a U.S. patent for 4DVD. We also plan to license the customized 4DVD systems to an insurance technology company and other interested business entities.
- R codes for NOAA climate data reading and analysis: We have written several R codes for reading and analyzing NOAA climate datasets, such as the NOAAGlobalTemp data and NCEP/NCAR Reanalysis' monthly temperature data. The R codes can be documented in readme files together with the existing Fortran reading instructions. The R codes enables users to easily read, analyze and plot the data since R is free and easy to use, unlike Fortran, C, and Python. Some of our R codes can convert the existing NOAA data into csv files with explicit grid box locations and time marks. Some codes are documented in my instruction manual for the NCEI short R course for climate data analysis.
- Instruction manual of R programming for climate data analysis: This 52-page manual will be made as an NCEI technique document available to the general public.

Presentations

- 2016: NOAA CICS-CREST science meeting, November 29-December 1, 2016, University of Maryland. Oral presentation entitled “Simplified reconstruction and visual delivery of big climate data.”
- 2016: UCLA Geography climate change group seminar, November 14, 2016, “4-dim visual delivery of big climate data.”
- 2016: NCAR seminar, October 12, 2016, “Statistical methods for quantifying the uncertainties in climate data reconstruction and climate signal detection,” a presentation for climate scientists.
- 2016: Colorado State University, Statistics Seminar, October 10, 2016, “Statistical methods for quantifying the uncertainties in climate data reconstruction and climate signal detection,” a presentation for statisticians.

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**3 (to be submitted)**
# of peer reviewed papers	**2**
# of NOAA technical reports	**0**
# of presentations	**4**
# of graduate students supported by your CICS task	**2**
# of graduate students formally advised	**6**
# of undergraduate students mentored during the year	**1**

The following three products or techniques are to be submitted to NOAA for consideration in operations use:

- 4DVD (4-dimensional visual delivery) of big climate data: We have already developed the system. We can install the system for NCEI or another big data provider under the 2015 NOAA big data agreement.
- R codes for NOAA data reading, analysis and plotting: We have written a suite of R codes to read, analyze and plot the NOAA climate data. We can work with the NCEI scientists to update the readme files of the relevant datasets and make the R codes available for the NOAA operational uses.
- Instruction manual about R programming for climate data analysis: We can work with the CICS/NCEI technical team to make this manual available as a NOAA technique.

Night Marine Air Temperature Near Real-Time Dataset Development	
Task Leader	Steve Stegall
Task Code	NC-SON-11-NICS-SS
NOAA Sponsor	Huai-min Zhang
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3; Goal 4: 0%

Highlight: Night marine air temperatures have been extracted from ICOADS data along with several other variables including SST and thermometer heights aboard ships/buoys. Missing heights are filled in using Pub. 47 data to give a more global representation.

Background

Night marine air temperatures (NMAT) provides the ocean's compliment to land surface temperatures and allows for a global representation of surface temperature. NMAT is also a great compliment to sea surface temperatures (SST) and is used to bias-correct SST data. NMAT is one of many observed variables in the International Comprehensive Ocean–Atmosphere Data Set (IOCADS). Many of the inputs into ICOADS are from the Voluntary Observing Ships (VOS) in the "International List of Selected, Supplementary and Auxiliary Ships," Publication Mo. 47 (Pub. 47).

Accomplishments

The marine air temperatures (both day and night) are extracted from the International Comprehensive Ocean–Atmosphere Data Set (IOCADS). This also includes sea surface temperatures (SST) and the height of the thermometer (height of the air temperature observations) as well as other variables, including day, latitude, longitude, day/night flag, and platform type. The data is further separated into night temperatures (NMAT) and daytime temperatures.

Extracted thermometer heights associated with the NMATs from ICOADS are largely missing. To fill in the heights, thermometer heights from the Voluntary Observing Ships (VOS) in the "International List of Selected, Supplementary and Auxiliary Ships," Publication Mo. 47 (Pub. 47) are used. The heights are cross checked with ICOADS ship ID's and are used only if the height is missing. In this way, a more representative dataset is generated. However, there are still numerous missing heights, thus the mean height from the Pub. 47 data from 2002–2014 is used to fill in the rest of the NMATs with an associated observed thermometer height. *Figure 1* illustrates the observed air temperature heights for January 2010 after the above method is done to fill in the heights.

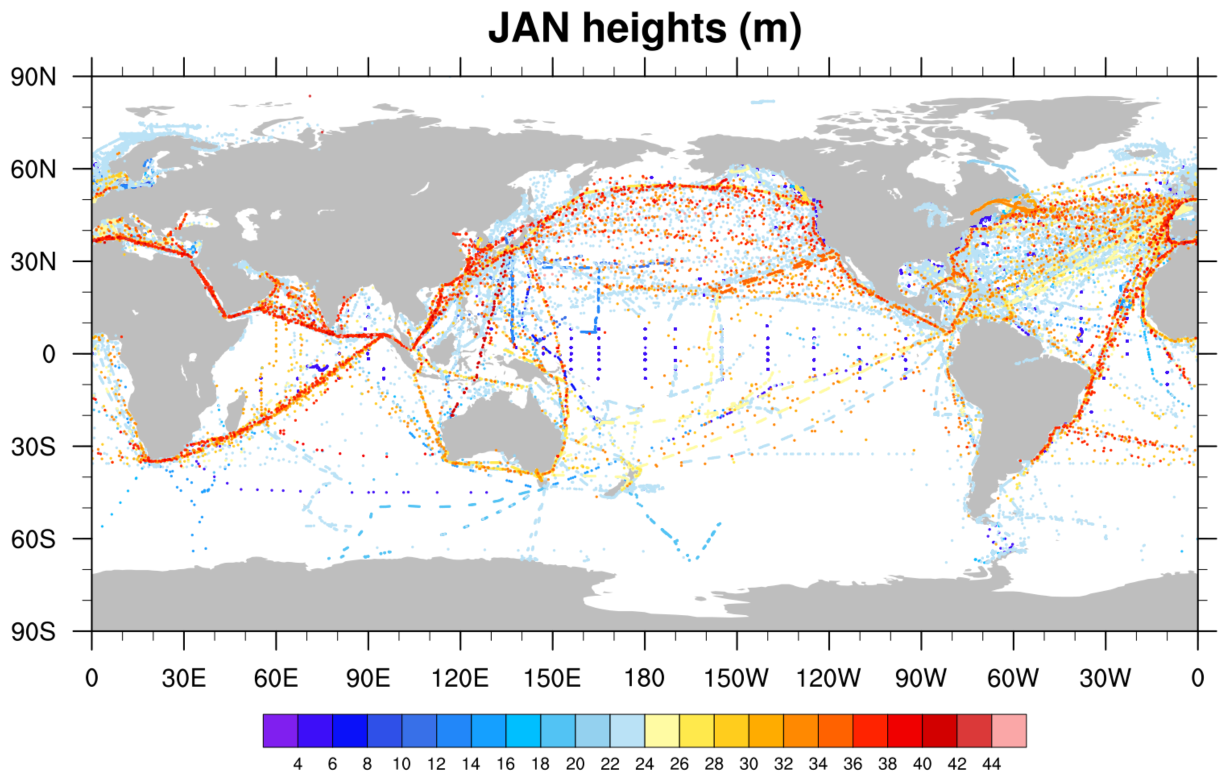


Figure 6. Heights of the observed Night Marine Air Temperature (NMAT) from both ships and buoys. Heights are extracted from ICOADS data. Additionally, ship heights that are missing from the ICOADS are extracted from Pub. 47 data. Remaining observed heights that are unknown are given a value of the averaged height of all Pub. 47 heights from 2002-2014.

Planned Work

- Formulate observed air temperature height uncertainty
- Adjust the observed ship/buoy NMAT's to a reference height of 10m
- Interpolate the NMAT's to a grid of 5°X5° or 10°X10°

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

Workforce Development

Workforce development is long-term investment in NOAA's future workforce. The National Centers for Environmental Information (NCEI) has a continuing number of research and workforce requirements that necessitate collaboration with the best climate science practitioners in the nation. This requires the hiring of outstanding scientific staff with unique skills and backgrounds in Earth System Science, and the use of observations for defining climate and its impacts. To meet this demand, CICS-NC has hired a cadre of dedicated research staff and is actively working to identify and train the next generation of scientifically and technically skilled climate scientists. Junior and/or aspiring scientists, including students and post-doctoral researchers, play an important role in the conduct of research at CICS-NC. While consistent funding remains a challenge, CICS-NC is nevertheless working to identify prospective future scientists, to nurture interest in climate applications, and to provide opportunities for training and mentorship on various levels.

Senior CICS-NC scientists hold research faculty positions in the Marine, Earth, and Atmospheric Sciences Department (MEAS) in the College of Sciences (COS) at NCSU and provide mentorship to junior scientists and students both in CICS-NC and MEAS. Several junior scientists have also secured adjunct appointments in pertinent NCSU departments and at other universities to gain experience and exposure with their academic peers and mentor graduate students. CICS-NC scientists also 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, and Liqiang Sun is an adjunct Research Associate Professor in NCSU's MEAS/COS. Kunkel serves as Ph.D. committee chair for CICS-NC research staff members Brooke Stewart and Sarah Champion.
- Carl Schreck holds adjunct faculty appointments with NCSU MEAS and with NC A&T University and serves as PhD co-advisor for Hilawe Semunegus (NCEI).
- Jesse Bell holds an adjunct faculty appointment with Emory University's Rollins School of Public Health where he mentors Masters in Public Health students investigating the relationship of climate to health issues.
- Jessica Matthews holds an adjunct Research Assistant Professor with NCSU's Mathematics Department and will be teaching an NCSU distance education course, "Mathematics of Climate Science," in the Fall 2017 semester.
- Jennifer Runkle holds an adjunct Research Assistant Professor appointment with Appalachian State University.

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

- Steve Stegall completed his Ph.D. from North Carolina A & T State University in Atmospheric Science and joined the CICS-NC team in May 2014 as a post-doctoral Research Scholar, transitioning to Research Associate in Fall 2016. He is collaborating on an assessment of the utility of HIRS 2-m air temperature on NCEI's global temperature product and is providing further analysis of CMIP5 temperature and precipitation trends.

- Andrew Ballinger completed his Ph.D. at Princeton University and joined CICS-NC as a post-doctoral Research Scholar in summer 2016. He is collaborating on the multi-institutional, NSF-sponsored Urban Resilience to Extremes—Sustainability Research Network (UREx SRN) project.

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

Summer 2016:

- *Jason Yu*, A. C Reynolds High School / University of North Carolina Chapel Hill, worked with Jen Runkle to design and test an approach for sentiment analysis of Twitter data on health and social impacts of climate-related events. He also worked with Ge Peng on a sensitivity analysis of Arctic sea ice coverage decadal trends for different average methods and intervals.
- *Jasmine Al-Aidy*, Georgia Tech, and *Colleen Clark*, Lenoir-Rhyne University, worked with Jen Runkle on a pilot occupational heat hazard study with NCSU outdoor grounds maintenance workers, utilizing wearable sensors to assess heat exposure in population health and climate change studies.
- NOAA Hollings Scholar, *Emma Scott* (North Carolina State University) worked with Ronnie Leeper to analyze precipitation extremes observed at U.S. Climate Reference Network (USCRN) stations. They compared USCRN's extremes with extremes observed at other nearby networks using NOAA Atlas-14. Results indicate USCRN observed a greater number of extremes for shorter duration (sub-daily) events.
- NOAA Hollings Scholar, *Theodore Hartman* (Iowa State University) worked with Jessica Matthews and Jesse Bell to analyze the drought monitoring capacity of NOAA's vegetation Climate Data Records and soil moisture and temperature observations from U.S. Climate Reference Network (USCRN) stations. This study aimed to answer the research question: How do Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI), and Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) relate to soil moisture and temperature data during a drought? Results indicate that all of NDVI, LAI, and FAPAR showed correlation with the soil indicators, while LAI had the strongest relationship. The work was presented as a poster at the AMS annual meeting in Seattle, WA in January 2017.
- *Andrew Dundas*, rising high school senior, working with Science Public Information Officer Tom Maycock to support Institute communication efforts. Andrew has written several stories for the Institute website, including stories highlighting peer-reviewed research papers produced by Institute staff and two interviews with institute staff published as part of a new "Meet the Staff" series. He made contributions to the development of the new Institute website, released in October 2016. Finally, he has also contributed to NCEI's communication efforts by drafting web stories and identifying and researching topics for the NOAA NCEI website. Andrew has continued to work with CICS-NC throughout the 2016/2017 academic year.

Spring 2017:

- The NASA DEVELOP team consisting of Daniel Martin (Appalachian State University, MS), Allison Daniel (University of Alabama Huntsville, BS), Jessica Vermillion (University of South Carolina, BS) and Kelly Meehan (Duke University, MS) completed their project "Utilizing NASA and NOAA Earth Observations to Enhance the United Nation's Office for the Coordination of Humanitarian Affairs in Storm Preparation and Disaster Relief Planning Methods in the Philippines," under project advisor Carl Schreck. The project examined typhoon vulnerability in the Philippines using a combination of NCEI's tropical cyclone data and the United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA) demographic data. https://develop.larc.nasa.gov/2017/spring/PhilippinesDisasters.html

- Bryan Van Alebeek, a University of North Carolina Asheville international exchange student, is working with Andrew Ballinger surveying climate extremes and their impacts on the National Parks using relevant GIS data and gridded LOCA climate extremes data. He is also assisting in visualizing and communicating extremes projections for the UREx project.

Water Sustainability and Climate Change: A Cross-Regional Perspective	
Task Leader	Steve Stegall
Task Code	NC-WD-01-NCICS-SS
Sponsor	NSF
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%
Highlight: Model simulations from the CMIP5 hindcast experiment were found to generally reproduce observed regional trends in the number of monthly precipitation extremes for the period 1981-2010. The NE and MW showing the largest differences in extreme precipitation Trends.	

Background

Water resource availability varies across the Sunbelt of the United States with a sharp East–West transition at 105° W. Arid regions west of the 105th Meridian produce less runoff. On the other hand, humid regions in the east produce greater than 40 cm of mean annual runoff. Consequently, reservoirs in the west are over-year systems holding multiple years of inflows, whereas reservoirs in the east are within-year storage systems, with the need to refill the system in the beginning of spring. Accordingly, water policies also differ substantially, with western states pursuing "prior appropriation" and the eastern states following "riparian rights" for allocation. These contrasting strategies also impact freshwater biodiversity, with the ratio of non-native to native fish species being nearly 6 times higher in the West compared to the East. In spite of these cross-regional differences, both regions face two common stressors: (a) uncertainty in available water arising from global climate change and (b) increased human demand due to population growth and consumption. Consequently, there is an ever-increasing need for an integrated assessment of fresh water sustainability under these two stressors over the planning horizon (10–30 years). The main objective of this study is to understand and quantify the potential impacts of near-term climate change and population growth on freshwater sustainability—defined here as integrating daily to annual flows required to minimize human vulnerability and maximize ecosystem needs (including native biodiversity) for freshwater—by explicitly incorporating the feedbacks from human-environmental systems on water supply and demand. Using retro-analyses involving CMIP5 multi-model climate change hindcasts, we will revisit how freshwater sustainability could have been better achieved over the past five decades across the Sunbelt. To couple the hydro-climatic and hydro-ecological system dynamics with the management of water infrastructure systems, a two-level agent-based modeling framework will explicitly simulate adaptive behaviors and feedbacks between policy and consumers.

This interdisciplinary project involves collaboration between three universities: North Carolina State University (NCSU), Arizona State University (ASU), and Florida International University (FIU). Findings from the CMIP5 retro-analyses will evaluate and recommend societal options (i.e., supply augmentation vs. demand reduction) for promoting future (2015–2034) freshwater sustainability across the Sunbelt. Cross-regional synthesis of policies and media sources for the targeted basins will identify decentralized adaptive strategies that have been employed independently and collectively to maintain flows, increase supplies, or reduce demands. Utilizing the near-term hydro-climatic projections, we will quantify how current policies on reservoir operations and groundwater extraction could impact the reliability of future water supplies for cities and also alter the key attributes of hydrographs that are critical for maintaining freshwater biodiversity. In doing so, the project will also investigate the degree to which regions have pursued 'hard path' (i.e., supply augmentation) vs. 'soft path' (i.e., demand reduction) strategies by explicitly modeling potential societal interventions for water sustainability.

Accomplishments

The major objective for this period was to complete an analysis of trends in monthly extremes and initiate an analysis of precipitation extremes. Monthly temperature and precipitation data for thirteen models from the CMIP5 30-yr hindcast experiment for 1980–2010 were used. Most of these models have more than one ensemble member. The total number of ensemble members for these thirteen models was 75. For temperature, an extreme index was constructed by calculating standardized monthly anomalies of temperature and precipitation for the observations and models for individual grid points. This index is then divided into two parts: a positive index for values that are $>+1.5\sigma$ (σ is the standard deviation of the standardized monthly anomalies) and a negative index for values that are $<-1.5\sigma$. The index is then aggregated into six regions of the United States: the Southeast, Southwest, Northeast, Northwest, Great Plains, and Midwest (these regions are defined in the Third National Climate Assessment; Melillo et al. 2014). For each region, the total numbers of grid point values above and below 1.5σ (POS and NEG indices respectively) are summed up for each of the 30 years for observations and the models

Figure 1 shows the percent difference of the observation and hindcast 1981–2010 99.5^{th} percentile precipitation for each region. The model mean for the NE region shows good agreement with observations as the percent difference is near zero. The SE regions shows the biggest disagreement with the model mean at −25% difference. Most of the ensemble members are below −10% difference. The MW and GP regions also show most of the ensemble members below −10% difference. These three regions overall underestimate the 99.5^{th} extreme precipitation. The NW and SW regions have model means that overestimate the 99.5^{th} extreme precipitation. *Figure 2* is the percent difference of the 1981–2010 99.5^{th} percentile precipitation observed trend and the CMIP5 hindcast trends for each region. The red circles are the observed trend, and the blue circles are the model mean trends. All the regions show trends with percent differences between ~5% to 10%. The NW shows very good agreement, with model mean trends and the observed trend. The NE and the MW have the biggest disagreement with the observed trend, with most of the ensemble members showing smaller trends than the observation.

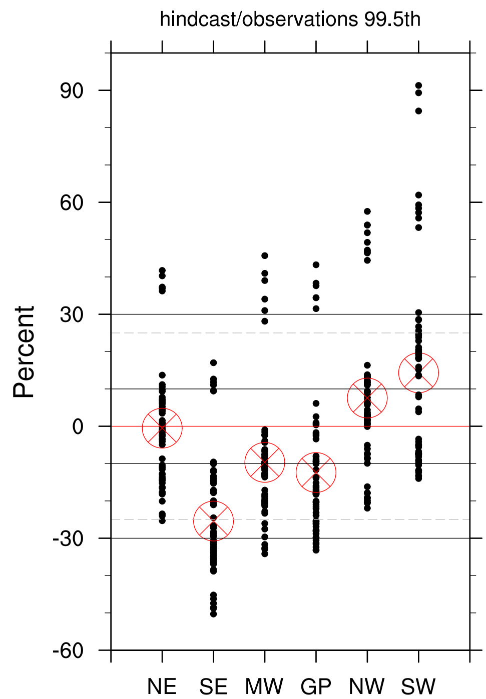


Figure 1. Percent difference between hindcast and observations (1981–2010) 99.5th percentile precipitation of all ensemble members and the model mean percent difference (large circles).

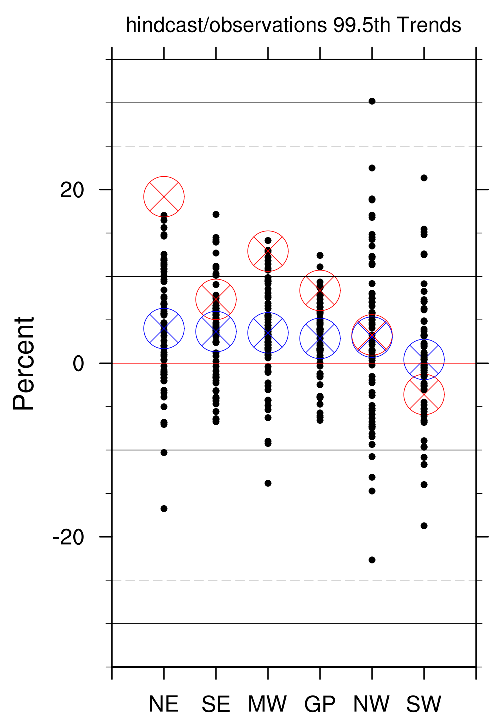


Figure 2. Percent difference of the trends (percent/decade) of the hindcasts and observations (1981–2010) for the 99.5th percentile precipitation.The blue cicrles are the model means, the black are the ensemble members, and the red are the observed trends.

Publications

- Stegall, S. and K. Kunkel, Monthly Extreme Temperature Trends in CMIP5 Hindcast–Prediction Simulations, 1981–2010 and 2006–35, DOI: 10.1175/JAMC-D-16-0281.1, accepted 2017.

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

Other CICS PI Projects

While CICS-NC activities are primary, some NCICS scientists also participate in and receive partial support through other sponsored research programs awarded through competitive proposal solicitations. NCICS scientists have submitted individual and collaborative climate science proposals through NCSU to federal solicitations from NASA, NSF, NOAA, DOE, DOD, and NIH and to various other non-federal entities.

Collaboration with the Centers for Disease Control on Issues Related to Climate and Health	
Task Leader	Jesse Bell
Task Code	NC-OTH-01-NCICS-JB
Other Sponsor	CDC
Contribution to CICS Research Themes (%)	Theme 1: 80%; Theme 2: 10%; Theme 3: 10%
Main CICS Research Topic	Climate Literacy, Education, Outreach, and Engagement
Contribution to NOAA goals (%)	Goal 1: 45%; Goal 2: 45%; Goal 3: 0%; Goal 4: 10%
Highlight: The goal of Dr. Bell's interaction with the Centers for Disease Control and Prevention is to build collaboration and interaction on issues related to climate and health. This work will increase the understanding of climate on human health and assist with projects that can further this knowledge.	

Background

Changes in the world's climate are having adverse impacts on human health and these impacts will likely increase in the future. Understanding the potential health risks associated with climate change is important for preparing for the future. The Centers for Disease Control and Prevention has dedicated time and resources to addressing the issues that will arise from global climate change. The CDC has formed the Climate and Health Program to focus solely on preparing for climate change and the impacts on the health of U.S. residents. Besides leading climate and health research, the Climate and Health Program is responsible for providing funding to state and city health departments to prepare for the adverse effects of climate change.

Accomplishments

In order to develop projects dealing with climate and health, Jesse E. Bell has continued his role in the Climate and Health Program (located in CDC's National Center for Environmental Health) as a Climate Science Advisor. He is also working closely with CDC's Health Studies Branch on issues related to drought and health. He is serving as a conduit to assist with the use of climate observations from NOAA for health projects at CDC. Through this interaction, he has helped develop projects dealing with extreme heat surveillance, soil moisture conditions and Valley Fever, evaluation of mental health outcomes from drought, and a project dealing with waterborne pathogens. He also assists with helping CDC grantees accessing and understanding climate data. He has also helped CDC gain access to NCA climate change projections and NIDIS drought data for the National Environmental Health Tracking Network.

Dr. Bell was also the lead author of the extremes chapter of the USGCRP Climate and Health Assessment (final release in April of 2016). His chapter evaluated the impacts of extreme events on human health. The report assessed that 1) climate change may increase exposure to health hazards associated with projected increases in the frequency and/or intensity of extreme precipitation, hurricanes, coastal inundation, drought, and wildfires in some regions of the United States; 2) adverse health outcomes associated with exposure to extreme events include death, injury, or illness; exacerbation of underlying medical conditions; and adverse effects on mental health; 3) the character and severity of health impacts from extreme events depend not only on the frequency or intensity of the extremes themselves but also on a population's exposure, sensitivity, and adaptive capacity. Many types of extreme events can cause loss of essential infrastructure (such as water, transportation, and power systems) required to safeguard human health. Key risk factors that individually and collectively shape a population's vulnerability to health impacts from extreme events include age, health status, socioeconomic status, race/ethnicity, and occupation.

Climate Change and Health — Flooding

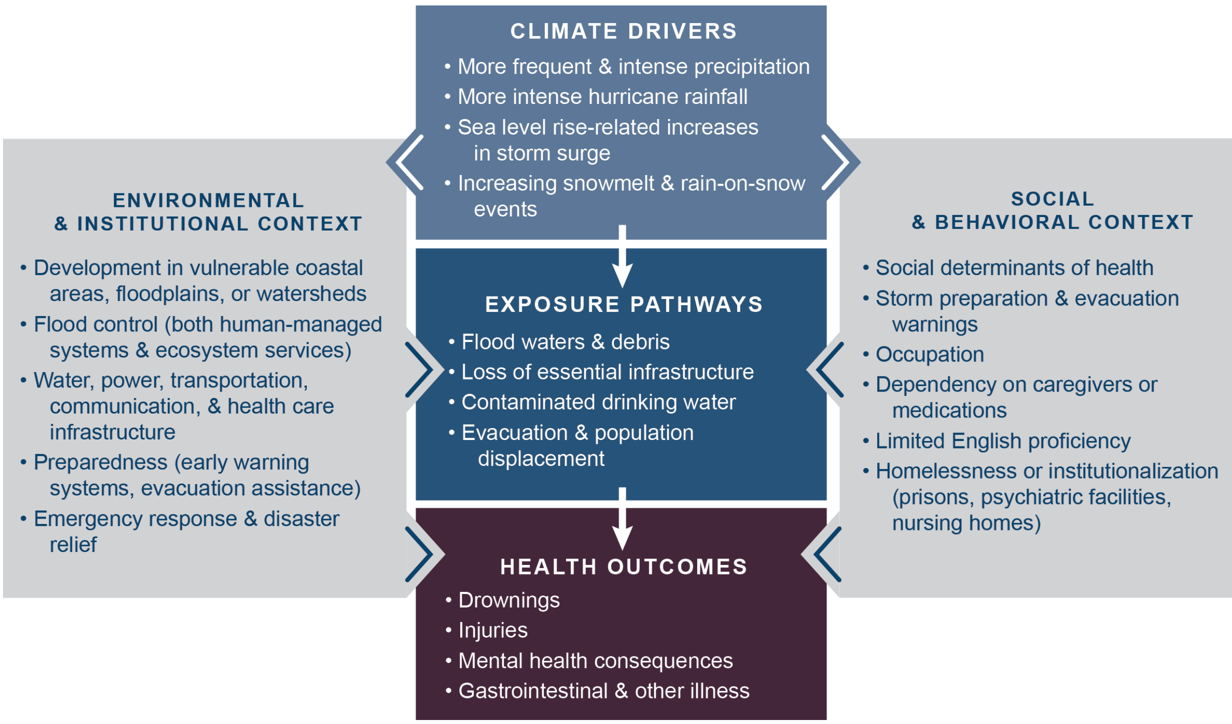


Figure 1. This conceptual diagram for a flooding event illustrates the key pathways by which humans are exposed to health threats from climate drivers, and potential resulting health outcomes (center boxes). These exposure pathways exist within the context of other factors that positively or negatively influence health outcomes (gray side boxes). Key factors that influence health outcomes and vulnerability for individuals are shown in the right box, and include social determinants of health and behavioral choices. Key factors that influence health outcomes and vulnerability at larger community or societal scales, such as natural and built environments, governance and management, and institutions, are shown in the left box. All of these influencing factors may also be affected by climate change.

Drought causes a wide variety of negative health outcomes; these can vary based on the severity, duration, and location of the drought. Some of the health outcomes of drought are more direct, such as water quality or food security issues. Other drought-related health issues may arise in a more indirect manner with concurrent or intervening events before a health consequence is evident (such as an extreme heat event intensified by drought or a wildfire caused by dry conditions). Health effects brought on by drought can also follow complex pathways before the outcome can be seen (such as mental health issues or vector-borne disease). Many of the health effects of drought may also be attributable to more than one cause and are not necessarily specific to drought. Because of the wide variety of outcomes, the indirect causal pathways, and other indirect associations, studying the health effects of drought can be difficult. In order to better study and understand the drought and health effects relationship, health professionals need to examine and analyze drought data and health data for linkages. Dr. Bell worked with Jared Rennie and CDC to devise a sound climatological method for drought data manipulation and a user-friendly platform to disseminate these data to health professionals interested in exploring the relationships with available health data.

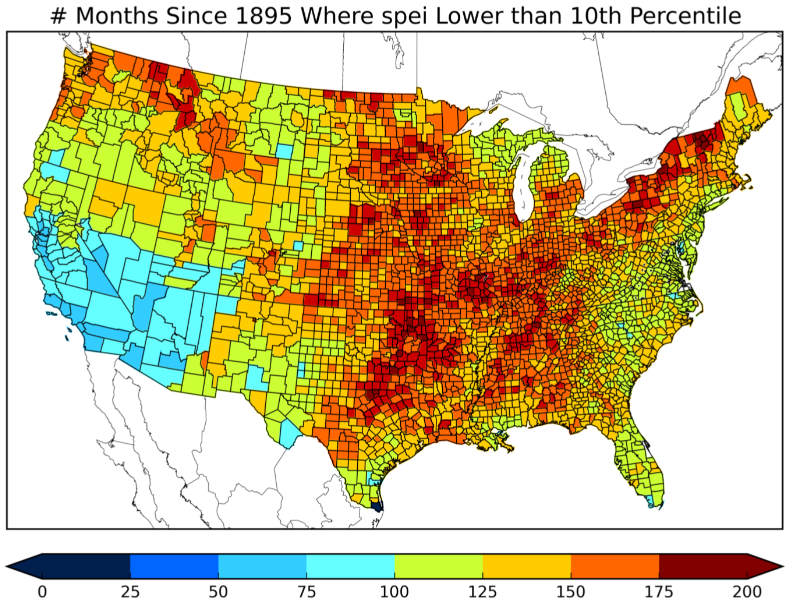


Figure 2. County level monthly drought estimates for the United States. These estimates were provided to CDC for comparison with health data and provided to state health departments for additional studies.

Dr. Bell is also an Adjunct Faculty member at Emory University, where he serves as an advisor to Emory University students working towards their Master of Public Health degree. Two of his students graduated in May of 2016.

Planned Work

- Submit Valley Fever work for publication.
- Evaluate use of drought data for health studies.
- Work on heat health analysis.

Publications

- Coopersmith, E. J., J. E. Bell, M. Cosh, K. Benedict, and J. Shriber. Forecasting valley fever (Coccidioidomycosis) incidence via soil moisture conditions. Accepted to GeoHealth.
- LaKind, J.S., Overpeck, J., Breysse, P.N., Backer, L., Richardson, S.D., Sobus, J., Sapkota, A., Upperman, C.R., Jiang, C., Beard, C.B., Brunkard, J.M., Bell, J.E., Harris, R., Chretien, J.P., Peltier, R.E., Chew, G.L., and Blount, B.C., 2016. Exposure science in an age of rapidly changing climate: challenges and opportunities. Journal of Exposure Science and Environmental Epidemiology, 26(6), pp.529-538.
- Bell, J.E., S. Burrer, & N. Wall. (2016). Drought's Fallout: Human Health. NIDIS Newsletter: Dry Times. Vol. 5 Issue 2.
- Crimmins, A., J. Balbus, J.L. Gamble, C.B. Beard, J.E. Bell, D. Dodgen, R.J. Eisen, N. Fann, M.D. Hawkins, S.C. Herring, L. Jantarasami, D.M. Mills, S. Saha, M.C. Sarofim, J. Trtanj, and L. Ziska, Eds. USGCRP, 2016: The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 312 pp. http://dx.doi.org/10.7930/J0R49NQX
- Bell, J.E., S.C. Herring, L. Jantarasami, C. Adrianopoli, K. Benedict, K. Conlon, V. Escobar, J. Hess, J. Luvall, C.P. Garcia-Pando, D. Quattrochi, J. Runkle, and C. Schreck, (2016). Ch. 4: Impacts of Extreme Events on Human Health. The Impacts of Climate Change on Human Health in the

United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC, 99-128. http://dx.doi.org/doi:10.7930/JOBZ63ZV

Products

- NOAA drought data were transferred to CDC for distribution on the Tracking Portal.

Presentations

- Bell, J.E. Assessment of climate variability to incidence of valley fever. AMS Annual Meeting. January 2017
- Bell, J.E. Climate and Health Assessment Chapter 4: Impacts of Extreme Events on Human Health. Society of Actuaries Educational Webinar. September 2016
- Bell, J.E. Impacts of Extreme Events on Human Health. NOAA Seminar Series. Silver Spring, Maryland. September 2016
- Bell, J.E. USGCRP Climate and Health Assessment. Invited Speaker at the Society of Actuaries Annual Health Meeting in Philadelphia, Pennsylvania. June 2016

Other

- CDC NCEH/ASTDR Honor Award for Excellence in Information Technology presented to the Aeroallergen Monitoring Unit
- Certificate of Appreciation for serving as a mentor to the NASA DEVELOP interns. 2016

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**5**
# of NOAA technical reports	**0**
# of presentations	**4**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**2**
# of undergraduate students mentored during the year	**3**

Emory University MPH students mentored: 2; NASA undergraduate DEVELOP students: 3

The Urban Resilience to Extremes Sustainability Research Network (UREx SRN)	
Task Leader	Kenneth Kunkel; Andrew Ballinger
Task Code	NC-OTH-02-NCICS
Other Sponsor	Arizona State University / NSF
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals (%)	Goal 1: 20%; Goal 2: 80%; Goal 3: 0%; Goal 4: 0%
Highlight: Analyzed a suite of downscaled climate model projections and developed "Scenarios Lite", a summary of climate extremes for seven of the UREx SRN pilot cities.	

Background

The Urban Resilience to Extremes Sustainability Research Network (UREx SRN) is a NSF-funded multiinstitutional project led by Arizona State University. It will develop a new framework for integrating Social, Ecological, and Technical System (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 given their location, concentration of people, and increasingly complex and interdependent infrastructure. The highly interdisciplinary and geographically dispersed UREx SRN team will develop 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 will work with six continental U.S. and three Latin American cities to co-produce the knowledge needed to transition to resilient SETS infrastructure in cities of the future. This portion of the project will include characterization of recent historical trends of climate extremes and the development of future climate extreme scenarios. The cities include Portland (OR), Phoenix, New York City, Baltimore, Syracuse, Miami, San Juan (PR), Hermosillo (Mexico), and Valdivia (Chile).

Recent historical trends of climate extremes will be characterized and future climate extremes scenarios will be developed. Historical events will be identified and characterized using established indices based on station data, following previous work to assess trends in extreme precipitation, heat waves, and drought. We will also examine the occurrence of multiple extreme events (e.g., drought and summer heat; heat and humidity). Such combinations can have dramatic societal impacts.

Serving as members of the Climate and Hydrologic Extremes Working Group (CHExWG) of UREx SRN are CICS-NC scientists Dr. K. Kunkel (lead) and Dr. A. Ballinger (post-doctoral scholar). The CHExWG is tasked with developing climate extremes products for the nine cities tailored to the city-specific vulnerabilities and the communication and explanation of those products to other members of the Network, including city practitioners. These products will be supported by the development and analysis of statistically downscaled datasets, application of dynamically-downscaled simulations as available and appropriate, summaries of historical extreme events, and written summaries of all products. For some cities, suitable downscaled datasets are not available and statistical downscaled models will need to be developed.

Accomplishments

Conducted climate analysis:

- Extreme climate indices were computed from the output of a suite of global climate models (CMIP5) that were statistically downscaled by the Localized Constructed Analogs (LOCA) methodology. The LOCA dataset covers the contiguous US and Mexico, and thus was used for analyzing future climate scenarios for seven of the UREx SRN pilot cities (Baltimore, Hermosillo, Miami, New York City, Phoenix, Portland and Syracuse).
- For Valdivia in Chile (one of the SRN pilot cities outside of the geographic bounds of the LOCA dataset), three city locations were identified and these station data were retrieved and subsequently used as training datasets for statistically-downscaling the CMIP5 models using the asynchronous regional regression model (ARRM). Extreme climate indices are currently being computed from the resulting dataset.
- Temperature-based climate extreme indices were computed, including the annual maximum and minimum daily maximum temperature, the annual numbers of frost and icing days, and the annual number of days in excess of certain temperature thresholds or historic percentiles.
- Rainfall-based climate extreme indices were computed, including the annual maximum daily precipitation, the annual numbers of wet and dry days, and the annual number of days with precipitation in excess of certain rainfall amounts or historic percentiles.
- Various statistical techniques were also applied to these data in order to describe changes in the distribution of temperature and precipitation extremes for the SRN pilot cities.
- Consecutive-day measures of rainfall and temperature extremes were analyzed, in order to better characterize heatwave and flooding potential.
- *Figure 1* provides an example of the cross-city comparison that has been undertaken, showing the changing severity of heatwaves across the project's pilot cities. There is a marked increase (over the 21st century) in the average maximum consecutive-day temperature that is exceeded in these urban regions.

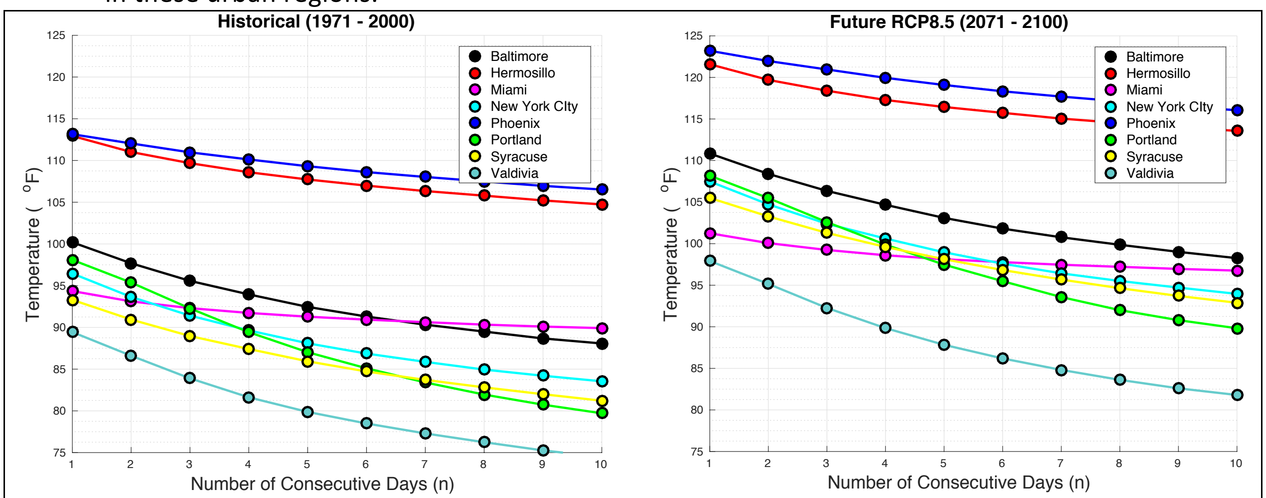


Figure 1: Plots showing the changing severity of heatwaves over the UREx SRN's pilot cities. The colored circles indicate the multimodel ensemble mean annual maximum temperature that is exceeded for a period of n consecutive days during each of the climatological periods indicated: Historical simulations, 1971 – 2000 (left panel), and future simulations under the RCP8.5 emissions scenario, 2071-2100 (right panel).

Developed "Scenarios Lite" summary documents:

- "Scenarios Lite" is a summary description of projected changes to several climate extreme indices under two future emissions scenarios (RCP4.5 and RCP8.5) through the 21st century.

- Each report (one per city) contained >60 figures (graphs and maps) and >10 tables distilling the results of climate extremes for each of the network cities.
- These documents provide a suite of examples of the type of climate extremes information that the project is able to provide city practitioners in order to facilitate risk assessment and resilience planning.
- We are now actively consulting the various city practitioners in order to receive general feedback and specific requests (for each city) to guide further analysis of the climate projections.

Coordinated working group meetings:

- Three video conference call meetings of the Climate and Hydrologic Extremes Working Group (CHExWG) were coordinated and led by K. Kunkel and A. Ballinger, in order to update members on the progress of research activities and to facilitate further collaboration and planning.
- Two additional in-person CHExWG breakout sessions were facilitated by K. Kunkel, held in conjunction with the second all-hands meeting of the UREx SRN project in New York City.

Communicated with city practitioners:

- A. Ballinger participated in a set of focused discussions with various city practitioners (energy/water utilities, emergency management, health services, etc.) in Portland, Oregon, providing presentations that gave an overview of the downscaled climate model dataset and specific examples showing projections of climate extremes over the Portland region.
- K. Kunkel participated in a panel discussion with city practitioners from across the entire UREx network, giving examples of how the LOCA-downscaled dataset can be used by decision-makers to better understand their city's future risk to climate extremes, with respect to changes in the frequency/intensity of heatwaves and heavy rainfall.

Planned Work

- Partner with the UREx SRN's Computation and Visualization Working Group (CVWG) to further develop various graphical products (figures, maps, tables, animations, etc.) that better communicate projections of climate extremes to city practitioners and members of their community.
- Collaborate with hydrologists at Arizona State University to compute various hydrological indices (streamflow, runoff, snowpack, snowmelt, etc.) using output from the Variable Infiltration Capacity (VIC) model forced with LOCA-downscaled temperature and precipitation data.
- Further the projected annual extreme indices by analyzing the seasonality of pertinent climate indicators for each city. For example, "Are there any projected changes in the date of the first 'major' rainfall event?" or "How is the frequency/intensity of heatwaves in May expected to change?" Recent feedback from practitioners has suggested that this type of "seasonal-timing of climate extremes" information will be of additional benefit to urban resilience planning.
- Create a gridded Standardized Precipitation Evapotranspiration Index (SPEI) from the LOCA dataset. This will be used for analyzing future projections of climatological drought over the relevant water-catchment regions that are of importance to urban communities.
- Enhance the suite of downscaled climate projections for each city by seeking additional complementary datasets that have been developed using alternative statistical or dynamical-downscaling techniques.
- Collaborate on several proposed manuscripts:
    - A cross-city comparison of the changing risk of climate extreme events

- Various urban climate-impact studies (interdisciplinary)
- Projections of drought (using SPI/SPEI) for the 21st century
- Relationship between the duration and intensity of rainfall, antecedent precipitation, and flood events.

Presentations

- K. Kunkel (May 12, 2016), "Developing climate extremes products to provide a uniform framework for evaluation across cities", Asheville, NC. *(webinar presentation)*
- A. Ballinger (February 9, 2017), "The LOCA dataset and the development of *Scenarios Lite* for Portland", Portland, OR. *(oral presentation)*
- A. Ballinger (February 10, 2017), "21st Century Projections of Climate Extremes for Portland", Portland, OR. *(oral presentation)*
- K. Kunkel (March 20, 2017), "Developing *Scenarios Lite* for Practitioners", Annual Meeting of the UREx SRN, New York, NY. *(oral presentation)*
- A. Ballinger (March 20, 2017), "Overview of the Climate and Hydrological Extremes Working Group", Annual Meeting of the UREx SRN, New York, NY. *(poster presentation)*

Other

- A. Ballinger (August 10-12, 2016) attended the NCAR Regional Climate Tutorial in Boulder, CO; a three-day workshop providing an overview of best practices for developing downscaled regional climate data and how to incorporate this into impact assessments.

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

Early in project timeline with the focus to-date on developing datasets and conducting analysis that will be yield outcomes/papers in future years of the project.

Incorporation of climate change into Intensity-Duration-Frequency Design Values	
Task Leader	Kenneth Kunkel (Leader), James Biard, Sarah Champion, Ronnie Leeper, Olivier Prat, Laura Stevens, Scott Stevens, Liqiang Sun
Task Code	NC-OTH-03-NCICS-KK/etal
Other Sponsor	DoD / SERDP
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%

Highlight: An algorithm to automatically identify the location and type of fronts in reanalysis data was developed and tested against a dataset of manually analyzed fronts from NOAA coded surface bulletins.

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 United States and found significant upward trends in the number of events from fronts and tropical cyclones but no increases from other meteorological causes. The likelihood that heavy precipitation will continue to increase is considered high because atmospheric water vapor concentrations will increase with global warming. Thus, the capacity of the atmosphere to produce intense precipitation will be higher in a warmer world. At the local scale, actual changes in heavy precipitation event occurrence will arise from changes in atmospheric capacity and opportunity (the frequency and intensity of weather systems causing heavy precipitation). While it is virtually certain that capacity will increase, it is less certain how opportunities will change and it is likely that the changes in opportunity will be spatially variable, modulating water vapor increases.

The overriding objective of this project is to develop a framework for incorporating the potential impact of future climate change into the Intensity-Duration-Frequency (IDF) values of heavy precipitation. 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 National Oceanic and Atmospheric Administration Atlas 14, will be provided.

Accomplishments

Considerable effort was put into the development of an automated detection algorithm for fronts, which has been found to be the most important generator of extreme precipitation events. A deep-learning convolutional neural network approach was chosen for developing an application to estimate the locations of frontal boundaries from gridded surface-level fields of climate models. Thirteen years of 3-hourly data from the North American Regional Reanalysis (NARR) and the NOAA Coded Surface Bulletins were chosen to use in training the neural network. Surface-level measurements from NARR were chosen as the source of input data for the training. The NARR dataset uses observations coupled with a weather/climate model to produce values on regular grids at multiple vertical levels. The five measurements chosen from NARR were 2m air temperature, specific humidity, pressure reduced to mean sea level, and the north-south and east-west components of wind at 10m. The grid images were down-sampled by 1/3, from ~32km resolution to ~1-degree resolution. Frontal boundary locations from the coded surface bulletins were used as truth data for training the neural network. The coded surface bulletins capture the frontal boundaries drawn by meteorologists every three hours using surface observation data, and is available at 1 degree latitude/longitude resolution from 2003 to present. A multilevel 2-D convolutional network was designed with assistance from collaborators at Lawrence Berkeley National Laboratory. A preliminary algorithm has demonstrated considerable skill in identifying fronts (*Fig. 1*).

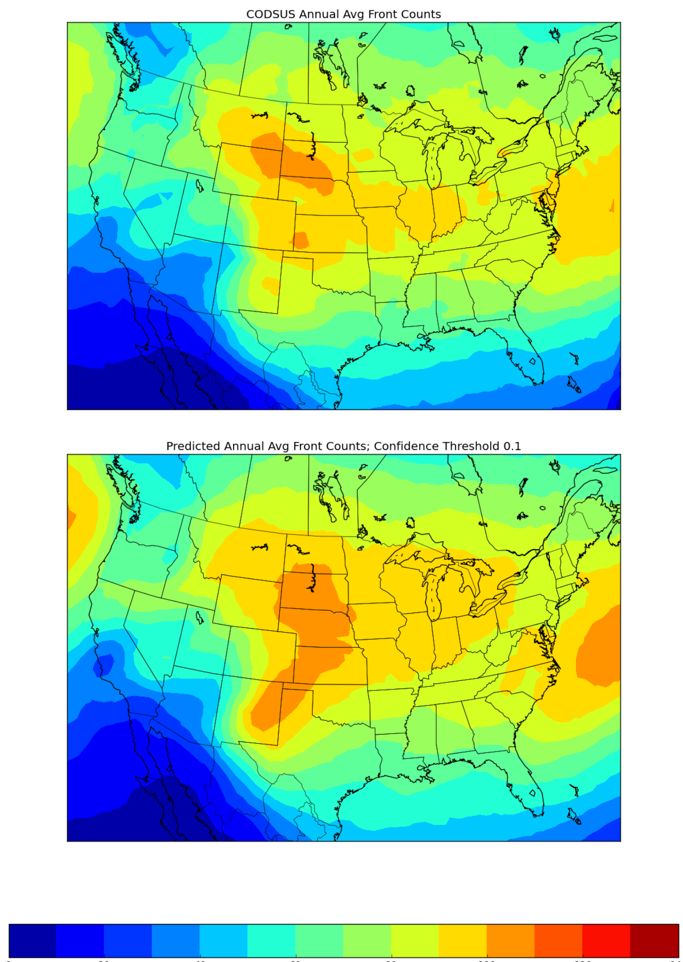


Figure 1. Spatial distribution of the annual frequency of occurrence of cold fronts for 2004-2016. Top panel is the distribution from the manually-analyzed NOAA coded surface bulletins. Bottom panel is the distribution from the automated detection algorithm. There is good agreement in both the magnitudes and the spatial pattern

An analysis of an existing frontal dataset from a previous project was performed. This dataset was restricted to a single definition of precipitation extremes, namely daily precipitation totals that exceed a recurrence level of 5 years, covering the period 1908–2013 for 930 long-term stations. Each station would experience, by definition, approximately 20 events over the period of analysis. Each event was evaluated and assigned a meteorological cause. This database was first screened for events occurring in July and August. A second screening was done to identify the July–August events that were caused by fronts. The number of events at each station passing these two screens were plotted on a map (*Fig. 2*). A notable feature is the large number of events at stations in the upper Midwest. Even further south in the southeast United States, more than a quarter of all events are frontally triggered events in the core summer months, even though fronts are weak.

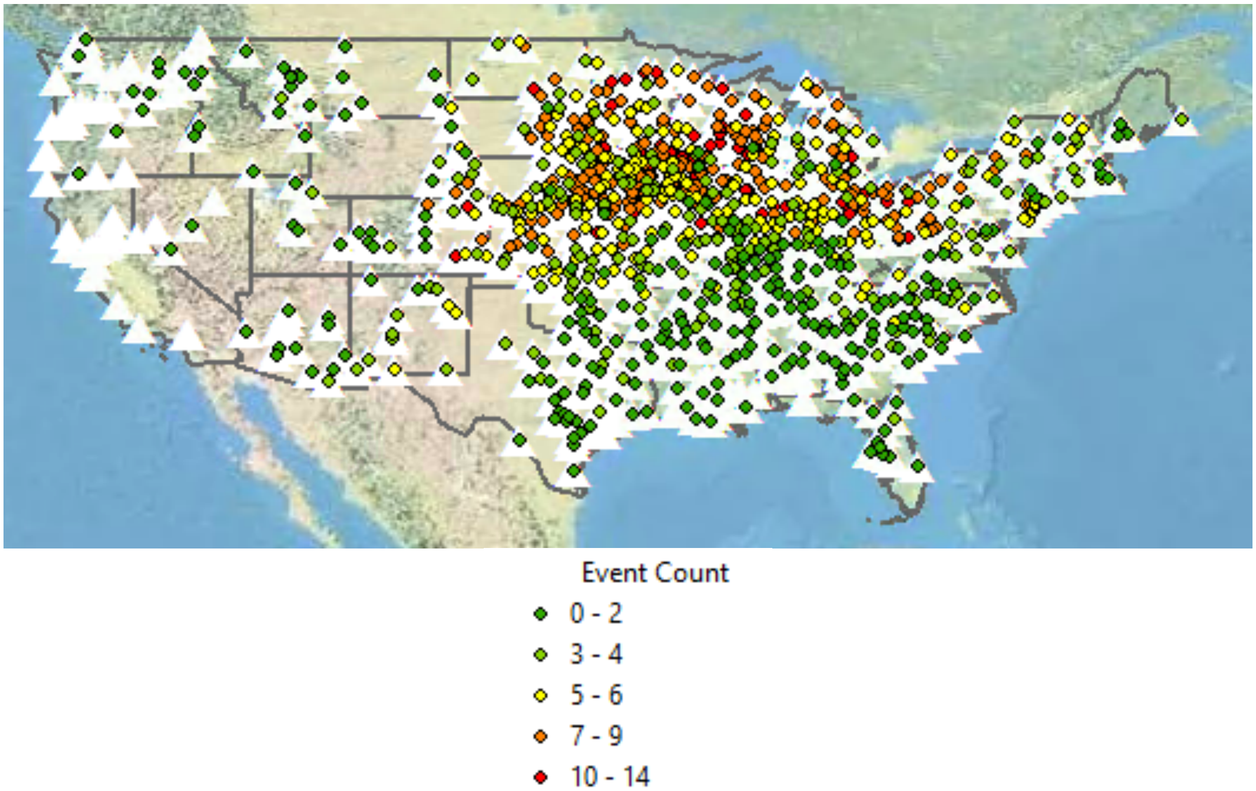


Figure 2. The number of historical extreme precipitation events caused by fronts during July and August at each of the long-term observing stations in our study. Extreme precipitation events are defined as daily precipitation totals exceeding a 5-year return level threshold during 1908–2013. In the upper Midwest, most 5-year events are in summer and most of these are caused by fronts. This shows that identification of summer fronts is an important issue that needs to be detected by our automated frontal algorithm.

An algorithm has been developed to determine the distance of a precipitation observation from a front. This algorithm will be applied to the assessment of causes, specifically whether an extreme event was caused by a front.

Analysis of NCEP/DOE Reanalysis 2 for the period of 1979–2005 indicates summer extreme daily precipitation events in New Mexico are attributed to extratropical cyclones (ETC), westward expansion of the North Atlantic Subtropical High (NASH), and tropical cyclones (TC). The ETC, NASH, and TC account for 62%, 28%, and 10% of the occurrence of the extreme summer daily precipitation events, respectively. The same analysis is applied to the CMIP5 data for the same period, and indicates that the ETC, NASH, and TC account for 53%, 37%, and 10% of the occurrence of the extreme summer daily precipitation events in CMIP5 models, respectively. Analysis of vertically integrated moisture and its convergence using 6-hourly NCEP/DOE Reanalysis 2 reveals that moisture flux convergence is highly correlated with the occurrence of summer extreme rainfall in New Mexico. The CMIP5 models also confirmed that summer extreme rainfall in New Mexico is associated with local moisture flux convergence.

For the period 1949-present, the contribution of TCs to precipitation extremes was analyzed for over 1000 GHCN-D stations. At a large number of stations in South and North Carolina and Virginia, TCs account for the majority (>50%) of daily extremes above 4 inches per day. The number of years during the 1949–2012 period for which TCs are associated with the annual daily maximum rainfall was found to be above 30% (i.e. approximatively once every three years) for Carolinas stations located east of the Atlantic Seaboard Fall Line. Conversely only a handful of stations in Florida display a ratio of 30% despite higher cyclonic activity. Future work consists in extending the analysis to extra-tropical cyclones (ETCs) and to evaluate the contribution of each precipitation system (TCs, ETCs).

An analysis was performed to assess the role of water vapor changes in the observed upward trend of daily extreme precipitation events with a 1-in-5-year recurrence. Integrated Global Radiosonde Archive (IGRA) data relating closely to the time of occurrence of these 1-day/5-year extreme precipitation events were identified across the northeastern United States. The monthly average change in precipitable water (1992–2013 minus 1971–1991) was then calculated for each radiosonde site and as a spatial average. Increases in atmospheric water vapor were mostly identified for the period of June to October, in which 86% of the extreme events occurred.

Planned Work

- Optimize the frontal automated detection algorithm. This will involve additional training runs with varying values for different hyper-parameters to find the combination that produces the best result
- Produce estimates of probability of the presence of the five types of frontal boundary at each cell of the down-sampled NARR grid for each NARR time step and extract polylines like those in the coded surface bulletins
- Apply the frontal algorithm to climate model surface level fields and analyze for future changes
- Complete the analysis of the role of water vapor changes in the observed upward trend in extreme events
- Complete estimates of the influence of tropical cyclones on future changes in extreme events. Complete the analysis of historical variations in moisture surges as it affects North American Monsoon extreme events

Publications

- Paquin, D., A. Frigon, and K.E. Kunkel, 2016: Evaluation of total precipitable water from CRCM4 using NVAP-MEaSUREs dataset and ERA-Interim reanalysis. Atmosphere-Ocean, doi: 10.1080/07055900.2016.1230043.

Presentations

- Kunkel, K.E., 2017: Climate Change Adjustments for Intensity-Duration-Frequency Extreme Precipitation Values, poster, Annual Meeting of the American Meteorological Society, Seattle, WA (January 24).
- Kunkel, K.E., 2016: Incorporation of Anthropogenically-Forced climate change into Intensity-Duration-Frequency Values, invited talk (remote), Team Meeting of new SERDP project led by John Marra (November 17).

- Kunkel, K.E., 2016: Incorporation of Anthropogenically-Forced climate change into Intensity-Duration-Frequency Values, invited talk (remote), City of Seattle meeting on climate-perturbed IDFs (November 10).
- Kunkel, K.E., 2016: The SERDP project, invited talk, NCEI Science Council, Asheville, NC (October 13).

Other

- Kenneth Kunkel, Member, Task Committee on “Use of Atmospheric Numerical Models for Estimating Probable Maximum Precipitation”, Surface Water Hydrology Technical Committee; Risk, Uncertainty & Probabilistic Approaches Technical Committee; Hydro Climate Technical Committee; Watershed Council; Environmental & Water Resources Institute (EWRI), ASCE, 2015-2017.
- Kenneth Kunkel, Member, Project Review Board, Colorado-New Mexico Regional Extreme Precipitation Study, 2016-2018

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

One paper was published. Several invited talks were given on the project plans and results. One graduate student (Sarah Champion) is being advised by Kenneth Kunkel

Climate indicators to track the seasonal evolution of the Arctic sea ice cover to support stakeholders	
Task Leader	Ge Peng
Task Code	NC-OTH-04-NCICS-GP
Other Sponsor	NASA
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 75%; Goal 2: 0%; Goal 3: 0%; Goal 4: 25%
Highlight: Participated in the new climate indicator development.	

Background

Since 1979, satellite sea ice concentration data has been used to track climate change and variability. Sea ice extent (the area within the 15% concentration contour) and area (the area-integrated concentration) have long been considered key sea ice coverage climate indicators. However, these two parameters provide only limited information about the character of the sea ice; in addition, they have limited skill as indicators of future sea ice conditions, both seasonal and inter-annually.

This three-year project started July 2016 aims to utilize the NOAA/NSIDC (National Snow and Ice Data Center) Sea Ice Concentration Climate Data Record (CDR) to develop a consistent, high quality suite of sea ice climate indicators that track the seasonal evolution (sea ice melt onset, opening, retreat, freeze-up and advance) of the Arctic sea ice cover from spring through fall in addition to commonly used sea ice coverage indicators (area and extent). CICS-NC contributes to this effort by assisting with the CDR fields and integration of the fields with the melt/freeze and advance/retreat parameters.

Accomplishments

Participated in the climate indicator development discussions, provided product information on the sea ice concentration climate data record (CDR) dataset, addressed data quality issues, and examined the advance/retreat date fields. The decadal trends of the derived parameters are computed and shown in *Figure 1*, which shows a 4.39% decadal trend for DOR-DOO (*Figure 1c*) and −7% for DOAL-DOAF (*Figure 1f*), both significant at the 95% confidence level.

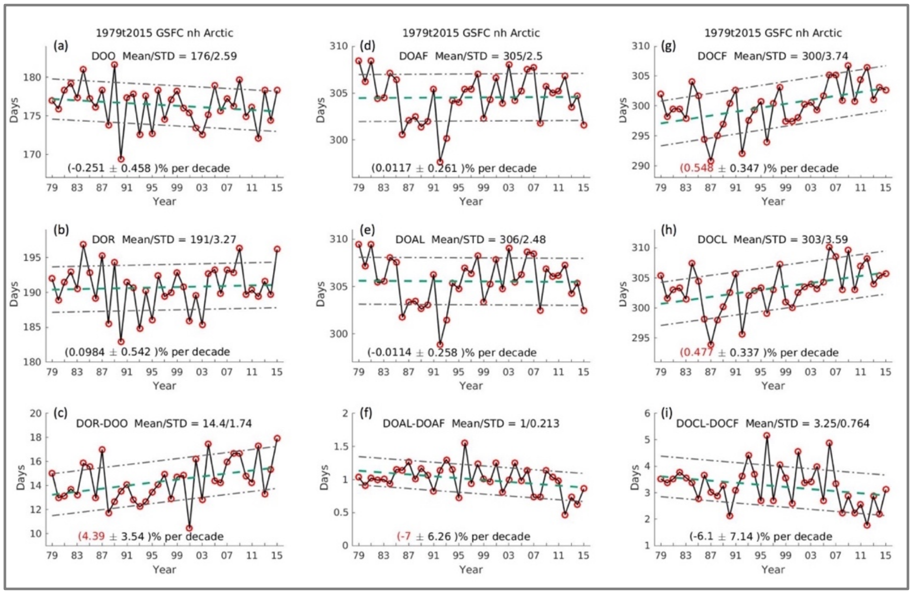


Figure 1. Time series of (a) DOO (Day of Opening—the first day sea ice concentration (SIC) drops below 80% before the first summer minimum), (b) DOR (Day of Retreat—the last day SIC drops below 15%), (c) DOR−DOO, (d) DOAF (First Day of Advance—the first day SIC goes above 15% after the last summer minimum), (e) DOAL (Last Day of Advance—the last day SIC goes above 15%), (f) DOAL−DOAF, (g) DOCF (First Day of Closing—the first day SIC goes about 80% after the last summer minimum), (h) DOCL (Last Day of Closing—the last day SIC goes above 80%), and (i) DOCL−DOCF (red circles with solid black line), its linear regression (thick green dashed line). The dot-dashed lines are one standard deviation of each times series. The trends in red are significant at the 95% confidence level using t-test.

Planned Work

- Carrying out the comparison analysis of sea ice climate indicators derived from the CDR with other established product(s),
- Examining regional variability of new climate indicators,
- Seeking input and feedback from stakeholders, and providing feedback to the PI and Co-PI of this project to improve the scientific quality of the derived indicator products.

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

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-05-NCICS-OP
Other Sponsor	Columbia University / DOE
Contribution to CICS Research Themes (%)	Theme 1: 50%; Theme 2: 0%; Theme 3: 50%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%

Highlight: This research project aims at comprehensively investigating the representation and associated uncertainties of rain microphysical processes in weather and climate models. In order to quantify those uncertainties in microphysical formulations, we develop an innovative Bayesian statistical framework that combines the extensive radar and ground-based data from ARM field campaigns, bin microphysical modeling, and a new bulk parameterization.

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 that, in turn, control downdraft characteristics and subsequent cold pool formation and convective structure and organization. It has never been more important to accurately represent these effects, as the increasingly fine resolution of regional and global climate models can now explicitly simulate these processes and quantify their impacts. Recent advances in observational capabilities, such as available ARM polarimetric and zenith-pointing radars, allow for unprecedented information on rain microphysical processes. However, the current state of microphysical parameterization schemes renders problematic the assimilation of observational insights into models. Microphysics schemes contain numerous assumptions, ad-hoc parameter choices, and structural uncertainties. In this work, we propose to investigate the uncertainties in the representation of microphysical processes in climate models. We use a Bayesian statistical approach combining real rainfall dual-pol radar data from ARM field campaigns, bin microphysical modeling, and a new bulk parameterization. This work is conducted in collaboration other partners: Dr. Marcus van Lier-Walqui (Columbia University), Dr. Matthew Kumjian (Penn. State University), and Dr. Hughbert Morrison (NCAR).

Accomplishments

The goal of this work 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 (BOSS) can use any combination of prognostic drop size distribution (DSD) moments without assuming an a-priori DSD. Dual-polarization radar observations provide a probabilistic constraint on scheme structure and microphysical sensitivities to environmental conditions. Because a same value of a given prognostic moment can corresponds to an infinite number of DSDs, we need to develop a moment-based polarimetric radar forward operator in order to determine the optimal combination of prognostic moments (2 or 3 moment scheme) that minimizes uncertainties.

Our contribution to the project, consisted in providing one-dimensional bin-model simulations (Prat et al. 2012) covering the totality of realistic drop size distributions (DSDs) encountered in nature. We use a normalized Gamma DSD formulation: $N(d) = N_w\, f(\mu)\, (d/d_0)^{\mu} \exp[-(3.67+\mu)\,(d/d_0)]$ where $f(\mu) = 6/(3.67)^4\, [3.67+\mu]^{(\mu+4)}/\Gamma(\mu+4)$ with a range of parameters [0.02 cm $< d_0 < 0.4$ cm; 100 mm^{-1} m$^{-3} < N_w < 80000$ mm^{-1}

m^{-3}; -1 < μ < 10]. The generated DSDs available at every output time and elevation resulted in about 199 million DSDs. *Figure 1* displays an example of simulation for an initial DSD [d_0=0.14; N_w=18000; μ =5.5] imposed at the top of the atmospheric column (h=3km) (left column). Transient conditions were considered by imposing a variation of the normalized Gamma DSD parameters (d_0, N_w, μ) at the top to the rainshaft (right column). The results presented are obtained when considering all microphysical processes activate (coalescence, collisional breakup, aerodynamical breakup). Each process is also considered separately to evaluate their respective contribution and impact on the dualpol variables.

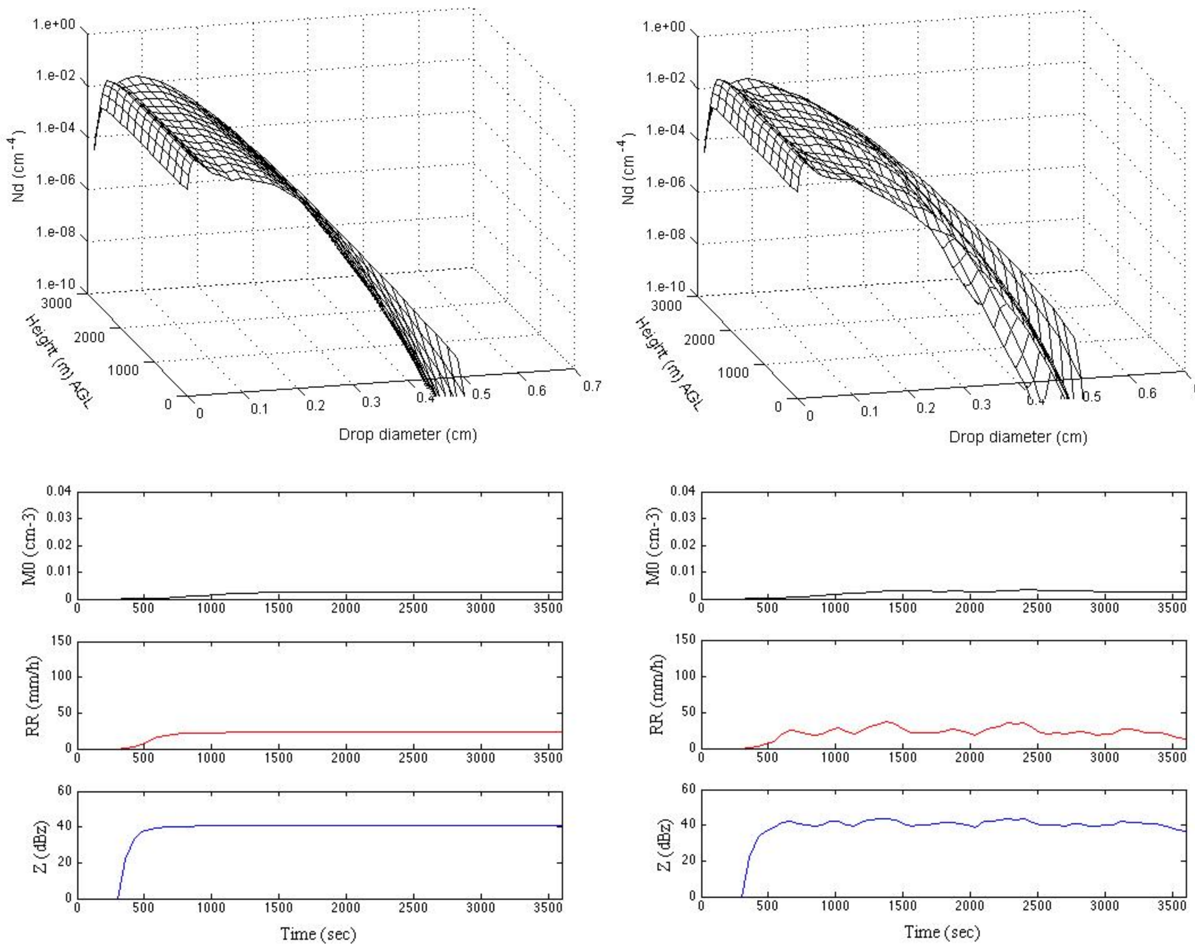


Figure 1. Evolution of the drop size distribution within the 1D vertical column after 1hr of simulation with a constant DSD imposed at the top (left column) along with integral properties at the ground (h=0) drop number concentration (M_0), rain rate (RR), and reflectivity (Z). Similar DSD and integral properties evolution when parameters for the DSD (d_0, N_w, μ) imposed at the top of the atmospheric column (h=3km) fluctuate by ±20% around their nominal values [d_0=0.14; N_w=18000; μ =5.5].

The transient and equilibrium DSDs are used with an electromagnetic scattering model (Kumjian and Ryzhkov 2012) that emulates the evolution of the polarimetric radar variables (Z_H, Z_{DR}, K_{DP}). Figure 2 presents the relationships between the moments of the DSD ($M_k = \sum N(d).d^k$) and the dual-polarization radar variables Z_H, Z_{DR}, and K_{DP} for all the DSDs considered. For each dual-pol variable (Z_H, Z_{DR}, K_{DP}), we determine the moment pair (M_j, M_k) that minimizes the distribution-weighted standard (not shown). The forward operator currently under development will provide for each moment pair (M_j, M_k), the average value of the radar polarimetric variables (Z_H, Z_{DR}, K_{DP}) and distribution information (standard deviation, skewness, covariance).

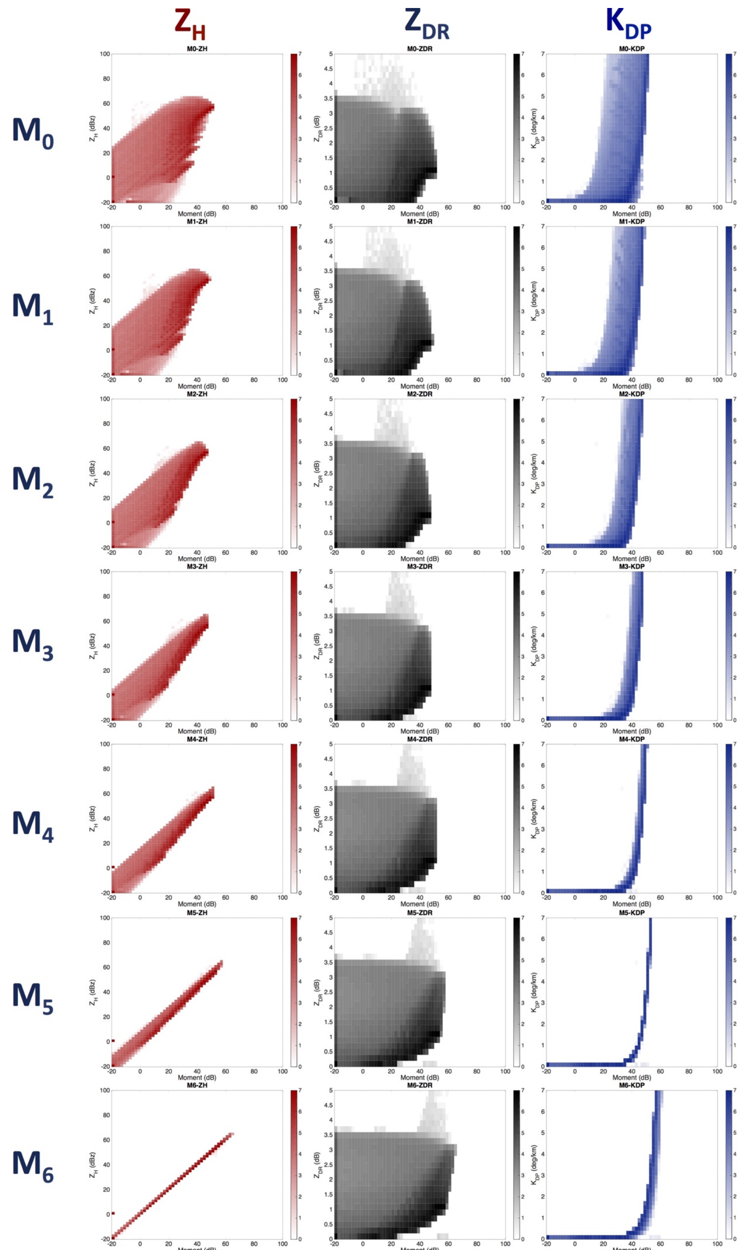


Figure 2. 2D histograms for all possible DSDs showing the relationship between the moments of the DSD $M_{k=1\text{-}to\text{-}6}$ and the dual-pol radar variables Z_H (red, left column), Z_{DR} (black, middle column), and K_{DP} (blue, right column). Occurrence is shaded according to log scale (figure adapted from Kumjian et al., 2017).

From a bin-microphysical perspective, current work consists in implementing parameterization for evaporation processes in the model. A sensitivity analysis including various kernel formulations and model parameters is conducted in order to further quantify the model uncertainties. In addition, rainfall observations from ARM fields campaigns are being used as an input to the model to emulate real rainfall events.

Planned Work

- Implement and test parameterization for evaporation processes in the bin microphysical model
- Improve kernel formulation for drop coalescence and breakup parameterization. In particular, better integrate in the bin microphysical model the different kernels (i.e. provide a smooth and more physically realistic breakup regime transition …)
- Extend possibly the number/mass conservative scheme to mass conservative/reflectivity conservative or number/mass/reflectivity conservative
- Perform sensitivity analysis of the bin microphysical model by testing other kernels, fall velocities; evaluate the impact of the different formulations on the dual-pol variables
- Perform bin microphysical simulations using DSD retrieved from field campaigns in complement to synthetic normalized gamma DSD covering the physically realistic DSD space
- Draft a manuscript for the bin microphysical component of the project

Publications

- Morrison, H, M. van Lier-Walqui, M. Kumjian, and O.P. Prat, 2017. A Bayesian approach for generalized statistical-physical bulk parameterization of warm microphysics, Part I: Scheme description. *Journal of the Atmospheric Sciences. In preparation.*

Products

- Manuscript describing the Bayesian statistical framework developed to quantify the uncertainties in in microphysical formulations used in climate models (first year of project). Two other manuscripts are also in preparation at an early draft stage.

Presentations

- Morrison, H., M. van Lier-Walqui, M.R. Kumjian, and O.P. Prat, 2016. Synthesis of observations and models using a new Bayesian framework for microphysical parameterization. *17th International Conference on Clouds and Precipitation*, July 25-29 2016, Manchester, England.
- Kumjian, M., O.P. Prat, M. van Lier-Walqui, H. Morrison, and C. Martinkus, 2016. Using polarimetric radar observations and probabilistic inference to develop the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS), a novel microphysical parameterization framework. *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA, USA.
- van Lier-Walqui, H. Morrison, M. Kumjian, and O.P. Prat, 2016. Rain microphysics uncertainty quantification and development of a polarimetric radar forward simulator for the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS). *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA, USA.
- van Lier-Walqui, H. Morrison, M. Kumjian, O.P. Prat, and C. Martinkus, 2017. The Bayesian Observationally Constrained Statistical-physical Scheme (BOSS), a novel microphysical parameterization framework that effectively leverages uncertain observational information. *2017 ARM/ASR Joint User Facility and PI Meeting*, March 13-16 2017, Vienna, VA, USA.
- Kumjian M., C. Martinkus, O.P. Prat, M. van Lier-Walqui, and H. Morrison, 2017. Development of a Polarimetric Radar Forward Operator for the Bayesian Observationally Constrained Statistical-physical Scheme (BOSS). *2017 ARM/ASR Joint User Facility and PI Meeting*, March 13-16 2017, Vienna, VA, USA.

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

One journal article is in its final stage of iteration and will be submitted in Spring 2017 (1). Five presentations were given on this project (5).

Drought Data for Human Health Studies	
Task Leader	Jared Rennie and Jesse Bell
Task Code	NC-OTH-06-NCICS-JR/JB
Other Sponsor	CDC
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%
Highlight: A project has been completed to provide county level drought information to the Centers for Disease Control and Prevention (CDC). The data has been organized to satisfy needs of CDC, and it has been sent to their website for public dissemination. Data is currently being used to build a statistical climatology of drought information, going back to 1895. **https://ephtracking.cdc.gov/download**	

Background

Drought events are important to understand, primarily because of their potential to reduce agricultural production, result in economic losses, and contribute to environmental degradation. In addition, drought events can create public health consequences, including adverse effects on air quality, decreased drinking water quantity and quality, compromised food availability and nutrition, and increased illness and disease. Over the past few decades, there have been efforts to quantify drought through simple indices that take into account both meteorological and hydrologic phenomena. The Palmer Drought Severity Index (PDSI) was the first index of its kind and included information such as prior precipitation, moisture supply, runoff, and evaporation demand at the surface level. While widely accepted, PDSI has limitations that include spatial comparability, strong influence of the calibration period, and fixed temporal scale. The Standard Precipitation Index (SPI) was developed to address these concerns, and can be calculated at different time scales to monitor useable water resources to assess drought. More recently, the Standard Precipitation Evapotranspiration Index (SPEI) was developed as an extension to SPI, adding both precipitation and temperature data, and an extensive climatic water balance by incorporating the differences in potential evapotranspiration over multiple periods of time.

NOAA's National Centers for Environmental Information (NCEI) has developed values of PDSI, SPI, and SPEI from 1895 to 2016. While all three indices provide independent, robust analyses of drought, these data are at different spatial resolutions that require manipulation and pre-processing before they are accessible for studies to determine the effects of drought on health. To support efforts by the Centers for Disease Control and Prevention's Health Studies Branch to assess the effects of drought on health outcomes, CICS-NC is working on a project to assess existing drought data and increase the usefulness and accessibility of drought data by public health professionals.

Accomplishments

The first step of this project is to develop a consistent approach to evaluate monthly drought data at the county level for the continental United States. Using distance weighting functions, gridded values of SPI and SPEI were calculated to county levels from 1895–2016. PDSI on the other hand, was downscaled from climate division level to county level. Data from the United States Drought Monitor (USDM) was also requested, and provided as county level categorical percentages. The period of record for USDM was only 2000–2016. Data processing has been validated and completed, and the four datasets were sent to the CDC in February 2017. Questions by CDC and their contract users were answered, and the datasets were released publicly to their health portal in March 2017. The website can be found here: https://ephtracking.cdc.gov/download

In addition to providing county drought information on the monthly scale, statistical techniques are applied to analyze onset, severity, and end of drought events. Percentiles are calculated to note where drought is more common. The methodology for percentiles is similar to that of the National Climate Assessment, noting the number of months where drought data for a particular county is lower than the 10th and 1st percentile (an example of the 1st percentile is provided in *Figure 1*). In addition, Mann-Kendall trends are analyzed to assess how drought conditions are changing in the United States over time (see an example in *Figure 2*). By identifying trends in drought and providing drought data in a homogenous temporal and spatial format consistent with health data, public health professionals can better assess relationships between exposures to drought and potential health conditions, particularly at the county level. Better understanding of linkages allows health departments to recognize potential impacts of drought in their communities and to identify opportunities to develop intervention strategies to improve health and save lives.

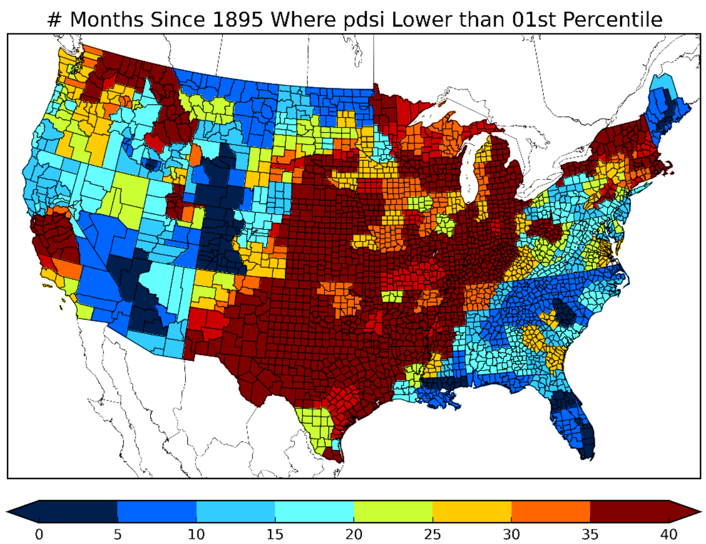


Figure 1. Number of months since 1895 where the Palmer Drought Severity Index was lower than the 1st percentile, which is calculated based on data during the normal period of 1981–2010.

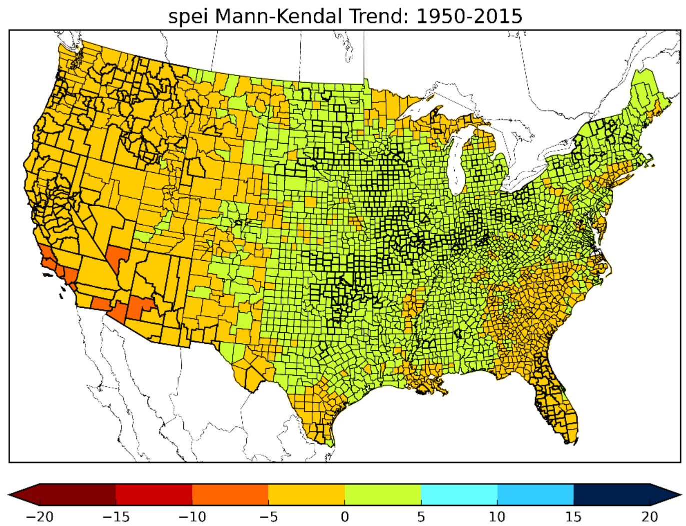


Figure 2. Mann-Kendall Z-Score from 1950–2015, using monthly data values of the Standardized Precipitation Evapotranspiration Index (SPEI). Lower values indicate drought has worsened over time.

Planned Work

- Address any data concerns from CDC.
- Continue statistical analysis of data.
- Write drought climatology manuscript with Jesse Bell and members of CDC.

Publications

- Rennie, J. and Bell, J.: Multivariate Analysis of Drought Conditions in the United States: 1895-2016, in preparation.

Products

- County-level drought information for 3 datasets (PDSI, SPI, SPEI) from 1895-2016 and 1 dataset (USDM) from 2000-2016

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

The dataset has been considered operational and published by the Centers for Disease Control and prevention. Currently a climatology manuscript is being drafted.

Multiscale Convection and the Maritime Continent	
Task Leader	Carl Schreck
Task Code	NC-OTH-07-NCICS-CS
Other Sponsor	NASA
Contribution to CICS Research Themes (%)	Theme 1: 0%; Theme 2: 50%; Theme 3: 50%.
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%, Goal 4: 0%

Highlight: Interactions between the Madden-Julian Oscillation, equatorial waves, and the diurnal cycles of islands in the Maritime Continent can be critical for sub-seasonal-to-seasonal forecasts.

Background

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

Many studies have examined the interactions between the MJO and convection over the MC. Far fewer have looked at the role of convectively couple equatorial waves, even though models that faithfully represent these waves also tend to produce more representative MJO signals. This study identifies avenues for model improvement by investigating the interactions between the MJO, equatorial waves, and the diurnal cycle over the MC. It will also complement a major international field campaign, the Year of Maritime Convection, proposed for 2017-2018.

Accomplishments

This research is being conducted in two intertwined branches. The first study is led by Ademe Mekonnen (NC A&T) and his PhD student, Lakemariam Worku. In that work, the team calculated and compared the diurnal cycles between the TRMM TMPA and ISCCP IR-WS (infrared weather states) over the Maritime Continent (*Fig. 1*). WS-3 (shown on the right) represents shallow and disorganized convection. It showed a stronger diurnal cycle that was more similar to the rainfall (left) than WS-1 and WS-2, which are associated with deep convection.

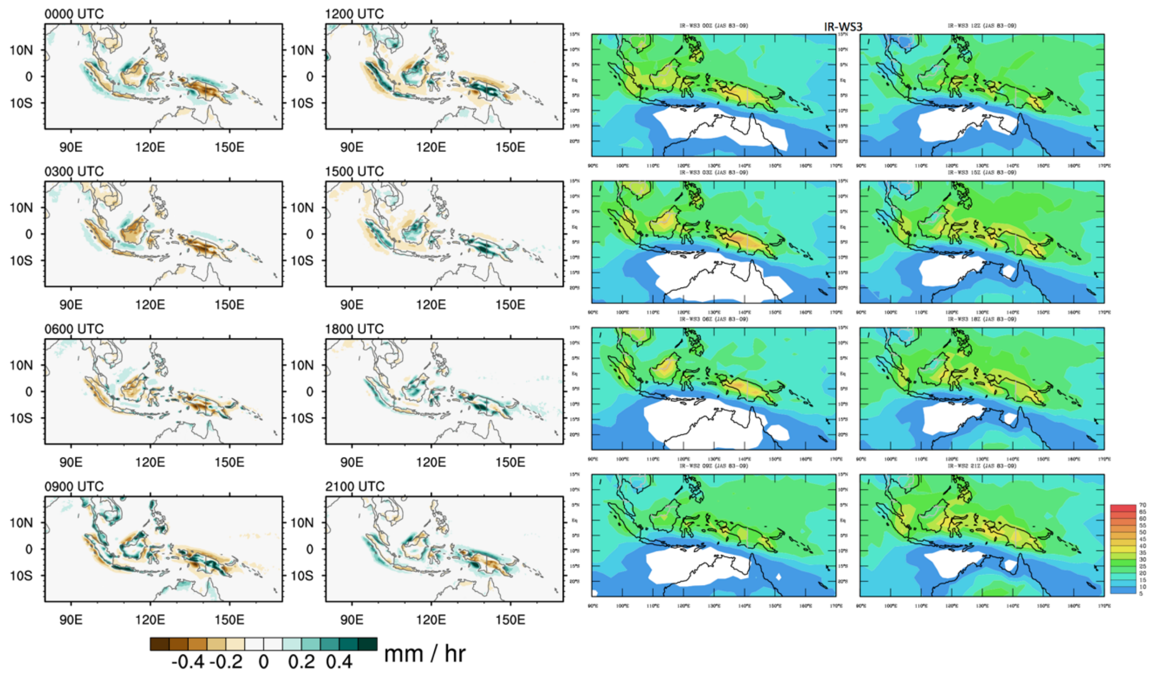


Figure 1. Diurnal cycles for (Left) TRMM TMPA rainfall anomalies and (Right) total counts of ISCCP WS3.

The second study, led by Schreck and Aiyyer (NCSU), is examining the skill of the CFSv2 for forecasting the rainfall associated with the MJO and equatorial waves over the Maritime Continent. The team obtained CFSv2 45-day tropical reforecasts for rainfall, outgoing longwave radiation, and zonal winds from 1999–2014. As a baseline, we have calculated forecasts of the MJO and equatorial waves based solely on the observations. Evaluation of these forecasts and the downloading of CFSv2 reforecasts are ongoing.

Planned Work

In year 2, the project will explore these relationships more deeply and see how they vary within different phases of the MJO, equatorial Rossby waves, and Kelvin waves. The team will also make similar analyses using the convective and stratiform rainfall estimates from TRMM. The results will be submitted for publication near the end of Year 2.

An NCSU graduate student (TBN) will also evaluate the skill of the CFSv2 forecasts for different initial states of the MJO and equatorial waves. Those results will be submitted for publication near the end of Year 2.

Presentations

- Schreck, C. J., A. Aiyyer, and A. Mekonnen, 2016: Multiscale interactions between the MJO, equatorial waves, and the diurnal cycle over the Maritime Continent. *NASA PMM Science Team Meeting*. 24-28 October 2016, Houston, TX.

Other

- This project is advising one current student at NC A&T.

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

Relationship Between Occurrence of Precipitation and Incidence of Traffic Fatalities Using NEXRAD Re-analysis	
Task Leader	Scott Stevens
Task Code	NC-OTH-08-NCICS-SS
Other Sponsor	CDC/NCEI
Contribution to CICS Research Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Climate Adaptation and Mitigation: 50% Weather-Ready Nation: 50%
Highlight: This project used six years of the NEXRAD reanalysis, along with coincident traffic fatality information, to form a quantifiable link between precipitation and an increased risk of traffic fatalities.	

Background

The high-resolution NEXRAD reanalysis provides the ability to study precipitation at a very fine scale in both space and time. Using data from the Fatality Analysis Reporting System (FARS), this project is able to cross-reference the time and location of every fatal accident in the United States with radar-based precipitation estimates over a six-year period (2006–2011), which includes nearly 200,000 fatal accidents. This allows scientists to determine if the incidence of precipitation has a measureable impact on the frequency of fatal crashes under a variety of conditions such as time of day, region, and season.

Accomplishments

Using established statistical methods, the project team has drawn a link between the incidence of precipitation and an increased risk of traffic fatalities. Analysis has shown that the magnitude of the increased risk is heavily dependent on time of day and season, and also varies spatially, with some states impacted far more than others.

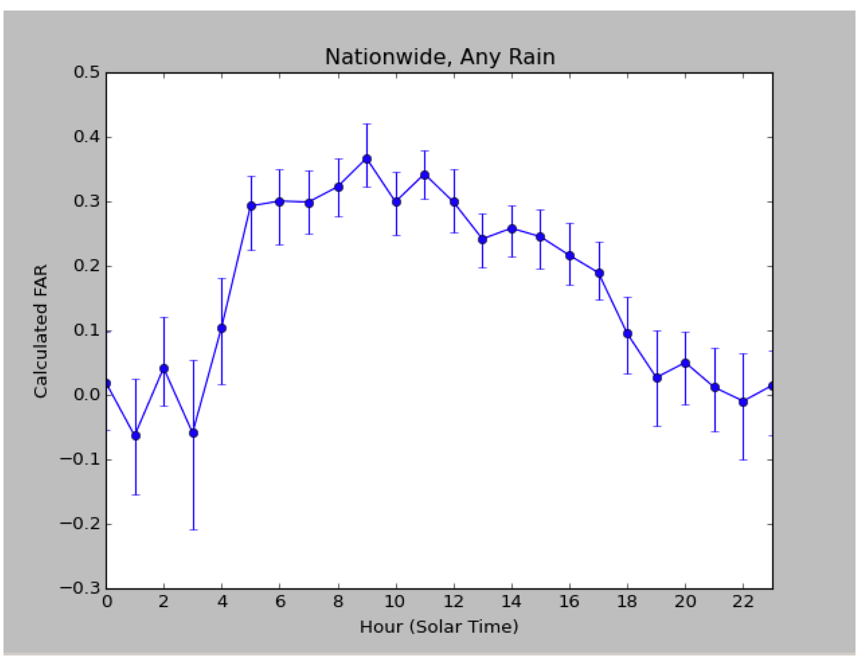


Figure 1 shows the risk contributed by precipitation to fatal crashes during each hour of the day. It is clear that there is a far greater impact during the daylight hours compared to overnight.

Planned Work

- Complete and submit manuscript for publication

Products

- Created climatology of NEXRAD reanalysis as part of this project

Presentations

- American Meteorological Society Annual Meeting, Jan 2017, Seattle, WA
- NCEI internal seminar, Feb 2017

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

Presented results at 2017 AMS Annual Meeting in Seattle, WA. and gave NCEI internal seminar in February 2017.

Appendix 1: Performance Metrics for CICS-NC

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**53**
# of products or techniques submitted to NOAA for consideration in operations use	**21**
# of peer reviewed papers	**41**
# of NOAA technical reports	**53**
# of presentations	**115***
# of graduate students supported by your CICS task	**7**
# of graduate students formally advised	**13**
# of undergraduate students mentored during the year	**24**

*Presentations: 99 science presentations; 16 outreach and engagement presentations

Appendix 2: CICS-NC Publications 2016–2017

Ashouri, H., P. Nguyen, A. Thorstensen, K. Hsu, S. Sorooshian, and D. Braithwaite, 2016: Accessing efficacy of high-resolution satellite-based PERSIANN-CDR precipitation product in simulating streamflow, *Journal of Hydrometeorology*, 17, 2061-2076. 2016. doi: 10.1175/JHM-D-15-0192.1

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Diamond, H. J., and **C. J. Schreck**, 2016: The tropics [in "State of the Climate in 2015"]. *Bulletin of the American Meteorological Society*, **97,** S93-S130. http://dx.doi.org/10.1175/2016BAMSStateoftheClimate.1

Fox, J., M. Hutchins, N. F. Hall, and K. Rogers. "Resilience Planning in Asheville, North Carolina: A Journey Toward Community Resilience." *Carolina Planning Journal*, in press.

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Stegall, S. T., and **K. E. Kunkel**, 2017: Monthly Extreme Temperature Trends in CMIP5 Hindcast/Prediction Simulations, 1981–2010 and 2006–35. *Journal of Applied Meteorology and Climatology*, **56,** 1141-1154. http://dx.doi.org/10.1175/JAMC-D-16-0281.1

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Runkle, J., K. Kunkel, R. Frankson, and B. Stewart, 2017: West Virginia State Summary. *NOAA Technical Report NESDIS 149-WV,* 4 pp.

Frankson, R., K. Kunkel, and S. Champion, 2017: Wisconsin State Summary. *NOAA Technical Report NESDIS 149-WI,* 4 pp.

Frankson, R., K. Kunkel, L. Stevens, D. Easterling, and **B. Stewart**, 2017: Wyoming State Summary. *NOAA Technical Report NESDIS 149-WY,* 4 pp.

Appendix 3: CICS-NC Presentations 2016–2017

Science / Project Presentations

- **Ballinger, A.,** 2017: The LOCA dataset and the development of *Scenarios Lite* for Portland, Portland, OR.**,** February 9, 2017. *(oral presentation)*
- **Ballinger, A.,** 2017: 21st Century Projections of Climate Extremes for Portland, Portland, OR. February 10, 2017. *(oral presentation)*
- **Ballinger, A.,** 2017: Overview of the Climate and Hydrological Extremes Working Group, Annual Meeting of the UREx SRN, New York, NY, March 20, 2017. *(poster presentation)*
- **Bell, J.E.,** 2016**:** USGCRP Climate and Health Assessment. Invited talk, Society of Actuaries Annual Health Meeting, Philadelphia, PA. June 2016
- **Bell, J.E.,** 2016**:** Climate and Health Assessment Chapter 4: Impacts of Extreme Events on Human Health, Society of Actuaries Educational Webinar. September 2016
- **Bell, J.E.,** 2016**:** Impacts of Extreme Events on Human Health. NOAA Seminar Series. Silver Spring, Maryland. September 2016
- **Bell, J.E.,** 2016**:** The impact of climate variability on Valley Fever, CICS Science Conference, College Park, MD, November 28-29, 2016
- **Bell, J.E**., 2017: Assessment of climate variability to incidence of valley fever. AMS Annual Meeting. January 2017
- **Biard, J.,** 2016: Linking netCDF Data with the Semantic Web: Enhancing Data Discovery Across Domains, CICS Science Conference, College Park, MD, November 28-29, 2016
- **Brown, O**., 2016: CICS-NC Overview and Accomplishments, CICS Science Conference, College Park, MD, November 28-29, 2016
- **Champion, S.,** 2016: Global Warming and Heavy Precipitation Design Values, CICS Science Conference, College Park, MD, November 29, 2016
- **Champion, S.** and **L. Sun,** 2016: NCA Technical Support Unit, CICS Science Conference, College Park, MD, November 29, 2016
- **Champion, S.,** 2016: NOAA's State Climate Summaries for the National Climate Assessment: A Resource for Decision Makers, CICS Science Conference, College Park, MD, November 29, 2016.
- **Copley, L.**: Common Ingest, NCEI Seminar Series, April 18, 2017
- Dougherty, C., Hall, N.F., Frimmel, J., and **Fox, J**. "The Emperor's New Clothes: Redressing the U.S. Climate Resilience Toolkit." Presentation at the Carolinas Climate Resilience Conference, Charlotte, NC, September 12–14, 2016.
- Groisman, P., 2016: Freezing Precipitation and Freezing Events over Northern Eurasia and North America: Climatology and the last decade changes, CICS Science Conference, College Park, MD, November 29, 2016
- Hartman, T., **Matthews,** J.L., **Bell, J.E.**, Monitoring Drought with Vegetation and Soil Moisture Data, 97th AMS Annual Meeting, Seattle, WA, 22-26 January, 2017. (poster presentation)
- **Hayhoe, K.**, "Climate Exercise – Day 1 and Day 2" *U.S.–India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 7-9, 2017.
- Hutchins, M., Rogers, K., and **Fox, J.** "The Application of the U.S. Climate Resilience Toolkit and its Five Steps to Resilience to Support Municipal Planning." Presentation at the Carolinas Climate Resilience Conference, Charlotte, NC, September 12–14, 2016.

- **Inamdar, A.,** 2016: Diurnal Cycle of Land Surface Temperatures under All-Sky Conditions, CICS Science Conference, College Park, MD, November 28-29, 2016
- Knapp, K.R., and **Matthews, J.L.** Reprocessing GOES GVAR data. *AMS 21st Conference on Satellite Meteorology*, 14-19 August 2016, Madison, WI.
- Kumjian, M., **O.P. Prat**, M. van Lier-Walqui, H. Morrison, and C. Martinkus, 2016. Using polarimetric radar observations and probabilistic inference to develop the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS), a novel microphysical parameterization framework. *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA.
- Kumjian M., C. Martinkus, **O.P. Prat**, M. van Lier-Walqui, and H. Morrison, 2017. Development of a Polarimetric Radar Forward Operator for the Bayesian Observationally Constrained Statistical-physical Scheme (BOSS). *2017 ARM/ASR Joint User Facility and PI Meeting*, March 13-16 2017, Vienna, VA.
- **Kunkel, K.E.,** 2016: Climate Scenarios for the U.S. National Climate Assessment, Scoping Workshop for the U.S.-India Partnership for Climate Resilience, Indian Institute for Tropical Meteorology, Pune, India, April 11, 2016.
- **Kunkel, K.E.,** 2016: Laudato Si and Climate Science, invited talk, Laudato Si Interdisciplinary Symposium, Franciscan University of Steubenville, Steubenville, Ohio, April 28, 2016.
- **Kunkel, K.E.,** 2016: Extreme Rainfall and Resilient Building Codes, invited talk, White House Conference on Resilient Building Codes, Washington, DC, May 10, 2016.
- **Kunkel, K.E., 2016:** Developing climate extremes products to provide a uniform framework for evaluation across cities, Asheville, NC, *webinar presentation,* May 12, 2016.
- **Kunkel, K.E.,** 2016: NOAA State Summaries for the National Climate Assessment, American Association of State Climatologists Annual Meeting, Santa Fe, New Mexico, July 1, 2016.
- **Kunkel, K.E.,** 2016: Extreme Weather Events: Ice Storms, invited talk (remote), National Academy of Sciences Panel on Enhancing the Resiliency of the Nation's Electric Power Transmission and Distribution System, July 11, 2016.
- **Kunkel, K.E.** and D.R. Easterling, 2016: The India National Climate Assessment, invited talk, NCEI Science Council, Asheville, NC, July 14, 2016.
- **Kunkel, K.E.,** 2016: The National Climate Assessment, invited talk, Journalists Workshop, Asheville, NC, August 16, 2016.
- **Kunkel, K.E.,** 2016: The SERDP project: Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values, invited talk, NCEI Science Council, Asheville, NC, October 13, 2016.
- **Kunkel, K.E.,** 2016: The NOAA State Summaries, invited talk, Fourth National Climate Assessment Federal Coordinating Lead Authors Meeting, Washington, DC, October 26, 2016.
- **Kunkel, K.E.** and **S. Champion,** 2016: Metadata requirements and system demonstration, invited talk, Climate Science Special Report 2nd Lead Authors Meeting, Boulder, CO, November 3, 2016.
- **Kunkel, K.E.,** 2016: Incorporation of Anthropogenically-Forced climate change into Intensity-Duration-Frequency Values, invited talk (remote), City of Seattle meeting on climate-perturbed IDFs, November 10, 2016.
- **Kunkel, K.E.,** 2016: Incorporation of Anthropogenically-Forced climate change into Intensity-Duration-Frequency Values, invited talk (remote), Team Meeting of new SERDP project led by John Marra, November 17, 2016.
- **Kunkel, K.E.,** 2016: Climate Scenarios for the Fourth National Climate Assessment and the Sustained Assessment Process, Fall Meeting of the American Geophysical Union, San Francisco, CA (December 14).

- **Kunkel, K.E.,** 2016: NOAA's State Climate Summaries for the National Climate Assessment: A Sustained Assessment Product, Fall Meeting of the American Geophysical Union, San Francisco, CA (December 14).
- **Kunkel, K.E.,** 2017: Effects of MMTS on Long-Term Extreme Temperature Trends", Annual Meeting of the American Meteorological Society, Seattle, WA (January 24).
- **Kunkel, K.E.,** 2017: NOAA's State Climate Summaries for the National Climate Assessment: A Resource for Decision Makers, Annual Meeting of the American Meteorological Society, Seattle, WA (January 24).
- **Kunkel, K.E.,** 2017: Climate Change Adjustments for Intensity-Duration-Frequency Extreme Precipitation Values, poster, Annual Meeting of the American Meteorological Society, Seattle, WA (January 24).
- **Kunkel, K.E.,** 2017: An Introduction to Downscaling Methods, U.S.-India Partnership for Climate Resilience Workshop on Development and Application of Downscaling Climate Projections, Indian Institute for Tropical Meteorology, Pune, India (March 7).
- **Kunkel, K.E.,** 2017: Developing *Scenarios Lite* for Practitioners, Annual Meeting of the UREx SRN, New York, NY (March 20)
- **Leeper, R. D.,** Palecki, M., **Bell, J. E.**, 2016: Analysis of Soil Moisture Metrics to Assess Societal Risks to Hydrological Extremes, Carolinas Climate Resilience Conference, Charlotte, NC, September 2016. *(poster presentation)*
- **Leeper, R. D.**, 2016: Evaluation of In Situ Soil Moisture Metrics to Monitor Hydrological Conditions. CICS Science Conference, College Park, MD, November 28-29, 2016.
- **Leeper, R. D.**, 2017: Monitoring hydrological conditions using soil moisture observations at NCEI Science Council meeting, Asheville, NC, January 2017.
- **Leeper, R. D**., 2017: Evaluation of In-Situ Soil Moisture Metrics to Monitoring Hydrological Extremes. American Meteorological Society Annual Meeting, Seattle, WA, January 23rd 2017. *(oral presentation)*
- **Matthews, J.L.**, 2016: What to expect in a non-academic career. SAMSI's Workshop for Women in Math Sciences, Durham, NC, April 6-8, 2016.
- **Matthews, J.L.**, 2016: Research applications at the National Centers for Environmental Information. Environmental Protection Agency, Research Triangle Park, NC, July 20, 2016.
- **Matthews, J.L.**, 2016: Research applications at the National Centers for Environmental Information. Clemson University Mathematical Sciences Department Colloquia, Clemson, SC, September 16, 2016.
- **Matthews, J.L.**, 2016: Research applications with NOAA's Climate Data Record Program, CICS Science Conference, College Park, MD November 28-29, 2016.
- **Matthews, J.L.**, 2016: Long-term HIRS-based Temperature and Humidity Profiles, CICS Science Conference, College Park, MD November 28-29, 2016.
- **Matthews, J.L**. and L. Shi, 2016: Long-term HIRS-based temperature and humidity proles. CICS Science Conference, College Park, MD, November 29-December 1, 2016. (poster presentation)
- **Miller, D**., L. Stewart, D. Hotz, J. Winton, A. Barros, J. Forsythe, A. P. Biazar, and G. Wick, 2016: Investigation of Atmospheric Rivers Impacting the Pigeon River Basin of the Southern Appalachians. 2016 International Atmospheric Rivers Conference, San Diego, CA. (oral presentation)
- Moroni, D., H. Ramapriyan, **Peng, G.**, and C.-L. Shie, 2016: Ensuring and Improving Information Quality for Earth Science Data and Products – Role of the ESIP Information Quality Cluster. ESIP 2017 Winter Meeting, 11 – 13 January 2017, Bethesda, MD. (poster presentation)

- Morrison, H., M. van Lier-Walqui, M.R. Kumjian, and **Prat, O.P.**, 2016. Synthesis of observations and models using a new Bayesian framework for microphysical parameterization. *17th International Conference on Clouds and Precipitation*, July 25-29 2016, Manchester, England.
- Nelson, B.R., **O.P. Prat,** and **S.E. Stevens**, 2016. Assessment of NOAA's NEXRAD reanalysis. *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA.
- **Peng, G.,** 2016: Challenges and potential approach in search relevance ranking from a dataset maturity perspective. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC. (oral presentation)
- **Peng, G.,** N. Ritchey, and H. Ramapriyan, 2016: A Holistic and Systematic Approach and Panel Discussion. Session. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC.
- **Peng, G.,** R. Duerr, S. Hou, and R. Downs, 2016: Maturity Models Use Case Study Updates and Training/Working Session. Session. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC.
- **Peng, G.,** W.N. Meier, J.T. Yu, and A. Arguez, 2016: Climate Normals and Variability of Arctic Sea Ice. 2016 CLIVAR Open Science Conference, 19 – 23 September 2016, Qingdao, Shangdong, China. (poster presentation)
- **Peng, G.,** 2016: Scientific Stewardship: What is it and what does it mean to us?, CICS Science Conference, College Park, MD, November 28-29, 2016
- **Peng, G**., H. Ramapriyan, and D. F. Moroni, 2016: The State of Building a Consistent Framework for Curation and Presentation of Earth Science Data Quality. Poster: IN41C.1666, AGU 2016 Fall Meeting, 12 – 16 December 2016, San Francisco, CA.
- **Peng, G.,** C. Lief, and S. Ansari, 2017: Improving Stewardship of Scientific Data Through the Use of a Maturity Matrix – A Success Story. 2016 NOAA Enterprise Data Management Workshop. 9 – 10 January 2017, Bethesda, MD. (oral presentation)
- **Peng, G.,** N. Ritchey, and S. Gordon, 2017: Towards Systematically Curating and Integrating Data Product Descriptive Information for Data Users. Session. ESIP 2017 Winter Meeting. 11 – 13 January 2017, Bethesda, MD.
- **Peng, G.,** H. Ramapriyan, and D. F. Moroni, 2016: The State of Building a Consistent Framework for Curation and Presentation of Earth Science Data Quality. ESIP 2017 Winter Meeting, 11 – 13 January 2017, Bethesda, MD. (poster presentation)
- **Prat, O.P.,** B.R. Nelson, E. Nickl, R. Adler, R. Ferraro, S. Sorooshian, and P. Xie, 2016. Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs) from the Reference Environmental Data Records (REDRs). *2016 EGU general assembly*, April 17-22 2016, Vienna, Austria.
- **Prat, O.P., Leeper, R.D., Stevens, S.E.**, Nelson, B.R., Easterling, D.R., and **Kunkel, K.E.**, 2016. Long-term quantification of extreme precipitation in relation with tropical and extra-tropical cyclonic activity over the Carolinas. *Carolinas Climate Resilience Conference*. September 12-14 2016, Charlotte, NC.
- **Prat, O.P.,** B.R. Nelson, and R.R. Ferraro, 2016. Evaluation of satellite Quantitative Precipitation Estimates (QPEs) products. *CICS Science Conference*, November 29-December 1 2016, College Park, MD.
- **Prat, O.P.,** and B.R. Nelson, 2016. Evaluation of satellite Quantitative Precipitation Estimates (QPEs) products. *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA.
- **Prat, O.P.,** and B.R. Nelson. Evaluation of extreme precipitation derived from long-term global satellite Quantitative Precipitation Estimates (QPEs). *2017 EGU General Assembly*, April 23-28 2017, Vienna, Austria.

- Ramapriyan, H., **Peng, G.,** D. Moroni, C.-L. Shie, 2016: Ensuring and Improving Information Quality for Earth Science Data and Products – Role of the ESIP Information Quality Cluster. SciDataCon, 11-16 September 2016, Denver, Colorado. (oral presentation)
- Ramapriyan, H., D. Moroni, **Peng, G.,** and S. J. Worley, 2016: Managing Earth Science Data Quality Information for the Benefit of Users I Posters. Session IN41C. 12 – 16 December 2016, San Francisco, CA.
- **Rennie, J.J.,** 2016: Shaken or Stirred: How Do You Want Your Climate Data? Ask the Audience Session, 2nd Carolinas Climate Resilience Conference, Charlotte, NC, 13 Sep 2016.
- **Rennie, J.J.,** and D.S. Arndt, 2017: Updating a Climatology of Extreme Snowfall Events in the United States, 29th Conference on Climate Variability and Change, AMS Annual Meeting, Seattle, WA, 24 Jan 2017. (poster presentation)
- Ritchey, N. and **Peng, G.**, 2016: Data stewardship maturity matrix (DSMM) – NCEI use case and application update. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC. (oral presentation)
- Ritchey, N., Milan, A., Jones, P., Li, Y., **Peng, G.,** and Collins, D., 2016: Advances in Earth Science metadata for NOAA's OneStop Project. ESIP 2016 Summer Meeting, 19 – 22 July 2016, Durham, NC. (oral presentation)
- Ritchey, N.A., **Peng, G.,** A. Milan, P. Lemieux, R. Partee, R. Lonin, and K.S. Casey, 2016: Practical Application of the Data Stewardship Maturity Model for NOAA's OneStop Project. IN42D-08. Talk. AGU 2016 Fall Meeting, 12 – 16 December 2016, San Francisco, CA.
- **Schreck, C. J.,** K. R. Knapp, J. P. Kossin, and C. Velden, 2016: Comparing CI-number/Pressure Relationships in the Western Pacific using HURSAT-ADT and Historical Reconnaissance. *32nd Conference on Hurricanes and Tropical Meteorology*, 17-22 April 2016, San Juan, PR.
- **Schreck, C. J.,** 2016: Cluster analysis of tropical modes. *NOAA's 41st Climate Diagnostics and Prediction Workshop*, 3-6 October 2016, Orono, ME.
- **Schreck, C. J.,** A. Aiyyer, and A. Mekonnen, 2016: Multiscale interactions between the MJO, equatorial waves, and the diurnal cycle over the Maritime Continent. *NASA PMM Science Team Meeting*. 24-28 October 2016, Houston, TX.
- **Schreck, C. J., 2017:** Subseasonal Variability of Tropical Cyclones: The MJO and Kelvin Waves. *Fourth Santa Fe Conference on Global & Regional Climate Change*, 6-10 February, Santa Fe, NM.
- Scott, E., **Leeper, R. D.,** Palecki, M. Evaluating Precipitation Extremes from a Sparse Network: the NOAA U.S. Climate Reference Network. American Meteorological Society Annual Meeting in Seattle, WA, January 23rd 2017. *(oral presentation)*
- **Shen, S.,** 2016: Statistical methods for quantifying the uncertainties in climate data reconstruction and climate signal detection, Colorado State University Statistics Seminar, October 10, 2016.
- **Shen, S.,** 2016: Statistical methods for quantifying the uncertainties in climate data reconstruction and climate signal detection, NCAR seminar, October 12, 2016.
- **Shen, S.,** 2016: 4-dim visual delivery of big climate data, UCLA Geography climate change group seminar, November 14, 2016.
- **Shen, S.,** 2016: Simplified reconstruction and visual delivery of big climate data. NOAA CICS-CREST science meeting, College Park, MD, November 29-December 1, 2016.
- Shi, L., **Matthews, J.L.**, **Stegall, S.,** and **Peng, G.**, 2016: A long-term global dataset of temperature and humidity profiles from HIRS. 2016 CLIVAR Open Science Conference, 19 – 23 September 2016, Qingdao, Shangdong, China. (poster presentation)
- **Stevens, L.E.,** 2016: NOAA's State Summaries for the National Climate Assessment, 2016 Carolinas Climate Resilience Conference, Charlotte, NC, September 13, 2016.

- **Stevens, L.E.,** 2017: NOAA's State Climate Summaries for the National Climate Assessment: State Level Trends in Temperature and Precipitation, American Meteorological Society Annual Meeting, Seattle, WA, January 24, 2017.
- **Stevens, S.,** Saha, S. and **Bell, J.E.**, 2017: Relationship Between Precipitation and Traffic Fatalities: A High-Resolution Comparison. American Meteorological Society Annual Meeting, Jan 2017, Seattle, WA.
- **Stevens, S.,** 2017: NEXRAD reanalysis use in determining relationship between precipitation and traffic fatalities NCEI seminar, February 2017.
- Stoner, A., **Hayhoe, K.**, Dixon, K., Lanzante, J., and Scott-Fleming, I., 2017: Comparing the performance of multiple statistical downscaling approaches using a perfect model framework, *U.S.–India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 7-9, 2017.
- **Stoner, A.,** 2017: Application Examples of Downscaled Output, *U.S.–India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 7-9, 2017.
- **Sun, L.,** 2016: Analysis of U.S. Regional Conditions Using LOCA Downscaling Data, invited talk, Risk Analysis and Environmental Disasters, Rio de Janeiro, Brazil (September 27, 2016).
- **Sun, L.,** 2016: Analysis of Climate Extremes over the Contiguous United States, CICS Science Conference, College Park, MD, November 29, 2016.
- Swaminathan, R., **Hayhoe, K.**, "Automated Quality Control of Observed Weather Station Data" by *U.S.–India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 7-9, 2017.
- van Lier-Walqui, M., H. Morrison, M. Kumjian, and **O.P. Prat**, 2016. Rain microphysics uncertainty quantification and development of a polarimetric radar forward simulator for the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS). *2016 AGU Fall Meeting*, December 12-16 2016, San Francisco, CA.
- van Lier-Walqui, H. Morrison, M. Kumjian, **O.P. Prat**, and C. Martinkus, 2017. The Bayesian Observationally Constrained Statistical-physical Scheme (BOSS), a novel microphysical parameterization framework that effectively leverages uncertain observational information. *2017 ARM/ASR Joint User Facility and PI Meeting*, March 13-16 2017, Vienna, VA.
- Zinn, S., J. Relph, **Peng, G.,** A. Milan, and A. Rosenberg, 2017: Design and implementation of automation tools for DSMM diagrams and reports. ESIP 2017 Winter Meeting, 11 – 13 January 2017, Bethesda, MD. (oral presentation)

Outreach and Engagement Presentations

- **Dissen, J.,** 2016: EHS, Sustainability and Climate Resilience – What's the Connection?, Research Triangle Park Foundation webinar, September 8, 2016.
- **Dissen, J.,** T. Owen, M. Brewer, E. Mecray, T. Houston, 2016: Engagement with the Energy Sector - Our Experience., 2016 Carolinas Climate Resilience Conference. September 2016, Charlotte.
- **Griffin, J., Runkle, J. and Scott S., 2016:** presentations to Brevard High School Science Club, Brevard, NC, June 12, 2016.
- **Hennon, P, Rennie, J, Stevens, S., and Stone, T.,** 2016: presentations on climate change, Cyclone Center, and coding in climate science, NCEI Science Week event, NCEI, Asheville, April 21, 2016.

- **Maycock, T.** and **Runkle, J.,** 2016: Climate and Health. *Asheville Museum of Science Beer City Science Pub Series*, October 28, 2016*,* The Collider, Asheville, NC.
- **Rennie, J.**, 2016: Weather, Climate, and Code, Ira B. Jones Elementary School, Asheville, NC, December 9, 2016.
- **Rennie, J.**, Stevens, L., and Stevens, S., 2016: NCEI weather and climate observations, Asheville Middle School, Asheville, NC, October 11-13, 2016.
- **Schreck, C.**, 2016: presentation on science, weather, and anemometers, St. Mark's Lutheran Church Vacation Bible School, Asheville, NC, June 20, 2016.
- **Schreck, C.**, 2016: presentation on hurricanes and rain gauges, North Buncombe Elementary School Career Day, Asheville, NC, November 22, 2016.
- **Stevens, L.**, 2017: presentation on meteorology and climatology as career options, Franklin School of Innovation Career Day, Asheville, NC, March 29, 2017.
- **Stevens, S.**, 2016: presentation on climate change, East Yancey Middle School, Burnsville, NC, April 27, 2016.
- **Stevens, S.**, 2017: The Value of 150 Years of Weather Data, Imagine Collegiate Invest (charter school), Asheville, NC, February 14, 2017.
- **Stevens, S.**, 2017: Meteorology as a Career, Etowah Elementary School Career Day, Etowah, NC, February 17, 2017.
- **Stone, T.**, 2016: multiple presentations on the National Climate Assessment, climate change, and the Cyclone Center, Isothermal Community College Science and Technology Expo, Spindale, NC, April 15, 2016.
- **Stone, T.**, 2017: multiple presentations on the use of satellites and radar in climate science with NCEI's Magic Planet, Isothermal Community College Science and Technology Expo, Spindale, NC, March 31, 2017.
- Thompson, T., **Brown, O., Dissen, J.,** 2016: Applying NOAA Big Data to Utilities – An Example., Utility Analytics Week (31 October 2016).