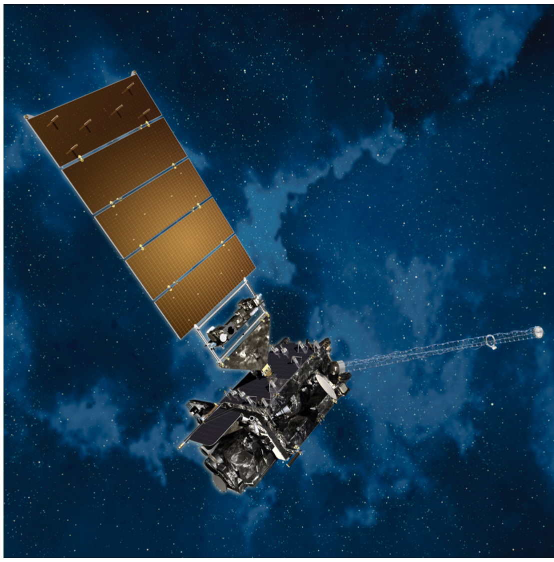


GOES-R

JPSS

COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

Annual Scientific Report

VOLUME III: CICS-NC TASK REPORTS

For the period:
April 1, 2017 – March 31, 2018
NOAA Grant NA14NES4320003

Dr. Fernando Miralles-Wilhelm, Director
April 30, 2018

CICS
Cooperative Institute for Climate and Satellites

Table of Contents

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. NCICS/CICS-NC is hosted by North Carolina State University (NCSU) and affiliated with the UNC academic institutions as well as a number of other academic and community partners. CICS-NC is collocated with the NOAA/NESDIS National Centers for Environmental Information (NCEI, 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 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 the Air Resources Laboratory's (ARL's) Atmospheric Turbulence and Diffusion Division (ATDD) as well as other federal agency collaborators with NOAA/NCEI, including the United States Global Climate Research Program (USGCRP), the Federal Emergency Management Agency (FEMA), the National Aeronautics and Space Administration (NASA), the U.S. Department of Defense, and the U.S. Department of State.

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

CICS' scientific vision centers on observation, using instruments on Earth-orbiting satellites and surface networks, and prediction, using realistic mathematical models, of the present and future behavior of the Earth System. Observations include the development of new ways to use existing observations, the invention of new methods of observation, and the creation and application of ways to synthesize observations from many sources into a complete and coherent depiction of the full system. Prediction requires the development and application of coupled models of the complete climate system, including atmosphere, oceans, land surface, cryosphere, and ecosystems. Underpinning all of these activities is the fundamental goal of enhancing our collective interdisciplinary understanding of the state and evolution of the full Earth System. This vision is consistent with NOAA's Mission and Goals and CICS scientists' work on projects that advance NOAA objectives. CICS conducts collaborative research with NOAA scientists in three principal 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 and environmental 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 needed 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 services. Main collaborative activities are currently organized and CICS is structured thematically by the following 8 task streams:

1) Administration (Task I)
2) Access and Services Development
3) Assessments
4) Climate Data Records and Scientific Data Stewardship
5) Climate Literacy, Outreach, Engagement, and Communications
6) Surface Observing Networks
7) Workforce Development
8) Consortium and/or Other CICS PI 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. Other CICS PI projects are generally supported through other (non-NOAA) sponsors.

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), and ARL's Atmospheric Turbulence and Diffusion Division (ATDD). While CICS-NC activities remain primary, NCICS scientists are also engaged in research projects (Other CICS PI Projects) supported by non-NOAA sponsors that currently include: The National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy (DOE), the U.S. Department of Defense (DoD), and the National Institute Institutes of Health (NIH).

Administration [NCSU/NOAA]
Information Technology Systems Improvement, Management, and Maintenance: CICS-NC IT staff provide modern approaches to keep CICS-NC at the competitive edge of technology advances, as well as maintaining core technologies as a stable base for staff operations. Improvements are focused towards system reliability and providing infrastructure that is both flexible and scalable. Without current IT resources, CICS-NC staff would be unable to complete their respective support and research tasks.

Access and Services Development [OCIO/CPO/NCEI]
NOAA Big Data Project Support: Designed and implemented a pilot data hub/broker architecture to facilitate transfer of key NOAA environmental datasets to commercial public cloud providers allowing users to do analyses of data and extract information without having to transfer and store these massive datasets themselves. *https://ncics.org/data/noaa-big-data-project/*

Programming and Applications Development for Climate Portal: In support of the overall advancement of the NOAA's Climate Services Portal program, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) staff contributed to the continued development of the U.S. Climate Resilience Toolkit (*https://toolkit.climate.gov/*), the 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.

Website Information Architecture Development and User Interface Design for NOAA's National Centers for Environmental Information and NOAA OneStop: After researching NOAA OneStop's target audience and completing site analytics, Mediacurrent identified key performance indicators for tracking success, prioritized features based on user and stakeholder needs, conducted user testing, and developed an enhanced user interface design for improved user interaction. The outcome of this process was an end-to-end strategy audit, a web accessibility audit, as well as design mockups.

Assessment Activities [NCEI/CPO]
The NOAA Assessment Technical Support Unit (TSU), staffed largely by CICS-NC personnel, provides scientific, editorial, graphic design, metadata, project management, programming, and web development support for the U.S. Global Change Research Program's (USGCRP) Climate Science Special Report (CSSR or the Fourth National Climate Assessment Volume I) released in November 2017 and the Fourth National Climate Assessment (NCA4) Volume II, scheduled for release in late 2018. CICS-NC staff 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, Climate Change Indicators, and several author collaboration and report development tools.

National Climate Assessment Scientific Support Activities: The Assessment science team was integral to the completion of the Climate Science Special Report (CSSR or Fourth National Climate Assessment Volume 1) through authorship contributions to several chapters, development of numerous specialized scientific analyses and graphs, and completion of metadata collection and viewer**.** *https://science2017.globalchange.gov/*

National Climate Assessment Technical Support Activities: TSU technical staff provide technical and scientific writing and editing, graphics, and web development expertise in support of multiple National Climate Assessment (NCA) related products, including Volumes I and II of the Fourth NCA and other associated publications. The team also provided overall project coordination and contributed substantive content to multiple author guidance documents and other tools. *https://science2017.globalchange.gov/*

World Resources Institute (WRI) / Partnership for Resilience and Preparedness (PREP) Supporting the U.S. – India Partnership for Climate Resilience: CICS-NC collaborator, the World Resources Institute (WRI), and the Partnership for Resilience and Preparedness (PREP) are working with two Indian states, Madhya Pradesh and Uttarakhand, to help implement State Action Plans on Climate Change through collaboration in the development and use of tailored "climate preparedness dashboards" on the PREP platform. *www.prepdata.org*

U.S. – India Partnership for Climate Resilience (PCR) Workshop Support: CICS-NC collaborator, Texas Tech University, led the 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 at the past year's PCR workshops in India.

The Energy and Resources Institute (TERI) / Understanding Climate and Health in India (UCHAI) Initiative Supporting the U.S. – India Partnership for Climate Resilience: CICS-NC collaborator, The Energy and Resources Institute (TERI), and its UCHAI initiative have led, participated in and/or coordinated a number of activities and events in the past year to raise awareness on the effects of climate vulnerability and extreme weather patterns on human health, and adoption of measures that can help in risk reduction*.* *http://www.uchai.net/*

Climate Change Indicators: The TSU provided support to USGCRP efforts to produce a comprehensive suite of Climate Change Indicators. Significant progress was made in the development of new Indicators and collection of indicator metadata. A new Heavy Precipitation Indicator, developed with TSU input and support, was recently added to the USGCRP Indicators Platform. *https://www.globalchange.gov/browse/indicators*

Analytical Support for the Fourth National Climate Assessment: Utilizing LMI's proprietary *ClimateQ* toolkit**,** tailored *Fourth National Climate Assessment (NCA4)* climate-scenario products were developed for the NCA4 regional and sectoral chapter authors. To date, 28 Metropolitan Statistical Areas have been analyzed across 48 derived variables from 32 models.

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 previously completed. This year, short term trends in the MESH climatology and long-term trends in the NARR-based hail environments were analyzed. Severe-convective storm parameters evaluated using the North American Regional Reanalysis (NARR) exhibit positive trends over the period 1980-2015; trends in some of the quantifications were found to be statistically significant.

Climate Data Records and Scientific Data Stewardship [NCEI]

Scientific Subject Matter Expertise Support: CICS-NC scientists serve as subject matter experts on multiple CDR Integrated Product Teams supporting the transition of research-grade CDRs into an initial operational capability (IOC) status as well as acting as Product Leads and Portfolio Area Leads for a number of NOAA-NCEI products and portfolios.

Expansion of CDR User Base through the Obs4MIPs Program: CICS-NC scientists worked to make observational products more accessible for comparison with climate models by reformatting datasets in the standard form used by the Coupled Model Intercomparison Project (CMIP) community. https://ncics.org/data/obs4mips/

Common Ingest Agile Development Team: The team iteratively delivered a Common Ingest solution for the ingest of environmental data at NCEI. Common Ingest v2.0.0 delivers all of the functionality required to support the migration of all data sets from the current legacy ingest system to Common Ingest for NCEI-NC.

Spatial-Temporal Reconstruction of Land Surface Temperature from Max/Min Temperatures: Time series of daily maximum and minimum temperatures combined with estimates of net surface solar radiation (or surface solar absorption) derived from the geostationary visible channel is used to reconstruct the temporal evolution of LST under almost all-sky conditions. This strategy has potential applications to the new 5 km gridded daily nClimDiv max/min temperature data set that is being produced at NOAA.

Transitioning the International Satellite Cloud Climatology Project (ISCCP) Process to NCEI: The ISCCP H-series product for the full baseline period (July 1983 – 2009) was successfully transitioned in June 2017. Production for extended period (2010-2012) was completed and archived. A subset of the full ISCCP, ISCCP-Basic, with fewer variables was produced and made available to users. Ongoing efforts are being made to replace the drifting NOAA-18 with NOAA-19 as the anchor satellite for calibration. https://www.ncdc.noaa.gov/isccp

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***:** The data stewardship maturity matrix (DSMM) has been applied to more than 800 individual NCEI datasets: 300+ of those DSMM assessment ratings have already been captured by ISO standard collection-level metadata and used by the new NOAA OneStop Search and Discovery system for relevancy ranking and 300+ more are to be integrated.

Regional Variability of Sea Ice Coverage: Temporal and spatial variability of Arctic sea ice coverage and sensitivity of their trends and statistical projections were examined. Long-term, consistent time series of monthly sea ice area and extents were computed for the period of 1979-2015. For the Arctic as a whole, the analysis found significant changes in both annual SIE maximum and minimum.

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.

Toward Earlier Drought Detection Using Remotely Sensed Precipitation Data from the Reference Environmental Data Record (REDR) CMORPH: The feasibility of using satellite precipitation data from the REDR program (CMORPH) to detect and monitor drought on a global scale is being investigated with a focus on the implementation of the drought indices and their evaluation over CONUS.

Identifying Tropical Variability with CDRs: CICS-NC and UNC-Asheville co-hosted a *Workshop on Global Tropical Cyclone Reanalysis* at The Collider in May 2017 to discuss how to address the challenges posed by discrepancies in the historical tropical cyclone record. NCICS.org/mjo

ENSO Normals: A new methodology for identifying moderate and strong El Niño and La Niña events was developed and has been preliminarily applied to nClimGrid to identify typical conditions during each phase of ENSO.

Climate Literacy, Outreach, Engagement, and Communications [NCEI/NCSU]
Climate Literacy, Outreach, Engagement, and Communications: CICS-NC conducted numerous engagement activities to reach various types of stakeholders on the suite of environmental data and information, climate change and variability, adaptation and mitigation, and interdisciplinary uses and applications of the information to inform decision-making as well as inspiring activities for innovation. https://ncics.org/expertise/engagement/

Outreach to Higher Education Institutions: Engagement with academic institutions is a CICS-NC focus area being served through the instruction of a graduate level distance education course, invited speaking engagements with university student and faculty audiences, and mentorship of undergraduate and graduate students.

CICS-NC Communications: CICS-NC communication activities raise Institute awareness and highlight accomplishments of the Institute and its staff for its stakeholders through web stories, press releases, social media, and outreach events and advance the external and internal communications efforts of NOAA's National Centers for Environmental Information. https://ncics.org/

Surface Observing Networks [NCEI/ATDD]
Improving U.S. Climate Reference Network (USCRN) Soil Moisture Observations: Improvements in the quality and usability of United States soil moisture measurements are being made through application of quality-controlled methods to create improved soil observation datasets.
https://www.ncdc.noaa.gov/crn/

U.S. Climate Reference Network (USCRN) Applications: Several projects utilizing USCRN data were initiated including two satellite-based projects utilizing USCRN data for remote sensing validation and algorithm development, the update of an hourly precipitation dataset (HPD), an update of network wide precipitation extremes through 2017, and a sensor sensitivity study related to urbanization.

The Utility of In-situ Observations for the 2017 Great American Solar Eclipse: An interactive web product was created utilizing hourly cloud cover normals from automated weather stations to determine the likelihood of cloudiness for the solar eclipse hour at stations across the U.S. The website was viewed over 380 thousand times with more than 2 million interactions. An analysis of post eclipse in-situ data revealed the impact of reduced solar insolation on near-surface temperatures and relative humidity. *https://ncsu.maps.arcgis.com/apps/webappviewer/index.html?id=6771e9f10f904b7b8afa6cc99c4c7e7a*
NCEI Web Story: *https://www.ncei.noaa.gov/news/ready-set-eclipse*

Standardization of U.S. Climate Reference Network Soil Moisture Observations: A methodology to standardize hourly volumetric soil moisture observations from a short term (7-8 year) data record was developed. This approach was evaluated using station observations from the longer term (15-year) Soil Climate Analysis Network (SCAN). Results showed the methodology could produce a soil moisture climatology similar to the 15-year inter-annual mean with seven or more years.

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 Spring, Summer, and Fall 2017 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).

Maintenance and Streamlining of the Global Historical Climatology Network-Monthly (GHCN-M) Dataset: The next iteration of NOAA's global temperature product has been developed and released as a second public beta based on an open and transparent databank of land surface stations. A manuscript has been submitted, and the dataset will become operational once the manuscript is accepted. *http://www.surfacetemperatures.org*, *https://www.ncdc.noaa.gov/ghcnm/*

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool: A sub-monthly tool for monitoring impacts of temperature extremes in the United States has been created. The resulting dataset was used to assess heat extreme events in the United States from 1895–2016. *https://ncics.org/portfolio/monitor/sub-monthly-temperatures/*

Simplified and Optimal Analysis of NOAA Global Temperature Data: Data Validation, New Insights, Climate Dynamics and Uncertainty Quantification: A new software technology, 4DVD (4-Dimensional Visual Delivery of big climate data), was developed and released with the capability to rapidly deliver NOAA environmental data to classrooms, households, and the general public. A limited demo is available at: *http://climate2.mrsharky.com/*

Night Marine Air Temperature Near Real-Time Dataset Development: A preliminary gridded NCEI NMAT dataset from 2002 - August 2017 was generated that includes NMATs adjusted in the boundary layer to a homogenized height of 10m and gridded using a distance weighting scheme. Results agree well with HadNMAT2 between 30S and 60N.

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

Other CICS PI Projects
Collaboration with the Centers for Disease Control on Issues Related to Climate and Health: CICS-NC staff have established and strengthened a collaborative relationship between NOAA and CDC by integrating NOAA environmental data into targeted CDC health studies to increase the understanding of climate effects on human health. Projects over the past year have dealt with topics such as extreme heat surveillance, soil moisture conditions and Valley fever, and evaluation of mental health outcomes from drought. **[NCEI/CDC]**

Changes of freezing precipitation frequency: Several international efforts are underway to conduct environmental change research focused on the regions of the northern extratropics to better inform vulnerable societies and better prepare them for potential future developments. http://nefi-neespi.org **[MULTIPLE]**

The Urban Resilience to Extremes Sustainability Research Network (UREx SRN): CICS-NC scientists are leading the Climate and Hydrologic Extremes Working Group (CHExWG) efforts for a large multi-institutional project led by Arizona State University. Current efforts include characterization of recent historical trends of climate extremes and the development of future climate extreme scenarios for nine pilot cities in the U.S., Puerto Rico, Mexico, and Chile. **[NSF]**

Incorporation of climate change into Intensity–Duration–Frequency Design Values: An algorithm using Deep Learning methods to automatically identify weather fronts in climate model and reanalysis data in gas was completed. An analysis of historical extreme precipitation events found a strong correlation between the magnitude of the events and the atmospheric water vapor content, a finding that provides a strong basis for adjustment of IDF values. **[DOD / SERDP]**

Climate Model Data Support to the Assistant Secretary of Air Force Climate Projection Engineering Weather Data (EWD) Project: Future engineering design values were estimated for Air Force bases at Langley, VA and Thule, Greenland, based on two scenarios for future climate change. Substantial future increases were calculated for temperature and humidity variables. **[DOD / USAF]**

Water Sustainability and Climate Change: A Cross-Regional Perspective: Analysis of CMIP5 decadal experiment simulations indicate that future projections of extreme precipitation for 2006-2035 reflect increases in all regions with respect to 1981-2010. This suggests that there is merit in incorporating future extreme precipitation increases in planning in this near-term future time horizon. **[NSF]**

Climate indicators to track the seasonal evolution of the Arctic sea ice cover to support stakeholders: The NOAA/NSIDC (National Snow and Ice Data Center) Sea Ice Concentration Climate Data Record (CDR) was used 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 and examine long-term average and temporal variability of the new sea ice climate indicators. **[NASA]**

Synthesis of Observed and Simulated Rain Microphysics to Inform a New Bayesian Statistical Framework for Microphysical Parameterization in Climate Models: This multi-institutional research project 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, the team developed 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]**

Continuous Monitoring of Individual Exposure to Cold Work Environment: A Participatory Sensing Study: This pilot study utilizes new wearable sensor technology to test and implement more sensitive means of evaluating cold temperatures as an occupational hazard and develop effective report-back strategies as a means to communicate with participants about harmful occupational exposures and their associated health risks. **[NIH / NIOSH]**

Multiscale convection and the Maritime Continent: This multi-institutional team is examining the strong diurnal cycle of convection over the Maritime Continent and determining how it impacts subseasonal-to-seasonal forecasts. *NCICS.org/mjo* **[NASA]**

Investigations between Kelvin waves and Easterly waves using CYGNSS data: This team is using NASA's new Cyclone Global Navigation Satellite System (CYGNSS) retrievals to investigate surface interactions between Kelvin waves and easterly waves. **[NASA]**

Developing New Forecast Tools for the USAF 14th Weather Squadron's Tropical Pacific Convective Outlook: Key tropical subseasonal metrics from CICS-NC's Madden–Julian Oscillation (MJO) monitoring page (*NCICS.org/mjo*) are being transitioned into operations in the USAF 14th Weather Squadron. **[DOD / USAF]**

Investigation of Trends in Airport Weather Conditions: Several decades of surface observations were assessed to quantify a trend in the frequency of low-visibility conditions at the nation's busiest airports.

Collaborative Support for the Development of the Quantitative Urban-Scale Microclimatic Modeling Tool (QUEST): In collaboration with the Urban Redevelopment Authority of Singapore, **C**ICS-NC is providing climate modeling and customized global/regional datasets to support the development of a climate information system for urban heat island effect for Singapore urban planning. **[URA]**

Administration

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

Under the current NOAA Cooperative Agreement, CICS-NC serves as one of two CICS campuses and is collocated with NCEI in the Veach-Baley Federal Complex in Asheville, NC. The operation of CICS-NC is the primary activity of the North Carolina Institute for Climate Studies (NCICS), an Inter-Institutional Research Center (IRC) of the University of North Carolina (UNC) System. NCICS/CICS-NC is hosted and administered by North Carolina State University (NCSU) as an administrative unit under NCSU's Office of Research, Innovation, and Economic Development (ORIED). 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 personnel are hired as NCSU employees and serve under NCSU policies and administrative guidelines. CICS-NC administrative staff implement, execute, and coordinate administrative activities with pertinent CICS-MD, UNC, NCSU, 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 currently provides partial support for the director (2 summer months), a business manager (20%), a program specialist (10%), IT operations and systems support (10%), and travel funds, primarily for the Director, for administration and research facilitation purposes with the diverse climate science and applications community. NCSU provides support for the Director and administrative staff, basic office and institute operations, and a substantial investment in IT infrastructure associated with the goal of providing state of the art visualization and connectivity (including wi-fi access and telepresence) tools for the Asheville-based staff.

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

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

Information Technology Systems Improvement, Management, and Maintenance	
Task Leader/Task Team:	Jonathan Brannock, Scott Wilkins
Task Code	NC-ADM-01-NCICS-JB/SW
NOAA Sponsor	Task I (partial support)
NOAA Office	NESDIS/NCEI (and other line offices)
Contribution to CICS Research Themes	Theme 1: 33.3%; Theme 2: 33.3%; Theme 3: 33.4%
Main CICS Research Topic	Data Access and Services Development
Contribution to NOAA goals	Goal 1: 45%; Goal 2: 45%; Goal 3: 8%; Goal 4: 2%
NOAA Strategic Research Priorities:	All

Highlight: CICS-NC IT staff provide modern approaches to keep CICS-NC at the competitive edge of technology advances, as well as maintaining core technologies as a stable base for staff operations. Improvements are focused towards system reliability and providing infrastructure that is both flexible and scalable. Without current IT resources, CICS-NC staff would be unable to complete their respective support and research tasks.

Background

CICS-NC IT staff support a well-rounded set of IT resources and services and maintain the necessary infrastructure required to do so. Institute IT services are organized into 3 areas: the 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 with 528 processing cores and 3 terabytes of memory. The cluster head node is a powerful server where users can prototype ideas and perform light work tasks including coding and testing. The head node can then queue heavy workloads onto the cluster where a number of different processing queues are available to suit computing requirements. The network and storage network (SAN) 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. Quantum's Storage Manager serves 1,210 terabytes of Stornext file system disk storage and maintains up to two copies of the data on separate tapes providing recovery capability for project data.

A building-wide wireless network provides both CICS-NC and other partners in the building with strong-signal, fast wireless coverage. This allows CICS-NC to quickly integrate and work side-by-side with our NCEI partners. There are 37 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 place the access points in optimal locations.

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

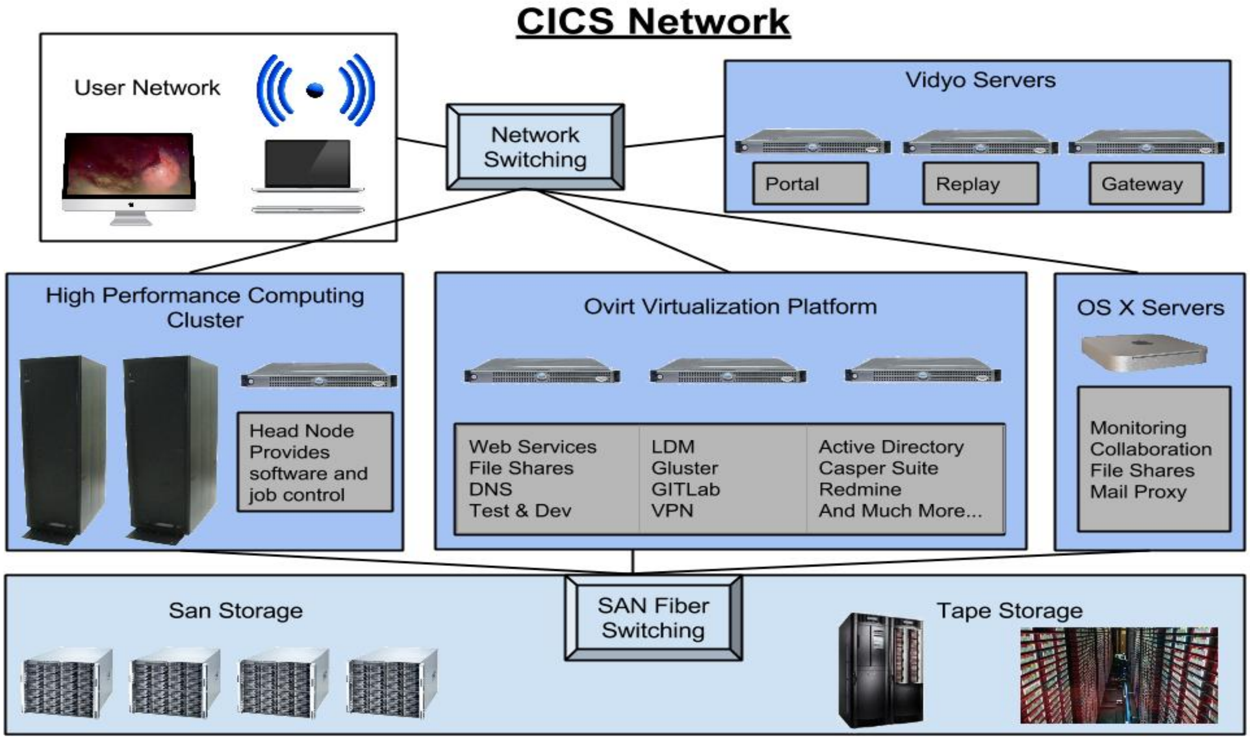


Figure 1*: Network and system diagram.*

Accomplishments

Server replacement. Replaced two aging servers in the Virtual Machine (VM) infrastructure, bringing the total CPU count to 224 and memory to 1.2 terabytes. The oVirt virtualization software provides enhanced security, OS support, and efficient use of these resources. This virtual cluster can support more than 120 reasonably configured virtual systems with a variety of operating systems and performance requirements, from critical network infrastructure to application development and testing. The six hardware servers are isolated from the SANs hosting the Stornext file systems to reduce impacts from downtime or maintenance. Two Promise Vess units provide the storage for the VMs with more than 40 terabytes available. The flexible architecture design allows VMs to leverage the Stornext cluster file systems, Gluster network file systems, and Ceph object storage as their needs require.

Extreme switch addition. An Extreme 100 gigabits per second switch was added to the network infrastructure providing greatly increased network bandwidth between servers and setting the stage for the replacement of our older 8 gigabits per second fiber channel storage with 40 gigabits per second Internet Small Computer Systems Interface (iSCSI) storage. The new switch also provides critical network redundancy in conjunction with the existing 10 gigabits per second switch infrastructure. This redundancy becomes especially critical as the NOAA Big Data Project gains visibility and importance.

Quantum tape library robotics and firmware upgrade. Quantum dropped support for the original (end of life) equipment and this upgrade allowed us to retain use of the library for several more years. Upgrading the robotics gives us the ability to continue to use the tape library as we transition the project data backup functionality to Amazon Glacier. The ultimate goal is to completely replace the functionality of the tape library with low-cost cloud-based storage.

NOAA and other building tenant support. CICS-NC IT provides regular IT support to our partners in the federal building. We regularly provide WIFI, audiovisual, and video conferencing in support of various meetings and engagements. We frequently provide support to augment existing resources and provide the required functionality to make NCEI meetings and events possible. We also support various internship programs within the building including the NASA DEVELOP and the NOAA Hollings internship programs. CICS-NC typically provides workstations, WIFI, video conferencing, virtualization, and high-performance computing resources. The short nature of the internships often means interns are without access to federal resources until they are halfway through the program. With CICS-NC-provided equipment, they are able to start and complete projects within the internship period.

Red Hat Enterprise Linux (RHEL) 7 migration. Migration of all of the hardware servers and core infrastructure VMs has been completed. There are a few remaining RHEL 6 user- and project-based VMs. We have provided RHEL 7 versions of these VMs for customers who wish to perform their own transitions. When requested, we have installed and configured the latest versions of the software for the customers and have assisted with making sure their code runs appropriately. All RHEL 7 servers and VMs have been enrolled with the new Satellite 6 subscription manager system from NCSU.

Planned work

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

Access and Services Development

Access and services development activities support improvements to access mechanisms for NOAA's National Centers for Environmental Information (NCEI)'s expansive data and product holdings. NOAA generates terabytes of data a day from satellites, radars, ships, weather models and other sources. NCEI has ongoing requirements to improve conveyance of data products and services to its stakeholders and clients. Current 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. The NOAA Big Data Project (BDP) was created in 2015 to explore sustainable models to increase access to NOAA open data. Increasing and improving access requires the input and guidance of scientific data management staff, software engineers, and other technical specialists with expertise to design, develop and/or enhance and provide tools and information to provide new and/or improvements to the current access mechanisms for NCEI's data and product holdings and, through improved access to information, facilitate improvement of society resilience to climate change.

CICS-NC continues to support the enhancement and expansion of NOAA's Climate Services Portal applications under this task umbrella. 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, offered the opportunity to update and enhance current services to customers with a more user-friendly design and interface to enable current and future users to more easily identify, locate, and access specific data products and services. The development of the NOAA OneStop portal launched in late 2017 provides yet another opportunity to enhance and expand data access services. To meet this demand, CICS-NC provides experts in data architecture, management, web services, and user interface design and development. In support of the Big Data Project, CICS-NC designed and implemented a pilot data hub architecture to facilitate transfer of key NOAA environmental datasets to public cloud providers.

While consistent support remains a challenge, CICS-NC continues to 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.

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

Highlight: Designed and implemented a pilot data hub/broker architecture to facilitate transfer of key NOAA environmental datasets to commercial public cloud providers allowing users to do analyses of data and extract information without having to transfer and store these massive datasets themselves.
https://ncics.org/data/noaa-big-data-project/

Background

NOAA's environmental data holdings include over 25 petabytes of comprehensive atmospheric, coastal, oceanographic, and geophysical data. While this data is publicly available, it can be difficult to download and work with larger datasets. NOAA's Big Data Project (BDP) is designed to facilitate public use of key environmental datasets by providing copies of NOAA's environmental information in the Cloud, making NOAA's data more easily accessible to the general public and allowing users to perform analyses directly on the data. See Figure 1 below for an overview of this process.

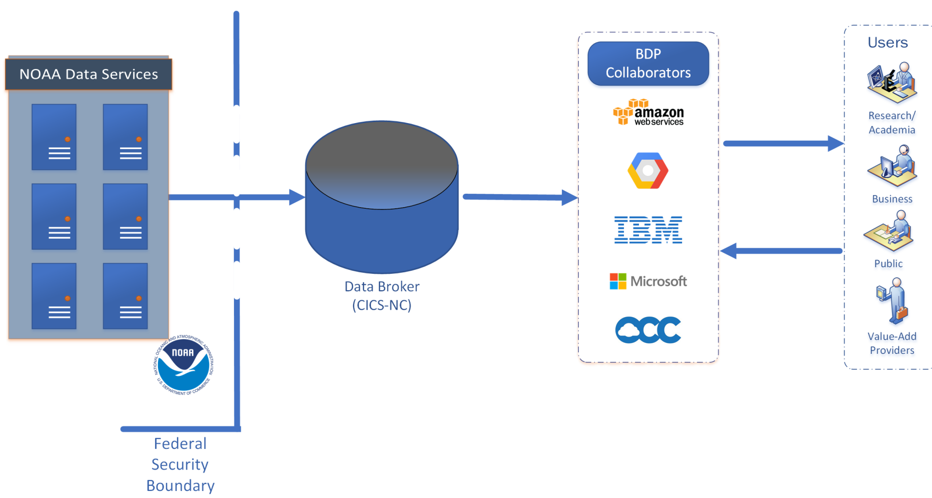


Figure 1. *Data Hub/Broker Overview.*

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

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

Accomplishments

CICS-NC designed the pilot data hub using a stream processing architecture based on Advanced Message Queuing Protocol (AMQP). Python was selected as the programing language of choice due to the library availability for each of the public cloud providers. Docker® was chosen to provide application delivery and scalability. Using a combination of these technologies, the data hub architecture provides high availability, low latency, scalable and portable architecture. See Figure 2 below.

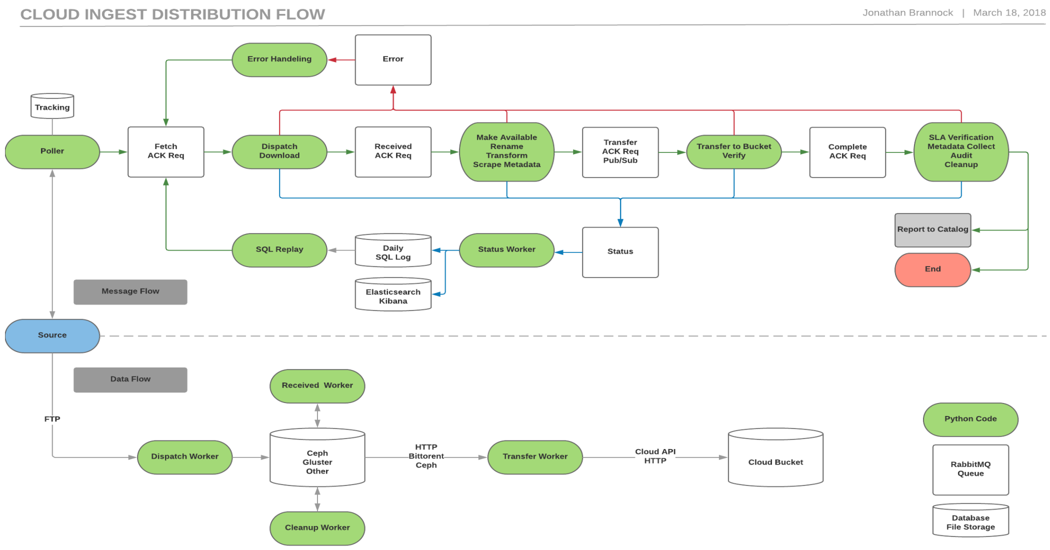


Figure 2. *Data Hub Flow.*

The largest data set currently being transferred is from the GOES-16 ABI and GLM instruments. The CICS-NC Data Hub began operating on the GOES-16 data on 7/12/2017 for public distribution. The table below reflects the product volume by both file count and data volume. It also shows the latency in seconds from the end of observation to the product being available on the partners distribution system. Some of this latency is introduced by the ground station and NOAA product generation. The latency contributed by the CICS data hub is represented in the final column.

Product	Daily count	Daily Volume (GB)	Latency (seconds)	Hub added Latency (seconds)
ABI-L1b-RadM	46,080	26.76	35.5	8
ABI-L1b-RadC	4,608	33.57	40	7.6
ABI-L1b-RadF	1,536	73.81	60	24.5
ABI-L2-CMIPM	46,080	25.34	33.8	7.3
ABI-L2-CMIPC	4,608	31.46	34	8
ABI-L2-CMIPF	1,536	69.98	55	24.9
ABI-L2-MCMIPM	2,880	11.06	37.4	10.8
ABI-L2-MCMIPC	288	14.16	55	24.3
ABI-L2-MCMIPF	96	30.25	145.8	108.7
GLM-L2-LCFA	4,320	1.21	40	7.3
TOTAL	112,032	318	N/A	N/A

Table I. *GOES-16 data transfer volume and latency between end of observation and availability on partners distribution system.*

The second largest undertaking to date is the transfer of NEXRAD data from NCEI's archive. This involved approximately 200 million files and 300TB of data to multiple cloud providers. Both historical and current data were/are transferred from the NCEI archive in batches. The historical data was processed by year and the current data is transferred every 2 hours.

Given the one-off nature of the NEXRAD transfer, numerous transferred data integrity issues were discovered. NCEI provided a copy of their catalog for the period of record and, using this, we loaded all of these records and all of the records for the cloud providers. We then performed a two-way difference and intersection of this metadata. Following these operations, we were able to produce a list of actions (moves, deletes, copy operations and orders) to bring the cloud providers into alignment with the NCEI archive. We worked with NCEI to order this data over the AIRS interface. When this did not result in a 100% match, discrepancies were discovered between the provided catalog listing and what was produced by the AIRS orders. This information was provided to NCEI to determine the necessary actions to reconcile the NCEI catalog and archive. As a result, the cloud providers are now at a 99.75% – 99.97% match to the NCEI archive. See Figure 3.

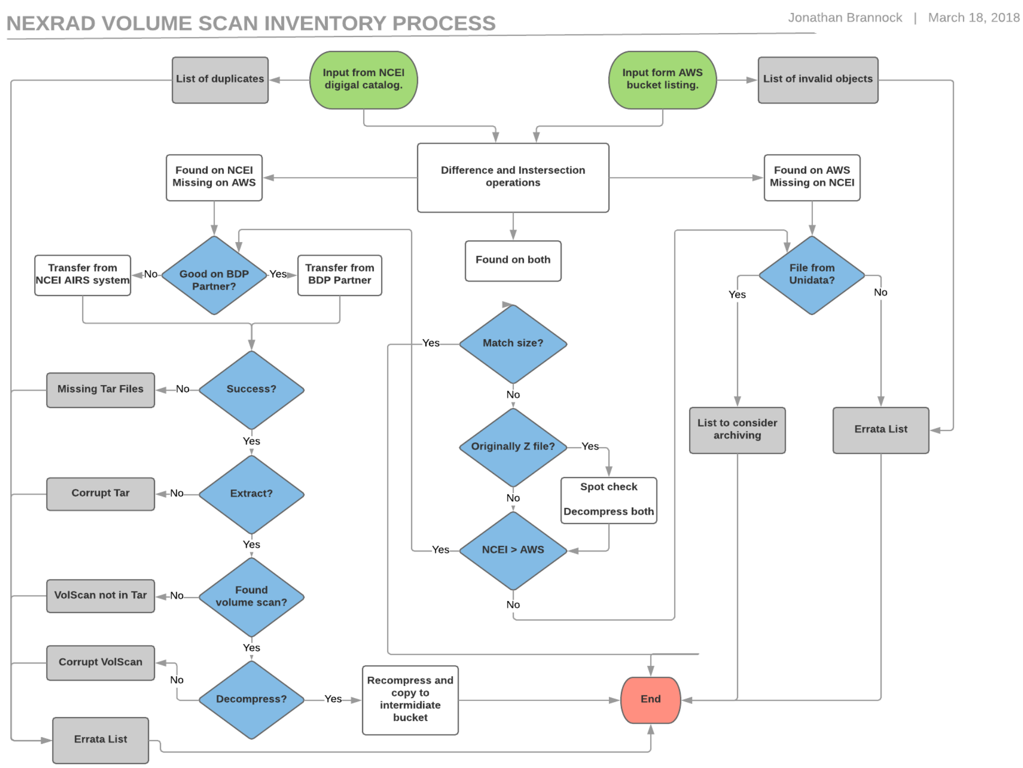


Figure 3. *NEXRAD Reconciliation.*

The software development cycle used is a spiral model. We used rapid iterations to prototype approaches to solving each of the challenges related to developing this software and incorporated best practices for working with containers, AMQP and cloud platforms. It is a design goal to develop simple repeatable tasks that can then be connected together in a workflow process to achieve the end goals. This allows us to leverage the container management platform and AMQP to launch as many instances as required for each activity. For example, we can run more workers to one cloud provider than another. This may be required due to design differences in each cloud platform. This also allows us to limit and efficiently use the session limits imposed by NOAA HTTP and FTP services in obtaining the data. Another benefit of this approach is that failures in one system do not impact the data flows to unrelated sources or endpoints. Only metadata is transferred via the AMPQ queues. This allows very small metadata and control packets to traverse the queues and operate on the data in a central data store.

We continue to receive numerous questions regarding the performance, latency and product mix running through the Data Hub. To address this, we added fine grained timing information to the metadata stream which is then shared with an Elasticsearch instance. We use the Kibana interface to produce high quality dashboards that rapidly display metrics for both historical and instantaneous transfer activities. This also allows for analytics of the product makeup including number of files, size and percentile ranks.

Planned work

- Add new datasets including NWM, GHCND, HRRR, and VIIRS as needed by the NOAA BDP team.
- Continue to improve software to support high availability, resiliency, and product modularity.
- Provide feedback to NOAA on design requirements and scope of required activities.

Products

- Pilot data hub/data broker

Presentations

Kearns, E. J., S. Glass, **O. Brown**, **J. Brannock**, A. Simonson, and J. O'Neil, 2018: 2B.1: Making Data Available on the Cloud for Decision Support Applications through NOAA's Big Data Project. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.

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

Programming and Applications Development for Climate.gov	
Task Leader:	James Fox
Task Code	NC-ASD-02-UNCA
NOAA Sponsor	David Herring / Dan Berrie / David Easterling
NOAA Office	OAR/CPO
Contr. to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities	Decision Science, Risk Assessment and Risk Communication

Highlight: In support of the overall advancement of the NOAA's Climate Services Portal program, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) staff contributed to the continued development of the U.S. Climate Resilience Toolkit (*https://toolkit.climate.gov/*), the 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.

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 applications development and data visualization expertise and resources in support of a number of web tools and enhancements.

- 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 the above include:

1. Graphics for Indicators and National Climate Assessment (NCA)
2. GIS/climate projections for NCA
3. Regional, state, local products
4. Internal management portals
5. 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 (CRT). Working with the larger editorial team, NOAA personnel, and other federal and academic partners, NEMAC contributed to content management for several key CRT features, including: (a) development and publication of a new page hosting information for the *New England Federal Partners* in the Northeast region; (b) the integration of *new videos* summarizing the

Steps to Resilience on the site's home page and within the appropriate Steps to Resilience section of the website; (c) development of a *new Great Lakes regional section* of the website estimated to launch in summer 2018; (d) assessment and user testing on existing *Tools,* resulting in the integration of new faceted filters for geographic regions and Steps to Resilience and integration of the Steps to Resilience into individual tool pages; (e) review and refinement of contributor resources and methods for submission of content; (f) collaboration to refine and improve the functionality of the site's webLyzard search tool; (g) the addition of 24 new *Case Studies* (total of 142 published case studies as of March 2018); and (h) the inclusion of 51 additional *Tools* (total of 395 published tools as of March 2018). NEMAC was an integral part of the planning committee and the facilitation team for the Resilience Ecosystem Workshop hosted by NOAA's Climate Program Office in Silver Spring, MD, on January 17–18, 2018.

Global Climate Dashboard. Updated the data feed for the individual metrics**;** redesign or redeployment is under discussion. This is part of a larger strategic discussion about the modularity of the data and information services that feed all of climate.gov. John Frimmel provided assistance in the migration of the Global Climate Dashboard module to the Drupal 8 redesign of climate.gov.

Climate Explorer and Online Map Viewers. Climate Explorer 2 (CE2) was developed by Habitat Seven (H7) and NEMAC, developer of Climate Explorer 1 (CE1), collaborated with H7 on the transition. CE2 was publicly launched on July 27, 2016. The next iteration (called CE2.5), which will feature many more climate projection variables and a threshold tool, is in final edits and expected to launch in early April 2018. 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 has been completed and awaiting final ingest by H7.

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

Graphics for Indicators and NCA. NEMAC supported the USGCRP Climate Indicators Working group with design, update, and development of static indicator graphics for the USGCRP website. This work included presentations at the 3rd Annual Meeting of the Indicators Interagency Working Group (November 7, 2017); meetings with the CICS/NCEI Indicators team (Laura Stevens and Jessica Blunden); and creating a shared data inventory and developing new versions of the following graphics: Sea Level Rise, Arctic Sea Ice Extent, Heavy Precipitation, and Frost-Free Season. NEMAC also updated the Indicators Style Guide to align with design standards from the National Climate Assessment.

National Climate Assessment (NCA) Regional and State Map Products. NEMAC created various maps at different scales displaying specific climate models, time periods, and variables. This included three main sets of maps: (1) projected seasonal precipitation scenarios for North America and Hawaii, (2) projected annual precipitation scenario for the Caribbean, and (3) projected seasonal precipitation scenarios for Nevada and California. For each map, original data files were processed at the global scale and then filtered to the scale of interest for the map. Appropriate hatching, stippling, and white-out overlays were added to the maps to represent statistical significance values in the data.

Internal Management Portals. NEMAC created 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 for the CICS/NCEI Technical Support Unit (TSU).

Decision Support. This work focused on the Steps to Resilience in the CRT and identifying ways of transferring this process to different scales. This included work with the Southeast Sustainability Directors Network (SSDN) and working with the cities of Asheville, Charleston, Ft. Lauderdale, Miami, Raleigh, Durham, Cary, and Chapel Hill to update the Steps to Resilience.

Planned Work

- Work will continue on the Climate Widget, the U.S. Climate Resilience Toolkit, and other interactive tools.

Products

- Data snapshots on Climate.gov (https://www.climate.gov/maps-data/data-snapshots/start)
- U.S. Climate Resilience Toolkit (https://toolkit.climate.gov)
- Climate Explorer 1 (http://climate-explorer.nemac.org/)
- Climate Explorer 2 (CE2) (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

Rogers, K., **J. Fox**, M. Hutchins, N. Hall, 2017: Moving Toward Resilience: A Structured Resilience Planning Process in Asheville, North Carolina, *National Adaptation Forum 2017*, Saint Paul, MN, May 9, 2017.

Fox, J., E. P. Gardiner, D. Herring, D. Kreeger, 2017: Using the U.S. Climate Resilience Toolkit's 'Steps to Resilience' Workshop, *National Adaptation Forum 2017*, Saint Paul, MN, May 11, 2017.

Performance Metrics	
# of new or improved products developed that became operational	**6**
# of products or techniques submitted to NOAA for consideration in operations use	**6**
# 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**

Website Information Architecture Development and User Interface Design for NOAA's National Centers for Environmental Information and NOAA OneStop	
Task Leader:	Brian Manning
Task Code	NC-ASD-03-Mediacurrent
NOAA Sponsor	Scott Hausman / Ken Casey
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: 33.3%; Theme 2: 33.3%; Theme 3: 33.4%
Main CICS Research Topic	Access and Services Development
Contribution to NOAA goals	Goal 1: 45%; Goal 2: 45%; Goal 3: 5%; Goal 4: 5%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: After researching NOAA OneStop's target audience and completing site analytics, Medicacurrent identified key performance indicators for tracking success, prioritized features based on user and stakeholder needs, conducted user testing, and developed an enhanced user interface design for improved user interaction. The outcome of this process was an end-to-end strategy audit, a web accessibility audit, as well as design mockups.

Background

In response to Public Law 113-235 Consolidated and Further Continuing Appropriations Act, 2015, which expresses the promise that "users will see an improvement in the overall value of our environmental data archives," NOAA developed and launched a new web portal, OneStop, in December 2017. OneStop was designed to improve accessibility to NOAA's extensive collections of environmental data by providing a User Interface that makes the data more discoverable and usable. While OneStop does not replace other NOAA data web portals, OneStop features include a search engine geared to promote relevant discovery of data at faster speeds and a user interface that provides an experience tailored to the user.

Mediacurrent was originally engaged to research and present solutions for providing improved access to high-value environmental data and information through informational architecture development, User Interface design, and user testing for the NOAA National Centers for Environmental Information (NCEI) website. This included recommendations for an enhanced user interface design based on nine primary user groups using one of three lenses (novice, expert, or disabled) that would improve the overall user experience with site navigation, content and layout. This past year, Mediacurrent completed supplemental work testing and assessing the OneStop Showcase User Interface using User and Usability best practices to quantify results in a manner that supports and improves the OneStop initiative (in both the short and long term).

Accomplishments

Working with NOAA's Cooperative Institute for Climate and Satellites North Carolina (CICS-NC) and building on their previous research with the NCEI website, MediaCurrent utilized a similar data-driven approach to gain an understanding of how users were interacting with the new NOAA OneStop website. As part of the discovery, we analyzed data via the Users Personas groups to provide an array of perceived strengths, weaknesses, and accessibility improvements that would enhance the NOAA OneStop user experience. Mediacurrent conducted User testing to provide an objective view of the usability of the website - which included an assessment of how the site addresses those with disabilities and compliance with Section 508, WCAG 2.0. We also performed a full competitive analysis on the existing NOAA Data Catalog and NCEI Geoportal.

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
  - High-Fidelity Wireframes for Primary Pages

Presentations

- 10/13/2017 - KPIs, Usability Testing, Site Audit, Analytics
- 10/31/2017 - Site Audit
- 11/7/2017 - Accessibility Audit, Design Mockups, Final Deck
- 11/28/2017 – Project Summary 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 many 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 now, the Fourth National Climate Assessment.

National Climate Assessment Scientific Support Activities	
Task Leader/Task Team:	Kenneth Kunkel (leader), James Biard, Sarah Champion, Laura Stevens, Liqiang Sun, Andrew Thrasher
Task Code	NC-CAA-01-NCICS-KK/et al
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI and OAR/CPO
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: 50%, Goal 2: 50%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: The Assessment science team was integral to the completion of the Climate Science Special Report (CSSR or Fourth National Climate Assessment Volume I) through authorship contributions to several chapters, development of numerous specialized scientific analyses and graphs, and completion of metadata collection and viewer**.** *https://science2017.globalchange.gov/*

Background

NOAA is participating in the high-level, visible, and legally mandated National Climate Assessment (NCA) process, which is being 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 formed an Assessment 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 (James Biard, Andrew Thrasher). The Lead Senior Scientist provides scientific oversight for the development of NOAA’s assessment services, focusing on a contribution to the NCA and, in support of the NCA 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.

Accomplishments

Substantial contributions were made to the Climate Science Special Report (CSSR), published in November 2017 as Volume I of the Fourth National Climate Assessment (NCA4). This included authorship contributions to four chapters, data analysis and development of 18 specialized graphics for several chapters, and collection and quality control of figure metadata for the entire report. Science team members were lead or contributing authors to the following chapters: “Our Globally Changing Climate,” “Temperature Changes in the United States,” “Precipitation Change in the United States,” and “Droughts, Floods, and Wildfires.”

Specialized analyses of CMIP5 and its downscaling data were completed. For example, at mid-century under a higher scenario (RCP8.5), decreases in snowpack are projected across the mountainous western portion of the Northern Great Plains, and streamflow is expected to increase across much of eastern part of the Northern Great Plains. These hydrologic changes have important consequences for water supplies, agricultural activities, and energy production.

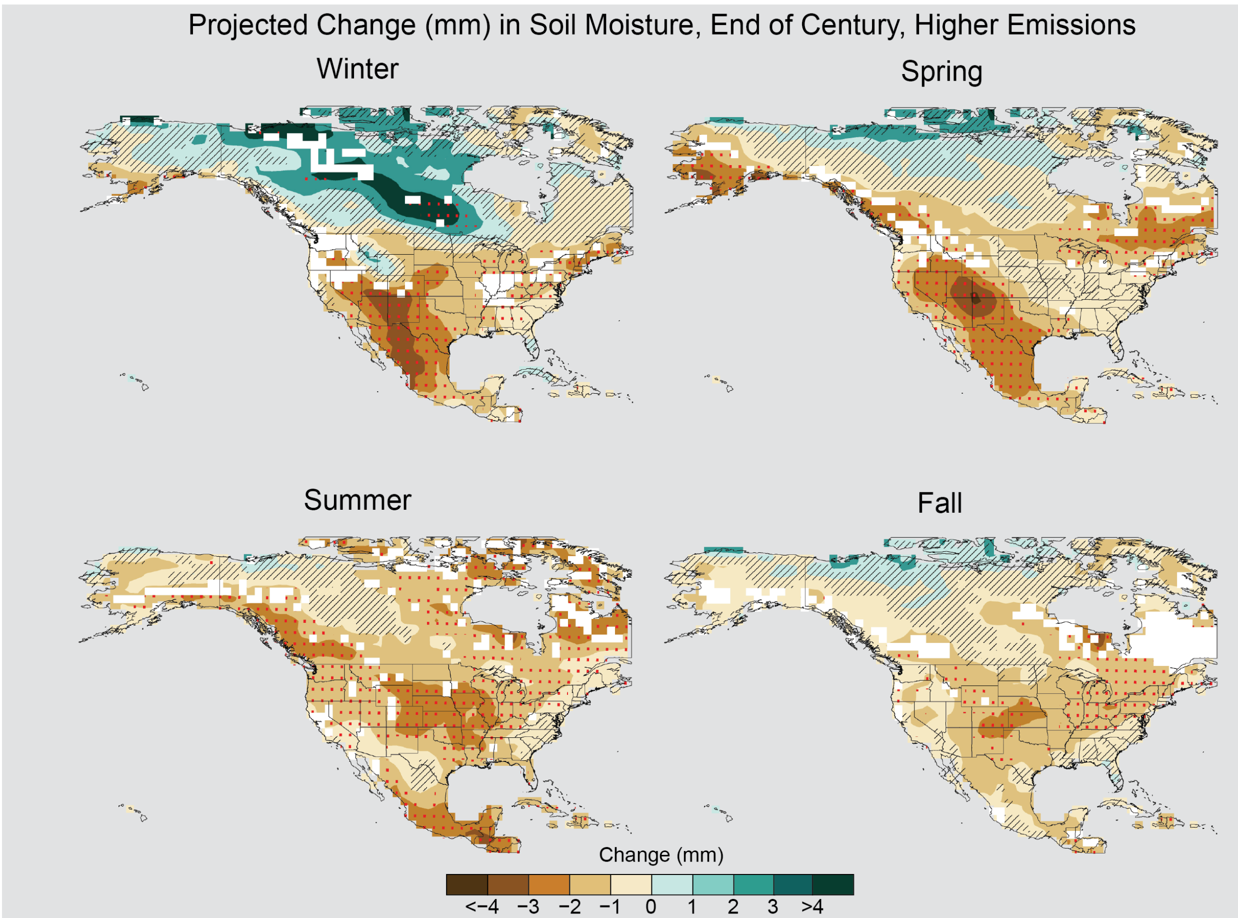


Figure 1. *Projected end of the 21st century weighted CMIP5 multimodel average percent changes in near surface seasonal soil moisture under the higher scenario (RPC8.5). Stippling indicates that changes are assessed to be large compared to natural variations. Hashing indicates that changes are assessed to be small compared to natural variations. Blank regions (if any) are where projections are assessed to be inconclusive.*

For the first time since initiation of the process development, a full set of metadata were successfully released alongside the delivery of the CSSR. As part of an ongoing effort to satisfy Information Quality Act (IQA) compliance, and as part of the Sustained Assessment process, work continues on improved design and capabilities of a metadata documentation, archive, and delivery end-to-end process. Adhering to the federal agency documentation standard of ISO-19115, team staff contributed to the improved functionality of a web-based metadata survey and interactive metadata viewer in support of the Climate Science Special Report and forthcoming Fourth National Climate Assessment. The web-based survey and web-based viewer have also been adopted for use in three other federal agency reports and projects: the Environmental Protection Agency (EPA) Climate Change and Risk Analysis (CIRA) Report, the Department of Energy (DOE) State of the Carbon Cycle 2 Report, and the USGCRP Climate Change Indicators Project.

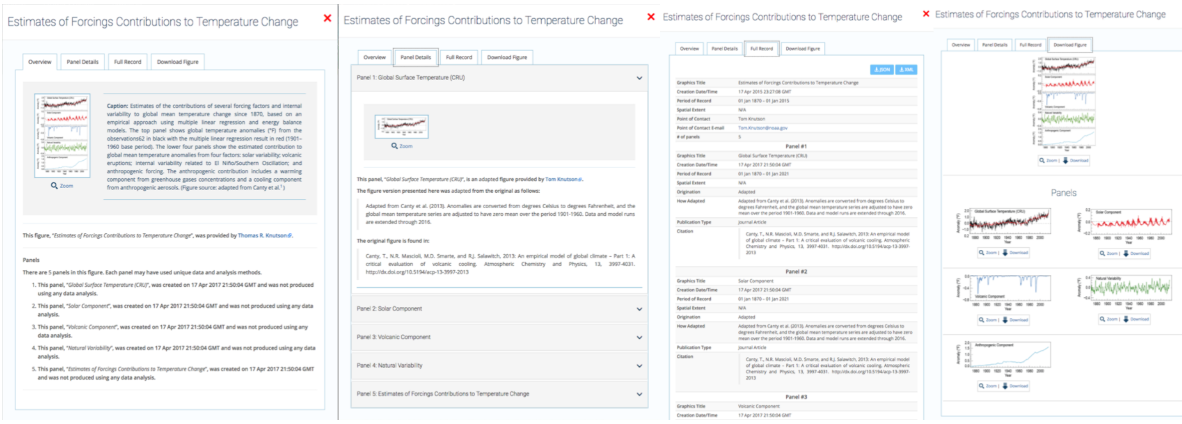


Figure 2: *Static view of the improved Metadata Viewer. From left to right, each panel presented above represents a tabular component of the viewer in which users can access, interact with, and download individual panel-level metadata, to include a plain-text version of all entered metadata for any figure included in the report.*

Processing of the Localized Constructed Analogs (LOCA) data set has produced new climate scenarios as the basis of physical climate and impacts analyses for NCA4. LOCA is a statistically-downscaled daily data set based on CMIP5 simulations at 1/16 degree spatial resolution for the contiguous United States. These data have been analyzed to produce regionalized scenarios products for 28 urban areas. Products include statistics and graphics depicting the multi-model mean and 5-95th percentile model distributions for 47 derived temperature and precipitation-based climate variables.

Support of Volume 2 of the NCA4 included development of graphics for several chapters, authorship on the Southeast and Midwest chapters, and initiation of metadata collection. The following special products were developed for chapter authors.

- Vapor pressure deficit (VPD) is the difference between how much moisture is in the air and the amount of moisture in the air at saturation. VPD is projected to increase over the Midwest in the late 21st century for lower and higher scenarios (RCP4.5 and RCP8.5). Increased VPD has a drying effect on plants and soils, as moisture transpires and evaporates.
- Extreme weather events (e.g., hot days with maximum temperature above 90°F, cold days with minimum temperature below 28°F, and days with greater than two inches of precipitation) are projected to change significantly over the Northern Great Plains in the middle of the 21st century for lower and higher scenarios (RCP4.5 and RCP8.5).

Planned work

- Completion of lead author contributions to the Midwest and Southeast chapters of Volume 2 of the Fourth National Climate Assessment (NCA4).
- Collection and delivery of a full set of metadata to accompany the release of the NCA4.
- Initiation of analyses for the Fifth NCA.
- Publication of a NOAA State Climate Summary for Puerto Rico.
- Publication in *Journal of the Air & Waste Management Association* (currently in press).

Publications (all peer-reviewed)

Easterling, D. R., **K. E. Kunkel**, J. R. Arnold, T. Knutson, A. N. LeGrande, L. R. Leung, R. S. Vose, D. E. Waliser, and M. F. Wehner (lead authors), **S. M. Champion, L. Sun** (contributing authors), 2017: Precipitation change in the United States. *Climate Science Special Report: Fourth National Climate*

Assessment, Volume I, November 3, 2017 ed., D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 207-230. http://dx.doi.org/10.7930/J0H993CC

Kopp, R. E., D. R. Easterling, T. Hall, K. Hayhoe, R. Horton, **K. E. Kunkel**, and A. N. LeGrande, 2017: Potential surprises — compound extremes and tipping elements. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, November 3, 2017 ed., D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 411-429. http://dx.doi.org/10.7930/J0GB227J

Kossin, J. P., T. Hall, T. Knutson, **K. E. Kunkel**, R. J. Trapp, D. E. Waliser, and M. F. Wehner, 2017: Extreme storms. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, November 3, 2017 ed., D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 257-276. http://dx.doi.org/10.7930/J07S7KXX

USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I.* November 3, 2017 ed. U.S. Global Change Research Program, 470 pp. http://dx.doi.org/10.7930/J0J964J6

Vose, R. S., D. R. Easterling, **K. E. Kunkel**, A. N. LeGrande, and M. F. Wehner (lead authors), **L. Sun** (contributing author), 2017: Temperature changes in the United States. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, November 3, 2017 ed., D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 185-206. http://dx.doi.org/10.7930/J0N29V45

Wehner, M. F., J. R. Arnold, T. Knutson, **K. E. Kunkel**, and A. N. LeGrande (lead authors), **L. Sun** (contributing author), 2017: Droughts, floods, and wildfires. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, November 3, 2017 ed., D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 231-256. http://dx.doi.org/10.7930/J0CJ8BNN

Wuebbles, D. J., D. R. Easterling, K. Hayhoe, T. Knutson, R. E. Kopp, J. P. Kossin, **K. E. Kunkel**, A. N. LeGrande, C. Mears, W. V. Sweet, P. C. Taylor, R. S. Vose, and M. F. Wehner (lead authors), **L. E. Stevens** (contributing author) , 2017: Our globally changing climate. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*, November 3, 2017 ed., D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 35-72. http://dx.doi.org/10.7930/J08S4N35

Products

• Two-phase/component web-based metadata survey with locally-stored content, as well as dynamically connected content from the Global Change Information System (GCIS) for consistent and accurate climate metadata.

• Interactive and embedded Metadata Viewer used to demonstrate compliance with the Information Quality Act requirements of transparency and reproducibility and an enhanced user experience.

Presentations

Bell, J., **J. Rennie**, **K. Kunkel**, S. Herring, and H. M. Cullen, 2017: GC23E-01: Assessment of the Long-Term Trends in Extreme Heat Events and the Associated Health Impacts in the United States. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.

Champion, S., 2017: Metadata and the Sustained Assessment: Data Transparency as Climate Science Communication. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 28, 2017.

Champion, S., and **K. E. Kunkel**, 2017: IN52A-08: Sustained Assessment Metadata as a Pathway to Trustworthiness of Climate Science Information. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.

Dissen, J., D. R. Easterling, **K. Kunkel**, A. Kulkarni, F. H. Akhtar, K. Hayhoe, A. M. K. Stoner, R. Swaminathan, and B. L. Thrasher, 2017: GC31H-04: Key Findings from the U.S.-India Partnership for Climate Resilience Workshop on Development and Application of Downscaling Climate Projections. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Easterling, D. R., **K. E. Kunkel**, R. S. Vose, and M. F. Wehner, 2017: U23A-03: Observed and Projected Changes in Climate Extremes in the United States. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.

Kunkel, K. E., 2017: CICS-NC / NCICS Overview. *American Association of State Climatologists (AASC) Annual Meeting*, Asheville, NC, June 30, 2017.

Kunkel, K. E., 2017: The Switch to MMTS Has Changed Extreme Temperature Trends. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 27, 2017.

Kunkel, K. E., 2017: Tools for Climate Change Adaptation: State Climate Summaries and New Climate Scenarios. *National Adaptation Forum*, St. Paul, MN, May 9, 2017.

Kunkel, K. E., 2017: Understanding the Physical Causes of Observed Trends in Extreme Precipitation: How Can Statistics Help? *SAMSI Opening Climate Workshop*, Asheville, NC, August 21, 2017.

Kunkel, K. E., 2018: Climate Science in the National Climate Assessment. *NCSU Department of Marine, Earth, and Atmospheric Sciences*, Raleigh, NC, January 22, 2018.

Kunkel, K. E., and **S. Champion**, 2018: 6.4: The Meteorology of Extreme Precipitation and Implications for Future Planning. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

Lee, J., D. E. Waliser, H. Lee, P. C. Loikith, and **K. E. Kunkel**, 2017: GC33E-1118: Evaluation of CMIP5 Ability to Reproduce 20th Century Regional Trends in Surface Air Temperature and Precipitation over CONUS. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Rennie, J., **J. E. Bell**, **K. E. Kunkel**, S. Herring, and H. Cullen, 2018: 4.1: Using a Daily Homogenized Temperature Product to Assess Long-Term Trends in Extreme Heat Events and Associated Health Impacts in the United States. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.

Sun, L., 2017: Climate downscaling for the National Climate Assessment: practices and challenges. *International Workshop on Climate Downscaling Studies*, Tsukuba, Japan, October 2, 2017.

Sun, L., 2017: Downscaling climate change information for the United States. International Research Institute for Climate and Society, *Columbia University*, New York, NY, November 30, 2017.

Thompson, T. R., **K. Kunkel**, **L. E. Stevens**, D. R. Easterling, **J. Biard**, and **L. Sun**, 2017: GC33E-1117: Localized Multi-Model Extremes Metrics for the Fourth National Climate Assessment. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Vose, R., D. R. Easterling, and **K. E. Kunkel**, 2018: 3A.7: Extremes and Attribution. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.

Other
Two TSU staff members, Brooke Stewart and Sarah Champion, are being advised by Kenneth Kunkel in the Ph.D. program of the North Carolina State University Department of Marine, Earth, and Atmospheric Sciences.

Kenneth Kunkel served on the Ph.D. committee of Emily Schlie of the Department of Atmospheric Sciences of the University of Illinois at Urbana-Champaign.

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	**7**
# of NOAA technical reports	**0**
# of presentations	**17**
# of graduate students supported by your CICS task	**1**
# of graduate students formally advised	**2**
# of undergraduate students mentored during the year	**0**

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

Highlight: TSU technical staff provided technical and scientific writing and editing, graphics, and web development expertise in support of multiple National Climate Assessment (NCA) related products, including Volumes I and II of the Fourth NCA and other associated publications. The team also provided overall project coordination and contributed substantive content to multiple author guidance documents and other tools.

Background

The National Climate Assessment (NCA) is conducted under the auspices of the U.S. Global Change Research Program (USGCRP) as mandated by the Global Change Research Act of 1990. The NCA is intended to provide the President, Congress, other stakeholders, and the general public with a report on the current state of climate change science, the impacts of climate change, and the effectiveness of mitigation and adaptation efforts. It is essential that the report 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. The Technical Support Unit (TSU) at NCEI serves as a major part of NOAA's contribution to the program as one of USGCRP's 13 agency members and provides technical expertise to support the development, production, and publication of the NCA and other associated products. TSU technical staff work collaboratively with the TSU Assessment Science team and in coordination with NCA authors, NCEI, and USGCRP.

The TSU *editorial team* provides scientific editing and writing services to the authors of the National Climate Assessment reports as well as to in-house scientists/authors. They also provide technical writing/editing, copy editing, and coordination of scientific figure development. They coordinate in-house publication across multiple teams and provide substantive input to product rollout and communications plans. The team provides similar support for related assessment products that are created as part of the sustained assessment process (i.e., interim reports that are produced between the mandated quadrennial publications). Team members assist CICS-NC and NCEI management as well as USGCRP management and staff with project planning and coordination including development of the overarching NCA project timeline. They independently develop as well as assist other staff with the creation of author guidance documents that serve as foundational guidelines for the generation of report content. Additionally, they assist with the overall coordination of the NCA process, including.

Editorial Team members include Brooke Stewart (managing editor & science writer/editor), Tom Maycock (science writer/editor), Andrea McCarrick (copy editor), Anne Waple (temporary science writer/editor), and Tyler Felgenhauer (temporary technical editor).

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

Angel Li coordinates a small TSU *web team* that designs, develops and implements on-line climate assessment reports (websites) with mobile device (e.g., phones and tablets) access.

Accomplishments

Volume I of the Fourth National Climate Assessment *[or* ***Climate Science Special Report (CSSR*** *)]*. The TSU technical staff successfully shepherded the design, development, production and publication and release of the report in November 2017 in print, digital, and web formats. The editorial team provided extensive project planning and management; substantive editing following revisions in response to concurrent public and NAS reviews and again after federal interagency review; and development and revision of the Executive Summary, report glossary and acronym list. The editorial team lead and communications specialist also coordinated with in-house designers, reference managers, web developers, data specialists and with USGCRP's National Coordination Office (NCO) managers and staff to finalize report publication and release. Graphic support included figure development and layout. The CSSR website (https://science2017.globalchange.gov), designed and implemented by the TSU web team, is notable for its utilization of a static website generator which provides a low maintenance post launch website but quick page service. The website also features a new metadata display module developed in conjunction with the Science Team data manager and software engineers that accurately displays the information collected from authors about the report's figures.

Figure 1. *CSSR website.*

Volume II of the Fourth National Climate Assessment (NCA4). The TSU technical staff assisted NCO management with the development of the full project timeline including a detailed account of the multi-layered iterative review process. The editorial team assisted with the development of guidance for authors on writing key messages and traceable accounts, provided a style guide with formatting and language standards and guidance on figure development, and drafted the "NCA4 Author Guidance: Writing on Uncertainty", to guide authors on the appropriate use of a variety of uncertainty language. Concurrent with the final editing cycle of CSSR, editors took on the first-round edits of Volume II and have subsequently provided substantive edits to science, technical, and stylistic aspects of the draft report following revisions in response to public and NAS reviews. Graphics has contributed to figure development and report layout templates while the web team has begun development of the NCA4 website. The Scenarios website (https://scenarios.globalchange.gov/) was updated to add the ability to display Localized Constructed Analogs (LOCA) variables. Anticipated NCA4 Volume 2 report release in December 2018.

Other Technical Support. The TSU Editorial Team has contributed to various other projects during the past year including editing of the Puerto Rico and U.S. Virgin Islands State Summary technical document (currently out for review); editing the NOAA Technical Report, *Patterns and Projections of High Tide Flooding Along the U.S. Coastline Using a Common Impact Threshold* (currently out for review); and worked with the director of the Chemical Sciences Division of NOAA ESRL to plan editorial support and web development for the forthcoming *Scientific Assessment of Ozone Depletion: 2018*. Graphics support was provided for two NCEI reports published in the *Bulletin of the American Meteorological Society*: *State of the Climate* (August 2017) and *Explaining Extreme Events* (December 2017).

Planned work

- Complete editing interagency review draft of NCA4.
- Coordinate in-house science review of NCA4.
- Edit and finalize NCA4 content after authors revise in response to agency comments.
- Coordinate final copy edit and production of full NCA4 report as well as derivative products.
- Finalize NCA4 report graphics with design team, authors, and NCO.
- Complete design and implementation of NCA4 website.
- Coordinate among team members and with NCEI librarian to finalize digital reference library.
- Provide technical support (editorial, project coordination, potential website development) to support the *Scientific Assessment of Ozone Depletion: 2018.*
- Provide technical support for other projects and assessment products as needed.

Products

- ***Climate Science Special Report*** (November 2017) - print, digital, and web formats https://science2017.globalchange.gov
- ***Scenarios website enhancement*** (https://scenarios.globalchange.gov)

Publications

USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I.* D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 470 pp. http://dx.doi.org/10.7930/J0J964J6

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	**0**

World Resources Institute (WRI) / Partnership for Resilience and Preparedness (PREP) Supporting the U.S. – India Partnership for Climate Resilience	
Task Leader:	Lauretta Burke
Task Code	NC-CAA-03-WRI
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI (DOS)
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: CICS-NC collaborator, the World Resources Institute (WRI), and the Partnership for Resilience and Preparedness (PREP) are working with two Indian states, Madhya Pradesh and Uttarakhand, to help implement State Action Plans on Climate Change through collaboration in the development and use of tailored "climate preparedness dashboards" on the PREP platform. *http://www.prepdata.org/*

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, 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. The NOAA National Centers for Environmental Information (NCEI), the NOAA Cooperative Institute for Climate and Satellites North Carolina (CICS-NC), and CICS-NC subcontractors (including the World Resources Institute - WRI) are providing key technical support for the PCR bilateral activities in collaboration with the U.S. Department of State.

Jointly coordinated by the U.S. Global Change Research Program (USGCRP) and WRI, the Partnership for Resilience and Preparedness (PREP) is a public-private collaboration that seeks to empower a data-driven approach to building climate resilience. PREP aims to facilitate the process for planners, investors, resource managers, and others to routinely incorporate climate risks into their decisions, by enhancing access to relevant data and facilitating collective learning.

PREPdata is a map-based, open-data online platform (www.prepdata.org) that allows users to access and visualize climate, physical, and socioeconomic data for climate adaptation and resilience planning. It is being developed as a flexible tool for climate adaptation planning, designed to address many of the gaps and challenges adaptation practitioners face.

India, as one of the most vulnerable countries to the impacts of climate change, must have robust risk management strategies in place to remain resilient to the adverse effects. The PREP initiative, which promotes tailor made climate information services to the operational context, has enormous relevance and use value for India. WRI and PREP are working with Governments in two Indian states, Madhya Pradesh and Uttarakhand, to support implementation of their respective State Action Plans on Climate Change through use of PREPdata.

Accomplishments

PCR Workshop Presentation and Selection of Pilot PREP States. Lauretta Burke and Nambi Appadurai provided an introduction to PREP dashboards and resilience efforts in India at the initial *U.S.-India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections* held at the Indian Institute of Tropical Meteorology (IITM) in Pune, India, March 7-9, 2017. They facilitated a session on PREP dashboard development and its relevance to the State Climate Action Plans in India. At the workshop, Burke conducted a User Needs Assessment (UNA) to discuss the data needs, resilience planning, barriers to implementation, and usefulness of PREP dashboards and insights. Through the UNA, few pre-determined criteria, and the level of advancement made in implementing the State Climate Action Plans, Madhya Pradesh and Uttarakhand were selected as pilot states for implementation of PREP in India.

Introductory meetings were conducted with the State Climate Change Centre (SCCC) in Uttarakhand and the State Knowledge Management Centre on Climate Change [(SKMCCC), a dedicated section in the Environmental Planning and Coordination Organization (EPCO)] in Madhya Pradesh (MP). PREP India also participated in partners meeting and presented on climate vulnerable sectors in the two selected states.

Stakeholder Meetings. The team conducted stakeholder meetings with UNA in Uttarakhand. Team met with the State Climate Change Centre (SCCC) which will be the focal point for coordination with state agencies, data collection and dissemination of PREP related information. The team also conducted meetings with officials from Agriculture and Horticulture Department, Agriculture Directorate, Tourism Development Board, Disaster Management and Finance Department, Directorate of Economics and Statistics, Planning Department, State Council for Science & Technology, Uttarakhand Irrigation Department, Uttarakhand Jal Sansthan, Central Ground Water Board, Disaster Mitigation & Management Centre (DMMC) and BAIF Development Research Foundation. The team also met with Directorate of Economics and Statistics, Environmental Information System Centre, Forest Department, Department of Agriculture and Horticulture, Water Resources Department, Disaster Management Institute, State Disaster Management Agency, State Council for Science & Technology, Madhya Pradesh Agency for Promotion of Information technology and UNDP in Madhya Pradesh. Post stakeholder meetings data sharing agreements were made with SCCC in Uttarakhand and SKMCCC in Madhya Predesh.

Through these meetings, the team could assess the sectors that are extremely vulnerable to climate change and those most important for the state in terms of economic activities. By bringing various departments under one roof to discuss availability of data for decision making, the team could also identify issues that affect or foster collaboration. The team could assess the level of fragmentation of data by departments and identify means to standardize and begin to integrate data. The meetings also provided the stakeholders an opportunity to share information on data sources, formats and methods to acquire them for inclusion on the PREP platform.

Throughout the project period, data source mapping was underway. The PREP global and India teams hold regular calls to share inputs on sources, formats and usability. PREP global team members conduct regular trainings for Pooja for data upload and visualization. Data prioritization along with data collection is currently underway. As only some data is available on live web portals of the states, much of the data is to be collected, cleaned and hosted on the PREP platform.

Figure 1*: Stakeholder meeting in Bhopal, Madhya Pradesh.*

Figure 2: *Stakeholder meetings in Uttarakhand.*

Planned work

- Data collection prioritization, cleaning and hosting and visualizing on PREP platform.
- Creating example dashboards and stories on MP and Uttarakhand based on the data hosted on the platform.
- Creating new state specific demos on the platform content and usability.
- Hold two workshops each in the states of Uttarakhand and Madhya Pradesh in June 2018. These will also be the project conclusion workshops. At these workshops the PREP India team will present the dashboards created for both states, as well as share data content for the two states. The workshop will also be an opportunity to provide training on use of the PREPdata platform – how to find and display data; how to develop widgets and dashboards; and how to upload your own data. The workshops will provide a forum to get participants input on the portal content and usability.

Products

We are in the process of designing sector-specific dashboards for resilience planning.

Presentations

Burke, L., 2017: WRI and the Partnership for Resilience and Preparedness (PREP) – An Overview, *U.S.-India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 9, 2017.

Appadurai, N., 2017: Resilience Efforts and Activities in India, *U.S.-India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 9, 2017.

Burke, L. and Appadurai, N., 2017: Development of Dashboards and its Utilization in State Action Planning, *U.S.-India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 9, 2017.

Pandey, P., 2018: PREP Demo – An Introduction to PREP Platform, *Stakeholder mapping meeting*, Dehradun, India, January 4, 2018.

Ginoya, N., 2018: PREP India – An overview of Madhya Pradesh and Uttarakhand*, Quarterly PREP Partners meeting*, Washington, DC, January 17, 2018.

Pandey, P., 2018: PREP Demo – An Introduction to PREP Platform, *Stakeholder mapping meeting*, Bhopal, India, February 26, 2018.

Pandey, P., 2018: PREP Demo – PREP Platform for Uttarakhand, *Stakeholder meeting*, Dehradun, India, March 7, 2018.

Pandey, P., 2018: PREP Demo – PREP Platform for Madhya Pradesh, *Stakeholder meeting,* Dehradun, India, March 22, 2018.

Other

- PREP global 2-pager
- PREP India 2-pager
- PREP postcard
- PREP poster

Performance Metrics	
# of new or improved products developed that became operational	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**8**
# 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 Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: CICS-NC collaborator, Texas Tech University, led the 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 at the pst year's PCR workshops in India.

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. The NOAA National Centers for Environmental Information (NCEI), the NOAA Cooperative Institute for Climate and Satellites North Carolina (CICS-NC), and CICS-NC subcontractors (including Texas Tech University - TTU) are providing key technical support for the PCR bilateral activities in collaboration with the U.S. State Department.

TTU's Katharine Hayhoe, a lead author for the National Climate Assessments since 2007, and Texas Tech Climate Science Center researchers Anne Stoner, Ian Scott-Fleming, and Ranjini Swaminathan, are supporting multiple PCR workshops 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

Over the last year, the team completed initial project outcomes and, in partnership with Indian practitioners and researchers, identified a new product that will extend the utility of this effort over time. This year, we: (a) enhanced our state-of-the-art climate products and analysis tools; (b) contributed to the design and implementation of two additional workshops 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 multiple hands-on exercises in Delhi and Hyderabad to train attendees in using these products; and (c) continued to build long-term collaborations with Indian practitioners, researchers, and other experts to expand on the original products, a collaboration which has led to a plan to build online training and data resources that will be made available to practitioners and researchers across the country. These steps are summarized below.

Climate Data and Analysis Tools. To generate climate information for resilience planning and sustainable development, we previously assembled and quality-controlled long-term daily temperature and precipitation observations from available Global Historical Climatology Network (GHCN) stations and from additional stations provided by Indian Institute colleagues (Figure 1). This year, we continued to solicit additional long-term weather records not archived in GHCN from Indian colleagues and add them to this database. New observational records were downscaled using daily simulations from the original six CMIP5 (Climate Model Intercomparison Project, Phase 5) global climate models (GCMs) and for an additional 14 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). The downscaling was accomplished using the Asynchronous Regional Regression Model version 2 (ARRM2), 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 extension of our 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. This year, the package was expanded to include additional indicators such as heating degree-days and return periods.

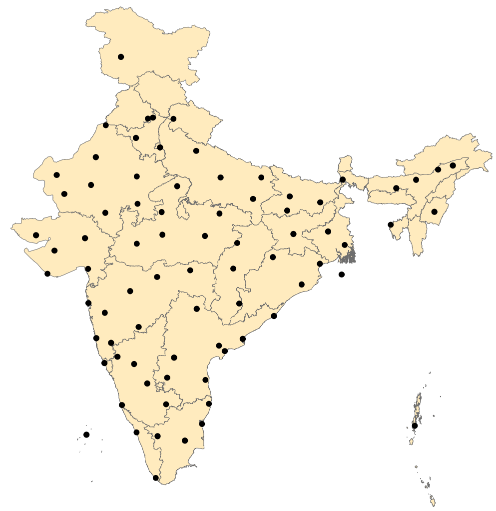


Figure 1. *Location of long-term weather stations for which daily projections were generated.*

Workshop Design and Implementation. To assist users in the application of this analysis package, we continued to build and expand our presentations and videos explaining the data and code, complemented by both single and two-day exercises as well as take-home activities that enable researchers and state policy makers to use the downscaled climate data, perform analysis, and even generate usable products, including plots and presentations. We also continued to supply the Excel and Powerpoint templates to permit 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. Through previous and new engagement with workshop participants, we are establishing collaborations for future work with the Indian organization, Environmental Protection Training and Research Institute (EPTRI), for web-based interface development activities and support for downscaling data for the State of Gujarat.

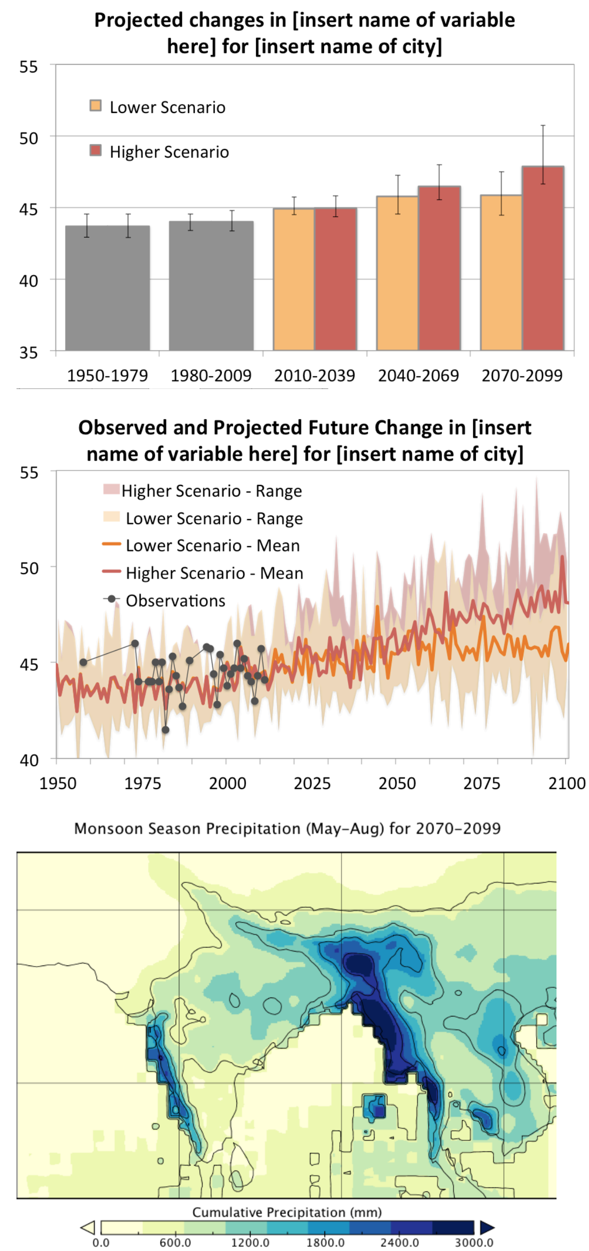


Figure 2. *Sample (top) bar charts, (middle) time series, and (bottom) maps users were able to create with the analysis code and plotting templates generated under this project.*

Planned work

- Expand the existing archive of instructional videos to provide a complete set of educational materials that could be used as an online course
- Continue to work with Indian colleagues and practitioners to obtain and quality control additional weather station records supplied by collaborators and generate high-resolution climate projections for these locations (currently in progress with the state of Gujarat and with EPTRI)
- Work with EPTRI to turn the data and analysis products into a user-friendly online dataset that can be accessed continuously by users
- Add monthly maximum and minimum temperature and precipitation time series for individual states to the analysis code
- Provide documentation in the form of a publication and/or report

Products

The products that were expanded during the past year include:

- Quality controlled daily temperature and precipitation data for approximately 10 additional weather stations across India
- Statistically downscaled daily precipitation to station level for 20 GCMs (previously 6) and 2 RCPs (RCP4.5, RCP8.5)
- An expanded user-friendly climate analysis R package including additional impact-relevant indicators and climate metrics
- Updated Excel sample spreadsheet to make time series plots and bar graphs and annual plots
- Updated Powerpoint sample presentation to make a presentation with analysis output
- Updated and expanded 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

Swaminathan, R., 2018: US-Indian Collaborations on Analysis of Observational Climate Data and Future Projections, 98th Annual American Meteorological Society Annual Meeting, Austin, TX, January 8, 2018.

Hayhoe, K., 2018: High Resolution Climate Projection: How to Select and Use. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Delhi, India, February 9, 2018.

Hayhoe, K. and Scott-Fleming, I., 2018: Downscaling Exercise and Discussion. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Delhi, India, February 9, 2018.

Hayhoe, K., 2018: High Resolution Climate Projection: How to Select and Use. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 12, 2018.

Hayhoe, K., 2018: Introduction to Asynchronous Regional Regression Model (ARRM). *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 12, 2018.

Hayhoe, K. and Scott-Fleming, I., 2018: Downscaling Exercise and Discussion. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 12-13, 2018.

Hayhoe, K., 2018: Applications of High Resolution Climate Projections – Agriculture, Water and Energy. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 13, 2018.

Other

Over this year, we have identified even more collaborative research opportunities for new projects with state practitioners, policy experts, and researchers 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	**7**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

[+] Improved and expanded products consist of: (1) quality-controlled station observations; (2) downscaled climate projections for each station; (3) an updated and expanded 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) updated templates and documentation to allow users to easily & accurately interpret and communicate the results of their analysis.

The Energy and Resources Institute (TERI)/ Understanding Climate and Heath Association in India (UCHAI) Initiative Supporting the U.S. – India Partnership for Climate Resilience	
Task Leader:	Meena Sehgal
Task Code	NC-CAA-05-TERI
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI (DOS)
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: CICS-NC collaborator, The Energy and Resources Institute (TERI), and its UCHAI initiative have led, participated in and/or coordinated a number of activities and events in the past year to raise awareness on the effects of climate vulnerability and extreme weather patterns on human health, and adoption of measures that can help in risk reduction. *http://www.uchai.net/*

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, 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. The NOAA National Centers for Environmental Information (NCEI), the NOAA Cooperative Institute for Climate and Satellites North Carolina (CICS-NC), and CICS-NC subcontractors (including The Energy and Resources Institute - TERI) are providing key technical support for the PCR bilateral activities in collaboration with the U.S. Department of State.

The Energy and Resources Institute (TERI) is a non-profit, policy research organization based in India working in the fields of energy, environment, sustainable agriculture and climate resilience. TERI serves as the current secretariat for the Understanding Climate and Health Associations in India (UCHAI) initiative, a network of professionals, experts, organizations and knowledge systems to address climate change and health issues in India. The UCHAI initiative aims to build capacity for use of downscaled climate data and enhance resilience of the health sector in India, with a focus on strengthening state-level adaptation plans.

Accomplishments

TERI and its UCHAI initiative have led, participated in and/or coordinated a number of activities and events in the past year to raise awareness on the effects of climate vulnerability and extreme weather patterns on human health, and adoption of measures that can help in risk reduction.

PCR High Resolution Climate Modeling Workshops

TERI/UCHAI participated in the initial March 2017 PCR technical downscaling workshop in Pune, India, coordinated by CICS-NC and NCEI. UCHAI Advisory Committee member, John Balbous (U.S. National Institute of Environmental Health Studies), presented, "Case Studies and Discussion on Connections of Downscaled Climate Information and the Health Sector." TERI organized and held a collaborative one-day climate modelling workshop on February 9th, 2018 in New Delhi, India, prior to the Indian Public Health Association National Conference and supported the February 11th -12th technical workshop hosted by the Environment Protection Training & Research Institute in Hyderabad, India. The aim of these workshops was to understand climate projection techniques, outputs and how it can inform decision-making. Participants gained hands-on knowledge of climate downscaling methods to generate high resolution climate projections and select and use climate projections for modelling in agriculture, water resources, health and infrastructure planning, climate risk dashboards, and additional climate information needs. Participants were a mix of research professionals, academicians, and students working in the field of climate modelling, climate science, and research and spanned geographic coverage across India. Video of the workshop can be found on http://www.uchai.net/ and http://www.teriin.org/event/workshop-high-resolution-climate-projections-and-analysis-india.

Webinar

UCHAI held a webinar, "Climate Change and Health: What Medical Students and Health Professionals Need to Know," on 18 August 2017. The webinar established key linkages between climate change, environmental, and health effects in different socio-economic groups. Topics included climate variability and change and its effect on temperature, precipitation patterns, and air quality, and how it can increase pathogens in the environment affecting health outcomes such as increase in vector-borne diseases, cardiovascular and respiratory diseases, heat stress, and displaced populations due to flooding, and extreme weather events. Those from lower socio-economic background, practicing farming, and dependent on weather patterns for food and water security are most vulnerable to the effects of climate change. More information about this event is available at: http://www.teriin.org/event/climate-change-and-health-what-medical-students-and-health-professionals-need-know; Infographic: http://www.uchai.net/infographics.html.

UCHAI Website

UCHAI created a website for its diverse network to address climate change and health issues in India. The website is a moderated, open platform enhanced by social media and instant messaging. The site gives up to date access to Knowledge Resources and News & Events and encourages users to get involved by sharing their research, writing blogs, becoming a member, or volunteering. Users network through the website to share information, resources, services, and best practices to mitigate the effects of climate vulnerability. 2,108 unique users have visited the site since January 2018 with 22,597 total hits or downloads. Users have been world-wide including users from India, United States, China, Ukraine, Russian Federation, Philippines, Brazil, Indonesia, Malaysia, Turkey, Poland, France, Canada, Pakistan, Saudi Arabia, and Australia, just to name a few. For more information, please visit the website: http://www.uchai.net/

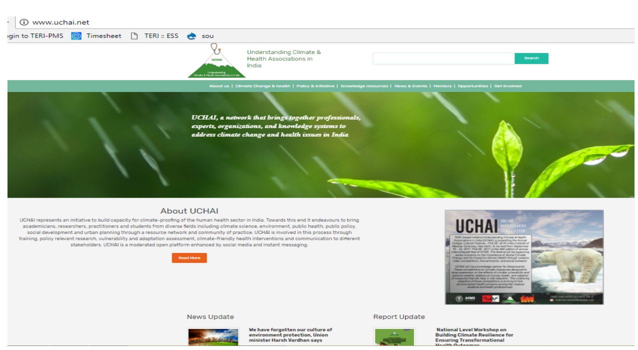


Figure 1. *UCHAI website*

The 62nd Annual National Conference of Indian Public Health Association (IPHACON2018)

TERI professional Mr. Barath Mahadevan, and various UCHAI members participated in the IPHACON2018 conference in the plenary session III *Climate science, pathways to health effects, and role of global and local level stakeholders in decision making* on 10th February, 2018. The panel focused on climate science and pathways to health effects. Eminent speakers included Dr. Anand Krishnan and R. Harshal Salve (All India Institute of Medical Sciences (AIIMS); Dr. Nitish Dogra [Indian Institute of Health Management Research (IIHMR)]; Dr. RC Dhiman (Indian Council of Medical Research - National Institute of Malaria Research (ICMR-NIMR); and Mr. Manjeet Saluja [World Health Organization (WHO)]. The panel was well attended with over 100+ participants representing members of the Parliament, policy planners, program managers, academics and members of the India climate and health community of practice. International representation included participants from Canada, Ireland, Banglaesh, Nepal, Oman and USA. For more information, please visit https://iphacon2018.com/.

PULSE

UCHAI supported events at the Annual College Cultural Festival, PULSE, at All India Institute of Medical Sciences (AIIMS), New Delhi, September 16th – 22nd, 2017. PULSE included a series of events on the Importance of Global Climate Change and Its Impact on Human Health through creative video competitions, fine-art events, and social outreach. This event and competition helped to raise awareness of the effects of climate vulnerability and extreme weather patterns on human health and methods for risk reduction. It also enabled capacity building on the use of medical knowledge to overall illness from heat stress, respiratory diseases and vector borne diseases. This event included over 100+ participants and reached hundreds of thousands of people through media. More information at http://www.uchai.net.

***Figure 2**. UCHAI supported events at the PULSE festival in September 2017.*

Planned work

- Convene professionals, academics and health and climate experts to support informed decision making.
- Organize and host the Climate and Health Workshop. (October 2018)
- Sponsor additional awareness/capacity-building workshops and initiatives on climate and health.
- Continue website update to improve understanding of users on climate health effects.

Presentations

• Datta, Arindam, 2017. Critical Climate Science and Pathways that Increase Risks to Health, *UCHAI Webinar*, August 18, 2017.

• Bhadwal, Suruchi, 2017. Disaster Risk Reduction (DRR), Sendai Framework, *UCHAI Webinar*, August 18, 2017.
• Mahadevan, Barath, 2018. Climate Science and Pathways to Health Effects, *The 62nd Annual National Conference of Indian Public Health Association*, February 10, 2018.

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

Climate Change Indicators	
Task Leader:	Laura Stevens
Task Code	NC-CAA-06-NCICS-LS
NOAA Sponsor	David Easterling / Derek Arndt
NOAA Office	OAR/CPO
Contribution to CICS Research Themes	Theme 2: 75%; Theme 3: 25%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: The TSU provided support to USGCRP efforts to produce a comprehensive suite of Climate Change Indicators. Significant progress was made in the development of new Indicators and collection of indicator metadata. A new Heavy Precipitation Indicator, developed with TSU input and support, was recently added to the USGCRP Indicators Platform. *https://www.globalchange.gov/browse/indicators*

Background

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

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

CICS-NC and NOAA NCEI were resourced to work with the IndIWG to better broker and administer the Indicator set, based on the synergy with, and similarity to, the work of the NCA Technical Support Unit (TSU). Laura Stevens (CICS-NC) and Jessica Blunden (NCEI) support the overall USGCRP effort with scientific and technical expertise. Other CICS-NC staff assist with specific components as needed, including metadata (Sarah Champion), editing (Tom Maycock and Brooke Stewart), and website support (Angel Li).

Accomplishments

NCA Technical Support Unit (TSU) staff members participate in bi-weekly calls with the USGCRP Indicators Interagency Working Group (IndIWG). Initial engagements with the IndIWG prompted the creation of a comprehensive process and tracking system. This new approach, implemented in order to more easily keep track of all future Indicator developments and updates, has been commended by the IndIWG, as each part of the process is now fully traceable and transparent to all involved.

A new Heavy Precipitation Indicator (Figure 1) was recently added to the Indicators Platform (Figure 2), with significant contributions from the TSU. This Indicator was drawn directly from the upcoming Fourth National Climate Assessment, Volume II, with major contributions from the TSU science team lead Kenneth Kunkel. Other recent work includes updates of the Arctic Sea Ice Extent Indicator and the Frost-Free Season Indicator.

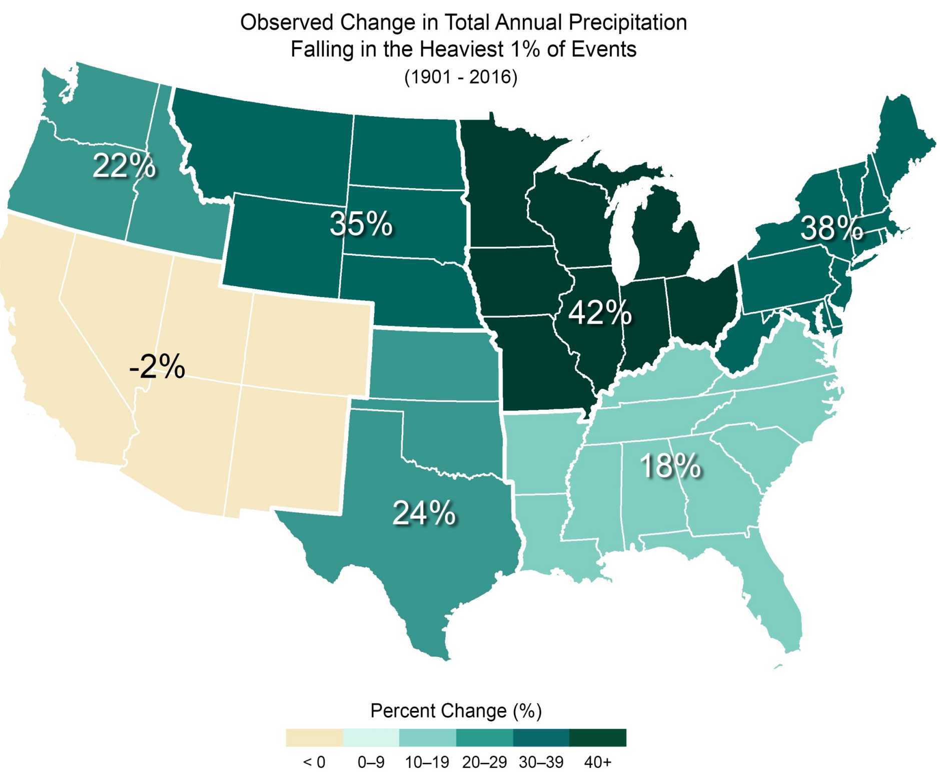


Figure 1. *The new Heavy Precipitation Indicator. This map shows the observed change in the amount of precipitation falling in the heaviest 1% of all events. The observed trends for 1901–2016 are calculated as the difference between 1986–2016 and 1901–1960 and are averaged over each National Climate Assessment region. Heavy precipitation is becoming more intense and more frequent across most of the United States, particularly in the Northeast and Midwest.*

The development of a new Indicator is multi-step process. The TSU works directly with Indicator "Champions" (members of partner agencies designated as experts responsible for each Indicator) throughout this process in order to:

- gather the most relevant and up-to-date data;
- present the Indicator to the IndIWG for approval;
- facilitate the development of the Indicator;
- create a textual description of the Indicator;
- gather comprehensive metadata;
- deploy the Indicator online;
- implement timely updates going forward.

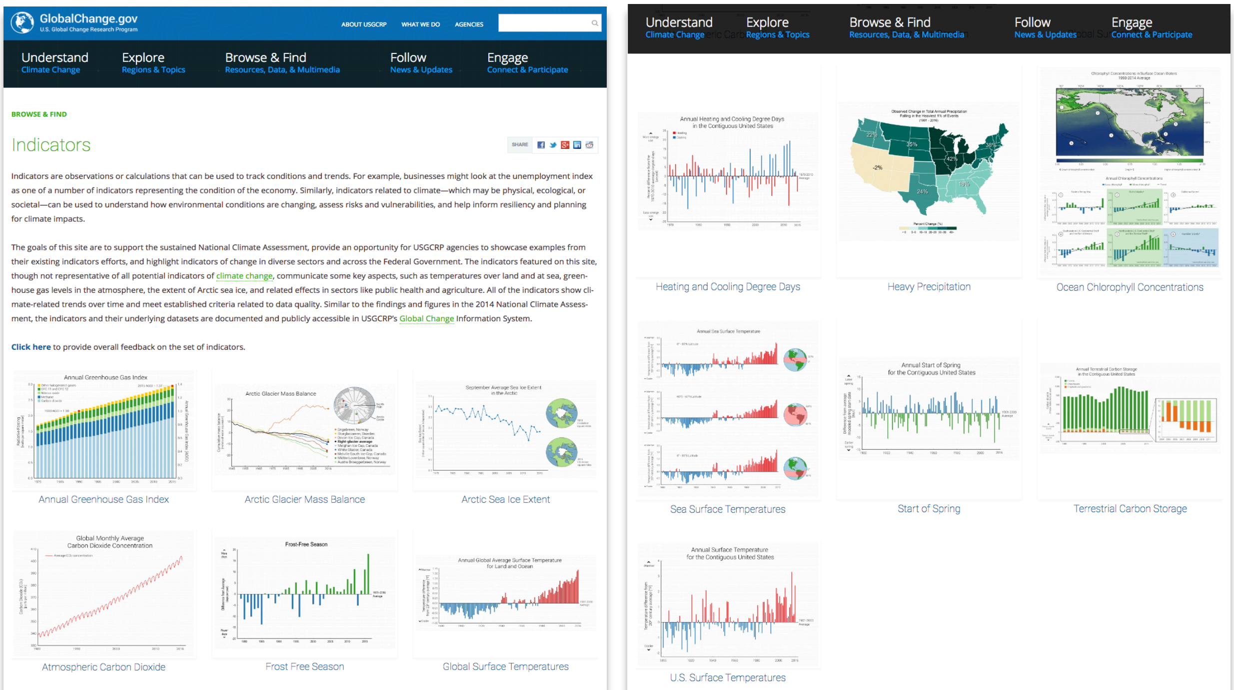


Figure 2. *The Indicators Platform at https://www.globalchange.gov/browse/indicators.*

As part of this Indicator development process, the TSU works with CICS consortium partner, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC), in the development of new Indicator figures. The TSU also works directly with USGCRP's web team in order to deploy new and updated Indicators online as part of the Indicators Platform.

In line with National Climate Assessment (NCA) efforts to satisfy the Information Quality Act (IQA), comprehensive metadata is collected for each Indicator in an aim to provide full transparency, traceability, and reproducibility. To do this most effectively, a simplified metadata collection system was developed and complete metadata will be gathered as appropriate for each new Indicator. A full set of metadata for all 13 current Indicators was collected and entered into the TSU's current metadata collection system.

Planned work

- Complete updates to the full suite of current Indicators.
- Assist the IndIWG with their goal of adding 10-12 new Indicators in the coming year.
- Complete a full set of metadata for all Indicators and ultimately implement the NCA Metadata Viewer into the Indicators Platform.
- Work with the IndIWG to define the role of Indicators, and potential opportunities, with regards to the Sustained Assessment, the Fifth National Climate Assessment (NCA5), and other USGCRP products and priorities.

Presentations

Arndt, D. S., J. Blunden, **L. E. Stevens**, and S. M. Champion, 2018: Managing a Multi-Agency Set of Climate Indicators. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

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

Analytical Support for the Fourth National Climate Assessment	
Task Leader:	Terence R. Thompson
Task Code	NC-CAA-07-LMI
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI **(**OAR/CPO)
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: Utilizing LMI's proprietary *ClimateQ* toolkit**,** tailored *Fourth National Climate Assessment (NCA4)* climate-scenario products were developed for the NCA4 regional and sectoral chapter authors. To date, 28 Metropolitan Statistical Areas have been analyzed across 48 derived variables from 32 models.

Background

LMI and The Climate Service (TCS) are working with the Cooperative Institute for Climate and Satellites North Carolina (CICS-NC) and the NCEI National Climate Assessment Technical Support Unit's Science Team to develop data products for use in the Fourth National Climate Assessment (NCA4). The primary application is to meet the climate-scenario needs of the NCA4 authors for regional and sectoral chapters. LMI/TCS coordinates closely with the NCEI National Climate Assessment Technical Support Unit Assessment Science Team to insure integrity, traceability, and reproducibility of products provided to NCA4 authors to meet Information Quality Act (IQA) requirements.

Accomplishments

During the past year, we have developed the following four major capabilities:

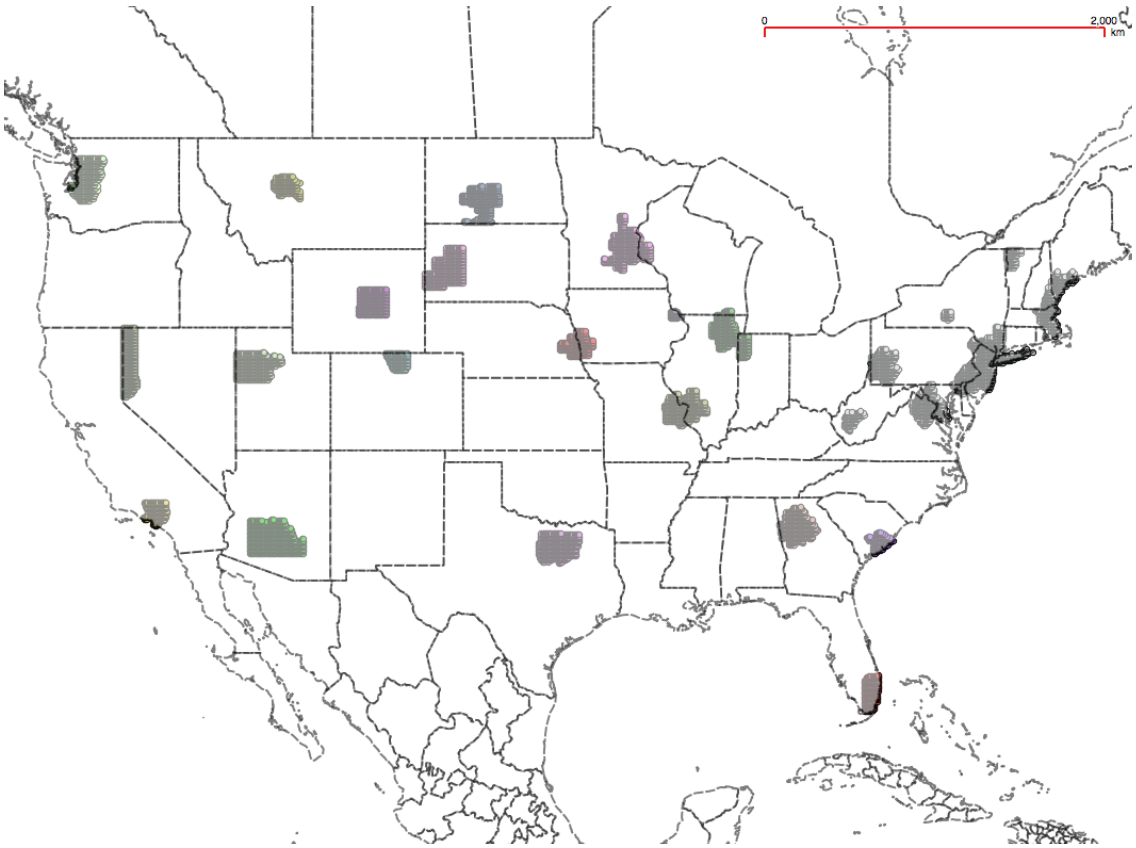
1. Determine Localized Constructed Analogs (LOCA) grid-cell centers that lie within a defined region.

2. 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.

3. 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.

4. Display region-specific evolution of the ensemble averages and single-model ranges across 48 LOCA-based derived variables.

Figures on the next page reflect the analyzed regions and selected results for one of these regions.



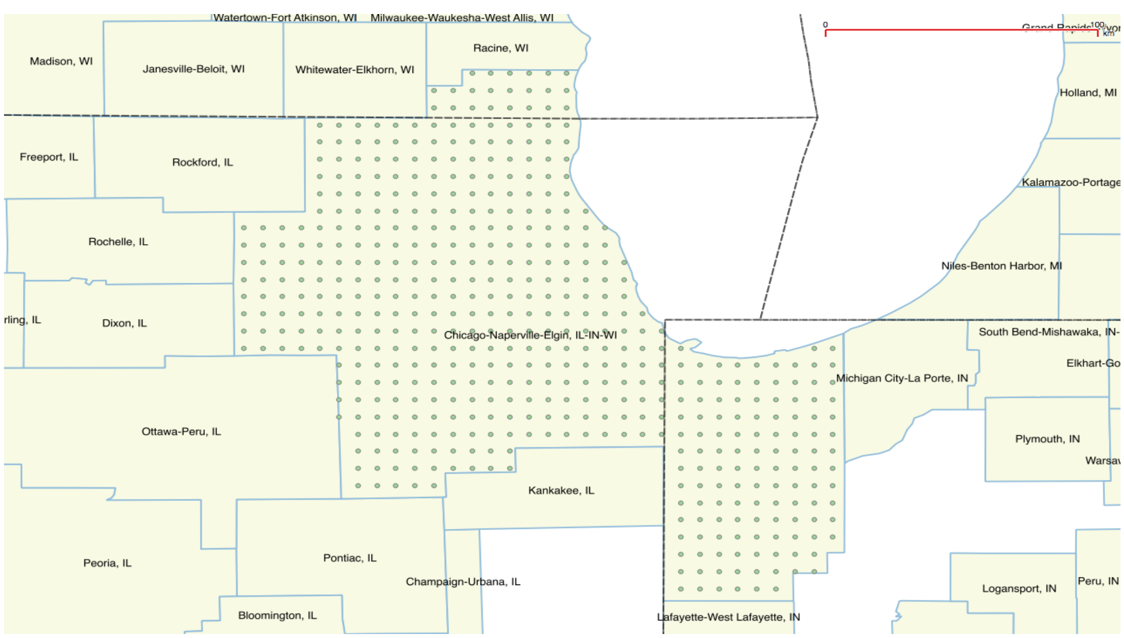


Figure 1: *The 28 Metropolitan Statistical Areas analyzed (top) and grid locations within the Chicago-Naperville-Elgin Metropolitan Statistical Area (bottom)*

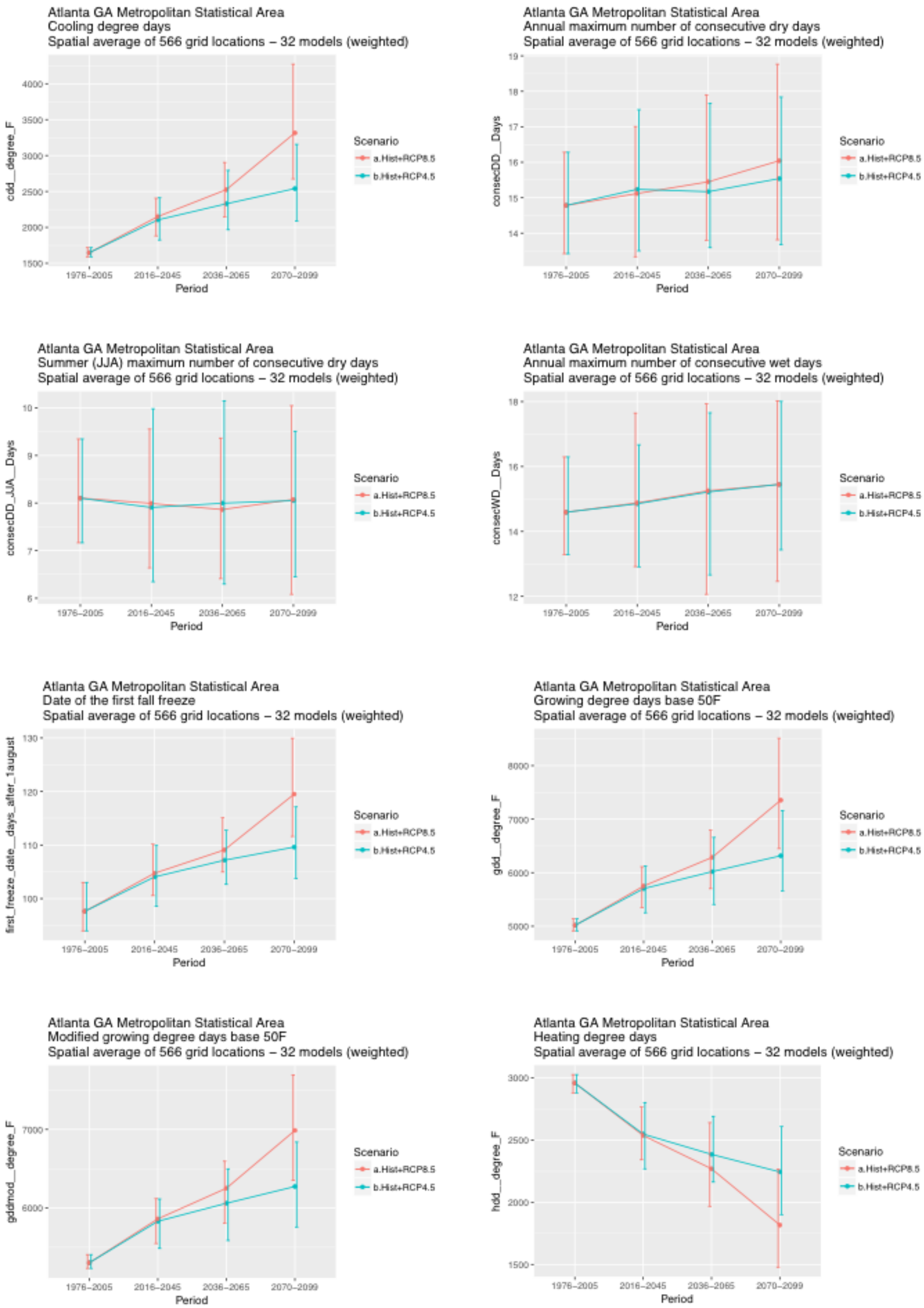


***Figure 2**: Selected elements from the 48 displays completed for the each of the 28 Metropolitan Statistical Areas (Atlanta MSA shown here).*

Planned work

- Additional analyses and/or products for the NCA4 chapter lead authors to assist in response to public review and National Academy of Sciences review comments 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.

Presentations

Thompson, T. R., K. E. Kunkel, L. E. Stevens, D. R. Easterling, J. C. Biard, and L. Sun, 2017: Localized Multi-Model Extremes and Trends for the 4th National Climate Assessment, *American Geophysical Union (AGU) Annual Conference*, New Orleans, LA, December 13, 2017.

Thompson, T. R., K. E. Kunkel, L. E. Stevens, D. R. Easterling, J. C. Biard, and L. Sun, 2017: Localized Trend Analysis of Multi-Model Extremes Metrics for the Fourth National Climate Assessment, *American Meteorological Society (AMS) Applied Climatology Conference*, Asheville, NC, June 26, 2017.

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

Products

The techniques used in this work and key results are described in the submitted project report: "Analytical Support for the Fourth National Climate Assessment", Technical Documentation, 21 September 2017, 52 pp. Supporting data sets were also submitted with this report.

Other

General descriptions of this work have been used in lectures on climate analysis at George Mason University.

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

An investigation into current and future trends in severe thunderstorms and their environments	
Task Leader:	Robert J. Trapp
Task Code	NC-CAA-08-UIUC
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/NCEI (OAR/CPO)
Contribution to CICS Research Themes	Theme 2: 75%; Theme 3: 25%
Main CICS Research Topic	Climate Assessment
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: A 12-year (2000-2011) MRMS radar-based hail climatology using the hail proxy Maximum Expected Size of Hail (MESH) was previously completed. This year, short term trends in the MESH climatology and long-term trends in the NARR-based hail environments were analyzed. Severe-convective storm parameters evaluated using the North American Regional Reanalysis (NARR) exhibit positive trends over the period 1980-2015; trends in some of the quantifications were found to be statistically significant.

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 coincide 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 to estimate the number of days with potential for severe thunderstorms. This general 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 data, with NEXRAD/in-situ gauge Climate Data Record (CDR) data as a constraint.

Accomplishments

During the past year, the North American Regional Reanalysis (NARR) was utilized to study trends in the frequency and spatial extent of environments supportive of severe hail and tornado outbreaks from 1980-2015. The Maximum Expected Size of Hail (MESH) dataset developed previously as part of this project was used along with SPC tornado reports as “ground truth” to determine proper thresholds for environments supportive of tornado or severe hail outbreaks respectively.

Two multivariate parameters, the supercell composite parameter (SCP) and significant tornado parameter (STP), were used to distinguish severe hail and tornado environments, respectively. Convective precipitation was used in combination with SCP and STP as a proxy for convection initiation. A positive trend was found for environments supportive of severe hail outbreaks over the period. This is consistent with the short term positive trend in severe hail outbreaks shown in Schlie et al. (2018). It also suggests that this environmental approach could cover a longer period than was possible with MESH alone. A statistically significant trend in overall severe hail days was also found for the same period. Regionally, events were confined to the Southeast, Northeast, Northern Great Plains and Midwest, although only the Southeast region showed a statistically significant positive trend in severe hail outbreak environments. The median area for severe hail outbreak environments showed a statistically significant, positive trend over the period as well. Moreover, severe hail outbreak days and median hail area exhibited a statistically significant, positive trend.

Similar to the results for severe hail outbreaks, a statistically significant positive trend was found in tornado outbreak environments over the period. This result supports the findings of Brooks et al. (2014) and Tippet et al. (2016) and provides further confidence that their results are not due to reporting biases. Regional results show outbreak activity restricted to the same four regions as severe hail outbreaks. However, both the Midwest and Southeastern regions had statistically significant positive trends for tornado outbreaks. Additionally, a positive trend was found in the yearly median area on outbreak days, over the period. A statistically significant, positive correlation was found between tornado outbreak days and median yearly area, similar to that of severe hail outbreaks. Lastly, variability in yearly tornado outbreak days and area had statistically significant positive trends over the period. This, again, supports the results of Brooks et al. (2014) who also found increases in tornado outbreak day variability over a similar period in reports.

The correlation between yearly outbreak days and median area in NARR environments supports the hypothesis that the increase in outbreak area is related to the larger scale forcing of environments supportive of outbreak events. This research will provide useful insight for possible future studies investigating the synoptic scale changes leading to this increase in area, and days, of environments supportive of severe hail and tornado outbreaks.

Planned work

• Complete revisions to the *International Journal of Climatology* radar-based study of severe hail outbreaks manuscript (currently in revision).
• Finalize and submit *Journal of Climate* NARR-analysis manuscript.

Presentations

Schlie-Janssen, E., 2017: A Historical Analysis of Severe Hail Outbreaks over the CONUS, *2nd European Hail Workshop*, Bern, Switzerland, April 19, 2017.

Schlie-Janssen, E., 2017: Observed U.S. Trends in Extreme Precipitation, *Hampton Roads Adaptation Forum: Modeling and Managing Extreme Precipitation*, Suffolk, VA, May 19, 2017.

Schlie-Janssen, E., 2017: A radar-based analysis of severe hail outbreaks over the contiguous United States for 2000-2011, *University of Maryland Earth System Science Interdisciplinary Center*, College Park, MD, June 26, 2017.

Schlie-Janssen, E., 2017: A radar-based Assessment of Historical severe hail outbreaks and outbreak environments over the contiguous United States, *Cooperative Institute for Climate and Satellites North Carolina (CICS-NC) and National Centers for Environmental Information (NCEI)*, Asheville, NC, October 30, 2017.

Other

This grant supported the completion of Dr. Emily Schlie-Janssen's Ph.D. dissertation, awarded in August 2017.

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

Climate Data Records and Science Data Stewardship

Climate Data Records (CDRs), also known as Reference Environmental Data Records (REDRs), provide climate-quality satellite and in situ observing datasets that document the Earth's climate and are part of the vast data holdings of the National Centers for Environmental Information (NCEI). NCEI is also responsible for preserving, stewarding, and maximizing the utility of the Federal government's billion-dollar investment in high-quality environmental data. Key objectives include the development and sustainment of as complete and consistent a climate record as possible; 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 of interim CDRs for early use of climate-relevant observations, development and transition from research to operations (R2O) of CDRs, and exploration of methods for more effective data ingest, quality assurance, product processing, and data archival.

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*

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

- Coordination and development of calibration and validation activities and approaches for high-quality baseline climate data sets from satellite and in situ observations.
- Development, refinement, and implementation of algorithms for daily, global, multi-sensor, optimally interpolated Climate Data Records (CDRs); characterization of the sources and

magnitudes of errors and biases in the CDRs and development of methodologies for the reduction of these errors and biases.

- Development of high-quality baseline climate data sets from satellite and in situ climate data and development of the relationship(s) between the observed tropospheric and stratospheric trends from the ground-based network with those observed from satellite.
- Software engineering 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.
- Research to operation transitions.
- “Transitions management” of various externally developed CDRs to NCEI.
- Interim CDRs development and implementation for early use of climate-relevant observations.
- Stewardship of archival and current climate observations and enhancement of data curation, standards-based data management, metadata and other data documentation.
- Enhancement of all aspects of NCEI data discovery and access services, including data interoperability, semantic technologies, no-SQL and graph database technologies, linked open data standards, and other related technologies and standards.
- Exploration of methods for more effective data ingest, quality assurance, product processing and data archival.

Scientific Subject Matter Expertise Support	
Task Leader/Task Team:	Anand Inamdar, Jessica Matthews, Ge Peng, Olivier Prat
Task Code	NC-CDR/SDS-01-NCICS-AI/JM/GP/OP
NOAA Sponsor	Jay Lawrimore/ Russell Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 45%; Goal 3: 5%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: CICS-NC scientists serve as subject matter experts on multiple CDR Integrated Product Teams supporting the transition of research-grade CDRs into an initial operational capability (IOC) status as well as 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) Integrated Product Teams (IPTs) are multi-disciplinary 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.

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 21 of 213 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 PI,
- conducting initial assessment of CDR readiness for transition from scientific perspective,
- reviewing PI-submitted draft products against IOC requirements,
- providing feedback to PI on draft products,
- verifying 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
- delivering presentation to the NCEI User Engagement Branch on the CDR.

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

Sectoral Engagement (Dissen)
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 / ISTI (Rennie)
CRN Science: Heat Health Indices (Bell)
Land Surface Data Sets / USCRN Science: Precipitation Extremes (Leeper)
Precipitation – CMORPH (Prat)
Land Surface Data Sets / Extreme Snowfall (Rennie)
Outgoing Longwave Radiation – Monthly CDR (Schreck)
Outgoing Longwave Radiation – Daily CDR (Schreck)
Total Solar Irradiance CDR (Inamdar)
Solar Spectral Irradiance CDR (Inamdar)
Sea Surface Temperature – WHOI CDR (Peng)
Near Surface Atmospheric Properties over Ocean CDR (Peng)
Heat Fluxes over Ocean – CDR (Peng)
Sea Ice Concentration CDR (Peng)
Sea Ice Normals (Peng)

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.

CICS-NC has acted as ***Product Area Lead*** for the following product areas during this reporting period:

Land surface properties (Matthews)
Radiative fluxes (Schreck)

The objective of a Product 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 Product Area Leads to support the NOAA NCEI product inventory.

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

Expansion of CDR User Base through the obs4MIPs Program	
Task Leader/Task Team:	Jim Biard, Jessica Matthews, Olivier Prat, Scott Stevens
Task Code	NC-CDR/SDS-02-NCICS-JB/JM/OP/SS
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 45%; Goal 3: 5%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: CICS-NC scientists worked to make observational products more accessible for comparison with climate models by reformatting datasets into the standard form used by the Coupled Model Intercomparison Project (CMIP) community. *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 Intercomparison Project (CMIP) Phases 5 (CMIP5) and 6 (CMIP6), which are managed by the Program for Climate Model Diagnosis and Intercomparison (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

After promising results producing obs4MIPs datasets from six CDRs during 2016, efforts were expanded to process these sets through their respective periods of record. In addition, two new datasets were added (Table 1). Regular communication with PCMDI proved to be helpful in their development of standards for obs4MIPs submissions. Once a final version had been settled, and with consultation from product subject matter experts, all eight datasets were processed in full and delivered to PCMDI.

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°
Blended Sea Winds	Daily	0.25°
Blended Sea Winds	Monthly	0.25°

Table 1. *Summary of input NOAA CDRs for this year.*

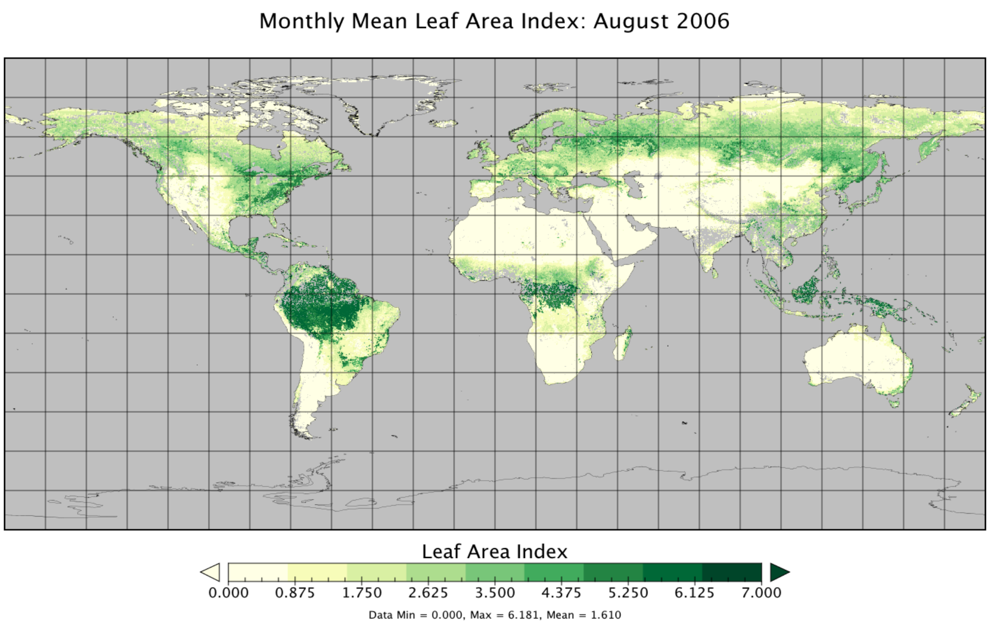


Figure 1. *A sample image from the obs4MIPs Monthly Leaf Area Index dataset.*

Planned work

- Investigate the retroactive application of process to previously submitted datasets.

Performance Metrics	
# of new or improved products developed that became operational	**8**
# 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/Task Team:	Linda Copley, Lou Vasquez
Task Code	NC-CDR/SDS-03-NCICS-LC/LV
NOAA Sponsor	Drew Saunders
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 40%; Goal 2: 40%; Goal 3: 20%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: The team iteratively delivered a Common Ingest solution for the ingest of environmental data at NCEI. Common Ingest v2.0.0 delivers all of the functionality required to support the migration of all data sets from the current legacy ingest system to Common Ingest for NCEI-NC.

Background

Common Ingest is the ingest solution delivered by the Common Ingest Agile Development Team for the ingest and archive of environmental information at NCEI. Common Ingest is currently being deployed at NCEI-NC for the ingest and archive of up to 6.7 terabytes per day of weather and climate data archives, packaged into as many as 39,000 archive information packages.

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

The system stores all steps of processing files through the system, resulting in persistent system status and full file provenance throughout the ingest process. Common Ingest employs a centralized message broker for routing of processing control and status messages throughout the system.

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

Accomplishments

As members of an agile software development team, CICS-NC staff work in concert with Federal employees and contractors to continually enhance, modify, and deploy the new Common Ingest system at NCEI-NC. A major effort this year involved supporting the NCEI-NC Operations team in migrating data sets from the legacy ingest system to the new Common Ingest system. As the migration progressed, and new requirements were identified, the team architected and developed solutions in ways that could be generically applied for the ingest of current and future datasets.

Iterative deliveries throughout the year culminated in the release of Common Ingest v2.0.0, which marked the completion of functionality required to implement all data sets for NCEI-NC. This milestone was achieved after much collaboration with NCEI-NC operators, testers, and IT personnel. Our operations support contributed to the 86% completion of migration from legacy ingest to Common

Ingest. Our testing support enabled the testers to construct tests to prove the most complex configurations of the system, leading to continuous improvement of Common Ingest. Our collaboration with IT was necessary to build the initial production system to suit operational needs, as well as to continually harden the infrastructure and improve performance. We also improved our own software development process by implementing a shared code repository and continuous build product and into our development pipeline.

To support evolving operational needs, we continue to provide enhancements to the system, including:

- Support for complex Nexrad2 and Nexrad3 ingest processing capabilities
- Archive to CLASS using CLASS Common Submission
- Ingest files via FTP/FTPS/SFTP pull
- Advanced file renaming
- Advanced archive packaging
- Email notifications of system events
- Many User Interface enhancements
- Cron scheduling monitor and pause functions
- Ingest files based on provider manifest
- System status persistence and recovery

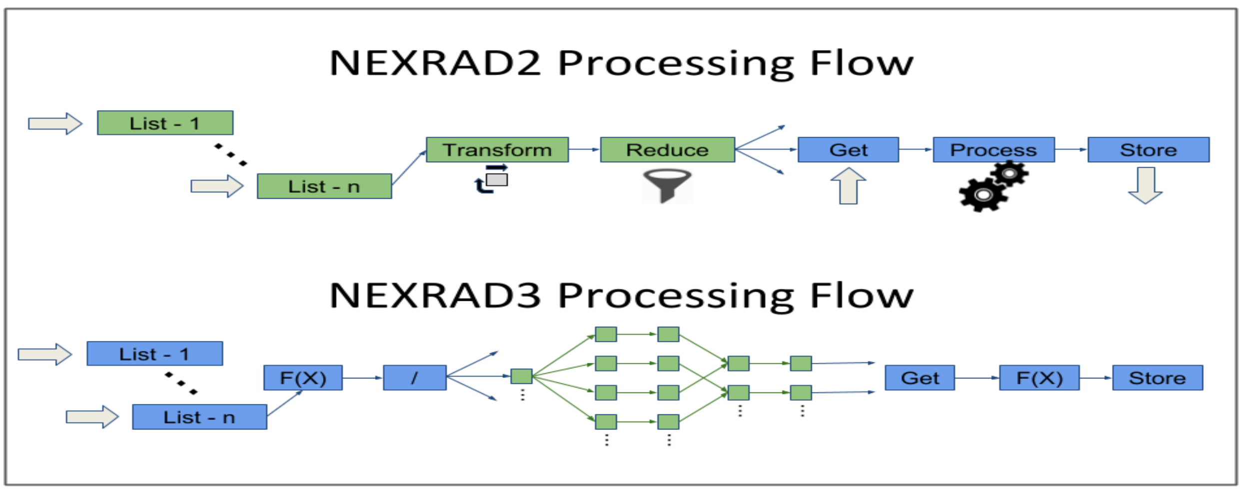


Figure 1. *Common Ingest Complex Processing Flows.*

NCEI Common Ingest unit of computation, the processing engine, was significantly upgraded to a light-engine, using a functional programming approach for distributed processing. This new light-engine approach removes dependencies on heavy infrastructure (e.g. Spring Framework, which is both unnecessary and limiting in a functional paradigm), replacing it with minimal input/output, and transform steps. This led to a smaller resource footprint, simpler engine creation, and convenient integration with our workflow needs. It was also one of several important factors allowing Common Ingest to expedite migration of data from legacy NCEI ingest.

We participated in the Mission Data Management System(MDMS) and Persistent Streaming Information(PSI) system design, solidifying it as an event sourcing system using the Kappa Architecture to handle the flow of metadata from its sources to endpoints that can be queried for state. This architecture was chosen to support immutable event retention, distributable processing, diverse scientific and specialized processing tools, diverse input and output events, scalable metadata storage, and cloud-ready workflows. Kappa Architecture is an upgrade to the industry standard Lambda Architecture that will position NCEI metadata storage, migration, and accessibility to meet the changing needs of the data community.

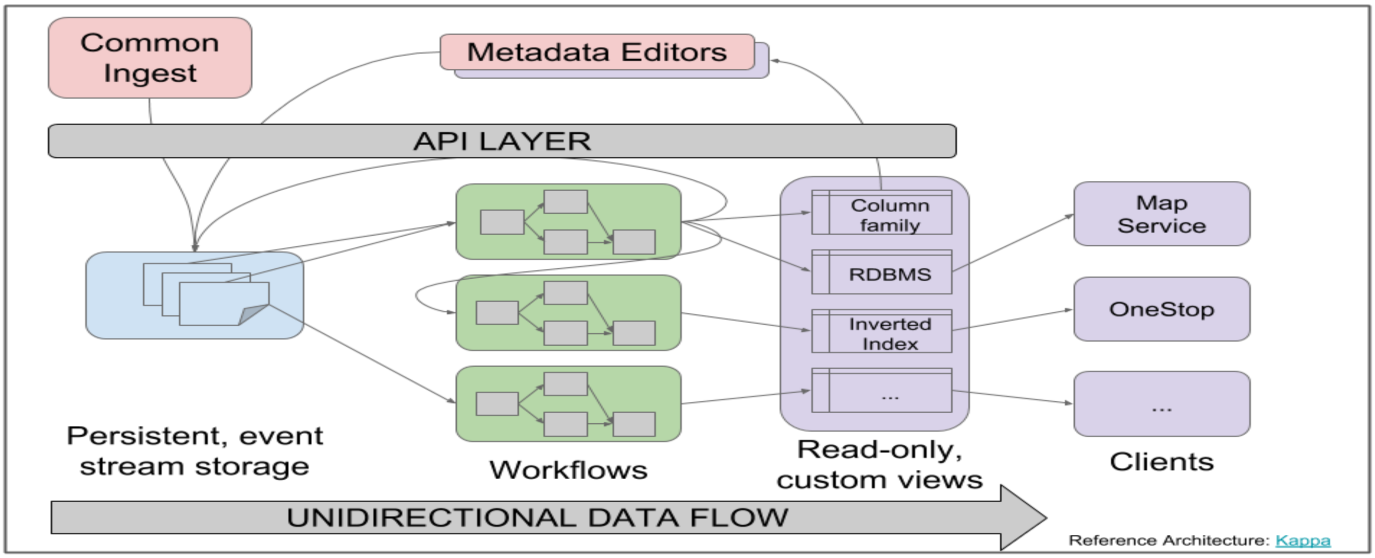


Figure 2. *MDMS / PSI Notional Architecture.*

The review, testing, evaluation and informal demonstrations of new approaches to distributed stream processing were performed as they became available during this process, in order to keep NCEI advancing technologically with the community. Specific tools investigated and implemented in a test environment were Apache Nifi, and Onyx-Platform. Apache Nifi is a user friendly, Directed Acyclic Graph (DAG), configurable, low latency/high throughput, extendable, secure, provenance tracking processing system. Onyx Platform is a cloud scale, high performance distributed computation system, with configurable DAG exposed information model workflows. It competes in the same arena as Spark, Storm, Flink and other existing industry standard solutions in the Common Ingest problem-space. While both of these solutions offered significant advantages to the NCEI ingest implementation underway, due to legacy migration timeline concerns, it was not time-effective to transition to these approaches at the time.

Planned work

- Plan and implement modifications to the existing Common Ingest architecture to improve system stability and scalability.
- Advise on integration of Common Ingest with NCEI systems.
- Define architectural approaches for Common Ingest to accommodate externalization of processors, API management, and continuous development/deployment.
- Separate reporting from processing within Common Ingest.
- Enhance workflow framework.
- Analyze and integrate recent processing framework solutions such as Kafka Streams, or Onyx Platform into Common Ingest.
- Containerization of processing composition components with tools like Docker under Kubernetes or Swarm.
- Contribute to MDMS/PSI development, including integration of Common Ingest with MDMS/PSI.

- Support NCEI in moving from disparate metadata stores with full support stacks, to a more flexible, workflow vision providing a modern, manageable, stream-oriented framework and event driven metadata generation for various data user and access provider needs.

Products

Common Ingest components deployed in NCEI production Common Ingest components deployed in NCEI production:
Ingest-manager v1.2.2 Manifested Feeding & UI Processor Configuration Editor
Ingest-manager v1.2.3 Security updates
Ingest-manager v1.2.4 Security updates
Ingest-manager v1.2.5 Feeder manifest deletion
Ingest-manager v1.3.0 Authoritative copy handling
Ingest-manager v1.3.2 Dynamic Feeding with Manifests
Ingest-manager v1.4.0 Nexrad2 workflow processing
Ingest-manager v1.4.1 CLASS connection info
Ingest-manager v1.4.2 Security updates
Ingest-manager v1.4.3 CLASS FTPS
Ingest-manager v1.5.0 Nexrad3 workflow processing
Ingest-manager v1.5.2 Dynamic manifest and Granule page
Ingest-manager v1.5.3 UI enhancements
Ingest-manager v1.5.5 Recursive FTP listing
Ingest-manager v1.5.6 HPSS retries
Ingest-manager v1.5.7 time-aggregator enhancements; HPSS custom permissions; restart workflow
Ingest-manager v2.0.0 time-aggregator hold mode; ingest throttle/partition; feeding window
Ingest-engines v1.2.2 Change manifest type
Ingest-engines v1.2.3 Feeder bootable jar and logging
Ingest-engines v1.2.4 Delete manifest ReplyTo
Ingest-engines v1.3.0 Authoritative copy handling
Ingest-engines v1.3.1 FTP passive mode
Ingest-engines v1.3.2 Dynamic Feeding with Manifests
Ingest-engines v1.4.0 Nexrad2 workflow processing
Ingest-engines v1.4.1 CLASS connection info
Ingest-engines v1.4.2 CLASS FTP
Ingest-engines v1.4.3 CLASS FTPS
Ingest-engines v1.4.4 CLASS manifest name
Ingest-engines v1.5.0 Nexrad3 workflow processing
Ingest-engines v1.5.1 CLASS archiver FTPS bin mode
Ingest-engines v1.5.2 Dynamic manifest and Granule page
Ingest-engines v1.5.3 Multi-feed processing
Ingest-engines v1.5.4 time-aggregator message size
Ingest-engines v1.5.5 Recursive FTP listing
Ingest-engines v1.5.6 HPSS retries
Ingest-engines v1.5.7 time-aggregator enhancements
Ingest-engines v2.0.0 time-aggregator hold mode; ingest throttle/partition; feeding window

Other

NESDIS Award for Outstanding Information Technology and Engineering Employees of the Year 2017.

Performance Metrics	
# of new or improved products developed that became operational	**37**
# of products or techniques submitted to NOAA for consideration in operations use	**37**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**0**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Delivered 37 Common Ingest components (see 'Products') that are deployed in the NCEI production environment.

Spatial-Temporal Reconstruction of Land Surface Temperature from Daily Max/Min Temperatures	
Task Leader:	Anand Inamdar
Task Code	NC-CDR/SDS-04-NCICS-AI
NOAA Sponsor	Jeff Privette
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 100%
Main CICS Research Topic:	Data Fusion and Algorithm Development
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: Time series of daily maximum and minimum temperatures combined with estimates of net surface solar radiation (or surface solar absorption) derived from the geostationary visible channel are used in reconstructing the temporal evolution of LST under almost all-sky conditions. This strategy has potential applications to the new 5 km gridded daily nClimDiv max/min temperature data set that is being produced at NOAA.

Background

Land surface temperature (LST) and its diurnal variation play a major role in the study of land-atmosphere interactions, climate change, hydrological cycle, vegetation and soil moisture conditions. They are also critical in the study of epidemiology, agriculture, urban heat island effects, and varying demands on energy consumption. Physically-based approaches that use thermal infrared measurements from remote sensing satellites and a combination of harmonic and exponential decay functions to model daytime and night-time variation of LST are applicable only under clear-sky conditions. 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 and Guillevic, 2015) provides a promising option to fill in the spatial and temporal gaps in LST values even under partially cloud-contaminated conditions.

Accomplishments

Results from an earlier study (Inamdar and Guillevic, 2015) have been employed in the reconstruction of diurnal variation of LST for year 2007. The daily maximum and minimum LST were used over selected NOAA Surface Radiation Network (SURFRAD) sites to demonstrate the methodology (Fig. 1). The constraints provided by the maximum and minimum LST have been used to determine temporal evolution of LST during the ascending limb (sunrise to time of maximum LST) of the solar cycle. To determine LST variability during the descending leg (time of max temperature to sunset), an initial LST profile is approximated by a harmonic function and an iterative non-linear curve-fitting approach is employed subject to the constraints of linear correlation between the surface solar absorption and LST. Fig. 1 shows that this method captures the diurnal variation during both the ascending and descending legs of the solar diurnal cycle.

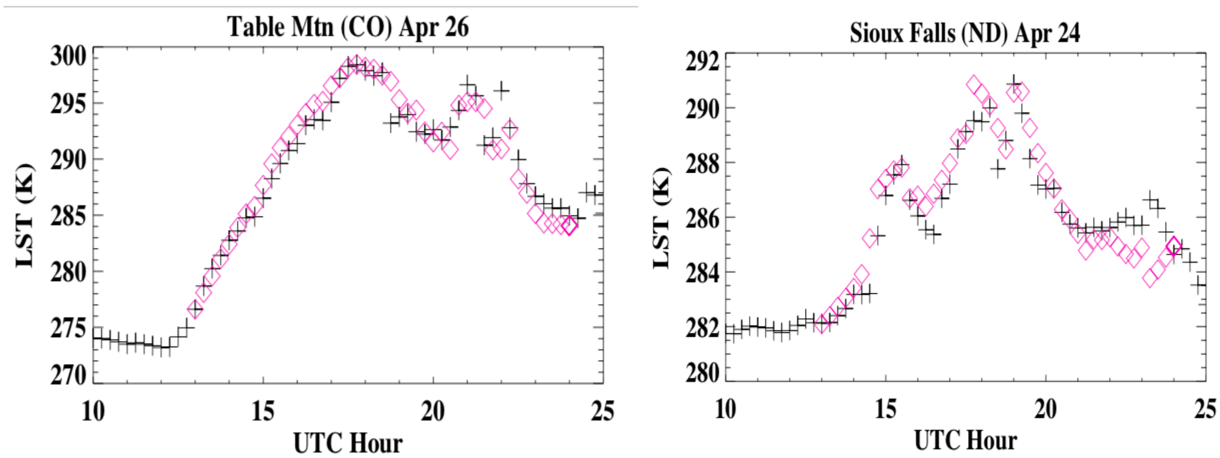


Figure 1: *Demonstration of the LST diurnal cycle reconstruction using only the day's maximum and minimum temperature and surface solar absorption for select SURFRAD sites. The black '+' signs are the actual in-situ observations and the magenta-colored diamond symbols represent the reconstructed LST.*

Planned Work

- Submit a manuscript (currently in preparation) for publication.
- Apply the strategy to the nClimDiv daily 5 km gridded data and validate with USCRN data.
- 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

Inamdar, A.K., and **R. D. Leeper**, 2018: Reconstructing diurnal cycle of land surface temperature from daily max/min temperatures. *98th American Meteorological Society Annual Meeting*, Austin, TX, January 9, 2018.

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

Transitioning of the International Satellite Cloud Climatology Project Process to NCEI-NC	
Task Leader:	Anand Inamdar
Task Code	NC-CDR/SDS-05-NCICS-AI
NOAA Sponsor	Alisa Young/Ken Knapp
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: The ISCCP H-series product for the full baseline period (July 1983 – 2009) was successfully transitioned in June 2017. Production for extended period (2010-2012) was completed and archived. A subset of the full ISCCP, ISCCP-Basic, with fewer variables was produced and made available to users. Ongoing efforts are being made to replace the drifting NOAA-18 with NOAA-19 as the anchor satellite for calibration. 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) as an activity of the Global Energy and Water Exchange (GEWEX) core project of the World Climate Research Programme (WCRP). ISCCP's objective is to derive a cloud climatology of the Earth by pooling the radiances from the suite of geosynchronous meteorological satellites around the globe and the polar orbiting AVHRR sensors. It is one of the longest lived and widely used satellite climate datasets in existence and has been extensively cited in the peer-reviewed literature. An example of its widespread application is the ISCCP simulator, an algorithm developed to mimic ISCCP observations from Global Climate Models (GCMs) in order to evaluate model simulations of the current environment. 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 and cloud feedbacks, and the relationship of clouds with numerous other phenomena.

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

Accomplishments

Production for the full baseline period of July 1983 - December 2009 was completed, results reviewed internally and approved by the PI (Rossow), and the product archived for public distribution at NOAA. A formal presentation to management was made on June 21, 2017 at the monthly NCEI Climate and Weather Center (CWC) Science Council meeting. Subsequently, extended period (beyond 2010) production commenced and the period January 2010 - June 2015 completed. Routine internal review of results and final PI approval are continuing: years 2010-2012 have been approved for archival to date. Figure 1 shows comparison of cloud amounts from both the D- and H-series for January 2009. The drift in NOAA-18 polar orbiter (the anchor satellite for calibration of all geostationary satellites) during the 2013-2015 period presented a challenge for the team as well as a flawed procedure for the matching of geostationary and polar orbiter pixels provided in the original calibration document distributed by ISCCP. The team focused on an upgrade to the match-up procedure to yield a new set of Normalized calibration coefficients with reference to the anchor NOAA-18 satellite. This resulted in improved calibration for all of the geostationary satellites. The revised matching procedure was endorsed by the PI and it will be added to a calibration add-on document for the ISCCP Build 5 package. Separately, we are working on introducing a new anchor satellite, NOAA-19, in operation since 2012. The new HBT (radiance calibration tables) have been created and we plan to investigate how much this can mitigate the effects of drift in NOAA-18. In addition, a smaller version of the full ISCCP (called ISCCP-Basic) has been created with fewer variables for users needing a simpler version.

The next version of ISCCP Radiation Package, ISCCP-FH, has been produced by its PI, Dr. Y. Zhang, using the cloud properties of H-series. The ISCCP team has coordinated a series of inter-team meetings among the Surface Radiation Budget (SRB) group headed by Dr. Paul Stackhouse at NASA Langley and the nnHIRS team at NOAA/NCEI with the objective of exposing the ISCCP data to a larger group of users. Stackhouse is also closely affiliated with the Global Energy and Water Exchange (GEWEX) team and has an extensive user data base and is a major user of ISCCP.

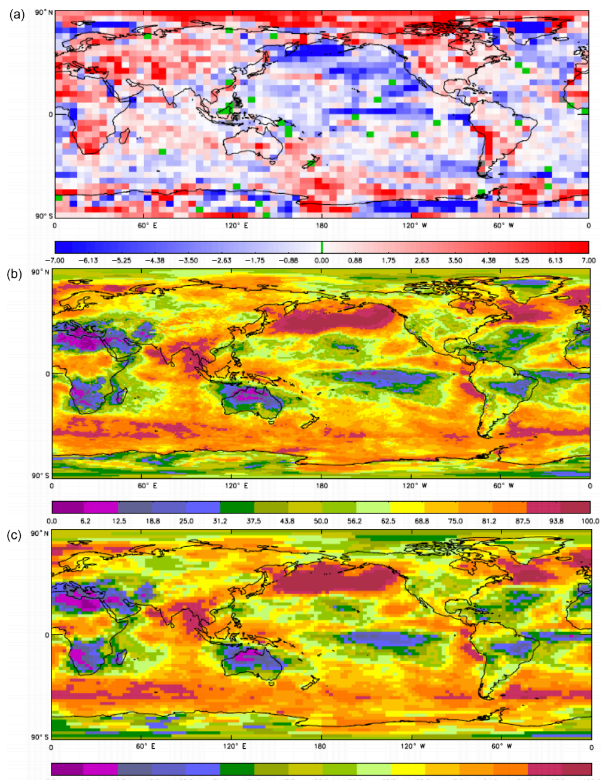


Figure 1*. January 2009 ISCCP percentage of global cloud amount for (a) differences between H- and D-series, (b) H-series HGM product at 1◦, and (c) D-series D3 product at 2.5◦. As shown, in (a) the differences between the products are greatest in the polar and coastal regions where for this case the H-series product has a slightly higher cloud fraction. In general, the H- and D-series distributions of cloud amount have good agreement.*

Planned Work

- Extend baseline period production to 2017 December which will include the new GEO satellite HIMAWARI-8;
- Introduce new polar orbiter NOAA-19 as the anchor to replace the drifting NOAA-18. Create HBTs and new GEO HBTs based on NOAA-19 from 2012 in a test environment to check and compare with the NOAA-18-based calibration.

- 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.
- Explore proposal submission to the NASA ROSES call on Cloudsat and CALIPSO Science team.
- Submit a manuscript to *Bulletin of the American Meteorological Society* (May 2018).

Publications *(peer-reviewed)*

Young, A. H., Knapp, K. R., **Inamdar, A.,** Hankins, W., and Rossow, W. B.: The International Satellite Cloud Climatology Project H-Series climate data record product, *Earth Syst. Sci. Data*, **10**, 583-593. https://doi.org/10.5194/essd-10-583-2018

Products

- H-series cloud products for the base period (1983-2009)
- H-series cloud product for the extended period (2010-2015)
- HBT calibration tables for the extended period
- ISCCP FH radiation product

Presentations

Knapp, K. R., A. H. Young, **A. K. Inamdar**, W. Hankins, and W. B. Rossow, 2018: 6B.2: Reprocessing 30 Years of ISCCP: Introducing New ISCCP H Data. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 11, 2018.

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	**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**

Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES data	
Task Leader:	Jessica Matthews
Task Code	NC-CDR/SDS-06-NCICS-JM
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: The GSA algorithm is being implemented as the US contribution to an international collaboration between Europe, Japan, and the US to produce a joint climate data record of land surface albedo. *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). NCEI is implementing the Geosynchronous Surface Albedo (GSA) algorithm for GOES data to contribute to an international effort in collaboration with EUMETSAT, JMA, and Meteo-Swiss in support of the Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM). 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 Albedo of the Americas (AOTA). This product will be focused on the Americas, which is the primary CDR user-base, and will provide greater temporal resolution and historical extent than other available albedo data sets. In short, the plan is to process 1995-2017 GOES-GVAR data (GOES-8 through 15) using the SCOPE-CM algorithm with a unified approach to calibration, handling of NWP inputs, and cloud masking.

Accomplishments

This project is one of only 10 selected by the SCOPE-CM Executive Panel from an 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 intercalibration method, exploration of different temporal resolutions and formats of output, and validation of Level 2 products. We are now in year 5 (2018) of this 5-year plan.

As a look forward to next generation reprocessing efforts, a pilot study is underway using this project to explore satellite data reprocessing in the cloud. Leading-edge computing techniques are being implemented to replicate traditional high-performance cluster computing in the cloud environment. Careful cost comparisons, in terms of both dollars and time, are being calculated to understand the scale of future reprocessing of massive next generation remote sensing data.

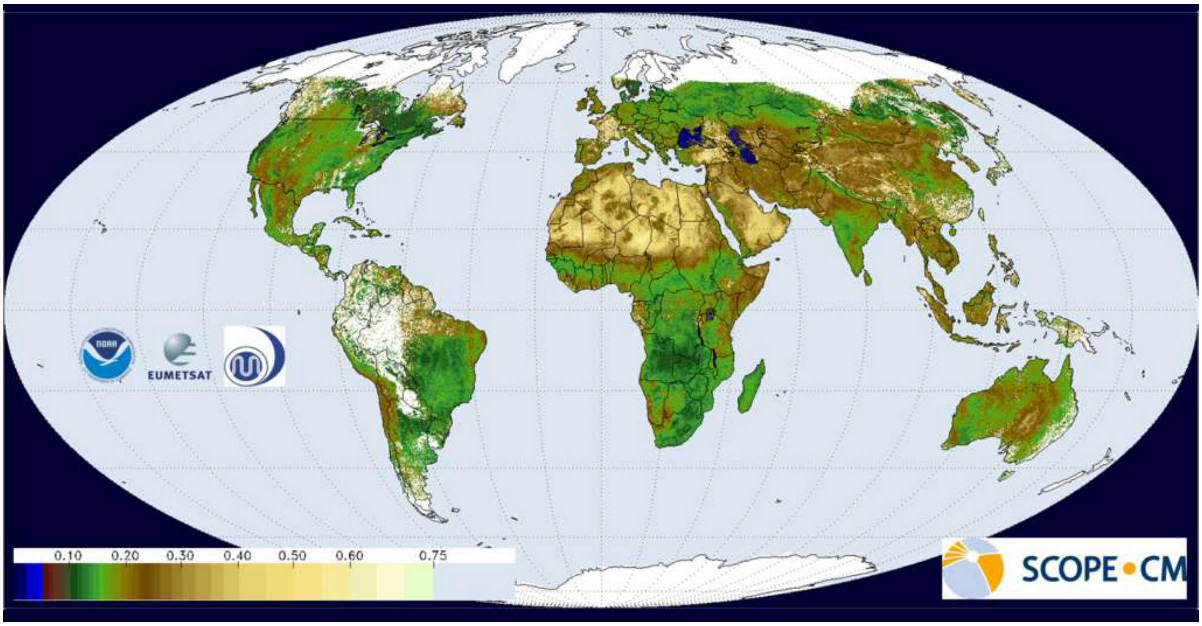


Figure 1*: Broadband black sky albedo spatial composite product for the period 1-10 May 2001.*

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 1995-2017 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

Matthews, J. L., E. Mannshardt, B. Reich, and J. Guinness, 2017: Fusing Data from Multiple Remote Sensing Instruments. *Joint Statistical Meeting*, Baltimore, MD, July 30, 2017.

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

HIRS Temperature and Humidity Profiles	
Task Leader:	Jessica Matthews
Task Code	NC-CDR/SDS-07-NCICS-JM
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Environmental Observations

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

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 NOAA Polar Orbiter Environmental Satellite HIRS data from various platforms.

In previous dataset versions, HIRS Channels 2-12 were used as inputs for the temperature profiles, while HIRS Channels 4-8 and 10-12 were used for the humidity profiles. These selections were based on the known relations of the channel information to the different physical variables. The HIRS data coupled with CO_2 data were used as inputs to a neural network. The neural networks were calibrated according to surface pressure bins. There 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 CO_2 inputs (assumed to be global) were obtained from the Scripps CO_2 program.

Accomplishments

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, improve the bias correction, and convert output to netCDF.

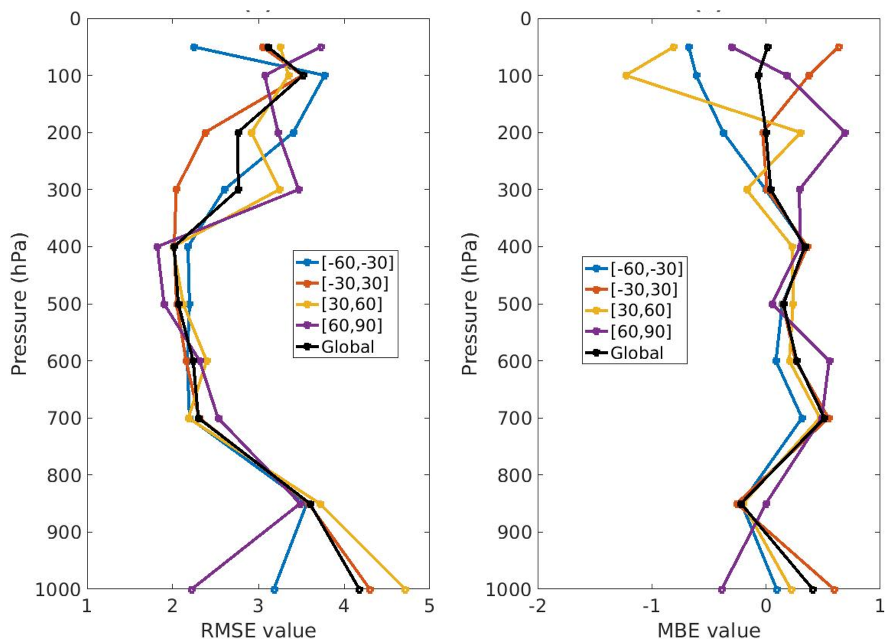


Figure 1: *Preliminary v2016 validation using 2013-2014 COSMIC2013 and RS92 temperature data, comparing global summaries with latitudinal bands.*

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 a manuscript on validation of full time series and initial analysis.
- Continue collaborations with user groups (including ISCCP and NASA's Surface Radiation Budget Team).

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**

Scientific data stewardship for digital environmental data products	
Task Leader:	Ge Peng
Task Code	NC-CDR/SDS-08-NCICS-GP
NOAA Sponsor	Kenneth Casey
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: The data stewardship maturity matrix (DSMM) has been applied to more than 800 individual NCEI datasets: 300+ of those DSMM assessment ratings have already been captured by ISO standard collection-level metadata and used by the new NOAA OneStop Search and Discovery system for relevancy ranking and 300+ more are to be integrated.

Background

U.S. governmental directives, e.g., Information Quality Act of 2001 and Federal Information Security Management Act of 2002, and expert bodies recommendations require that environmental data be (Peng 2018):

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

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 Data Stewardship Division, and NCEI Center for Weather and Climate, a consistent framework, the Data Set Maturity Matrix (DSMM), has been applied to over 800 individual datasets 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

Supported the OneStop program application of DSMM and coordinated the development of a data use/service maturity matrix.
Communicated with community to increase the awareness of DSMM and of consistently curating data quality descriptive information for both human and machine end-users.
Organized/co-chaired several conference sessions, and lead/co-authored several conference presentations on systematically curating and presenting data quality information to users.
Lead/co-lead online publications to provide DSMM resources for users.

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, pending travel approval.

Publications

Peer-reviewed

Ramapriyan, H., **G. Peng**, D. Moroni, C.-L. Shie, 2017: Ensuring and Improving Information Quality for Earth Science Data and Products. *D.-Lib Magazine,* **23**. doi:10.1045/july2017-ramapriyan

Peng, G., 2018: The State of Assessing Data Stewardship Maturity – An Overview. *Data Science Journal*, **17**.

Non-peer-reviewed

Peng, G., 2017a: Getting to know and to use DSMM. *Figshare*. Version: 25 August 2017. doi:10.6084/m9.figshare.5346343

Lemieux, P., **G. Peng**, D.J. Scott, Donna J, 2017: Data Stewardship Maturity Report for NOAA Climate Data Record (CDR) of Passive Microwave Sea Ice Concentration, Version 2. *Figshare*. Version: 8 July 2017. doi:10.6084/m9.figshare.5279932

Presentations

Moroni, D., H. Ramapriyan, and **G. Peng**, 2017: A Platform to provide international and inter-agency support for data and information quality solutions and best practices. *International Ocean Vector Winds Science Team Meeting*, San Diego, CA, May 3, 2017.

Moroni, D., **G. Peng,** and H. Ramapriyan, 2017: Scientific quality – Plenary Panel. *Earth Science Information Partner (ESIP) 2017 Summer Meeting,* Bloomington, IN, July 26, 2017.

Moroni, D. F., H. Ramapriyan, **G. Peng**, and Y. Wei, 2017: Information Quality as a Foundation for User Trustworthiness of Earth Science Data. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.

Moroni, D., **G. Peng**, and H. Ramapriyan, 2018: Formulation of a White Paper on Earth Science Data Uncertainty. *Earth Science Information Partner (ESIP) 2018 Winter Meeting*, Bethesda, MD, January 11, 2018.

Moroni, D., H. Ramapriyan, **G. Peng**, and Y. Wei, 2018: OD24A-2726: The multi-dimensionality of oceanographic data's information quality: Prompting transparency, reproducibility and scientific integrity. *2018 Ocean Science Meeting*, Portland, OR, February 13, 2018.

Peng, G., 2017: Data Stewardship Maturity Matrix – Introduction and Application. *Library of Congress Annual Digital Preservation - DSA Meeting*, Washington, DC, September 18, 2017.

Peng, G., 2017: Towards consistent and citable data quality descriptive information for end-users. *2017 Earth Science Information Partners (ESIP) Federation Summer Meeting*, Bloomington, IN, July 26, 2017.

Peng, G., 2018: Data Stewardship Maturity Matrix - Application Update. *Earth Science Information Partner (ESIP) Winter Meeting*, Bethesda, MD, January 11, 2018.

Peng, G., 2018: ESIP Information Quality Cluster - Fostering collaborations in managing Earth Science Data Quality. *Research Data Alliance (RDA) Europe*, January 15, 2018.

Peng, G., N. Ritchey, An. Milan, S. Zinn, K.S. Casey, D. Neufeld, P. Lemieux, R. Ionin, R. Partee, D. Collins, J. Shapiro, A. Rosenberg, T. Jaensch, and P. Jones, 2017: Towards Consistent and Citable Data Quality Descriptive Information for End-Users. 2017 *DataONE User Group Meeting*, Bloomington, IN, July 24, 2017.

Other

- External reviewer for Data Science Journal and Library High Tech.
- Reviewed the CEOS WGISS Data Management and Stewardship Maturity Matrix.
- Reviewed GEOSS Implementation Guidelines for Data Sharing Principles and Data Management Principles.
- Co-convener, Co-Chair, or moderator of five ESIP conference sessions.

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	**14**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Regional Variability of Sea Ice Coverage	
Task Leader:	Ge Peng
Task Code	NC-CDR/SDS-09-NCICS-GP
NOAA Sponsor	Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities:	Arctic

Highlight: Temporal and spatial variability of Arctic sea ice coverage and sensitivity of their trends and statistical projections were examined. Long-term, consistent time series of monthly sea ice area and extents were computed for the period of 1979-2015. For the Arctic as a whole, the analysis found significant changes in both annual SIE maximum and minimum.

Background

There has been an observed 49% sea ice reduction in extent and 80% in volume from the late 1970s through 2012. With rapid and accelerated Arctic sea ice coverage depletion, it is critical to examine the historical change and continue monitoring the current sea ice state to understand the vulnerability, and to provide reliable projections for climate adaptation and risk mitigation. To help put these changes in historical perspective, it is useful to baseline long-term sea ice state from a consistent, inter-calibrated, long-term time series of sea ice. Spatial sea ice variability may lead to a large spread in climate model sea ice projections and therefore induces a high level of uncertainty on regional scales. It is also beneficial to baseline the regional temporal and spatial variability. Regional temporal variability of Arctic sea ice coverage and its decadal trends are examined for 15 sub-regions (see Figure 1) with the implication of spatial variability, using a passive microwave sea ice concentration climate data record (CDR) dataset for the period of 1979-2015. The sensitivity of Arctic sea ice extents to time average methods and intervals and the sensitivity of extent projections by six commonly used statistical curve fitting methods have been examined.

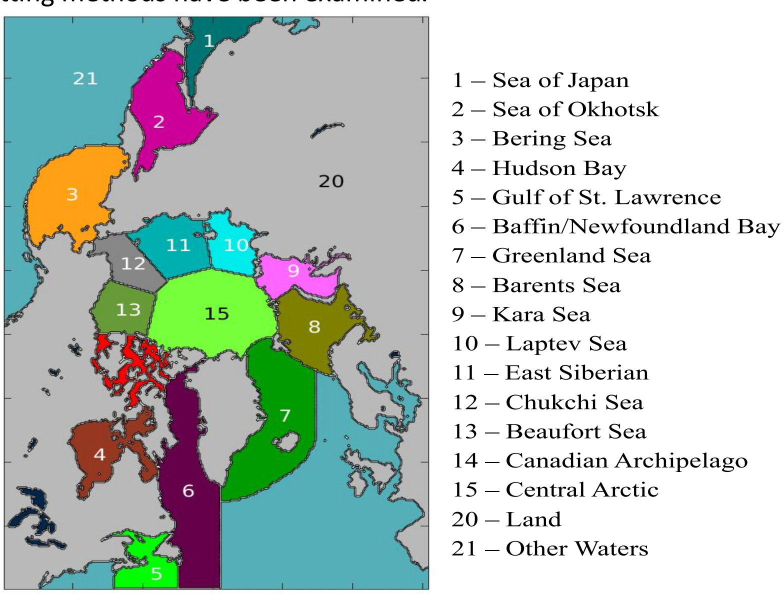


***Figure 1**: Location map of sub-regions in Arctic.*

Accomplishments

The regional and temporal variability of Arctic sea ice extents and their trends were captured in a peer-review paper published by *Annals of Glaciology* (Peng and Meier, 2017) and baselined in a conference poster (Peng et al., 2017). For the Arctic as a whole, the analysis found significant changes in both annual SIE maximum and minimum, with -2.41±0.56 % per decade and -13.5±2.93 % per decade change relative to the 1979–2015 climate average, respectively. On the regional scale, the calculated trends for the annual SIE maximum range from +2.48 to -10.8 % decade^{-1} while the trends for the annual SIE minimum range from 0 to up to -42 % decade^{-1}.

The sensitivity of temporal averaging methods and intervals was examined. The sensitivity of decadal annual SIE maximum/minimum trends to different temporal averaging methods and intervals was found to be less than 6.67%/1.04%, respectively, relative to those derived from the original daily SIE time series (Peng et al., 2018).

The sensitivity of six commonly used statistical curve fitting methods to different record periods has been examined and the results demonstrated that none of the six methods are superior in all analyzed time periods. The most persistently probable curve-fit model from all the methods examined appears to be Gompertz, even if it is not the best of the subset for all analyzed time periods. The first ice-free Arctic summer year (FIASY) projections based on the fittings from these six models are converging to the time frame of 2037 ± 6 but with a spread of 17 years, with the earliest first FIASY projected at 2031 (Peng et al., 2018).

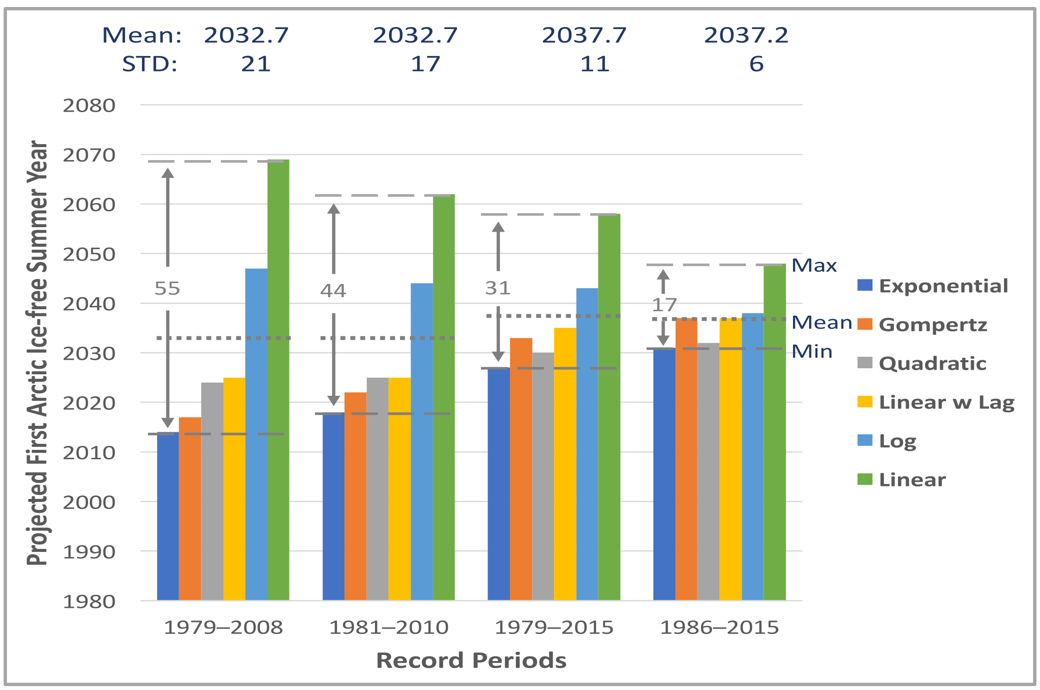


Figure 2*: The projected first ice-free Arctic summer year (FIASY) by six commonly used statistical models grouped by time domain of calibration: the first 30 years (1979–2008), the climate normal period (1980–2010), the whole record period (1979–2015), and the last 30 years (1986–2015), respectively. The long-dashed lines denote the minimum and maximum of the projections for each record period. The short-dashed lines denote the mean of the projections for each record period. The values bounded by solid arrow lines denote the spread of the projections. The means and standard deviations of the projected FIASY for each time period are noted at the top of the graph.*

Planned work

- Compare sea ice climate normal products derived from the NOAA/NSIDC sea ice concentration CDR with other existing products such as those generated by NSIDC to establish and improve their accuracy and precision.
- Prepare a manuscript for submission to a peer-reviewed journal.
- Support the integration of the sea ice normal products into NCEI climate monitoring as experimental regional sea ice monitoring products.

Publications

Peng, G., J.L. Matthews, and J.T. Yu, 2018: Sensitivity Analysis of Arctic Sea Ice Extent Trends and Statistical Projections Using Satellite Data. *Remote Sensing*. ***10***(2), 230. doi:10.3390/rs10020230

Peng, G. and W.N. Meier, 2017: Temporal and spatial variability of Arctic sea ice coverage from Satellite data. *Annals of Glaciology.* doi:10.1017/aog.2017.32

Presentations

Peng, G., 2017: Temporal and Regional Variability of Arctic Sea Ice Extent from Satellite Data. *CICS Science Conference*, College Park, MD, November 7, 2017.

Peng, G., W.N. Meier, A. Bliss, M. Steele, and S. Dickinson, 2017: Spatial and Temporal Means and Variability of Arctic Sea Ice Climate Indicators from Satellite Data. 2017 *AGU Fall Meeting*, December 12, 2017, New Orleans, LA. https://doi.org/10.6084/m9.figshare.5613613

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**2**
# of NOAA technical reports	**0**
# of presentations	**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-10-NCICS-OP
NOAA Sponsor	Brian Nelson
NOAA Office	NESDIS/NCEI/CWC
Contribution to CICS Research Themes	Theme 1: 50%; Theme 2: 50%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: The project team conducted a long-term assessment of the different satellite-based precipitation products from 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/MHS Hydrological 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/MHS Hydro-bundle is a 15-year record of rain rate over land and ocean, snow cover and surface temperature over land, and sea ice concentration, cloud liquid water, and total precipitable water over ocean among others. The different satellite-based QPEs are evaluated over the concurrent period. The products' 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 US Climate Reference Network (USCRN).

Accomplishments

The evaluation of the different satellite precipitation REDRs was extended at the daily scale with a focus on extreme events (top percentiles). One of the challenges in validating satellite precipitation products at the daily scale with in-situ data is that the gauge reporting time (as a function of the location) doesn't match the satellite daily accumulation (0Z-0Z). To alleviate this limitation, we used hourly data from USCRN and computed daily totals for the same duration. Figure 1 displays the distributions (and associated CDFs) of daily rainfall as derived by the satellite and the USCRN stations for concurrent events. Results indicate that CMORPH performs better in capturing daily extremes. However, it tends to overestimate the light rainfall portion of the spectra. On the other hand, PERSIANN-CDR tends to underestimate the top 99th percentile due to the fact that it is monthly bias-corrected with GPCP which has a lower resolution.

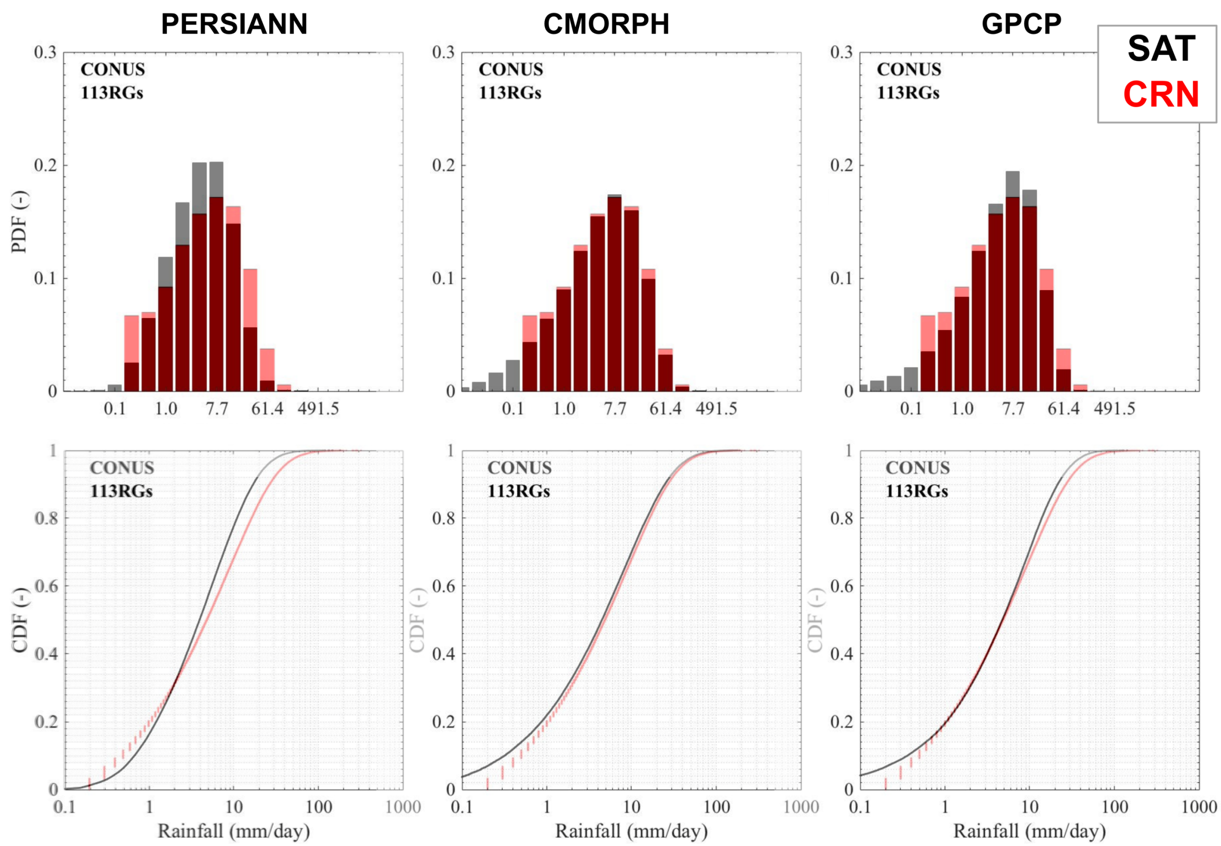


Figure 1: *Distribution (top row) and CDF (bottom row) of daily rainfall derived from each satellite REDRs (PERSIANN, CMORPH, GPCP) compared with USCRN daily rainfall computed using the hourly accumulations to match the satellites' daily totals (0Z-0Z). The distributions are for concurrent events for the period 2007-2016. The comparison with USCRN makes it possible to compare the same daily total as the satellites products regardless of the gauge time reporting (GHCN-Daily).*

We performed the evaluation of the AMSU/MHS Hydro-Bundle, which unlike the other REDRs is a satellite-only product. In addition to providing further hydro-climatic variables beyond precipitation, the combination of multiple satellites provides a better diurnal cycle sampling. Figure 2 presents a comparison of annual daily-averaged rainfall derived from the AMSU/MHS Hydro-Bundle at 1-deg resolution. The Hydro-Bundle combines precipitation estimates from NOAA-15, NOAA-16, NOAA-17, NOAA-18, and MetOp-A depending on each satellite's launch date. Comparison with gauge-adjusted REDRs (GPCP, PERSIANN, CMORPH) shows that the AMSU/MHS Hydro-Bundle matches well other REDRs rainfall patterns. Higher totals are found for the AMSU/MHS Hydro-Bundle over Africa and Amazonia (Equatorial belt), along the Gulf Stream and the Kuroshio Current when compared to other REDRs. Comparison at the monthly scale similarly indicates comparable rainfall patterns between the AMSU/MHS Hydro-Bundle and the other REDRs (not shown). For the month of January, we found a better agreement over the zones of higher rainfall (Equatorial belt, Gulf Stream) with the other REDRs. For the month of July, we found a higher monthly accumulation over the central US as a possible effect of summer time convection over the Great Plains. Because it is a MW satellite-only product, rainfall biases are expected when compared to the other REDRs (PERSIANN, GPCP, CMORPH). The AMSU/MHS Hydro-Bundle REDR is particularly useful for blended product development (e.g. NASA GPM, CMORPH) because it is possible to differentiate between precipitation phases (rain/snow, snow cover).

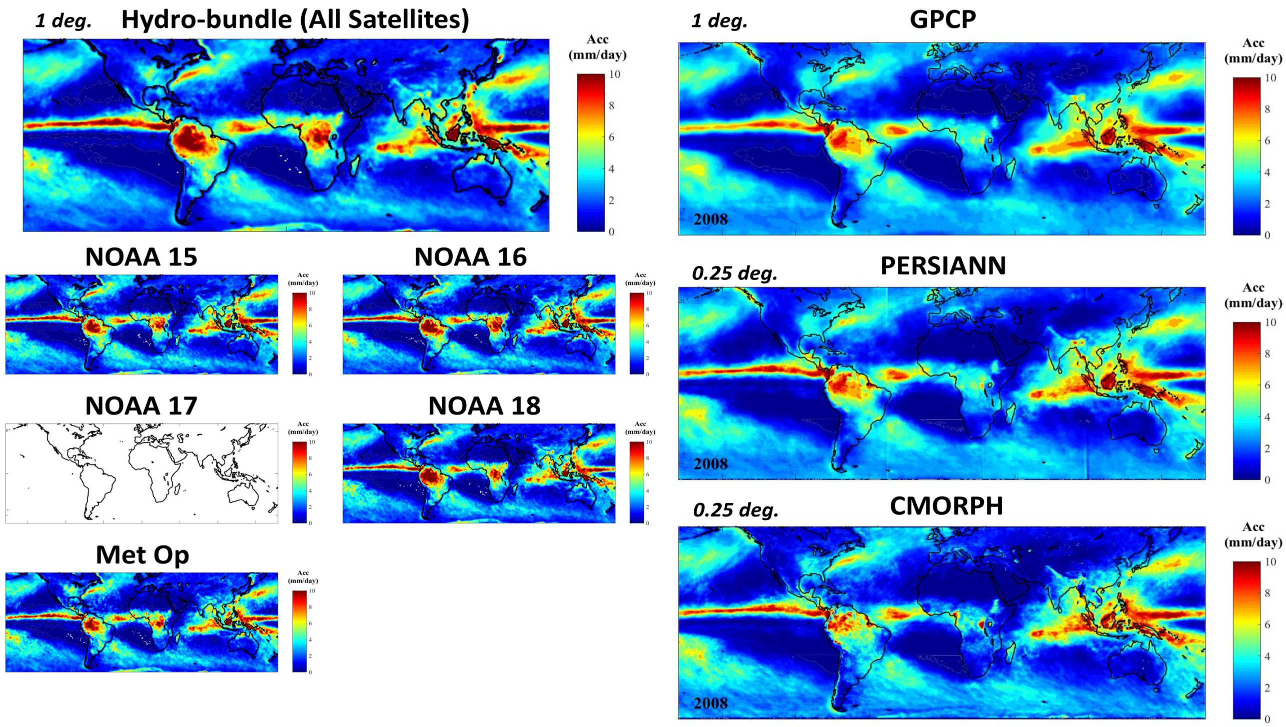


Figure 2: *Annual precipitation derived from the AMSU/MHS Hydrological Bundle for the year 2008 (top left column). Precipitation estimates from NOAA satellite constellation are shown in the smaller figures (bottom left column). NOAA 17 availability is limited (2002-2003) due to a sensor failure resulting from a solar storm.*

We mentored four undergraduate students participating in a 10-week NOAA Hollings Scholar or NASA DEVELOP Program internship. The first project used the PERSIANN-CDR dataset to analyze long-term tropical cyclone rainfall. The second project evaluated the application of different satellite precipitation products (IMERG, TMPA, PERSIANN-CDR) to capture extreme precipitation with a focus on recent extreme events that impacted the Carolinas (October 2015 North America Storm, Hurricane Matthew).

Planned work

- Finalize a manuscript on the evaluation of the precipitation REDRs (CMORPH, PERSIANN, GPCP).
- Finalize a manuscript on the evaluation of AMSU/MHS Hydro-Bundle (co-author).
- Finalize a book chapter on "Satellite precipitation measurement and extreme rainfall" as part of the book, *Satellite Precipitation Measurement* (Springer, Editor in Chief: Vincenzo Levizzani).

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.

Presentations

Prat, O.P., 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*, Asheville, NC, June 26, 2017.

Prat, O. P., B. R. Nelson, E. Nickl, and R. R. Ferraro, 2017: Evaluation of daily extreme precipitation derived from long-term global satellite Quantitative Precipitation Estimates (QPEs). *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.

Nelson, B. R., **O. P. Prat**, and **R. D. Leeper**, 2017: Use of NEXRAD radar-based observations for quality control of in-situ rain gauge measurements. *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.

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

Toward Earlier Drought Detection Using Remotely Sensed Precipitation Data from the Reference Environmental Data Record (REDR) CMORPH

Task Leader/Task Team:	Olivier Prat, Ronald Leeper, Jesse Bell
Task Code	NC-CDR/SDS-11-NCICS-OP/RL/JB
NOAA Sponsor	Steve Ansari
NOAA Office	NIDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: The feasibility of using satellite precipitation data from the REDR program (CMORPH) to detect and monitor drought on a global scale is being investigated with a focus on the implementation of the drought indices and their evaluation over CONUS.

Background

Satellite precipitation data from the REDR program (CMORPH-CDR) is being utilized to detect and monitor drought on a global scale. Precipitation data is used to compute the Standardized Precipitation Index (SPI) and their evaluation over the continental United States. In order to evaluate the relevance of using satellite data for the purpose of early drought detection and drought monitoring, several scenarios have been tested using the rain-gauge adjusted version of the satellite QPE, the near real-time version of the satellite QPE, and a mixed combination of gauge-adjusted and near real-time versions of the satellite QPE. The drought indices are evaluated over CONUS for which numerous in-situ data as well as drought products exist. In particular, the difference between indices obtained with the corrected (CMORPH-CDR) and near real-time (CMORPH-RAW) versions of CMORPH is evaluated. Additionally, showcases of selected severe drought events are used for validation. The four droughts episodes (the 1998-2004 western US drought, the 2006-2007 SE US drought, the 2010-2012 Texas-Mexican drought over the Southern Plains, and the 2012 summer Midwestern US drought) are the drought testbeds selected as case studies to assess the capabilities of drought products to monitor and predict as defined by the Drought Task Force (DTF) Protocol released on April 2013. Those drought episodes which influenced the development of the NIDIS early warning system are all within the period of record of the CMORPH-CDR dataset (1998-present). Following the assessment metrics in the DTF Protocol, the SPI products are evaluated on the basis of their ability to estimate the onset and recovery, duration and severity, probability of drought condition, and the value given at the observed period. Finally, we plan on developing an interactive visualization tool that will allow easy comparison of the results for the selected drought events.

Accomplishments

The Drought Group ingested and developed algorithms for the implementation of the drought indices (SPI) using the CMORPH precipitation data sets. Preliminary runs provided for short and long-term SPI (1-month, 3-month, 6-month, 9-month, 12-month, 24-month) derived from raw CMORPH and bias adjusted CMORPH. The different SPI are computed on a monthly basis. Figure 1 displays the comparison for SPI indices (1-month and 6-month) for selected months. Results show that SPI indices obtained using raw/bias-adjusted satellite QPEs present similar patterns with some noticeable quantitative differences.

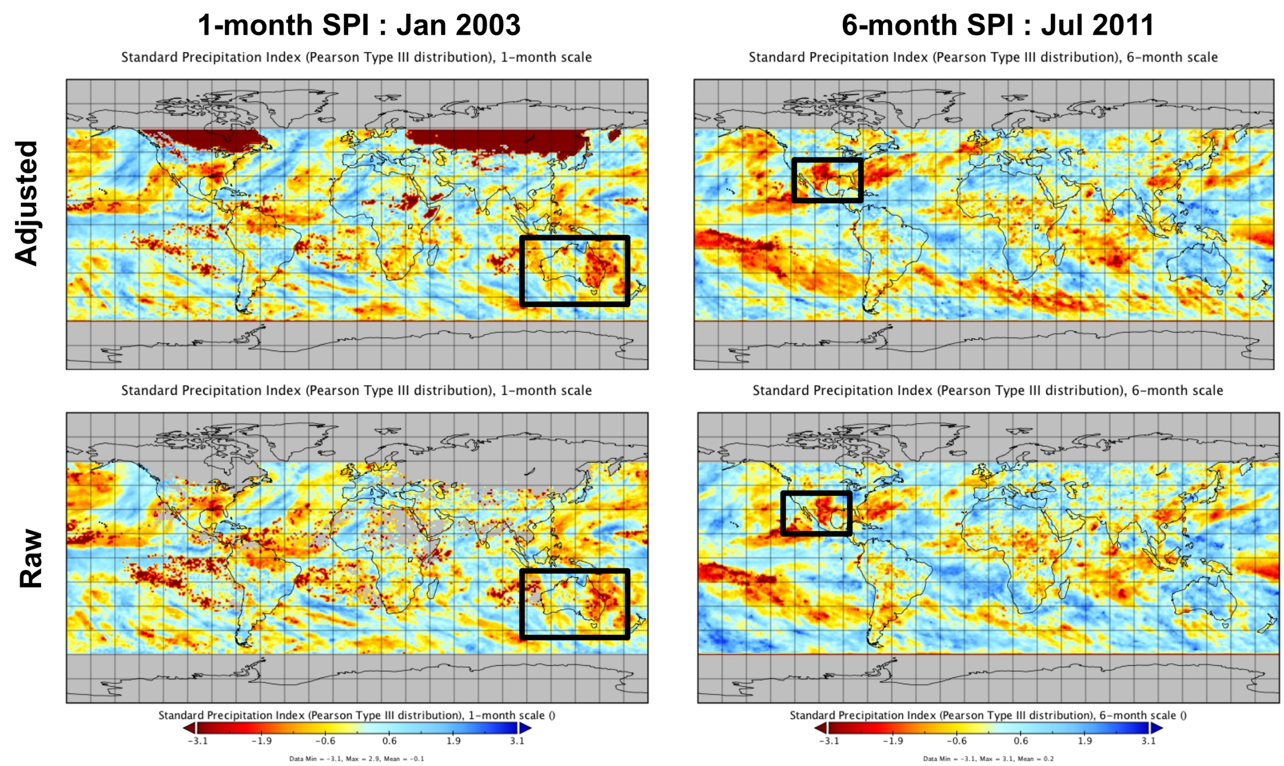


Figure 1: *SPI indices (1-month and 6-month) derived from bias-adjusted CMORPH (top row) and uncorrected CMORPH (bottom row). The boxes focus on the 2000s Australian drought (left column) and the 2010–13 Southern United States and Mexico drought (right column).*

From the monthly-based SPI, the current work consists of computing SPI indices on a daily basis. Different scenarios will be tested that will use: (1) the corrected version of the CMORPH satellite product for the full period of record; (2) the uncorrected version of the CMORPH satellite product for the full period of record; and (3) a combination of the corrected version of the CMORPH satellite product for the period of record from the beginning and up to 3-months prior to any given date and the uncorrected version of the CMORPH satellite product for the 3-months prior to any given date. Results will be compared against SPI computed from in-situ data.

Planned work

- Finalize the implementation of the short and long-term SPI (updated daily).
- Perform an evaluation of the short and long-term SPI.
- Analyze results for selected North American droughts (1998-2004 Western-US, 2006-2007 Southeast-US, 2010- 2012 TEX-MEX, 2012 Midwest-US).
- Develop an interactive visualization tool that displays comparison results by overlaying traditional in-situ drought indexes with SPI derived from CMORPH CDR data sets.
- Draft and submit a manuscript to a peer-reviewed journal.
- Project presentation at the *2018 EGU General Assembly (April 2018)*.

Products

Short and long-term SPI updated daily to be used for drought detection and monitoring.

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

Identifying Tropical Variability with CDRs	
Task Leader:	Carl Schreck
Task Code	NC-CDR/SDS-12-NCICS-CS
NOAA Sponsor	Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: CICS-NC and UNC-Asheville co-hosted a *Workshop on Global Tropical Cyclone Reanalysis* at The Collider in May 2017 to discuss how to address the challenges posed by discrepancies in the historical tropical cyclone record. 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 sector pay particular attention to these modes, harnessing their long time-scales and global impacts to anticipate energy demand in the United States. Climate Data Records (CDRs) play a key role in the identification and forecasting of these modes. This project endeavors to develop new diagnostics for tracking tropical modes using CDRs.

Accomplishments

Climate data records have become a key resource for the annual State of the Climate report, particularly in the "Tropics" chapter. Figure 1 pairs the Optimum Interpolated Sea Surface Temperature (OI-SST) with the recently developed provisional version of the International Best Track Archive for Climate Stewardship (IBTrACS). Scientifically, this figure provides a nice overview of tropical cyclone activity for 2017 and the conditions within which it occurred. From a stewardship perspective, generating this figure also provided a valuable test case for the new version of IBTrACS. Many omissions and issues with the data were discovered and addressed.

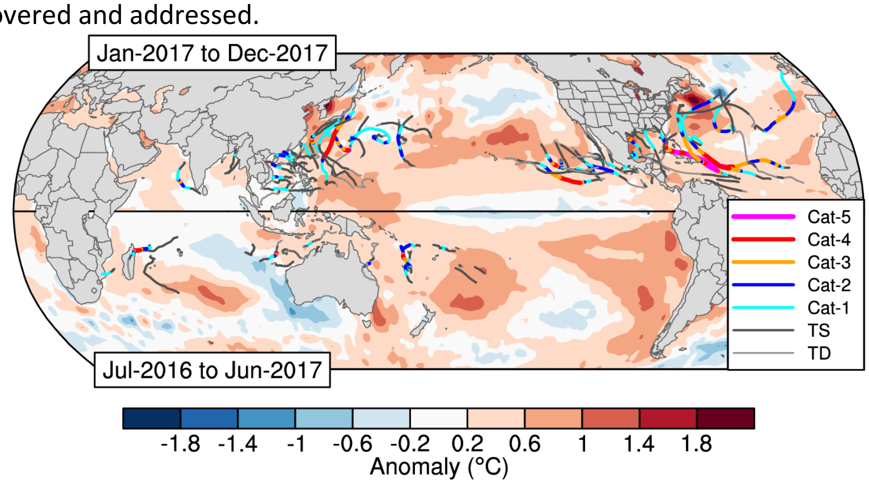


***Figure 1**. Global summary of TC Tracks for the 2017 TC season overlaid on the associated OISST anomalies relative to 1982–2010.*

Historical tropical cyclone activity is described by the “best track” datasets produced by forecast agencies after each season. These data describe the location, intensity, and sometimes size and shape of the storm based on all available data at a given time. Variations in observing platforms and operational practices can lead to discrepancies in time and space. In some basins, differences between agencies can even lead to disagreements about the same storms. These produce large uncertainties in the climatologies of tropical cyclones and particularly in evaluating the effects of climate change on them. A *Workshop on Global Tropical Cyclone Reanalysis* was co-hosted by CICS-NC and UNC-Asheville at The Collider 22-23 May 2017 to discuss these challenges. The consensus outcome was a desire to seek funding from scientific agencies and the private sector, particularly the reinsurance industry, to fund a global reanalysis of best track data.

Climate variability of water vapor is a key issue both for understanding the hydrologic cycle and also the associated radiative forcing. Two commonly used satellite-based datasets sense upper tropospheric humidity (UTH) and total column water vapor (TCWV), respectively. The latter is more sensitive to variations in the lower troposphere where water vapor concentrations are largest. A manuscript in preparation looks at how these two datasets describe different aspects of climate variability and teleconnections. Figure 2, for example, shows their correlations with ENSO. TCWV is more sensitive to variations in convection in the equatorial Pacific while UTH responds more the compensating subsidence in the subtropics.

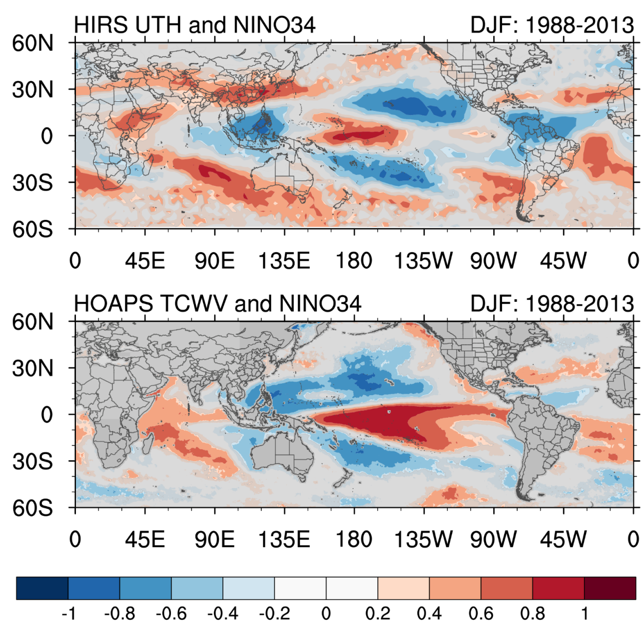


Figure 2. *Correlations between Niño 3.4 index and HIRS UTH (upper panel) and between Niño 3.4 index and HOAPS TCWV (lower panel) for DJF. Gray shading masks the correlations that are not statistically significant at the 95% level.*

Planned work

- Continue using CDRs to support the annual State of the Climate report.
- Submit a manuscript to the special issue on “Satellite Climate Data Records and Applications” in the journal *Remote Sensing*. This manuscript will compare the CDR of outgoing longwave radiation with previous versions.

- Submit manuscript comparing tropical variability and teleconnections of CDR of upper tropospheric humidity with another satellite dataset of total column water vapor.

Publications

Diamond, H. J., and **C. J. Schreck**, eds., 2017: The tropics [in "State of the Climate in 2016"]. *Bulletin of the American Meteorological Society*, **98**, S93-S128. doi:10.1175/2017BAMSStateoftheClimate.1.

Emanuel, K., P. Caroff, S. Delgado, C. C. Guard, M. Guishard, C. Hennon, J. Knaff, K. R. Knapp, J. Kossin, **C. Schreck**, C. Velden, and J. Vigh, 2017: On the Desirability and Feasibility of a Global Reanalysis of Tropical Cyclones. *Bulletin of the American Meteorological Society*, **99**, 427-429. doi:10.1175/BAMS-D-17-0226.1.

Herring, S. C., N. Christadis, A. Hoell, **C. J. Schreck**, and P. A. Stott, eds., 2018: Explaining Extreme Events of 2016 from a Climate Perspective. *Bulletin of the American Meteorological Society*, **99**, S1-S157. doi:10.1175/BAMS-ExplainingExtremeEvents2016.1.

Semunegus, H., A. Mekonnen, and **C. J. Schreck, III**, 2017: Characterization of convective systems and their association with African easterly waves. *International Journal of Climatology*, **37**, 4486-4492. http://dx.doi.org/10.1002/joc.5085.

Schröder, M., and Coauthors [including **C. J. Schreck**], 2017: *GEWEX water vapor assessment (G-VAP)*. WCRP Report 16/2017; World Climate Research Programme (WCRP), Geneva, Switzerland, 216 pp.

Presentations

Schreck, C. J., Impacts of Western Pacific Uncertainties on the Global Climatology. *Workshop on Global Tropical Cyclone Reanalysis.* Asheville, NC, May 22, 2017.

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	5
# 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

ENSO Normals	
Task Leader/Task Team:	Carl Schreck and Anand Inamdar
Task Code	NC-CDR/SDS-13-NCICS-CS/AI
NOAA Sponsor	Imke Durre
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: Climate and Satellite Research and Applications 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 2: A Climate Ready Nation 100%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: A new methodology for identifying moderate and strong El Niño and La Niña events was developed and has been preliminarily applied to nClimGrid to identify typical conditions during each phase of ENSO.

Background

Climate normals have traditionally been calculated every decade or so as the average values over a long period of time, often 30 years. Such an approach assumes a stationary climate, so several so-called alternative normals have been recently introduced. These typically attempt to account for trends associated with global climate change by using a shorter averaging period, more frequent updates, and/or extrapolating the linear trend. While such approaches account for monotonic climate change, they fail to harness known interannual climate variability such as that associated with the El Niño-Southern Oscillation (ENSO). Similar to climate change, ENSO systematically alters the background state of the climate. These effects and their uncertainties are relatively well established, but they are not reflected in any readily available climate normals' datasets. This project seeks to fill that gap by developing normal for temperature and precipitation for the contiguous United States using nClimGrid, the Gridded 5km GHCN-Daily Temperature and Precipitation Dataset.

Accomplishments

A key component of this project is identifying the phase of ENSO during each calendar month. NOAA's Climate Prediction Center (CPC) uses the Oceanic Niño Index (ONI) for this purpose. They define El Niño as five consecutive months of ONI ≥ 0.5°C. La Niña is defined similarly for ONI ≤ −0.5°C. The challenge for our project is that ENSO has a marked annual cycle in which it is more active in boreal fall and winter and less active in spring and summer. Since CPC uses a fixed threshold, the number of ENSO events varies by season. We overcame this challenge by identifying thresholds for each of the 12 overlapping 3-month seasons using the percentiles of the ONI during that season. Weak events were identified using terciles, which roughly equate to CPC's 0.5°C during the winter. Meanwhile, stronger events were identified using the top and bottom one-sixth of the ONI record for a given season. During winter, this threshold was roughly 0.8°C, equivalent to the threshold used by Australia's Bureau of Meteorology. Figure 1 shows that the events identified with our methodology compare favorably with those from CPC, although our definition naturally extends the events farther into the spring and summer. Preliminary composites for these events (not shown) present reasonable but still scientifically interesting patterns.

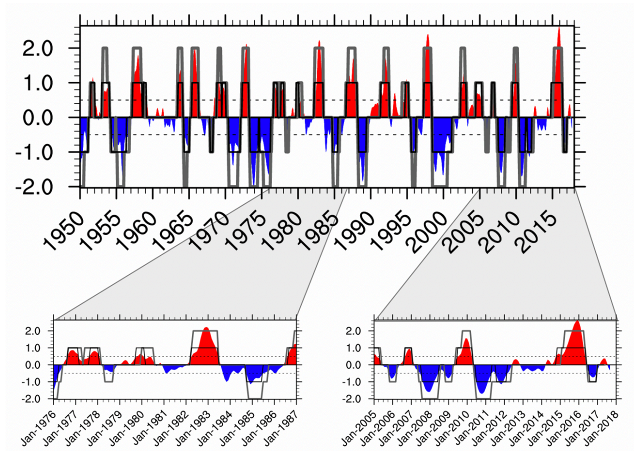


__Figure 1.__ Monthly ONI values (shading) along with events identified by either CPC (black lines) or our new percentile methodology (gray line). For the percentile method, shorter lines are weak events and taller ones are strong. The bottom two panels highlight events for which the two methods may differ.

Planned work

- Compute the normal for temperature and precipitation for all 12 months.
- Incorporate the component from secular climate change.
- Use composites of sea surface temperatures, outgoing longwave radiation, and dynamical fields to confirm the observed teleconnections.
- Submit the methodology and findings for publication.

Presentations

Schreck, C. J., III, 2017: Different Flavors of Normals: Accounting for ENSO and Climate Change. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 27, 2017.

Schreck, C. J., III, 2017: Different flavors of normals: Accounting for ENSO and climate change. *42nd NOAA Climate Diagnostics and Prediction Workshop*, Norman, OK, October 24, 2017.

Schreck, C. J., III, A. Arguez, **A. K. Inamdar**, A. H. Young, and M. Palecki, 2018: 118: Different Flavors of Normals: Accounting for ENSO and Climate Change. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.

Performance Metrics	
# of new or improved products developed that became operational	**0**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**3**
# 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 the aggregate carbon intensity. 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 impacts that are already occurring and how we can strategically adapt to these changing conditions.

Anticipated climatic changes, which vary regionally, can include more intense precipitation events, warmer temperatures, shorter snow seasons, and changes in growing seasons, among 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 to the changing environment.

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 support to NCEI activities 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 4: 20%
NOAA Strategic Research Priorities:	Scientific Outreach and Education

Highlight: CICS-NC conducted numerous engagement activities to reach various types of stakeholders in the areas of environmental data and information, climate change and variability, adaptation and mitigation, and interdisciplinary uses and applications of the information to inform decision-making as well as inspiring activities for innovation. *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 and observations and apply information in a decision-context and/or to build resilience. This in turn improves understanding of how environmental information is used in design, planning, engineering, operations, investments, etc. As the information exchange builds, the improved analytics on users, users' applications and needs help inform areas like advancement in scientific research, assessments, and 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 as 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 framing and analyzing the information exchange, innovative case studies, and building a network of experts in multiple disciplines that incorporate climate information in their respective context.

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, as well as providing ongoing operational support to NOAA and NCEI to advance their science and services capabilities.

Accomplishments
The past year's key accomplishment highlights are framed under the following areas:

- Providing operational support to NOAA NCEI CWC Information Services Division in 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 other public.

CICS-NC supports and advises NCEI CWC Climatic Information Services and Customer Engagement on strategic and operational stakeholder engagement activities and supports the NCEI CWC Climatic

Analysis and Synthesis Branch (CASB). Work effort and initiatives are primarily in building capabilities within NCEI information services, engagement with business and industry, support for the NOAA-Department of State interagency agreement, and other interdisciplinary activities that advance NCEI and NOAA mission goals with partners. Task Leader Jenny Dissen serves as the Product Lead for NCEI CWC sectoral engagement.

Dissen supported the successful implementation and transition activities of the NCEI CWC customer engagement solution, Salesforce. The solution was launched in fall 2017 with the primary access to customer representatives and select group of scientists and engagers across the Center. Current holding includes over 25,000 customer information entries with the ability to derive initial analytics based on customer type, type of environmental data downloaded, and case studies on uses and applications of the data.

Engagement activities in collaboration with NCICS and CASE Consultants International in the areas below were organized with the goal of reaching business and industry sectors as well as other public and NGO organizations. For NCEI, there were target sectors of opportunities, where NCICS or NCEI scientists were speakers and the engagement identified science or data needs that would be catalogued for NCEI requirements repository.

- Game Changing Resilient Infrastructure | June 22, 2017 | The Collider
- The Climate Resilience Grid | June 13 – 14, 2017 | The Collider (NCEI sponsored, CICS-NC lead; speakers included Jessica Matthews, Otis Brown, Jenny Dissen)
- Climate Wise Brownfields | June 13, 2017 | The Collider
- Climate and Respiratory Health – A Focus on Asthma | November 9, 2017 | The Collider (speakers included Ken Kunkel and Jesse Bell)
- ClimateCon |Mar 20, 2018| The Collider, Panel on the Foundational Role of Government in Climate Products and Services (included panelist Carl Schreck)

Figure 1: *Stephanie Herring at the Climate Resilient Grid.*

In collaboration with NCEI subcontractor GST, CICS-NC led engagement activities at the 2018 Annual American Meteorological Society: CICS-NC organized panel session on "Inspiring Engagement for Climate Resilience" (website) and organized NCEI led Town Hall on "Environmental Information for Resilience in Infrastructure (website).

Dissen reviewed NCEI sub-contractor work on the Value of the Data Stories, covering the following sectors: agriculture, transportation, reinsurance, drought, retail, and weather service providers. These case studies are part of NOAA NCEI website as success stories on user engagement (website).

Other interdisciplinary and innovative sectoral engagement activities include:

- Continued engagement and dialogue with Franklin Nutter, the President of Reinsurance Association of America which resulted in NOAA NCEI lead speaking role at the 2018 Cat Modeling Risk Conference in Orlando, FL.
- NCICS special topics seminar hosted by Dane Ratliff on "The Intersection of Climate Science and Law/Policy – Climate Induced Displacement."

Dissen supported the internal NOAA review of the USGCRP National Climate Assessment 4 Chapter on Energy Supply, Delivery and Demand, and currently serves on the NOAA Energy Team.

Engagement with the NCEI Climatic Analysis and Synthesis Branch

CICS-NC led the development and coordination of two follow up workshops, as part of the NOAA/ Department of State interagency agreement on U.S.-India Partnership for Climate Resilience:

1. In partnership with The Energy Resource Institute (TERI India), convened a workshop on high resolution climate modeling to target academics, policy makers and India State Action Planners on Climate Change on February 9, 2018 (TERI website). Nearly 100+ participants engaged in a hands-on exercise to downscale climate information for India and prepared presentations for use in their respective organizations that portrayed future climate for the Indian subcontinent.
2. In collaboration with the Institute for Tropical Meteorology Pune (IITM- Pune), U.S. Department of State, and NOAA NCEI, convened a workshop with the Environmental Protection Training Research Institute (EPTRI) on high resolution climate modelling and analysis techniques in India to help inform decision making across various state action planning and other sectors. Workshop was held February 12th-13th 2018 at the EPTRI campus, Hyderabad (EPTRI website).
3. Additional details from the workshops will be posted on the NCICS website here.

Figure 2: *Participants and India State Action Planners at the EPTRI workshop, Hyderabad, India.*

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. The past year's outreach activities included the following:

- 4/3/17: Black Mountain Elementary School, Black Mountain, NC. Carl Schreck presented information on hurricanes, the jet stream, the Gulf Stream, and ENSO to ~110 5th graders.

- 4/8/17: Western North Carolina Science Fest, Asheville, NC. CICS-NC team members helped plan and supported NCEI's exhibit booth.
- 5/18/17: Claxton Elementary Science Inquiry Symposium, Asheville, NC. Carl Schreck talked to 5th grade students about their weather and climate science fair presentations.
- 6/23/17: PercCollider: 2017 Eclipse Viewability Web Application, Asheville, NC. CICS-NC staff demonstrated the Eclipse track web application to an audience of ≈50 and gave interviews to *The New York Times* and the *Palm Beach Post*.
- 8/21/17: Asheville Museum of Science (AMOS) Solar Eclipse Festival, Asheville, NC. CICS-NC team members supported and participated in the Solar Eclipse Festival.
- 8/21/17: Pisgah Astronomical Research Institute (PARI) Total Solar Eclipse event, Rosman, NC. CICS-NC team members helped plan and participated in the event activities.

International Business Times

Total Solar Eclipse Weather Forecast: Will Clouds Block Your View?

By Elana Glowatz @ElanaGlow
08/20/17 AT 9:00 AM

As if it wasn't enough of a bummer that the total solar eclipse on Aug. 21 will be limited to a relatively narrow band across the United States, leaving all the other schlubs to view just a partial eclipse, there might be something else getting in the way of our enjoyment: clouds.

The National Oceanic and Atmospheric Association has released a map that shows how cloudy that day has typically been through history, and it's not a pretty sight. While the western half of the U.S. looks like it might be clear enough on Monday, if past cloud coverage is any indication, the eastern half of the nation is pocked with dark circles, particularly in the Northeast.

Major cities are the ones showing the most coverage, according to an interactive map, which NOAA made in conjunction with the North Carolina Institute for Climate Studies. The darkest circles are concentrated over places like Minneapolis, Chicago, Detroit, Washington, D.C., New York City and Tampa.

Figure 3: *Example of Solar Eclipse Event Media Coverage.*

- 9/18/17: Emory University Rollins School of Public Health Global Climate Change: Health Impacts and Responses graduate course lecture, Atlanta, GA. Jesse Bell lectured on, "Climate Data and Climate Science."
- 9/23/17: North Carolina Arboretum ecoEXPLORE Lunch with a Scientist, Asheville, NC. Laura Stevens was an invited scientist and discussed weather and climate with ~25 K-8th grade students.
- 9/26/17: Asheville Museum of Science (AMOS) Seven Minutes of Science podcast, Asheville, NC. Carl Schreck was interviewed on hurricane formation.
- 9/30/17: Citizens' Climate Lobby Workshop, University of North Carolina Asheville, Asheville, NC. Scott Stevens served on a panel discussing climate change communication.
- 10/5/17: University of Nevada-Reno Perspectives on Western Hydroclimate graduate class webinar. Kenneth Kunkel presented, "Climate Science in the National Climate Assessment."
- 10/5/17: WLOS-TV Climate Change Round Table, Asheville, NC. Carl Schreck was a panelist for the discussion, "Climate Change: Causes, Impacts, & Solutions." *http://wlos.com/news/local/wlos-to-host-round-table-climate-change-causes-impacts-solutions*
- 10/9/17: Buncombe County Schools Professional Development Day, Asheville, NC. Carl Schreck taught climate change science to ~50 middle and high school teachers.
- 10/13/17: Owen Middle School, Swannanoa, NC. Jared Rennie spoke about weather and climate to ~160 7th graders.
- 10/17/17: STEM Teachers: From Western NC to India and Back into the Classroom, Asheville, NC. Jenny Dissen was an invited panelist for the Collider's discussion on applications of India STEM education findings.
- 10/24/17: SAMSI Education and Outreach Undergraduate Workshop, Research Triangle Park, NC. Jared Rennie and Scott Stevens were invited speakers; Rennie was a career opportunities

panelist and Rennie and Stevens presented, “How was this made?: making dirty data into something usable at NCEI” to an audience of ~50.

- 10/24/17: The Collider: Climate, Sustainability, and Chocolate, Asheville, NC. Scott Stevens was a panelist for a discussion on climate change effects on cacao harvesting and chocolate production.
- 11/7/17: Waynesville Middle School, Waynesville, NC. Jared Rennie spoke to ~40 6th graders about weather, climate, and coding.
- 11/14/17: American Mock World Health Organization (AMWHO) 2017 International Conference, Emory University, Atlanta, GA. Jesse Bell was an invited panelist for a discussion on Climate Change and the Global Health Response.
- 11/20/17: Clemson University Introduction to Mathematical Sciences class, Clemson, SC. Jessica Matthews gave an invited lecture, “What to expect in a nonacademic career” to ~60 students and informally discussed career-related questions with ~10 participants at an Association for Women in Mathematics (AWM) student chapter event.

Figure 4: *Jared Rennie at North Buncombe Elementary.*

- 11/21/17: North Buncombe Elementary School Career Day, Weaverville, NC. Jared Rennie gave two talks about weather instruments and CICS-NC to ~200 K-4 students.
- 11/29/17: Trinity Presbyterian Church, Hendersonville, NC. Carl Schreck gave a presentation, "Climate Change, Hurricanes, and North Carolina," to ~80 church members.
- 1/22/18: Christ School, Arden, NC. Jared Rennie presented “Coding Weather and Climate Data" to ~20 AP Computer Science students.
- 2/7-2/8/18: 2018 Region 8 Western Regional Science Fair, Western Carolina University, Cullowhee, NC. Jared Rennie, Carl Schreck, Laura Stevens, Scott Stevens, Tom Maycock, and Erika Wagner hosted an interactive exhibit for event participants (~60 3rd-5th grade and ~200 6th-12th grade students) and Schreck served as a project judge.
- 2/16/18: The Collider, Asheville, NC. Tom Maycock presented, “Climate Change and Human Health” to a visiting group of *East Tennessee State University* faculty and graduate students.
- 3/14/18: NC State University Water Resources Research Institute (WRRI) Annual Conference, Raleigh, NC. Jesse Bell served as a “Careers in Water Resources” panelist.
- 3/18/18: St. Mark’s Lutheran Church Ministry Fair, Asheville, NC. Carl Schreck talked to ~75 congregation members about “Caring for Creation.”
- 3/19/18: ClimateCon Summit for Emerging Climate Leaders, Asheville, NC. Scott Stevens presented “No Wrong Path” and Jared Rennie served as a judge for the Policy & Research Pitch Competition with ~150 in attendance.
- 3/20/18: ClimateCon Climate Solutions Showcase, Asheville, NC. CICS-NC/NCEI jointly hosted a climate data/research information table for ~150 participants.
- 3/23/18: Black Mountain Elementary School, Black Mountain, NC. Carl Schreck presented, “Hurricanes, the Jet Stream, and El Nino,” to ~120 5th grade students.

- 3/24/18: Citizens' Climate Lobby Southeast Regional Conference, Asheville, NC. Carl Schreck presented, "Climate change, zombies, and the southeast" to ~45 participants.

Planned Work

- Partner with local, regional and national relevant organizations and companies to host a series of engagement discussions on select sectors.
- Build the initiated engagement with the American Bar Association and the legal community on access to NCEI data, as well as case studies on uses for the legal industry.
- Develop sectoral themes in preparation for a NCEI Data Users Conference (in development).
- Develop additional user success stories on uses and applications targeting NCEI product areas.
- Continue to build stakeholder engagement in the use of Salesforce and generate targeted and meaningful analytics to portray customer engagement.
- Support the NCEI development of performance measures for information services and customer engagement.
- Continue support and engagement in adaptation-based workshops in India as part of the NOAA-DoS interagency agreement.
- BAMS publication on The Climate Resilient Grid.

Presentations

Dissen, J., 2017: The Role of Environmental Intelligence for the Energy Industry. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 26, 2017.

Dissen, J., D. R. Easterling, K. Kunkel, A. Kulkarni, F. H. Akhtar, K. Hayhoe, A. M. K. Stoner, R. Swaminathan, and B. L. Thrasher, 2017: Key Findings from the U.S.-India Partnership for Climate Resilience Workshop on Development and Application of Downscaling Climate Projections. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Dissen, J., 2018: Inspiring Engagement for Climate Resilience (session chair). *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

McGuirk, M., **J. Dissen**, and S. Herring, 2018: The Climate Resilient Grid: A Report on the Forum on Energy, Climate, and the Grid. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.

Other

• Mentored Kara Piarulli, NCSU Professional Sciences Master's program in Climate Change and Society.
• Mentoring Elijah Bird, Nesbitt Discovery Academy (high school), and candidate for NCSU or UNC.
• North Carolina School of Science and Mathematics Morganton Campus External Engagement Steering Team member (ncssm.edu).
• Strategic engagement activities for and with the Collider, Asheville based think-tank organization aiming at catalyzing innovative solutions in climate services (www.thecollider.org/).
• Strategic support for the Asheville Museum of Science and service on the Exhibit Committee (ashevillescience.org/).

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	2
# of presentations	4
# of graduate students supported by your CICS task	0
# of graduate students formally advised	0
# of undergraduate (high school) students mentored during the year	1

Outreach to Higher Education Institutions	
Task Leader:	Jessica Matthews
Task Code	NC-CLOEC-02-NCICS-JM
Other Sponsor	North Carolina State University (NCSU)
Contribution to CICS Research Themes	Theme 1: 50%; Theme 2: 50%
Main CICS Research Topic	Climate Literacy and Outreach
Contribution to NOAA goals	Climate Adaptation and Mitigation: 100%
NOAA Strategic Research Priorities:	Scientific Outreach and Education

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

Accomplishments

Distance Education Course development and delivery. Dr. Matthews taught the first offering of "Mathematics of Climate Science," a graduate level distance education course available to North Carolina State University (NCSU) students in the Fall 2017 semester. This new course was developed to satisfy the need for training graduate level researchers in how mathematics contributes to the study of the Earth's climate. The course was taught remotely from a key climate data hub, NOAA's National Centers for Environmental Information (NCEI) in Asheville, NC, through NCSU's North Carolina Institute for Climate Studies. This course, developed by Dr. Matthews in collaboration with NCSU Distance Education and Learning Technology Application (DELTA) staff under a competitive grant award, was the first NCSU graduate-level mathematics course offered in an online environment.

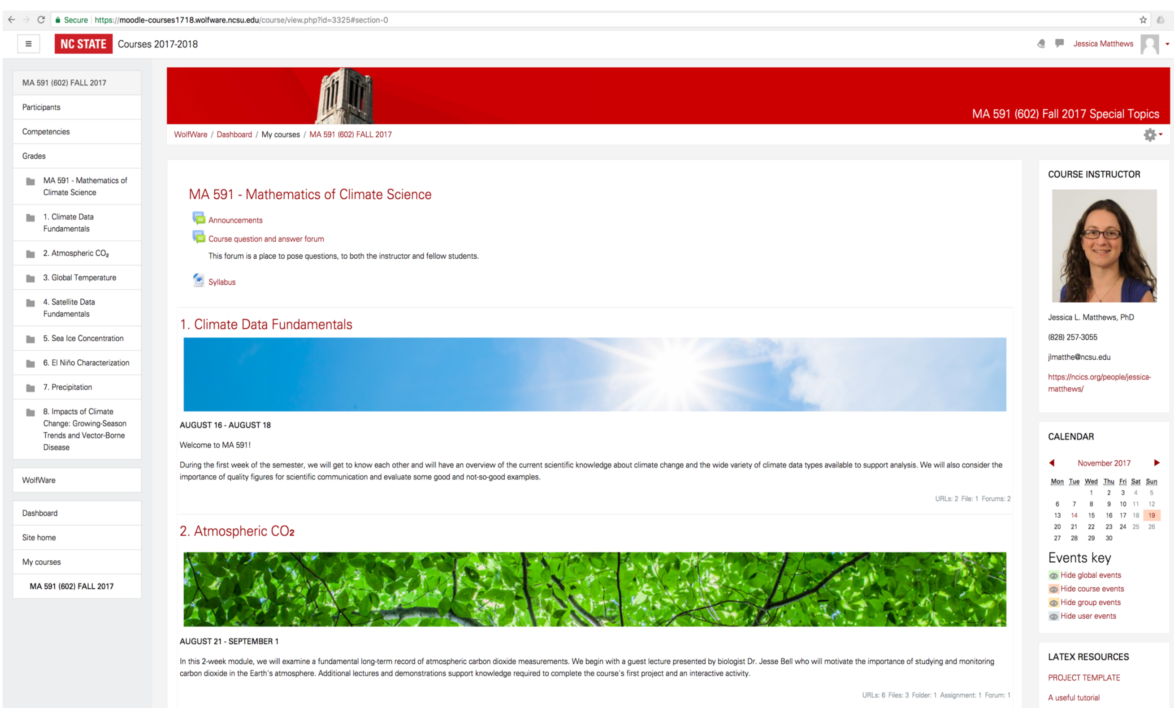


Figure 1: *The "Mathematics of Climate Science" course webpage.*

Course goals were to provide students with the opportunity to:

- Experience working with real data,

- Apply mathematical methods to climate-focused questions, and
- Explore important climatological data sets.

Course topics included climate and satellite data fundamentals, atmospheric carbon dioxide, global temperatures, sea ice concentration, El Niño characterization, precipitation, and impact of climate change in growing season trends and vector-borne diseases.

Speaking Engagements. Throughout the year, Dr. Matthews engaged with university students and faculty via a variety of mechanisms including giving several invited talks regionally. In June, she spoke with academic and industry representatives interested in leveraging climate data for energy system resiliency. In July, she met with academic statisticians from around the country at a targeted workshop on the "Theory of Data " at NASA's Jet Propulsion Laboratory. In November, she spoke to undergraduate and graduate students at Clemson University about career aspirations for applied mathematicians.

Other Activities. 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 currently supported through the National Science Foundation's Mathematical Sciences Institutes program. SAMSI's "Program on Mathematical and Statistical Methods for Climate and the Earth System" has been conducted during the 2017-18 academic year. This program brings 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. Dr. Matthews is co-leader of the working group focusing on Remote Sensing, and also leads a subgroup of researchers investigating optimization methodologies. As part of these activities she co-organized a workshop at the California Institute of Technology in February 2018: "Remote Sensing, Uncertainty Quantification and a Theory of Data Systems Workshop".

Planned work

- Invited keynote speaker for the 12th "UTK Undergraduate Math Conference" on April 21, 2018 at the University of Tennessee, Knoxville (http://www.math.utk.edu/UGConf/).
- Invited speaker at the Institute for Research on Statistics and its Applications 2018 conference at the University of Minnesota (http://irsa.dl.umn.edu/session/statistics-and-data-science-earth-systems).
- Organize a session at the SIAM Mathematics of Planet Earth 2018 conference on Remote Sensing research being done in the academic statistical and mathematical communities.
- Continue to engage with academic institutions as invited to speak and, as opportunities arise, mentor undergraduate and graduate students.

Presentations

Matthews, J., 2017: Next-generation Environmental Intelligence for the Solar Industry, *The Climate Resilient Grid: A Forum on Energy, Climate, and the Grid*, Asheville, NC, June 14-15, 2017.

Matthews, J., 2017: What to expect in a non-academic career. *"Introduction to Mathematical Sciences" class, Clemson University*, Clemson, SC, November 20, 2017.

Matthews, J., 2018: Optimization methods in Remote Sensing. *Remote Sensing, Uncertainty Quantification, and a Theory of Data Systems Workshop*, Pasadena, CA, February 12-14, 2018.

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

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 and Outreach
Contribution to NOAA goals	Goal 1: 100%
NOAA Strategic Research Priorities:	Scientific Outreach and Education

Highlight: CICS-NC communication activities raise Institute awareness and highlight accomplishments of the Institute and its staff for its stakeholders through web stories, press releases, social media, and outreach events and advance 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 with a primary focus on sharing research findings of CICS-NC scientists and their NCEI colleagues through web stories, press releases, social media, and outreach events. Other activities include working to improve the science communication capabilities of CICS-NC staff, such as editorial and graphic design support for papers and presentations. CICS-NC also provides science writing, editing, and graphic design support to NCEI's Communications and Outreach Branch. The Science Public Information Officer works to coordinate communication efforts between NCEI and CICS-NC.

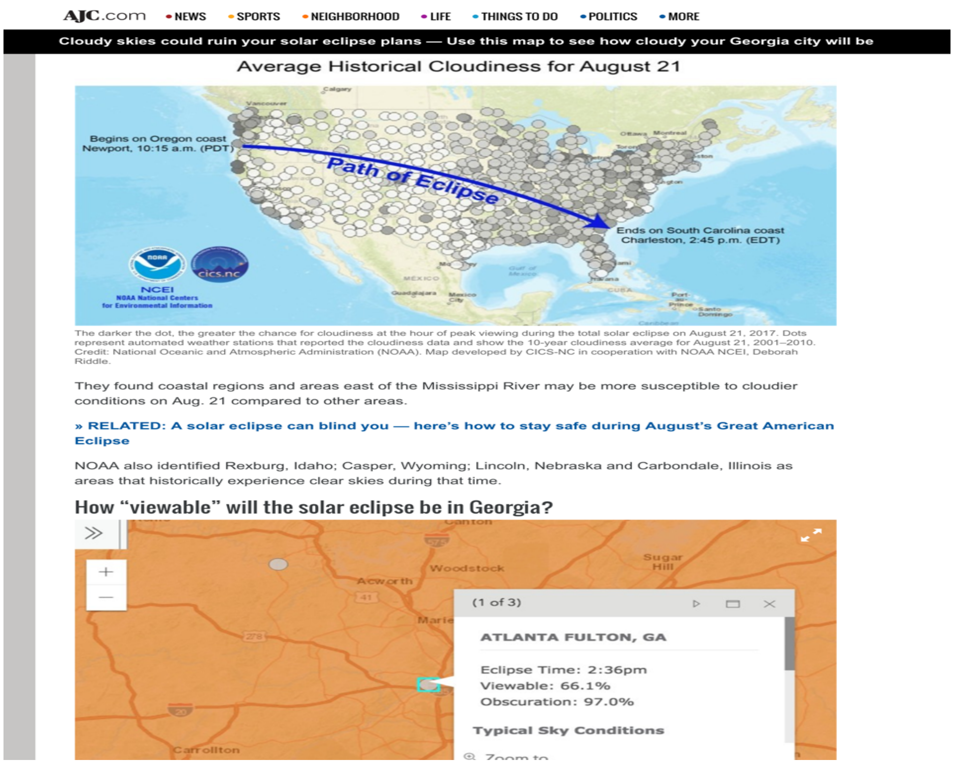
Accomplishments

2017 Solar Eclipse Activities. The most visible CICS-NC communications activity this year revolved around the August 21, 2017, total solar eclipse. Coordination between CICS-NC scientists and both NCEI and CICS-NC communication staff resulted in the production of an online GIS map of "eclipse viewability" that used station-based historical cloudiness data to project the likelihood of having clear skies for locations across the country at the time of the eclipse. Web stories and social media posts from NCEI and CICS-NC generated tremendous national interest and garnered media coverage in at least two dozen newspapers and other media outlets. The NCEI version of the web story received nearly 248,000 page views, more than any other NCEI web page in 2017.

Social Media Efforts. Another focus this year was building the audiences for the Institute's Facebook and Twitter social media platforms and leveraging those platforms to increase visibility of research and engagement activities. Results included a 19% growth in Facebook audience (to 634 followers) and a 33% growth in Twitter followers (to 343). Our most intensive social media effort was aimed at promoting the many presentations, posters, and other activities by Institute staff at the American Geophysical Union Fall Meeting and the Annual Meeting of the American Meteorological Society. Tweets for those two events resulted in more than 48,000 impressions and 80 clicks to accompanying web stories. Tweets highlighting a new research paper projecting possible dates of an ice-free Arctic generated another 10,000 impressions, with more than 80 users clicking through to read the web story.

Website. Nine news stories were posted to the Institute website, and work continued to build out content on the revamped Institute website, which was rolled out in October 2016. New content this year included new "Portfolio" pages providing access to new monitoring tools and highlighting our [contributions](#) to the U.S. Global Change Research Program Climate Science Special Report. We also added a [page providing easy access to NOAA data sets](#) offered by cloud providers as part of NOAA's Big Data Project.

Institute Newsletter and Video Display. Two editions of our *Trends* newsletter were produced as well as a video loop of slides featuring high-impact images and brief text descriptions that provides an attractive, snapshot view of most of the Institute's major ongoing activities and recent accomplishments.


AJC.com • NEWS • SPORTS • NEIGHBORHOOD • LIFE • THINGS TO DO • POLITICS • MORE

Cloudy skies could ruin your solar eclipse plans — Use this map to see how cloudy your Georgia city will be

Average Historical Cloudiness for August 21

The darker the dot, the greater the chance for cloudiness at the hour of peak viewing during the total solar eclipse on August 21, 2017. Dots represent automated weather stations that reported the cloudiness data and show the 10-year cloudiness average for August 21, 2001–2010. Credit: National Oceanic and Atmospheric Administration (NOAA). Map developed by CICS-NC in cooperation with NOAA NCEI, Deborah Riddle.

They found coastal regions and areas east of the Mississippi River may be more susceptible to cloudier conditions on Aug. 21 compared to other areas.

» RELATED: A solar eclipse can blind you — here's how to stay safe during August's Great American Eclipse

NOAA also identified Rexburg, Idaho; Casper, Wyoming; Lincoln, Nebraska and Carbondale, Illinois as areas that historically experience clear skies during that time.

How "viewable" will the solar eclipse be in Georgia?

Figure 1: *Web version of a July 26, 2017 story in the Atlanta Journal-Constitution featuring the CICS-NC/NOAA NCEI eclipse viewability map and online tool. Source:* [*https://www.ajc.com/news/local/cloudy-skies-could-ruin-your-solar-eclipse-plans-use-this-map-see-how-cloudy-your-georgia-city-will/w68xw6tkRp0lCGT2D8LO3N/*](https://www.ajc.com/news/local/cloudy-skies-could-ruin-your-solar-eclipse-plans-use-this-map-see-how-cloudy-your-georgia-city-will/w68xw6tkRp0lCGT2D8LO3N/)

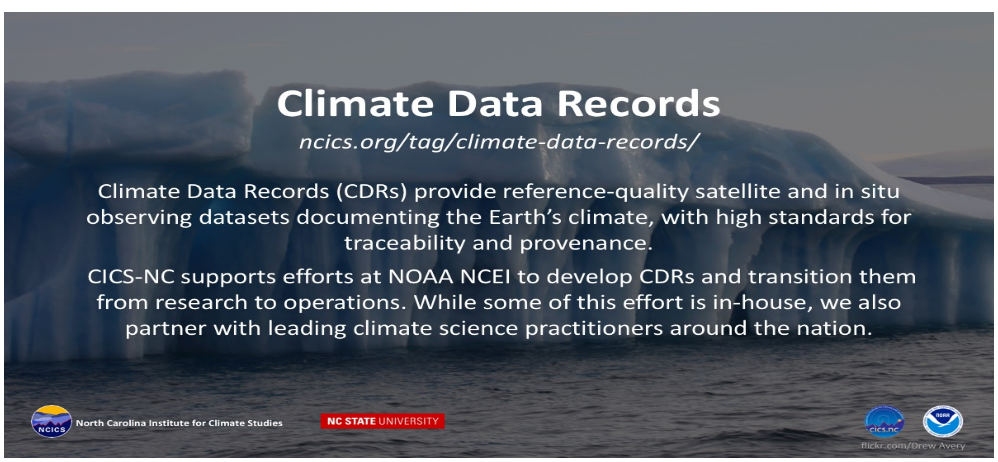


Figure 2: *One of eighteen images from a video loop highlighting major Institute projects and accomplishments.*

Planned work

- Continue to build and leverage our social media audience.
- Expand focus on promoting research outcomes through press releases and media outreach.
- Produce two issues of *Trends* newsletter.
- Provide additional editorial and graphic design support to Institute scientists with a goal of enhancing the communications effectiveness of papers and conference abstracts and presentations.
- Build relationship with communications staff at NC State University.

Presentations

Matthews, K. V., D. S. Arndt, J. Crouch, J. F. Fox, G. Hammer, and **T. Maycock**, 2017: Communicating Climate with Media - Tactics and Strategies. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 28, 2017.

Matthews, K. V., G. Hammer, S. Osborne, J. Fulford, and **T. Maycock**, 2018: 6.3: Climate Science and Social Media: Success Reaching the Masses. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

Osborne, S., K. V. Matthews, G. Hammer, J. Fulford, H. McCullough, K. Boseo, A. Sallis, and **T. Maycock**, 2018: 6.2: Communicating Science on Social Media: Strategic Keys to Success. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

Other

The Science Public Information Officer mentored high-school intern, Andrew Dundas, who wrote several web stories for the CICS-NC website and developed material for NCEI news stories.

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

Surface Observing Networks

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

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 Hawaii and Alaska to provide for the detection of regional climate change signals is ongoing under the management of NCEI, in partnership with NOAA's Air Resources Laboratory (ARL) 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, technical, and software engineering expertise in the following areas:

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

Improving U.S. Climate Reference Network (USCRN) Soil Observations

Task Leader:	Jesse Bell
Task Code	NC-SON-01-NCICS-JB
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Modeling 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1:50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: Improvements in the quality and usability of United States soil moisture measurements are being made through application of quality-controlled methods to create improved soil observation datasets. *https://www.ncdc.noaa.gov/crn/*

Background

The US Climate Reference Network is a series of climate monitoring stations maintained and operated by NOAA. To increase the network's capability of monitoring soil processes and estimating drought, USCRN instrumentation was augmented to collect soil observations with the installation of soil observational probes in the contiguous United States stations in 2011. Each station now transmits hourly relative humidity, soil temperature, and soil moisture measurements along with the traditional measurements of surface air temperature, precipitation, infrared ground surface temperature, wind speed, and solar radiation. These data are maintained and stored at NOAA's National Centers for Environmental Information (NCEI) with station installation and maintenance performed by NOAA's Atmospheric Turbulence and Diffusion Division (ATDD). Multiple projects have been implemented to utilize these data for satellite measurement calibration, health studies, and drought monitoring.

Accomplishments

At most USCRN locations, measurements of soil temperature and soil moisture are made at five depths from 5 to 100 cm in three triangular directions surrounding the USCRN tower for a total of 2,976 individual belowground observations. The substantial number of sensors combined with the environment in which the sensors operate requires continued and sustained attention to identify potential instrument problems. To aid in quality control efforts, vital software was developed to plot soil measurements on-the-fly, plot sensors individually, visualize quality control statistics, and produce 3-panel graphs showing statistics on soil sensor values (dielectric constants, precipitation, and volumetric soil moisture) (see Figure 1). These plots are consolidated in individual multi-page PDFs and analyses of the data are also provided in corresponding spreadsheets. These are shared with researchers and the NOAA Air Resources Laboratory (ARL) Atmospheric Turbulence and Diffusion Division (ATDD) for the evaluation of sensor performance, providing for a more thorough and efficient quality control process for soil moisture and temperature measurements.

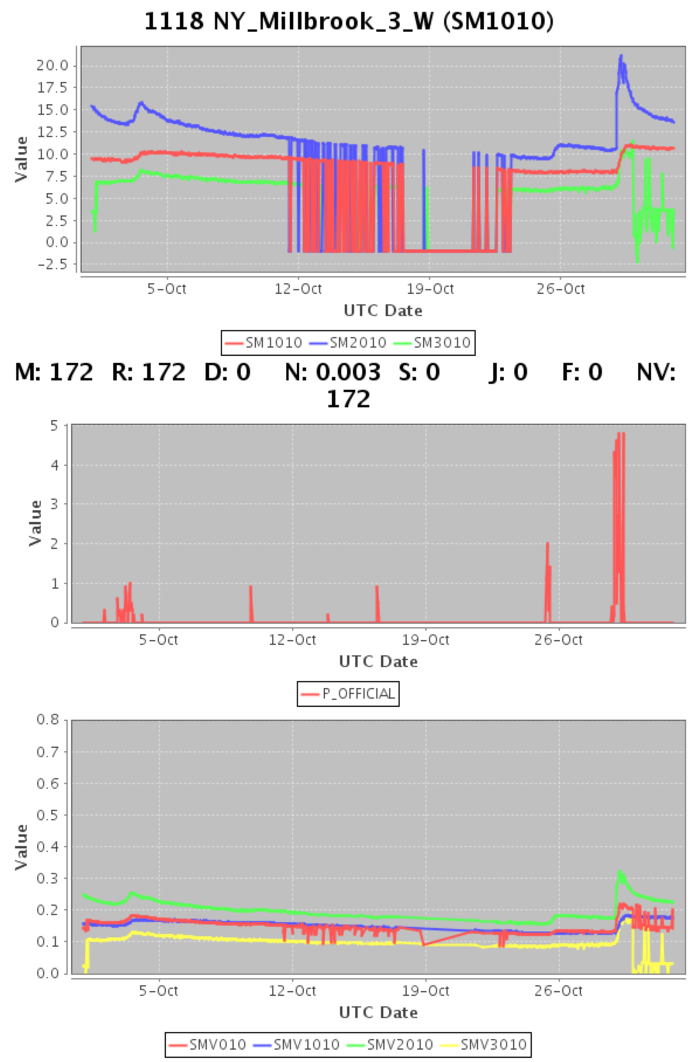


Figure. 1. *Graphing feature within the procedure for quality control of USCRN soil moisture and temperature observations.*

Planned work

- Continue to improve USCRN soil sensor quality by removing faulty sensor observations.
- Continue to research opportunities to use USCRN soil observations for applied belowground climatology.
- Continue to develop USCRN for improved drought monitoring.

Publications

Coopersmith, E. J., **J. E. Bell**, K. Benedict, J. Shriber, O. McCotter, and M. H. Cosh (2017), Relating coccidioidomycosis (valley fever) incidence to soil moisture conditions, *GeoHealth*, **1**. doi:10.1002/2016GH000033.

Products

Quality controlled soil observations for USCRN.

Performance Metrics	
# of new or improved products developed that became operational	1
# 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	0
# of graduate students supported by your CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

U.S. Climate Reference Network (USCRN) Applications	
Task Leader:	Ronald D. Leeper
Task Code	NC-SON-02-NCICS-RL
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: 20%; Theme 2: 80%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: 100%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: Several projects utilizing USCRN data were initiated including two satellite-based projects utilizing USCRN data for remote sensing validation and algorithm development, the update of an hourly precipitation dataset (HPD), an update of network wide precipitation extremes through 2017, and a sensor sensitivity study related to urbanization.

Background

The U.S. Climate Reference Network (USCRN) is a systematic and sustained network of climate monitoring stations with sites across the conterminous U.S., Hawaii, and Alaska. These stations use high-quality instrumentation to measure temperature, precipitation, wind speed, soil conditions, and more. Several projects utilizing USCRN data were initiated including two satellite-based projects (providing USCRN data and support for remote sensing validation and algorithm development), the update of an hourly precipitation dataset (HPD), an update of network wide precipitation extremes through 2017, and a sensor sensitivity study related to urbanization.

While numerous studies have shown the impact of urbanization on temperature measurements from traditional sensors (min-min thermometer) placed in unaspirated shields (i.e., cotton region shelters/multiplate), there are relatively fewer studies that have explored how newer, more sensitive, sensing technologies in well-ventilated shields, such as those in use at USCRN stations, respond to urban conditions. Data from a field campaign conducted from November 2012 to August 2013 were analyzed to evaluate the impact of an urban environment on temperature observations from multiple sensor suites selected to match both the traditional National Weather Service Cooperative Observer Program (COOP) network and modern USCRN design. These sensor sets were deployed at four locations (towers): Tower A, representing the urban scenario, was located 4 meters down-wind of an urban area with Tower D, the remote location, located 309 meters away.

Accomplishments

Temperature observations taken from COOP station NIMBUS sensors in an unaspirated multiple plate shield (MPS) were compared with collocated platinum resistance thermistors (PRTs) in the same unaspirated (MPS) and aspirated MetOne shield used at USCRN stations. The newer (PRT) sensing technology in the same shield had slightly cooler daily maxima compared to the traditional MMTS sensor (Fig .1a) at Tower A. Minimum temperature offsets between the types of sensors were slightly less, but also slightly cooler. Comparisons between the urbanized (Tower A) and remote (Tower D) settings revealed an urban signature in both unaspirated maximum and minimum temperatures (Fig 2); however, nearly no urban bias between aspirated daily maximums appeared. Overall, minimum temperatures seemed to be more sensitive to urban affects than maximum temperatures. The urban effects on maximum temperatures could be difficult to detect since the signal would be mixed throughout a deeper planetary boundary layer (PBL) than the shallower nocturnal PBL in place when daily minima are generally observed.

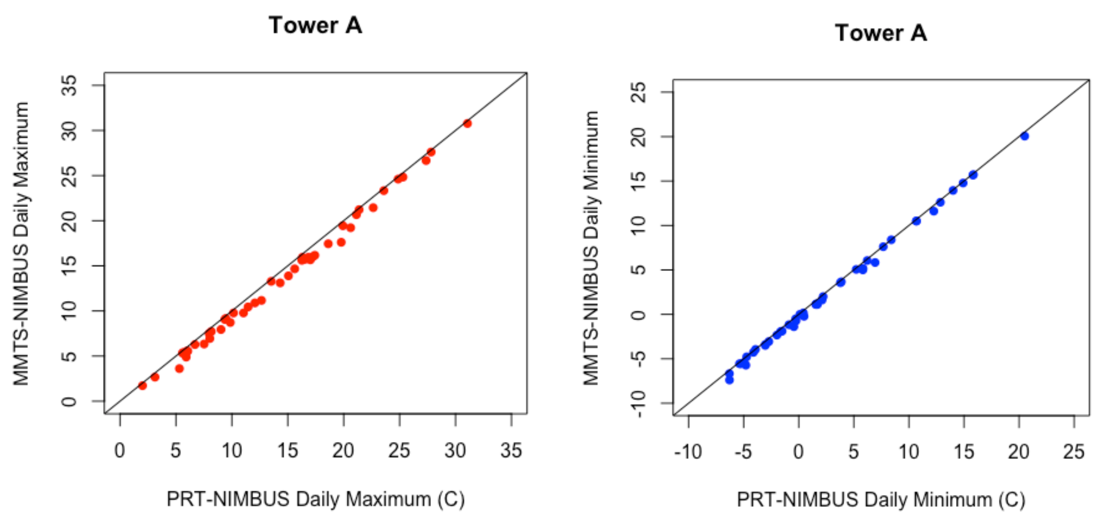


Figure 1. *Tower A (urban) scatter plots of daily maximum (right) and minimum (left) observed by NIMBUS and PRT sensors within the same unaspirated multiplate shield.*

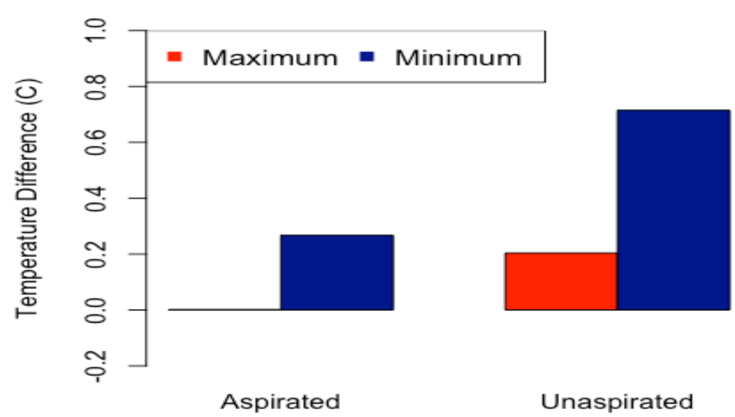


Figure 2. *Mean maximum (red) and minimum (blue) temperature differences computed as Tower-A (urban) minus Tower-D (remote) between fan aspirated and unaspirated PRTs.*

Planned work

- Provide USCRN data and support for ongoing satellite and HPD analysis.
- Complete temperature comparison study between urbanized and remote temperature observations.
- Complete and submit a manuscript for the precipitation extremes study with coauthors.

Presentations

Lawrimore J. H., D. Wuertz, M. A. Palecki, K. Dongsoo, **S. E. Stevens**, **R. Leeper**, B. Korzeniewski, 2017. Improved Hourly and Sub-Hourly Gauge Data for Assessing Precipitation Extremes in the U.S., *Annual American Geophysical Union Fall Meeting,* New Orleans, LA, December 15, 2017.

Other

• Mentored Timothy Henderson, North Carolina State University (NCSU) undergraduate student, who helped analyze urban biases on daily temperature extremes.

Performance Metrics	
# of new or improved products developed that became operational	**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	**1**

The Hourly Precipitation Dataset (HPD) has been released as an alpha product. USCRN precipitation extremes dataset is being considered as a potential product.

The Utility of In-situ Observations for the 2017 Great American Solar Eclipse	
Task Leader/Task Team:	Ronald D. Leeper, Jared Rennie, Carl Schreck, and Tom Maycock
Task Code	NC-SON-03-NCICS-RL
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Climate and Satellite Research and Applications: 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: 90%; Goal 2: 10%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: An interactive web product was created utilizing hourly cloud cover normals from automated weather stations to determine the likelihood of cloudiness for the solar eclipse hour at stations across the U.S. The website was viewed over 380 thousand times with more than 2 million interactions. An analysis of the post eclipse in-situ data revealed the impact of reduced solar insolation on near-surface temperatures and relative humidity. NCEI Story: *https://www.ncei.noaa.gov/news/ready-set-eclipse*; *https://ncsu.maps.arcgis.com/apps/webappviewer/index.html?id=6771e9f10f904b7b8afa6cc99c4c7e7a*

Background

The Great American Solar Eclipse of 2017 was the first time in over a century that the path of a total eclipse of the Sun traversed the U.S. from coast-to-coast. This track provided spectators a rare opportunity to view a total solar eclipse along the path provided weather (i.e., clouds) did not obscure one's view. In addition, the eclipse presented an opportunity to monitor the impact of the solar eclipse on surface measurements of air temperature and humidity. To this end, researchers at the Cooperative Institute for Climate and Satellites (CICS-NC) were interested in providing a long term forecast of cloud conditions leading up to the August 21st 2017 event and the archival of sub-hourly measurements to support a post-Eclipse analysis.

Accomplishments

Hourly climate normals of clear, few, scattered, broken, and overcast conditions from automated weather stations were combined for the eclipse hour to estimate the likelihood of viewing the eclipse, which we termed Eclipse Viewability. A map of these results revealed that western locations outside of the coast had some of the lowest potentials for cloudy conditions or higher probability of viewing the eclipse cloud-free. These probabilities slowly decreased as the track moved eastward, likely due to the predominance of afternoon clouds during the eclipse for this portion of the country. These data were made available online through a Geographic Information System based interactive web application. The web application was deployed in conjunction with the National Centers for Environmental Information (NCEI) and CICS-NC communication teams, which resulted in one of the most visited NCEI pages of 2017. The web-based application was viewed over 380K times, 2 million plus interactions, and caught the interest of numerous media outlets leading to 4 interviews, including 1 with The New York Times.

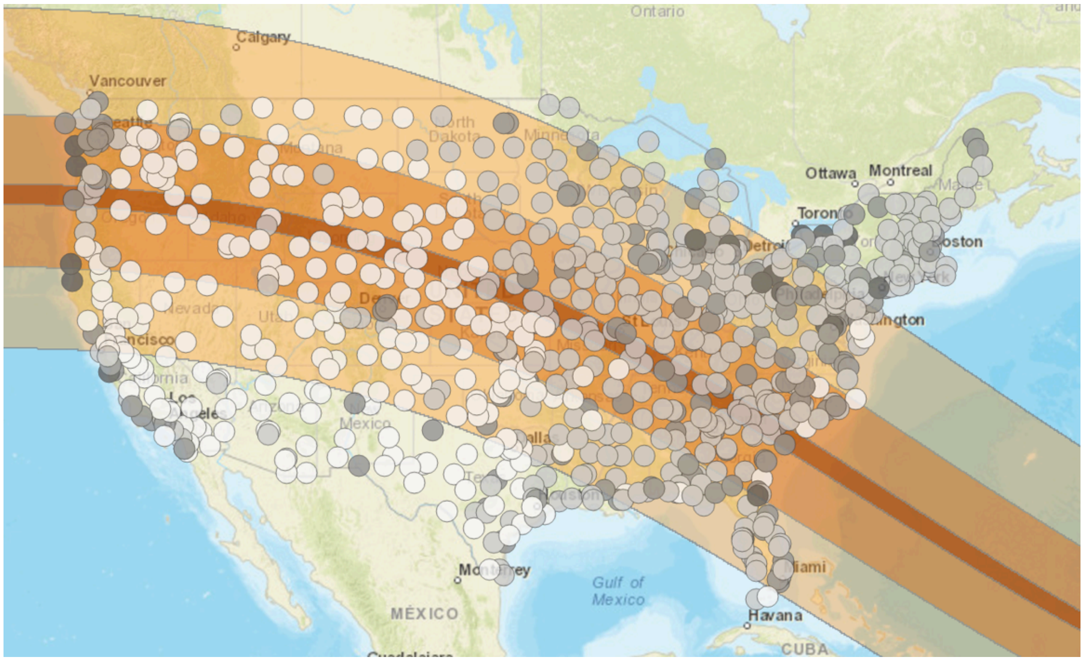


Figure 1. *Map of station viewability during the Great American Solar Eclipse of 2017.*

Following the eclipse, sub-hourly station measurements from the U.S. Climate Reference Network (USCRN) were analyzed to evaluate the impact of the eclipse on temperature and humidity. Air temperature measurements from stations along the path decreased by up to 5 °C (Fig. 2) with surface temperatures dropping by as much as 15 °C.

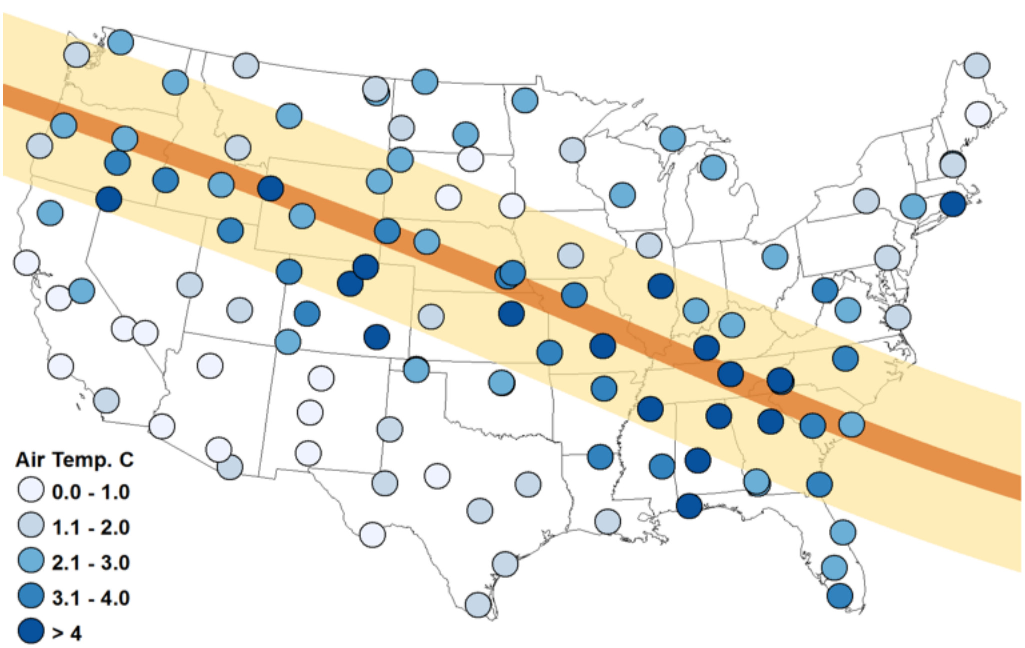


Figure 2. *USCRN observed temperature change during the Great American Solar Eclipse of 2017.*

Planned work

- Evaluate how well the eclipse viewability percentages compared with station measurements of cloud conditions.
- Generate station viewability probabilities for upcoming solar eclipses using the latest climate normals.
- Facilitate publication of manuscript in *Earth Observation Science* (currently in press).

Products

An interactive web-based GIS application of the Great American Solar Eclipse Viewability percentage.

Presentations

Fulford, J., Hammer, G., **Leeper, R., and Rennie, J**., 2017: August Eclipse; A public engagement opportunity. *NCEI Tuesday Seminar Series*, Asheville, NC, June 20, 2017.

Other

• The web story was the number one viewed NCEI webpage for 2017.
• Generated large-scale media interest including interviews from *The New York Times, Palm Beach Post* of Palm Beach, FL, *The Post and Courier* of Charleston, SC, and *Island Packet* of Hilton Head, SC.

Performance Metrics	
# of new or improved products developed that became operational	**1**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**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 interactive web application was incorporated into a National Centers for Environmental Information (NCEI) web story product.

Standardization of U.S. Climate Reference Network Soil Moisture Observations	
Task Leader:	Ronald D. Leeper
Task Code	NC-SON-04-NCICS-RL
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Climate Adaptation and Mitigation: 100%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: A methodology to standardize hourly volumetric soil moisture observations from a short term (7-8 year) data record was developed. This approach was evaluated using station observations from the longer term (15-year) Soil Climate Analysis Network (SCAN). Results showed the methodology could produce a soil moisture climatology similar to the 15-year inter-annual mean with seven or more years.

Background

Soil moisture observations are notoriously challenging to interpret and use. The interoperability issues stem from the sensitivity of observations to localized factors such as soil characteristics, vegetation cover, topography, and climate (i.e., precipitation patterns). As such, the same soil moisture observation can have very different meanings depending on where the measurement was taken and the time of year. These challenges can be overcome by placing measurements into historical context. For instance, providing soil moisture anomalies can inform decision making about how wet or dry conditions are compared to normal. Percentiles provide a measure of how extreme current hydrological conditions are. The usefulness of such metrics requires a representative climatology.

Accomplishments

The USCRN has been monitoring soil moisture conditions since 2009. With only seven to eight years of soil moisture observations, it would be difficult to generate soil moisture climatologies using traditional methods. Applequist et al. (2009) developed an approach to calculate ASOS normals that at the time had less than 10 years of data. Their sampling approach was applied to calculate hourly USCRN soil moisture climatologies (Fig. 1) and derive soil moisture anomalies and percentiles. An experimental (alpha) product was released based on this analysis.

The approach was evaluated using a Monte Carlo simulation on a longer-term soil moisture dataset from the Soil Climate Analysis Network (SCAN). Monte Carlo simulations consisted of 100 randomly sampled years from the longer-term dataset. The number of years randomly chosen ranged from 3 to 11 (3, 5, 7, 9, and 11) years for a total of 500 simulations per depth. Comparisons between the hourly Monte Carlo and full-term climatologies revealed that seven or more years of soil moisture data is necessary to reconstruct a longer-term climatology.

Standardized volumetric soil moisture measures (i.e., anomalies and percentiles) were compared with the U.S. Drought Monitor. The standardized measures for differing drought conditions were found to be more broadly consistent across the network than volumetric soil moisture observations (figure 2). In addition, soil moisture percentiles were more sensitive to drought intensification and improvement.

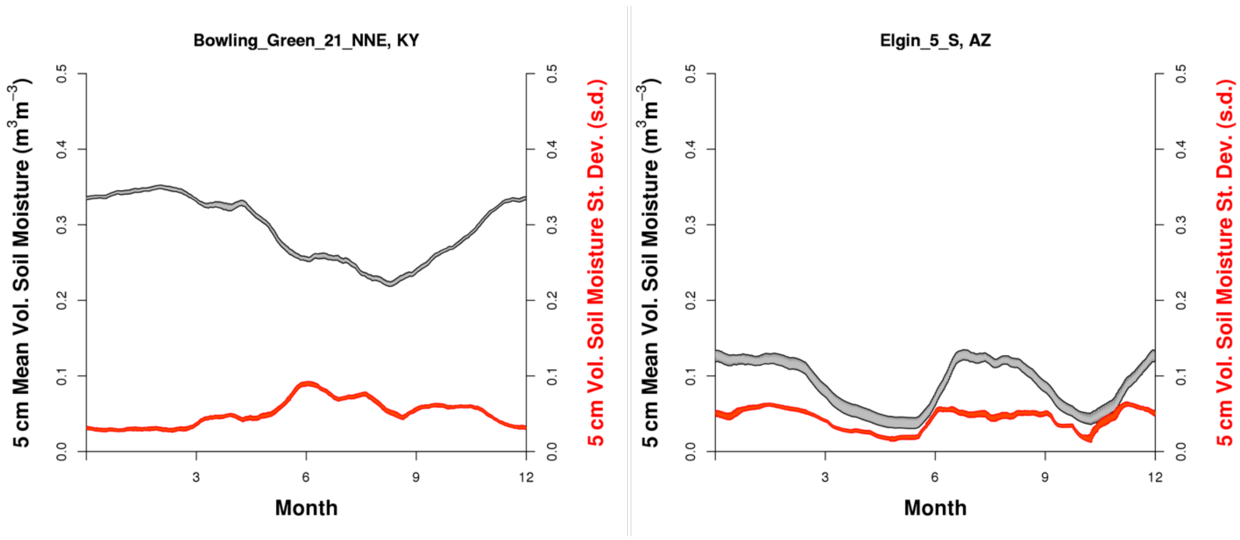


Figure 1. *USCRN sampled 5cm soil moisture climatology (gray) and standard deviation (red) for two diverse USCRN stations in Bowling Green, KY and Elgin, AZ.*

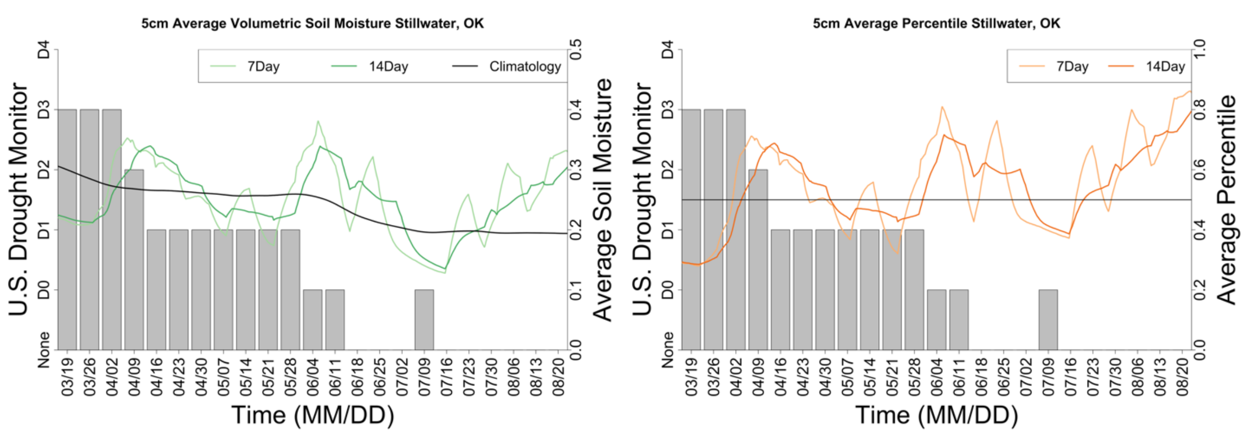


Figure 2. *USCRN 7 and 14 day averaged volumetric soil moisture (left) and percentile (right) overlaid on U.S. Drought Monitor conditions (gray bars) for an improving drought event at Stillwater, OK in 2013. The percentile measure shows moistening conditions throughout the year whereas volumetric measures misleadingly indicate drying soils due to an active vegetation layer.*

Planned work

- Evaluate how well the last 7 years of soil moisture observations compare with the longer-term climatology.
- Evaluate the quality of USCRN soil moisture observations on the standardized product.
- Release a beta product and fully transition product to operations.
- Produce a series of publications documenting the product and its utility in monitoring hydrological extremes.

Products

The analysis has begun to transition to an operation product with the release of the alpha version.

Presentations

Leeper, R., 2017: Standardizing In-Situ Soil Moisture Observations to Improve Hydrological Monitoring. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 26, 2017.

Bell, E. J., and **R. D. Leeper,** 2017: Standardizing USCRN Soil Moisture and Other Activities. *USCRN meeting with NOAA Air Resources Lab Atmospheric Turbulence Diffusion Division (ATDD) Partners*, Oak Ridge, TN, November 15, 2017.

Leeper, R., 2018: 20: An Evaluation of Recent U.S. Drought Events Using a Newly Available Standardized Soil Moisture Dataset. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.

Leeper, R. D., Bell, E. J., and Palecki, M. 2018, Standardizing USCRN Soil Moisture Observations. *USCRN meeting with Drought.gov Partners*, Asheville, NC, February 19, 2018.

Performance Metrics	
# of new or improved products developed that became operational	**1**
# 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	**4**
# of graduate students supported by your CICS task	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

An alpha product based upon this analysis was developed and released in Aug. 2017.

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-05-UNCA
NOAA Sponsor	Steven Goodman
NOAA Office	NESDIS/GOESPO
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring – 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: Completed Spring, Summer, and Fall 2017 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 each gauge visit with quality-controlled precipitation CSV format files can be accessed at:

Spring 2017, https://drive.google.com/open?id=0B9P8oUaRiBOwRHlVaWFBajRKN3c
https://drive.google.com/open?id=0B9P8oUaRiBOwV2NhcTExVFpfeGM
Summer 2017, https://drive.google.com/open?id=0B9P8oUaRiBOwUTRNbkRKNEhwUVE
https://drive.google.com/open?id=0B9P8oUaRiBOwaUY5NTY4M2FUSVk
Fall 2017, https://drive.google.com/open?id=1tnwnUItgWv9r37AIwoKp5UMddKZttdbl
https://drive.google.com/open?id=1vO7J_X8EHhz7lkqoLkIV8ITW3HVd21H9

Background

The Duke University Great Smoky Mountains National Park Rain Gauge Network (Duke GSMRGN), originally funded by NASA to measure rainfall accumulation at 32 mid (~3400 feet) and high (~6600 feet) elevation locations in the Pigeon River basin (Figure 1 and Table 1 of Miller et al. 2018), 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 rain-rate retrieval algorithms. Although analysis of the nine-year (July 2007-June 2016) record of precipitation observations continues, significant findings have emerged and been published (e.g., Wilson and Barros 2014, Duan et al. 2015, Miller et al. 2018).

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

Accomplishments

Gauge visitation in support of the Duke Great Smoky Mountain Rain Gauge Network (GSMRGN) occurred over 10 days spanning a seven-week period during each of the following cycles: spring 2017 (24 March – 10 May 2017), summer 2017 (26 May – 9 August 2017), and fall 2017 (7 October – 11 November 2017). Volunteers accompanied technicians to assist with personal safety (should someone become injured during a particular series of gauge visits) but were not directly involved in gauge visit tasks. The primary purpose of each gauge visit is to [1] perform downloads of gauge tip observations since the previous gauge visits, [2] complete maintenance tasks (general gauge maintenance and ML1 logger condition monitoring), [3] clear vegetation and tree limbs within a five-foot radius of the rain gauge, and, [4] where necessary, calibrate the rain gauges (three calibration trials using the 50, 100, and 300 mm nozzles) and/or replace lithium batteries that have drained to a low voltage. Tasks may vary slightly depending on the season and/or issues identified in previous gauge visits.

Spring 2017: 24 March – 10 May 2017
Fourteen technicians and volunteers made the visits and performed the required work.

In addition to the general tasks completed at every gauge visit, specialized tasks were to determine status of a missing rain gauge (g001), replace an apparently damaged data logger at a location where the gauge cover had been removed in the autumn 2016 (g010), and re-visit a gauge (g109) that had registered a low number of tips during the winter season and troubleshoot the source of missing tip counts.

The lithium battery life of ML1-420 loggers is much less predictable than the ML1-FL loggers, three had an unacceptably low voltage (ALL data logger lithium batteries were refreshed in the fall 2016). A solution is currently being sought from Hydrological Services of America. Three sites (g311, g300, g308) will require a clever solution to remove higher tree branches starting to encroach over the gauge. Data logger lithium or HOBO batteries were replaced at gauges having a low voltage (HOBO; g005, g008, g010, g108, ML1-420 lithium; g108, g103, g300) and two gauges were calibrated (g008 and g005) running three trials using the 50, 100, and 300 mm nozzles using the Duke #2 calibration tube.

Challenges encountered during spring 2017 gauge visits included: (i) the missing gauge (g001) had been bulldozed (literally) by NC Wildlife personnel, working to clear a section of the forest (data loggers from the gauge were recovered, but the gauge itself was a total loss), (ii) replacement of the g010 data logger whose funnel cover had been removed by an animal (unfortunately, the logger battery was completely drained during the 15 April 2017 visit and the most recent reported tip occurred in 6 January 2017), (iii) the switch at g109 was found to have a faulty terminal and functioned properly when the logger cables were changed to the other terminal (unfortunately, rainfall observations at g109 are unreliable between the summer 2016 and the date of the switch fix on 8 April 2017), (iv) extended closure of the Heintooga Loop Rd that required the assistance of Mr. Paul Super to help us gain access to the Balsam Mountain Ridge trailhead on 26 April 2017 to visit g307 and g304, and (v) a locked barbwire fence blocking access to the catwalk at the Mt. Sterling fire tower (g310).

26 May – 9 August 2017
Four technicians and volunteers made the visits and performed the required work.

In addition to the general tasks completed at every gauge visit, specialized tasks were to install a new gauge (g011) at a location close to old g001, which had been run over by a bulldozer in January 2017 and the trimming of tree limbs using an extension saw at several locations to improve the sky view.

The lithium battery voltage of the ML1-420 and ML1-FL loggers was uniformly good (greater than 3.50 Volts) at all of the gauge locations during the summer months. Battery voltage and internal temperature files (DUBVT) were downloaded from most of the ML1-420 loggers and emailed to engineers at Hydrological Services of America to aid in the diagnoses of why battery voltage drains rapidly in the newer loggers. Six sites (g110, g105, g311, g103, g308, and g300) had tree limbs removed using an extension saw and two locations (g304 and g305) will need tree limbs cleared during the autumn 2017 visit. Batteries were all functioning at appropriate level and no calibration was required during the summer 2017 visit campaign.

Challenges encountered during summer 2017 visits included: (i) severe clogging of the siphon at g107 (Lookout Point) resulted in missed tips after ~ 13 May 2017 due to debris from the surrounding field [the land owner indicated the overgrowth may be a more regular occurrence as a number of their cattle were sold and grazing would be reduced], and (ii) overgrowth of a single briar plant at g305 which likely resulted in under catch during the summer months. Otherwise, the gauge network was functioning as smoothly as is possible. A new Davis Pro weather station has been installed near the Mount Sterling fire tower (now locked, but we have access), next to g310. The owner of the weather station (and data) at Duke Power is being pursued so the observations can be used to help diagnose the phase of falling precipitation during the cold season.

<u>7 October – 11 November 2017</u>
Eight technicians and volunteers made the visits and performed the required work.

In addition to the general tasks completed at every gauge, specialized tasks included replacement of ALL lithium data logger or HOBO batteries in anticipation of cold winter weather (when lithium batteries respond with a drop in operating voltage), the trimming of tree limbs using an extension saw at several locations to improve the sky view (gauge sites 002, 003, 005, 008, 304, 307, 305, 309, 310), the replacement of four AA batteries of the T/RH sensor at the fire tower on Mount Sterling (near g310) to record air temperature during the cool season, and a visit at g107 to check that the drain ports had not clogged (as they had in the summer 2017) in anticipation of the arrival of Tropical Depression Irma.

Two ML1 loggers showed a poor response using the TA command (g104 and g110, TA error “Adjustment too big”) and may require replacement during the spring 2018 visit. Five sites (g003, g005, g008, g304, and g309) had tree limbs removed using an extension saw and one location (g305) will need tree limbs cleared during the autumn 2018 visit. The lithium battery voltage of the ML1-420 and ML1-FL loggers was good (greater than 3.50 Volts) at all but three (g010, g300, g311) of the gauge locations upon arrival. All batteries were replaced. A battery voltage and internal temperature file was downloaded at g300 to share with Hydrological Services of America as the ML1-420 logger has required a new lithium battery at nearly every visit.

Challenges encountered during autumn 2017 visits included: (i) severe time drift at g104 and g110 due to the TA of +1 s every 1-h, which makes the logger time much faster than the actual (GPS) time, and (ii) the ripping off of the gauge cover at g010 by a bear that had also happened late in the summer 2016. Otherwise, the gauge network was functioning as smoothly as is possible.

Planned work
<u>*March – May 2018:*</u> Duke GSMRGN gauge visitation during the spring 2018 will occur over at least thirteen days spanning March through early May 2018. In addition to the general visit tasks, all rain gauges will be calibrated [last calibration in autumn 2016]. Calibrations are scheduled at ALL rain gauge locations during the spring season due to the increased availability of daylight hours and to a seasonal (March, April, May) minimum in precipitation observed in the Pigeon River Basin (Miller et al. 2018).
<u>*Summer and Fall 2018*</u>*:* Duke GSMRGN gauge visitation during the 2018 summer and fall seasons will focus on downloading precipitation observations, performing maintenance, clearing vegetation and tree

branches from overhanging gauges (if applicable) and replacing data logger lithium batteries (during fall 2018 visits).

Details of every gauge visit along with each gauge precipitation record will be posted online and will 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.

The current technician roster during the 2017-2018 academic year consists of Rachel Dunn, Ben House, Jackie Hoyle, Tyler Moore, Carly Narosky, Samuel O'Donnell, and Zachary Tuggle. New undergraduate research students at UNC Asheville will be recruited as field technicians for the Duke GSMRGN project in the spring 2018 as four students will be graduating from UNC Asheville in May 2018.

Publications

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

Products

Ralph Ferraro's group (NOAA NESDIS STAR) 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). Bob Kuligowski's group plans to use observations of the Duke GSMRGN as part of validation efforts in their research.

Presentations

Miller, D., L. Stewart, D. Hotz, J. Winton, A. Barros, J. Forsythe, A. P. Biazar, and G. Wick, 2017: Atmospheric Rivers and the Great Smoky Mountains National Park; Fact and Fiction. Oconaluftee Visitor Center, Great Smoky Mountains National Park, October 5, 2017.

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

Seven 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.

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.

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.

Maintenance and Streamlining of the Global Historical Climatology Network-Monthly (GHCN-M) Dataset	
Task Leader:	Jared Rennie
TaskCode	NC-SON-06-NCICS-JR
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals	Climate Adaptation and Mitigation: 100%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: The next iteration of NOAA's global temperature product has been developed and released as a second public beta based on an open and transparent databank of land surface stations. A manuscript has been submitted and the dataset will become operational once the manuscript is accepted.
http://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 information 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 addressed this issue by developing a state of the art databank of global surface temperature observations. Released in 2014, the first version of the databank contains over 30,000 surface temperature stations, has an open and transparent design, and documents observations back to the original source data. Many international organizations have heralded this development and provided feedback that has gone into subsequent updates. All versions are available online, and the current operational version is v1.1.1, released in late 2017.

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

Accomplishments

The ISTI databank was updated based on user feedback. As a result, numerous changes have been made to underlying stations' data and metadata. Queries from users were vetted by the ISTI and GHCN team, and, if verified, were updated in the database. In addition, a bug was found in the ISTI code where values in the merged Stage 3 product were different from their underlying Stage 2 source data. In all cases, they were off by a factor of 0.01, due to a numerical issue in the software. The code was changed to prevent this error from happening, with a subsequent update to ISTI version Version 1.1.1 was released in November, 2017 with appropriate documentation updates.

Version 1.1.1 of the databank serves as the starting point for version 4.0.0 of GHCN-M. Shortly after the ISTI release, GHCN-M was updated to its second beta (v4.b.2). This version incorporates the changes noted above, in addition to updates in the GHCN processing software. This includes a more robust update system, a consecutive 10-year threshold for ISTI data to be included in GHCN-M, and an updated algorithm to remove consecutive duplicate data in both space and time.

The Pairwise Homogeneity Algorithm (PHA) was also updated to produce a third version of GHCN-M Version 4. Existing versions included quality controlled, unadjusted data (QCU), and quality controlled, adjusted data (QCF). Adjustments are made from detecting non-climatic influences in the station data via the PHA. The latest version includes estimated station data from 1961-1990 (QFE). The publicly provided QFE product is intended for monitoring climate activities (e.g., using a 30-year climatology to estimate trends). This estimation is done in order to have the most robust data during the 30-year period, as is needed before an anomaly can be calculated for any given station. Using QFE data will bring more stations into climate analysis; its effect on station coverage can be seen in Figure 1.

Updates to both ISTI and GHCN-M were set up on a three-tiered system, including development, test, and production environments. Nightly runs were performed internally and checked by the ISTI and GHCN team to ensure adequate data quality. A manuscript has been developed and sent to *Journal of Climate* for review. Once accepted, GHCN-M Version 4 will be operational at version 4.0.0.

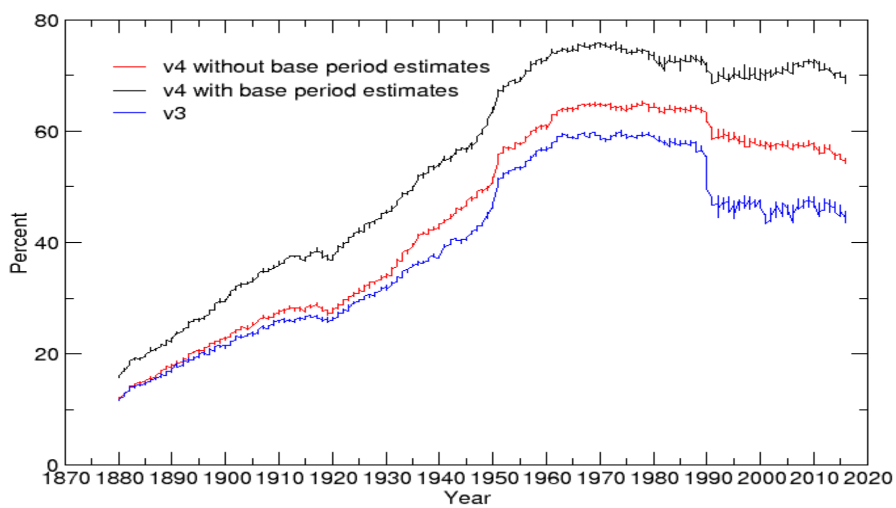


Figure 1: *Time series of the percent of 5° x 5° grid boxes that contain any land areas, which also contain anomalies from at least one land station.*

Planned work

- Continue to engage with public on feedback regarding both the ISTI Databank version 1.1.1 and GHCN-M version 4.b.2. Provide updates to processing as needed.
- Complete journal manuscript revisions if needed.
- Release GHCN-M version 4.0.0 as an operational product. Engage with user community on constructive feedback. Provide updates as needed.

- Incorporate GHCN-M v4.0.0 into the NOAA Global Temperature product, which merges land temperature data with sea surface temperatures (ERSST).

Products

• Updates if needed to ISTI Databank (v1.1.1) and GHCN-M (v4.b.2) following user community feedback.
• 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	**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	**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.b.2, based on the International Surface Temperature Initiative's Databank version 1.1.1, is under consideration for operational use.

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool	
Task Leader/Task Team:	Jared Rennie, Ken Kunkel, and Jesse Bell
Task Code	NC-SON-07-NCICS-JR/KK/JB
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 1: 50%; Theme 2: 50%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: A sub-monthly tool for monitoring impacts of temperature extremes in the United States has been created. The resulting dataset was used to assess heat extreme events in the United States from 1895–2016. *https://ncics.org/portfolio/monitor/sub-monthly-temperatures/*

Background

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

The Global Historical Climatology Network-Daily (GHCN-D) dataset provides a strong foundation of 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, 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 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 extract 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 aggregated to the state level and then region level (as defined by the National Climate Assessment (NCA)). Daily plots are made to analyze US temperature values and anomalies. Once daily averages for each state and NCA region are made, probability distribution functions are generated to provide ranks on different time scales. These are important to understanding recent extremes in a changing climate. The process runs every morning to incorporate the latest data from GHCN-D and can be found at: https://ncics.org/portfolio/monitor/sub-monthly-temperatures/.

Using this homogeneous record of temperature data from 1895-2016, heat events can then be identified in a consistent manner. To identify an event, the distribution of temperature for a particular area is taken from 1895 to 2016, and the 98th percentile of the distribution is taken as the threshold for a much higher than normal heat event. A distribution of each temperature element (maximum and minimum) is taken independently of each other, and all days are used in generating this threshold. It is hoped that by using the 98th percentile, the most extreme events will be identified.

Using this temperature threshold, data are run through to search for a consecutive period of three days or more where the value exceeds this threshold. Once an event is found, information including the onset, length, and severity is extracted. Statistics are calculated, including departure from normal, extreme daily maximum and minimum temperatures, as well as ranks against its period of record. Probability density functions are used to determine how severe the event is against its period of record. Trends are calculated using the Mann-Kendall method, which assesses the significance of a monotonic upward or downward trend over time. Overall results show an increase in event number, length, and severity. Overnight minimum temperature events are occurring more than daytime maximum (Figure 1), which is consistent with the literature. The spatial extent varies by state, however most states show increases since 1950 (an example of heat event length is noted in Figure 2).

A manuscript is in preparation for submission to the *Journal of Climate*. Once accepted, this dataset will be used as the baseline to match heat event data with available health data. A project is underway with the Centers for Disease Control and Prevention (CDC), Climate Central, and the Society of Actuaries (SOA) to locate and match health data. Current areas of interest include the states of North Carolina, Kansas, and Illinois. Once matches are made between heat and health events, an attribution study will be performed.

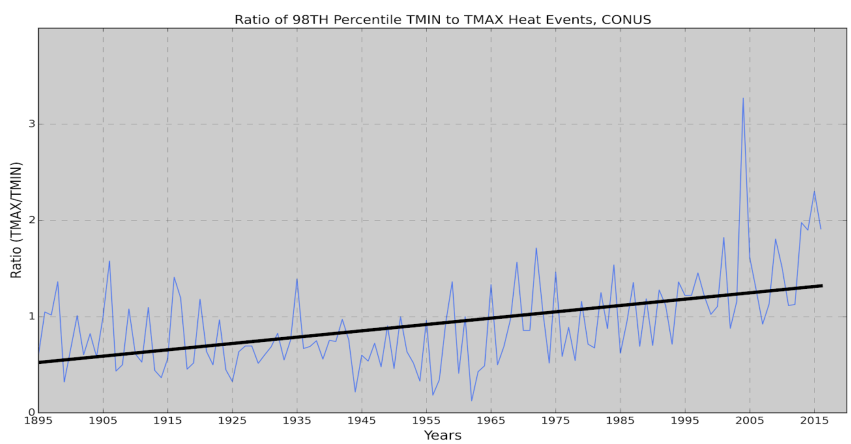


Figure 1: *Number of annual heat events for maximum and minimum temperature (1895-2016), defined as a ratio of TMIN to TMAX.*

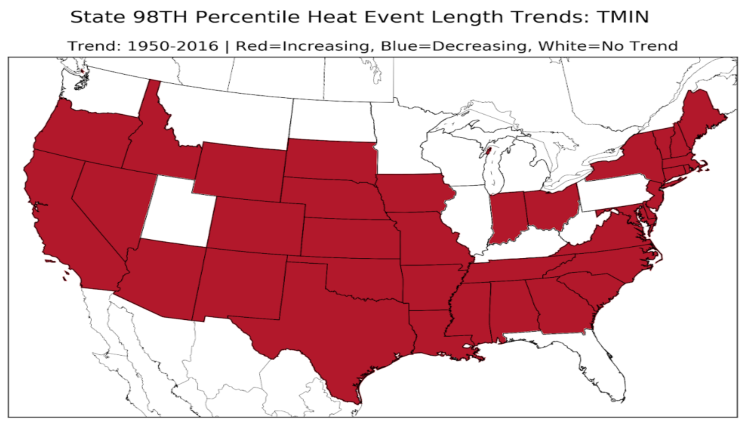


Figure 2: *States experiencing an increase in heat event length in overnight minimum temperatures (TMIN). Trends are from 1950-2016 and red indicates an increasing trend while white is no trend.*

Planned work

- Continue to engage with users on the monitoring product.
- Submit manuscript to *Journal of Climate*.
- Work with CDC, SOA, and Climate Central to identify heat events with available health data.
- Perform attribution study to assess extreme heat events in a changing climate.

Products

• A new, state of the art monitoring tool for sub-monthly data for the United States.
• Public facing website to display updated maps and ranks.
• Database of heat events, based on a 98th percentile threshold, from 1895-2016.

Presentations

Rennie, J., J. E. Bell, K. E. Kunkel, S. Herring, and H. Cullen, 2018: 4.1: Using a Daily Homogenized Temperature Product to Assess Long-Term Trends in Extreme Heat Events and Associated Health Impacts in the United States. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.

Performance Metrics	
# of new or improved products developed that became operational	**2**
# of products or techniques submitted to NOAA for consideration in operations use	**0**
# of peer reviewed papers	**0**
# of NOAA technical reports	**0**
# of presentations	**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 monitoring product is considered operational and is running daily on CICS-NC servers. A heat event database has been derived from this product.

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-08-SDSURF
NOAA Sponsor	Jeff Privette
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring: 100%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: A new software technology, 4DVD (4-Dimensional Visual Delivery of big climate data), was developed and released with the capability to rapidly deliver NOAA environmental data to classrooms, households, and the general public. A limited demo is available at: http://climate2.mrsharky.com/

Background

Modern climate data have helped improve understanding of climate dynamics that operate in the background of global temperature increase and have 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 attained five major accomplishments during the past year. 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. Limited access can be viewed at http://climate2.mrsharky.com/. 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.

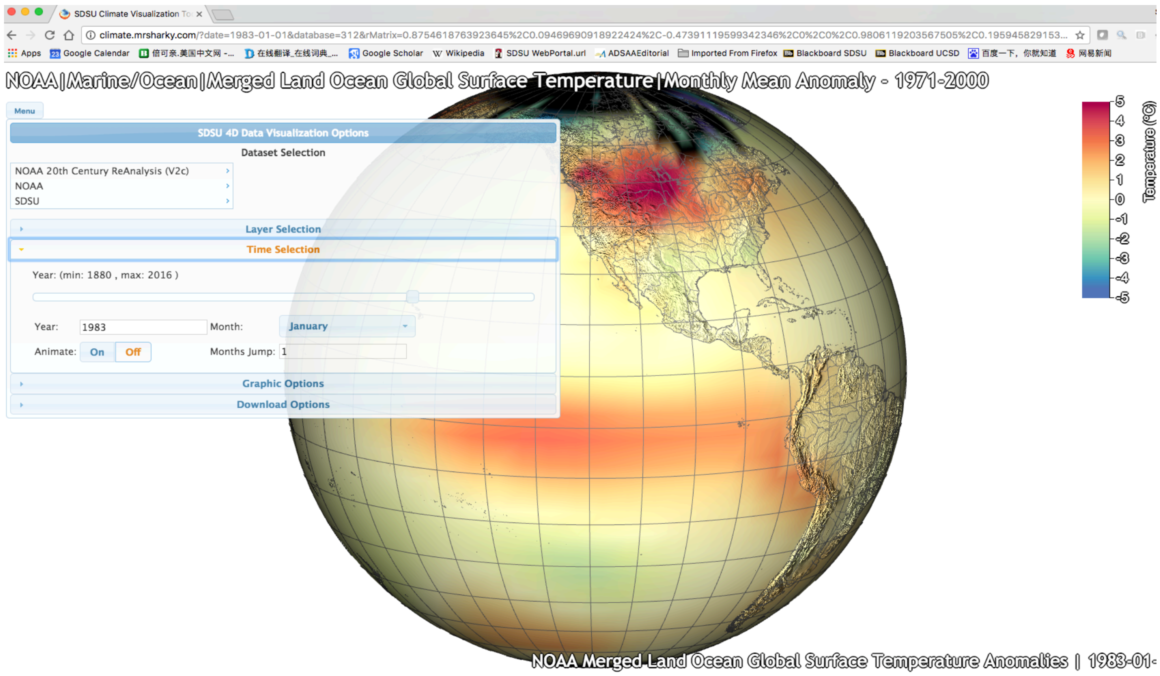


Figure 1. *4DVD display of NOAAGlobalTemp data: January 1983 temperature anomalies.*

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 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 these 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.

   The instruction manual for the CICS-NC/NCEI R course taught on May 31-June 3, 2017 has been revised into a 152-page lecture notes for the climate community. About 30 CICS-NC/NCEI scientists attended the class. Some parts of the notes will be included in my book, "Climate Mathematics," to be published by Cambridge University Press in December 2018. These R documents will be the place to go for the climate community on the R tools for climate data analysis.

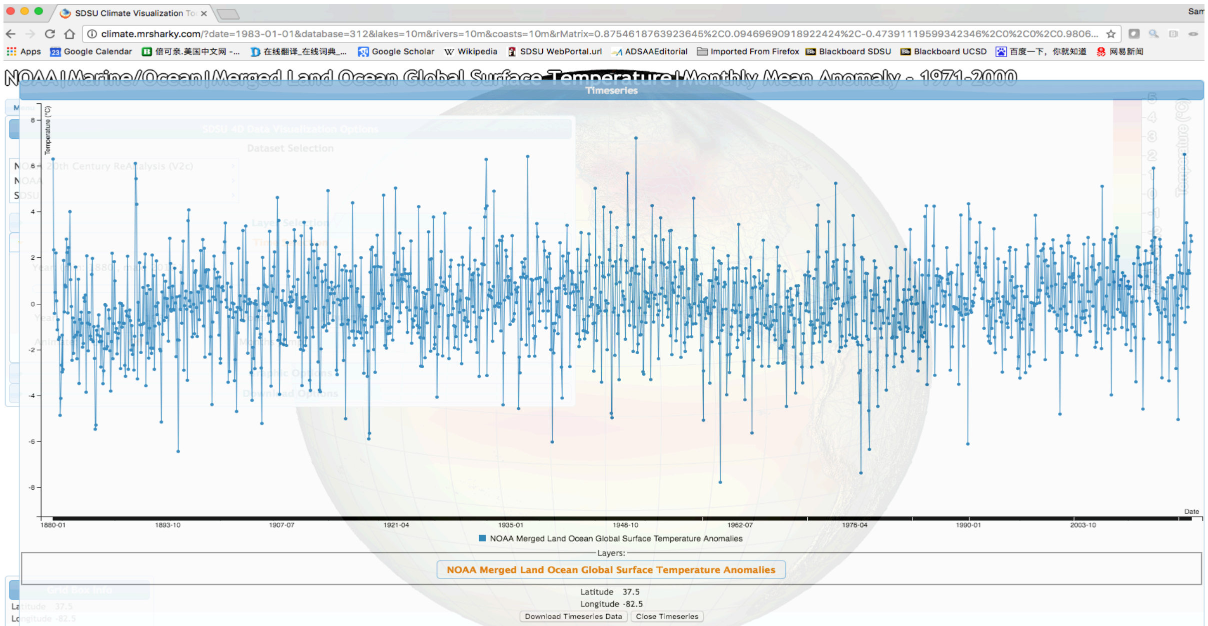


Figure 2*. 4DVD display of the temperature anomaly history of the Asheville, NC grid box.*

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 Estimators), B-SHADE (Biased Sentinel Hospital based Area Disease Estimation), and MSN (Mean of Surface with Non-homogeneity). 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

- **Product development and publication:** Write and publish the daily ¼ degree gridded precipitation data over the contiguous United States from 1 January 1895 to present.

- **Complete the "Climate Mathematics" book manuscript:** Include the theory on averages by SOA, B-SHADE and MSN.
- **Complete journal manuscript revisions if needed:** Currently Accepted in *Advances in Data Science and Adaptive Analysis.*

Publications

Peer-reviewed

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*, **9**. doi: 10.1142/S2424922X17500061.

Non-peer-reviewed

Shen, S.S.P., 2017: R Programming for Climate Data Analysis and Visualization: Computing and plotting for NOAA data applications. The first revised edition. San Diego State University, San Diego, USA, 152pp.

Products

1. **4DVD (4Dimensional visual delivery) visual delivery system for big climate data:** The software product can temporarily be accessed in a limited way on the website *http://climate2.mrsharky.com/*. 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.

2. 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. The codes and their documentation can be downloaded from https://shen.sdsu.edu/pdf/R-TextBySamShen2017.pdf

Presentations

Shen, S.S.; Behm, G.P.; Song, Y.T.; Qu, T.; Pierret, J.; Tucker, T.; and Knapp, S., 2018: Dynamically Consistent Reconstruction and Visualization of Monthly Ocean Temperature with 1-Degree Resolution since January 1950 by the Spectral Optimal Gridding Method. *2018 Ocean Sciences Meeting*, Portland, OR, February 15, 2018.

Other
Advised a NOAA EPP graduate student: Tyler Tucker, MSc., 2016-2018.

Performance Metrics	
# of new or improved products developed that became operational	**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	**1**
# of graduate students supported by your CICS task	**1**
# of graduate students formally advised	**3**
# of undergraduate students mentored during the year	**2**

1. **4DVD (4-dimensional visual delivery) of big climate data:** A web and database application to provide space-time visualization and delivery of big climate data. The full application will be made available to CICS-NC/NCEI upon request. Demo: http://climate2.mrsharky.com/
2. **Argo data visualizer:** an Argo data visualization software named Argovis, that is already linked to Argo website. See demo: http://www.argovis.com/map

Night Marine Air Temperature Near Real-Time Dataset Development	
Task Leader:	Steve Stegall
Task Code	NC-SON-09-NICS-SS
NOAA Sponsor	Boyin Huang
NOAA Office	NESDIS/NCEI
Contribution to CICS Research Themes	Theme 2: Climate and Satellite Observations and Monitoring 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Climate Adaptation and Mitigation: 100%
NOAA Strategic Research Priorities:	Environmental Observations

Highlight: A preliminary gridded NCEI NMAT dataset from 2002 - August 2017 was generated that includes NMATs adjusted in the boundary layer to a homogenized height of 10m and gridded using a distance weighting scheme. Results agree well with HadNMAT2 between 30S and 60N.

Background

Night marine air temperature (NMAT) provides the ocean's complement to land surface temperatures and allows for a global representation of surface temperature. NMAT also complements sea surface temperature (SST) and is used to bias correct SST data. NMAT is one of many observed variables in the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). 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 Large and Yeager (2004) approach was used to adjust NMAT temperatures measured at different heights above the ocean surface, largely due to different ship types, to a common height (homogenized height) set to 10m. Five variables are needed to provide this correction: NMAT, SST, HOA (height of the anemometer), HOT (height of the thermometer), and wind speed. These corrections agree well with the HadNMAT2 corrections. In addition, some Height of Anemometer (HOA) entries in the Pub.47 metadata were reported as 0.0m. Other sources were searched for these HOAs to create a look up table (LUT) for 43 ships with a known HOA to further improve height homogenization.

A distance weighted gridding scheme was implemented for the corrected temperatures to 5°X 5° lat/lon grid. The radius of influence used in the gridding varies by the cosine of the latitude. A preliminary global ocean monthly NMAT was generated on a 5°X 5° grid from January 2002 to August 2017. Numerous NCEI NMAT and HadNMAT2 comparisons were completed between 2002 and end of 2010 as HadNMAT2 is only produced through the end of 2010. Overall, there is good agreement between NCEI NMAT and HadNMAT2 between 30S and 60N. There is larger warm bias in the NCEI NMAT in the Arctic region (above 60N) and in the Southern Ocean (between 30S and 60S). These two regions are also where there is sparse observational data. Globally the differences are ~0.5, but the warm bias is due to the larger disagreements in Arctic and Southern Oceans.

Planned work

- Extend the NCEI NMAT back to at least 1981 and forward to near real time.
- Continue to investigate large differences in data sparse regions.
- Further QC as needed of the NMATs, HOTs and HOA's.
- Submit and publish a peer reviewed manuscript of the NCEI NMAT dataset.

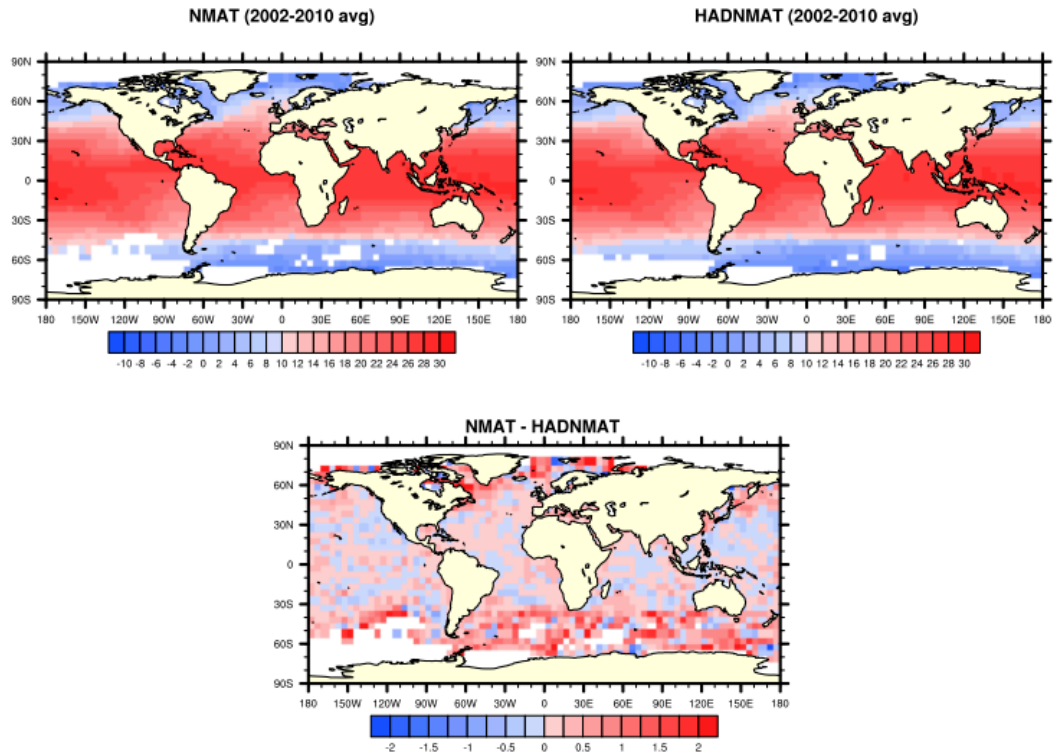


Figure 1. *The 2002-2010 gridded mean NCEI NMAT and the HadNMAT2 in degrees C (top two plots). The bottom plot is the NCEI minus the HadNMAT2.*

Publications

Jing, Z., **S. T. Stegall**, and X. Zhang, 2018: Wind–sea surface temperature–sea ice relationship in the Chukchi–Beaufort Seas during autumn. *Environmental Research Letters*, **13**, 034008. http://dx.doi.org/10.1088/1748-9326/aa9adb

Presentations

Stegall, S., 2018: 442: A Monthly Near-Real-Time Night Marine Air Temperature Dataset. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

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

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.

Research Faculty. 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 mentor students formally and informally (CICS-NC student internships, NOAA Hollings Scholars, NASA DEVELOP team members, etc.) and engage in various outreach activities to promote awareness and increase interest in K–12 climate science studies.

- Otis Brown and Kenneth Kunkel hold Research Professor appointments, 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 served 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 created and taught 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.

Post-doctoral Scholars. 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. Currently, CICS-NC personnel includes one post-doctoral scholar:

- Andrew Ballinger, post-doctoral Research Scholar, is in his second year working with Kenneth Kunkel and collaborating on the multi-institutional, NSF-sponsored Urban Resilience to Extremes—Sustainability Research Network (UREx SRN) project (see project report under *Other CICS-NC PI Projects*).

Students (Graduate/Undergraduate/High School). 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. CICS-NC scientists also serve as mentors and advisors for the NOAA Hollings Scholars and NASA DEVELOP team members that complete their 10-week internship projects at NCEI.

Spring 2017:

- Timothy Henderson, North Carolina State University student, worked with Ronald Leeper to help analyze urban biases on daily temperature extremes.

Summer 2017:

- The NASA DEVELOP team comprised of *Michael Marston* (Virginia Tech), *Aaron Mackey* (University of North Carolina-Greensboro), and *Brittany Thomas* (North Carolina State University) completed their project, “A Step Ahead: Analyzing Cyclone Vulnerability to Coordinate Disaster Relief Efforts in the Philippines,” under project advisors Carl Schreck and Ken Knapp (NCEI). The project examined the use of NASA and NOAA earth observations to enhance storm preparation and disaster relief planning methods by the United Nation’s Office for the Coordination of Humanitarian Affairs. https://develop.larc.nasa.gov/2017/summer/PhilippinesDisastersII.html
- NOAA Hollings Scholar *Chase Graham* (University of North Carolina-Asheville) worked with Olivier Prat and Brian Nelson (NCEI) focusing on the nature of tropical cyclones in the southeastern United States. They used precipitation data from the PERSIANN Climate Data Record dataset and tropical cyclone track information to characterize how tropical cyclones contributed to rainfall in the region from 1998-2012.
- NOAA Hollings Scholar *Rachel Phinney* (University of Nebraska-Lincoln) worked with Jared Rennie to create a visualization tool demonstrating how precipitation extremes have changed and will change in the future. They used Global Historical Climatology Network-Daily dataset to calculate historic extreme precipitations metrics across the United States then projected these trends to 2100 using downscaled climate model projections based on the localized constructed analogs (LOCA) dataset. The information is then displayed to tell a story to its users.

Fall 2017:

- The NASA DEVELOP team comprised of *Lilian Yang* (University of California-Santa Barbara), *Laurel Mahoney* (George Mason University), and *Shannan Hurley* (Old Dominion University) completed their project, “A Mountain of Data, Can We Climate?,” under project advisors Anand Inamdar and Anthony Arguez (NCEI). The project examined the development of annual, seasonal, and monthly temperature indices over the northeastern united states to represent recent temperature trends using NASA and NOAA datasets. https://develop.larc.nasa.gov/2017/fall/NortheastUSCC.html
- *Kara Pirarulli*, Climate Change and Society Masters program student at North Carolina State University, worked with Jenny Dissen to develop a curriculum methodology for teachers to access and teach students about the NOAA NCEI Storm Events Database.

Spring 2018:

- The NASA DEVELOP team comprised of *Shelby Ingram* (University of North Carolina-Asheville), *Andrew Shannon* (University of Pennsylvania), and *Michael Vonhegel* (University of North Carolina-Asheville) completed their project, "Extreme Precipitation," under project advisors Olivier Prat and Brian Nelson (NCEI). They examined the use of precipitation estimates from NASA earth observations and NOAA climate data records to enhance understanding of extreme events in the Carolinas. https://develop.larc.nasa.gov/2018/spring/CarolinasDisasters.html
- *Evan Fisher*, Asheville Christian Academy senior, spent a week "shadowing" Jared Rennie and Ronald Leeper, meeting with scientists and technicians, performing hands-on data analysis, visiting the Collider and the NC Arboretum USCRN station, and participating in the CICS-NC Quarterly Science Meeting.
- *Elijah Byrd*, Nesbitt Discovery Academy senior, is working with Jenny Dissen on understanding customers and users of NOAA NCEI and their use of the environmental data by building information in the customer information database. In additional, Eli has developed his own research effort on comparing Buncombe County school closure due to inclement weather against official record from NOAA NCEI to understand any patterns and trends, and if the analysis can inform planning for the future.
- *Zachary Fisher*, a high school senior at Nesbitt Discovery Academy, is spending the semester in an internship working with Jennifer Runkle on a climate and health literature review.
- *Laura Thompson*, Appalachian State University, is working with Jennifer Runkle on a pilot cold study with ASU outdoor grounds maintenance workers, utilizing wearable sensors to assess cold exposure in population health and climate change studies.

Ongoing:

- *Katie Lynch*, Emory University Rollins School of Public Health MPH student, is working with Jesse Bell (8/17-5/18) to study the impacts of drought on human health.
- *Sridhar Mantripragada*, North Carolina State University PhD student, is working with Carl Schreck on his NASA grant, using NASA's new Cyclone Global Navigation Satellite System (CYGNSS) retrievals to investigate the surface interactions between Kelvin waves and easterly.
- *Lakemarium Worku*, North Carolina A&T PhD student, and *Cody Yeary*, North Carolina State University PhD student, are working with Carl Schreck on his NASA Maritime Continent grant, examining the strong diurnal cycle of convection over the Maritime Continent and demonstrating how it impacts subseasonal-to-seasonal forecasts.

Other CICS PI Projects

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

CICS' 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. In this context, observations include the development of new ways to use existing observations, the invention of new methods of observation, and the creation and application of ways to synthesize observations from many sources into a complete and coherent depiction of the full system. Prediction requires the development and application of coupled models of the complete climate system, including atmosphere, oceans, land surface, cryosphere and ecosystems. Underpinning all institute projects and activities is the fundamental goal of enhancing our collective interdisciplinary understanding of the state and evolution of the full Earth System.

While CICS-NC projects and activities under the CICS cooperative agreement are primary within NCICS, some NCICS scientists also participate in and receive partial support through other sponsored research programs awarded through competitive proposal solicitations. Individual and collaborative climate science proposals are submitted through NCSU to relevant federal solicitations from NASA, NSF, NOAA, DOE, DOD, and NIH (including CDC and NIOSH) 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	Centers for Disease Control and Prevention (CDC)
Contribution to CICS Research Themes	Climate and Satellite Research and Modeling 100%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals	Goal 1: 45%; Goal 2: 45%; Goal 4: 10%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: CICS-NC staff have established and strengthened a collaborative relationship between NOAA and CDC by integrating NOAA environmental data into targeted CDC health studies to increase the understanding of climate effects on human health. Projects over the past year have dealt with topics such as extreme heat surveillance, soil moisture conditions and Valley fever, and evaluation of mental health outcomes from drought.

Background

A Memorandum of Understanding (MOA-2011-069/8371) between the National Oceanic and Atmospheric Administration (NOAA) and the Centers for Disease Control and Prevention (CDC) was signed in 2011 to strengthen the science and service linking environment and public health impacts. Changes in the world's climate are having increasing adverse impacts on human health. Understanding the potential health risks associated with climate change, climate variability, and extreme events is important for preparing for the future. The CDC focuses national attention on developing and applying disease control and prevention with special focus on infectious disease, food borne pathogens, environmental health, occupational safety and health, health promotion, injury prevention, and educational activities designed to improve the health of United States citizens. Integrating NOAA's vast archive of environmental data into CDC health studies is advantageous for improving CDC's analyses and can help save lives.

Accomplishments

CICS-NC's Jesse Bell has utilized his expertise in climate data and ecology to foster a collaborative relationship with the CDC in support of the NOAA/CDC MOU and maintains an office and work at both the CDC and NCEI. He has worked in CDC's Climate and Health Program and now serves as Senior Climate Science Consultant to the CDC Mycotic Diseases Branch while also interacting with other CDC branches and programs to bring climate observations from NOAA to CDC for health analyses. He has helped develop diverse projects dealing with extreme heat surveillance, soil moisture conditions and Valley fever, evaluation of mental health outcomes from drought, and precipitation rates on traffic accidents. He also assisted with CDC grantees accessing and understanding climate data. Under his guidance, CDC gains access to NCA climate change projections and NIDIS drought data for the National Environmental Health Tracking Network.

For example, Coccidioidomycosis (also called Valley fever) is caused by a soil-borne fungus, Coccidioides spp., in arid regions of the southwestern United States. Though some who develop infections from this fungus remain asymptomatic, others develop respiratory disease as a consequence. Less commonly, severe illness and death can occur when the infection spreads to other regions of the body. Previous analyses attempted to connect the incidence of coccidioidomycosis to broadly-available climatic measurements, such as precipitation or temperature. However, with the limited availability of long-term, in situ soil moisture datasets, it has not been feasible to perform a direct analysis of the relationships between soil moisture levels and coccidioidomycosis incidence on a larger temporal and spatial scale. Utilizing in situ soil moisture gauges throughout the southwest from the U.S. Climate Reference Network (USCRN) and a model with which to extend those estimates, this work connects periods of higher and lower soil moisture in Arizona and California between 2002 and 2014 to the reported incidence of coccidioidomycosis. The results indicate that in both states, coccidioidomycosis incidence is related to soil moisture levels from previous summers and falls. Stated differently, a higher number of coccidioidomycosis cases are likely to be reported if previous bands of months have been atypically wet or dry, depending on the location.

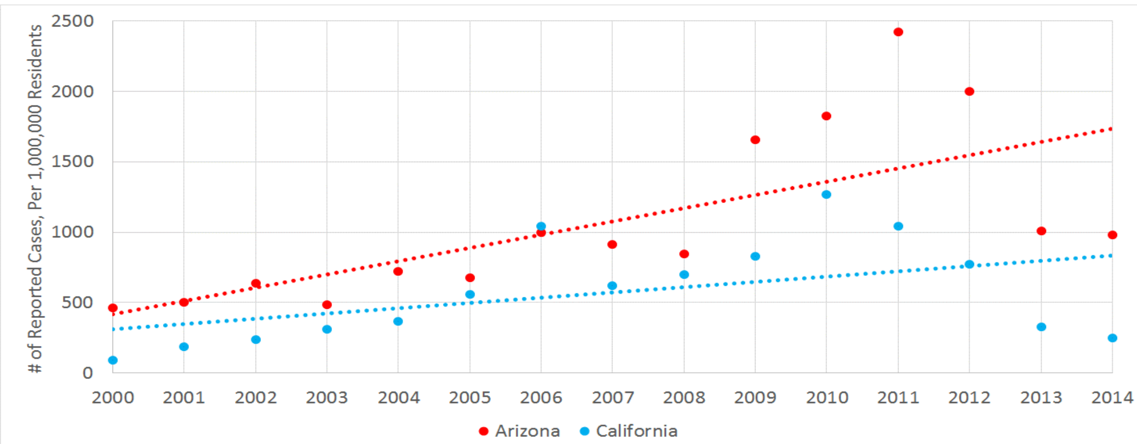


Figure. 1. *Incidence of coccidioidomycosis per 1,000,000 residents, selected counties in Arizona and California (2000-2014)*

Planned work

- Expand work on Valley fever to investigate forecasting of disease.
- Publish work on heat health.
- Publish work on traffic accidents and precipitation.

Publications

Coopersmith, E. J., **J. E. Bell**, K. Benedict, J. Shriber, O. McCotter, and M. H. Cosh, 2017: Relating coccidioidomycosis (valley fever) incidence to soil moisture conditions. *GeoHealth*, **1**. doi:10.1002/2016GH000033.

Shriber, J., Conlon, K. C., Benedict, K., McCotter, O. Z., & **Bell, J. E.**, 2017: Assessment of Vulnerability to Coccidioidomycosis in Arizona and California. *International Journal of Environmental Research and Public Health*, **14**(7), 680. http://www.mdpi.com/1660-4601/14/7/680

Products

• NOAA data were transferred to CDC for health studies.
• NOAA drought data are on CDC's platform for access.

Presentations

Bell, J., 2017: Using extreme event attribution to determine the health impacts of climate change. *American Public Health Association* (APHA) Annual Meeting, November 6, 2017.

Bell, J., 2017: Analysis of Drought Conditions in the United States: 1895-2016. *Centers for Disease Control and Prevention* (CDC) webinar, December 4, 2017.

Bell, J., 2017: Changes in Extreme Events and the Potential Impacts on National Security. *AGU*, New Orleans, LA, December 11, 2017.

Bell, J., 2017: Assessment of the Long-Term Trends in Extreme Heat Events and the Associated Health Impacts in the United States. *AGU*, New Orleans, LA, December 12, 2017.

Performance Metrics	
# of peer reviewed papers	**2**
# of presentations	**4**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Changes of freezing precipitation frequency	
Task Leader:	Pavel Groisman
Task Code	NC-OTH-02-NCICS-PG
Other Sponsor	Multiple
Contribution to CICS Research Themes	Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA goals	Climate Adaptation and Mitigation: 100%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication; Environmental Observations

Highlight: Several international efforts are underway to conduct environmental change research focused on the regions of the northern extratropics to better inform vulnerable societies and better prepare them for potential future developments.

Background

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

- generate major trends in food production for the global market (e.g., the U.S. Midwest, East China, fertile steppe and black soil regions of northern Eurasia) and
- are susceptible to external harmful forcing such as droughts, floods, and other harmful weather anomalies.

Accomplishments

Northern Eurasia Future Initiative (NEFI). The Northern Eurasia Future Initiative (NEFI; http://nefi-neespi.org), designed as an essential continuation of the Northern Eurasia Earth Science Partnership Initiative (NEESPI), was launched. NEESPI sought to elucidate all aspects of ongoing environmental change, to inform societies and better prepare them for future developments. A key principle of NEFI is that these developments should be secured through science-based strategies co-designed with regional decision makers. Nine NEFI research foci were identified: warming of the Arctic; changing frequency, pattern, and intensity of extreme and inclement environmental conditions; retreat of the cryosphere; changes in terrestrial water cycles; changes in the biosphere; pressures on land-use; changes in infrastructure; societal actions in response to environmental change; and quantification of Northern Eurasia's role in the global Earth system. Integrated Assessment Models are deemed needed as the final stage of global change assessment.

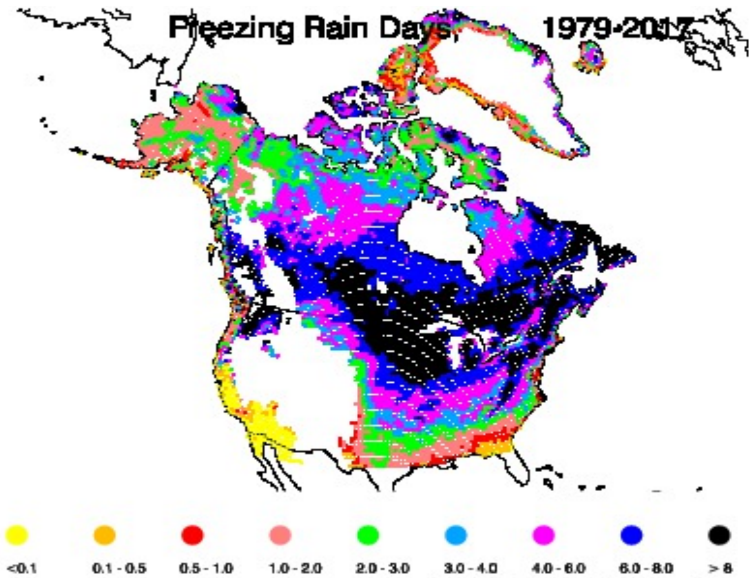


Figure 1. *Freezing rain climatology of North America at elevations below 1200 m (days per year) based on our algorithm of weather conditions conducive to freezing rain (WCCFR). The algorithm was developed using the synoptic and aerologic networks of the northern extratropics and is now applied to the output of the CFSRv2 reanalysis.*

- ***GEWEX project*.** To improve understanding of future changes in hazardous cold/shoulder season precipitation and storms, especially occurring near 0°C, an international GEWEX project was launched to study human-related extreme events that occur around the 0°C. We studied the occurrence of freezing precipitation (freezing rain and drizzle, FR and FD) events over the northern extratropics and documented their major changes that occurred during the past decade at high latitudes. An algorithm was developed to define the weather conditions conducive to freezing rain (WCCFR) using the synoptic and aerologic networks. Climatology and dynamics of these WCCFR changes were estimated over the northern extratropics using the modern reanalysis output. Figure 1 above presents the WCCFR climatology for North America based on the CFSRv2 reanalysis.

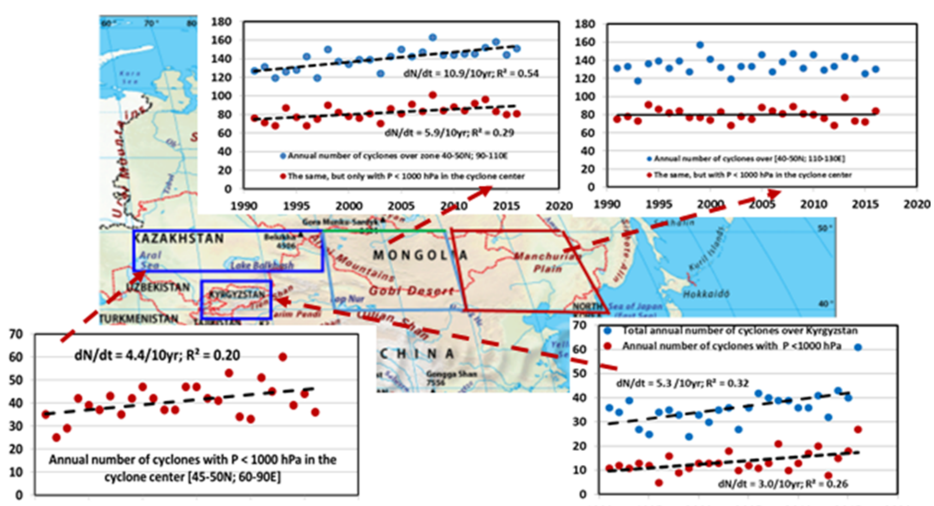


Figure 2. *Annual number of atmospheric cyclones area-averaged of the four regions of the Asian Dry Land Belt of Northern Eurasia during the post-USSR period.*

- ***Dry Land Belt of Northern Eurasia (DLB) study***. The DLB is a region where environmental changes are becoming more controlled by human activity. Following an international workshop in Mongolia (June 2017), a multidisciplinary international study was initiated to address changes in DLB and to develop a sustainable strategy of its development.
- ***Global temperature time series homogeneity.*** Progress in documenting global climate change (e.g., new instruments) created concerns about the homogeneity of global temperature time series. Our perspective is to maintain a "conservative" estimate of global and zonal surface air temperature changes since 1881 using fixed in situ station networks and optimal area-averaging technique that has not changed during the past one and half centuries.
- ***Daily Precipitation Distribution Climatologies***. In collaboration with Iowa State University, daily precipitation distribution climatologies (median, quantiles, including extremes, and probability of no-rain events) for the past 60 years with a ten-year running time step were created and their changes at monthly, seasonal and annual scales were studied.

Planned work

- Present latest project results at appropriate international conferences.
- Draft and submit WCCFR paper(s) to peer-reviewed journals.
- Submit proposal to US funding agencies to facilitate development of the WCCFR product for climatological projections of FR occurrence and risk management associated with these events.
- Support development of NEFI studies including (a) convening international NEFI Conferences and Sessions at large International Conferences; (b) maintain major NEFI publication outlet (presently, *Environmental Research Letters* Special Issues); and (c) promote NEFI Science Plan science questions. (http://nefi-neespi.org)
- Update the homogeneous time series of global, zonal and regional mean monthly near-surface air temperature from 1881 up to date with time delay of several months.
- Complete analysis of changes of daily precipitation distributions (including extremes) over the contiguous United States during the past 60 years.

Publications *(all peer-reviewed)*

Partasenok, I.S. S.V. Povajnaya, E.V. Kamarouskaya and **P.Ya. Groisman**, 2017: Peculiarities of Precipitation Near 0 °C Regime and Freezing Events Occurrence over the Territory of Belarus. *Natural Resources*, 2017, No.1, 69-76. Minsk, Belarus. ISSN 1810-9810

Monier, E., D. Kicklighter, A. Sokolov, Q. Zhuang, I. Sokolik, R. Lawford, M. Kappas, S. Paltsev, and **P. Groisman**, 2017: A Review of and Perspectives on Global Change Modeling for Northern Eurasia. *Environ. Res. Lett.,* **12,** 83001**.** http://iopscience.iop.org/article/10.1088/17489326/aa7aae/meta

Qi, J., X. Xin, R. John, **P.Groisman**, J. Chen, 2017: Understanding Livestock Production and Sustainability of Grassland Ecosystems in the Asian Dryland Belt. *Ecological Processes*, 6:22, 10 pp. doi:10.1186/s13717-017-0087-3.

Groisman, P.Ya., et.al. and The NEFI Science Plan Preparation Team, 2017: Northern Eurasia Future Initiative (NEFI): facing the challenges and pathways of global change in the twenty-first century. *Progress in Earth and Planetary Science***, 4:41.** doi:10.1186/s40645-017-0154-5.

Liu, X., Q. Tang, X, Zhang, P**. Groisman**, et al., 2017, Spatially distinct effects of preceding precipitation on heat stress over eastern China. *Environ. Res. Lett.* **12**, 115010.

Chen, Y.Z.; Ju, W.; **Groisman, P. Ya.;** Li, J.; Propastin, P., Xu, X.; Zhou, W.; Ruan, H., 2017: Quantitative assessment of carbon sequestration reduction induced by disturbances in Temperate Eurasian Steppe., *Environ. Res. Lett*., **12**. doi:iopscience.iop.org/article/10.1088/1748-9326/aa849b

Products
Algorithm of defining weather conditions conducive to freezing rain (WCCFR) was developed, tested and applied to North America and Northern Eurasia meteorological, aerologic and modeling (reanalysis) data.

Presentations
Groisman, P., 2017: Freezing Precipitation and Freezing Events over High Latitudes of the Northern Hemisphere: Climatology and the Last Decade Changes, *AMAP Conference on Arctic Science: Bringing Knowledge to Action*, Reston, VA, April 26, 2017.

Groisman, P., 2017: Freezing Precipitation and Freezing Events over High Latitudes of the Northern Hemisphere: Climatology and the Last Decade Changes, *BELMONT-3 Programmatic Workshop*, St. Petersburg, Russia, April 26, 2017.

Groisman, P., 2017: Transition from the Northern Eurasia Earth Science Partnership (NEESPI) to the Northern Eurasia Future Initiative (NEFI), *Japan Geoscience Union (JpGU)-American Geophysical Union (AGU) Joint Meeting 2017*, May 20, 2017.

Groisman, P., 2017: Northern Eurasia Future Initiative (NEFI): Nine Science Foci of Research, *Japan Geoscience Union (JpGU)-American Geophysical Union (AGU) Joint Meeting 2017*, May 20, 2017.

Monier, E., et.al. with **Groisman, P.**, 2017: A Review of the Perspectives on Global Change Modeling for Northern Eurasia, *Japan Geoscience Union (JpGU)-American Geophysical Union (AGU) Joint Meeting 2017*, May 20, 2017.

Georgievskiy, V., et.al. with **Groisman, P.**, 2017: Changes in main components of the water cycle or Lake Khanka during the 1949 - 2015 period, *Japan Geoscience Union (JpGU)-American Geophysical Union (AGU) Joint Meeting 2017*, May 20, 2017.

Bulygina, O., etal with **Groisman, P.**, 2017: Changes in the wind regime in Russia, *Japan Geoscience Union (JpGU)-American Geophysical Union (AGU) Joint Meeting 2017*, May 20, 2017.

Groisman, P., 2017: Northern Eurasia Future Initiative (NEFI): Nine Science Foci of Research, *UB2017 Synthesis Workshop Synthesizing Human and Nature Data from the Mongolian Plateau*, Ulaanbaatar, Mongolia, June 4, 2017.

Groisman, P., 2017: Contemporary global climatic changes and their manifestation in the Dry Land Belt (DLB) of Northern Eurasia, UB2017 Synthesis Workshop Synthesizing Human and Nature Data from the Mongolian Plateau, Ulaanbaatar, Mongolia, June 4, 2017.

Groisman, P., 2017: Understanding of Freezing Precipitation Processes and their Changes, *CITES-2017: International Conference and Young Scientists School on Computational Information Technologies for Environmental Sciences*, Zvenigorod, Russia, September 4, 2017.

Groisman, P., 2017: Northern Eurasia Future Initiative (NEFI) as a Successor of Northern Eurasia Earth Science Partnership Initiative (NEESPI), *All-Russian Forum: Science of the Future – Science of the Young*, Nizhniy Novgorod, Russia, September 13, 2017.

Groisman, P., 2017: Freezing Precipitation, Characterization of Weather Conditions Associated with it, and Changes of the Frequency of its Occurrence, *CICS Annual Science Meeting*, College Park, MD, November 7, 2017.

Groisman, P., 2017: Characterization of freezing precipitation events through other meteorological variables and their recent changes over Northern Extratropics, *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Streletskiy, D.; **Groisman, P.**; et.al., 2017: From the Northern Eurasia Earth Science Partnership Initiative to the Northern Eurasia Future Initiative, *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Bulygina, O.; Korshunova, N.; Razuvaev, V.; and **Groisman, P.**, 2017: New estimates of changes in snow cover over Russia in recent decades, *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Monier, E.; et.al, and **Groisman, P.**, 2017: Global change modeling for Northern Eurasia: a review and strategies to move forward, *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

Other

• Guest Editor of *Environmental Research Letters* Special Issues dedicated to Northern Eurasia Studies.

• Editorial Board Member of *Ice and Snow* (Лёд и Снег) since 2013.

• All-Russia Early Career Scientists Competition Organizing Committee member at the All-Russian Forum: Science of the Future – Science of the Young, Nizhniy Novgorod, Russia, 12-17 September, 2017.

Performance Metrics	
# of peer reviewed papers	**6**
# of presentations	**16**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

The Urban Resilience to Extremes Sustainability Research Network (UREx SRN)	
Task Leader/Task Team:	Kenneth Kunkel; Andrew Ballinger
Task Code	NC-OTH-03-NCICS-KK/AB
Other Sponsor	Arizona State University / National Science Foundation (NSF)
Contribution to CICS Research Themes	Climate Research and Modeling: 100%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Goal 1: 20%; Goal 2: 80%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: CICS-NC scientists are leading the Climate and Hydrologic Extremes Working Group (CHExWG) efforts for a large multi-institutional project led by Arizona State University. Current efforts include characterization of recent historical trends of climate extremes and the development of future climate extreme scenarios for nine pilot cities in the U.S., Puerto Rico, Mexico, and Chile.

Background

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 Urban Resilience to Extremes Sustainability Research Network (UREx SRN) is an NSF-funded multi-institutional project led by Arizona State University. The project is developing and implementing 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.

The highly interdisciplinary and geographically dispersed UREx SRN team is developing a diverse suite of methods and tools to assess how infrastructure can be resilient, provide ecosystem services, improve social well-being, and exploit new technologies in ways that benefit all segments of urban populations. The team is working with several pilot cities [Portland (OR), Phoenix, New York City, Baltimore, Syracuse, Miami, San Juan (PR), Hermosillo (Mexico), and Valdivia (Chile)] to co-produce the knowledge needed to transition to resilient SETS infrastructure in cities of the future. This portion of the project includes characterization of recent historical trends of climate extremes and the development of future climate extreme scenarios.

CICS-NC scientists Dr. K. Kunkel (lead) and Dr. A. Ballinger (postdoctoral scholar) are members of the UREx SRN Climate and Hydrologic Extremes Working Group (CHExWG) tasked with a) developing climate extremes products for the nine cities tailored to the city-specific vulnerabilities and b) communicating and explaining those products to other UREx SRN members. These products will be supported by the development and analysis of statistically downscaled data sets and/or the application of dynamically-downscaled simulations as available and appropriate.

Accomplishments

LOCA-downscaled gridded climate model data analyses: The Localized Constructed Analogs (LOCA) technique, developed by David Pierce at Scripps Institution of Oceanography, statistically downscales climate model data (maximum/minimum temperature and precipitation) to a ~6 km grid over CONUS and regions of Mexico and Canada. We have continued our analysis of the 32 LOCA-downscaled climate models (from CMIP5) for each of the 7 UREx SRN pilot cities within this domain: Baltimore, Hermosillo, Miami, NYC, Phoenix, Portland, and Syracuse.

- Expanded the list of climate extreme indices analyzed and available for each network city.
- Explored the seasonality of climate extremes (e.g. Figure 1), identifying relevant changes in the seasonal cycle for different network cities.
- Developed several cross-city comparisons of projected changes to extreme events (heat waves, multi-day rainfall, etc.).

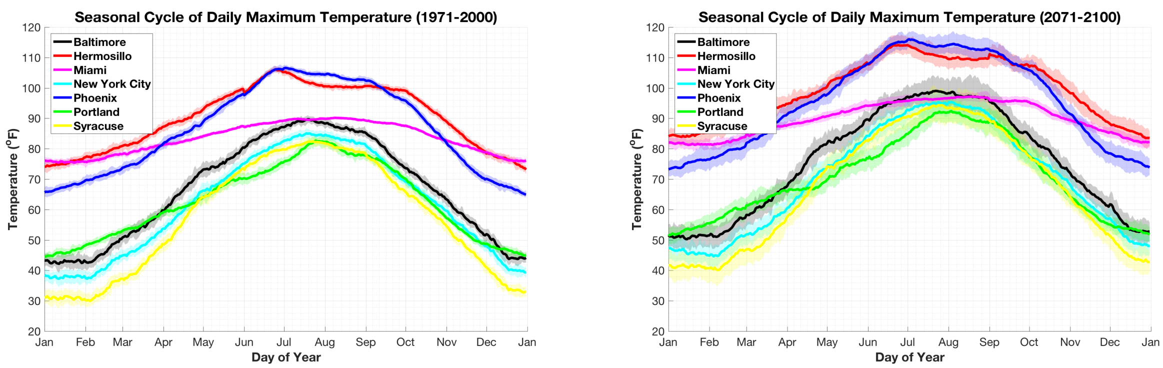


***Figure 1**: The multi-model ensemble-mean seasonal cycle of daily maximum temperature for several cities in the UREx network, analyzed from LOCA-downscaled CMIP5 simulations over the historic period (left panel), and projected 100 years into the future under the RCP8.5 emissions scenario (right panel).*

ARRM-downscaled climate model data analyses: The Asynchronous Regional Regression Model (ARRM) technique, developed by Katharine Hayhoe and colleagues at Texas Tech University, statistically downscales climate model data (maximum/minimum temperature and precipitation) to any point location/station that has a sufficiently good (quality and length) record of past observations. We have analyzed 23 ARRM-downscaled climate models (from CMIP5) for 3 locations in Valdivia (Chile) and 1 location in San Juan (Puerto Rico).

- Computed climate extreme indices for Valdivia and San Juan, similar to those that were previously developed for the pilot cities in CONUS and Mexico, enabling subsequent cross-city comparison with the LOCA-downscaled data.
- Produced a series of plots and figures for communicating future projections of climate extremes to researchers and practitioners (heatwaves, extreme precipitation, etc.)

CHExWG annual meeting: coordinated and hosted a 2-day CHExWG workshop in Asheville in August 2017 involving 15 participants from 9 different institutions across the U.S. (including Puerto Rico) and Mexico. Discussion topics included: a "listening session" conference call with other SRN working groups; approaches to downscaling hydrological modeling/analysis to the city scale; compound extremes and climate extreme metrics; and overall CHExWG deliverables and a group publication strategy.

Practitioner workshop preparations: provided downscaled projection analyses for practitioner-focused scenarios workshops conducted in Valdivia (May 2017) and Hermosillo (November 2017) helping to contextualize the current to future risk of climate extremes.

Research collaboration: providing climate data and analyses and Matlab programming tutorials to CHExWG colleagues and other project personnel for collaborative research into extreme precipitation, hydrological model analyses, and regional climate simulations.

Planned work

- Continue collaborations with the different UREx SRN city teams (researchers and practitioners) to provide tailored, relevant, and usable projections of climate extremes for city-specific workshops and research pursuits.
- Evaluate new and novel metrics for analyzing extremes and compound climate events.
- Create a gridded Standardized Precipitation Evapotranspiration Index (SPEI) from the LOCA dataset, to be used for analyzing future projections of climatological drought over the water-catchment regions of importance to urban communities.
- Publish journal article(s) that concentrate on the LOCA- and ARRM-downscaled climate model projections of climate extremes, exploring the similarities and differences across network cities.
- Foster collaborations with researchers in the CHEx working group, in particular towards the task of utilizing climate model output as input to higher-resolution urban hydrologic modeling.
- 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.
- Explore approaches to facilitate the adoption of new engineering design values.
- Incorporate supplemental field measurements and investigate a range of sustainability solutions that build resilience.

Presentations

Ballinger, A. P., 2017: Partnering with Cities to Build Resilience to Future Climate and Hydrological Extreme Events. *Climate Predictions Applications Science Workshop (CPASW)*, Anchorage, AK, May 2, 2017.

Ballinger, A. P., and **K. E. Kunkel**, 2018: TJ8.2: Communicating Projections of Weather and Climate Extremes for Urban Decision-Makers. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.

Other

A. Ballinger mentored Bryan Van Alebeek, a UNC-Asheville student who utilized ArcGIS software to explore innovative ways to visualize and communicate the future projections of the annual maximum temperature and rainfall for cities in the UREx network.

K. Kunkel advised/examined (as a PhD committee member) a CHExWG graduate student, Javad Shafiei Shiva (Syracuse University), on his UREx SRN research related to the changing nature of heatwaves in different network cities.

A. Ballinger participated in the Fifth AMS Conference for Early Career Professionals, in Austin, TX. (January 2018).

A. Ballinger received a North Carolina State University Graduate School and the Office of Postdoctoral Affairs Professional Development Award conference travel grant.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**2**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values	
Task Leader/Task Team:	Kenneth Kunkel (Leader), James Biard, Sarah Champion, Ronnie Leeper, Olivier Prat, Laura Stevens, Scott Stevens, Liqiang Sun
Task Code	NC-OTH-04-NCICS-KK/etal
Other Sponsor	DOD/SERDP
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Mai CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Goal 1: 50%, Goal 2: 50%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: An algorithm using Deep Learning methods to automatically identify weather fronts in climate model and reanalysis data in gas was completed. An analysis of historical extreme precipitation events found a strong correlation between the magnitude of the events and the atmospheric water vapor content, a finding that provides a strong basis for adjustment of IDF values.

Background

There is overwhelming evidence that today's climate system is non-stationary and is expected to remain so for the foreseeable future. Primary drivers include human-caused changes in atmospheric greenhouse gas concentrations. Increases in heavy precipitation events are one of the more robust climate change signals in the observed record. Previous work examined the meteorological causes of historical trends in the U.S. and found significant upward trends in the number of events from fronts and tropical cyclones but no increases from other meteorological causes. The likelihood 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 are being 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

Two separate analyses explored the potential role of atmospheric water vapor in the observed trends. One analysis examined the precipitable water (PW) associated with daily extreme events exceeding a threshold for a 1-in-5yr recurrence. This found upward trends in PW in the regions of the U.S. with upward trends in the number of extreme precipitation events. The second analysis examined PW associated with annual maximum daily precipitation. This analysis found that years with high values of the magnitude of the annual maxima had higher PW values associated with the events while years with lower magnitudes had lower PW values. The positive correlation of extreme precipitation magnitudes and frequencies with water vapor concentration provides the basis for the incorporation of a water vapor adjustment in IDF values. An increase in extreme water vapor concentrations will accompany any future warming with high certainty due to the fundamental relationship between saturation water vapor pressure and temperature. The observed correlations are consistent with this relationship.

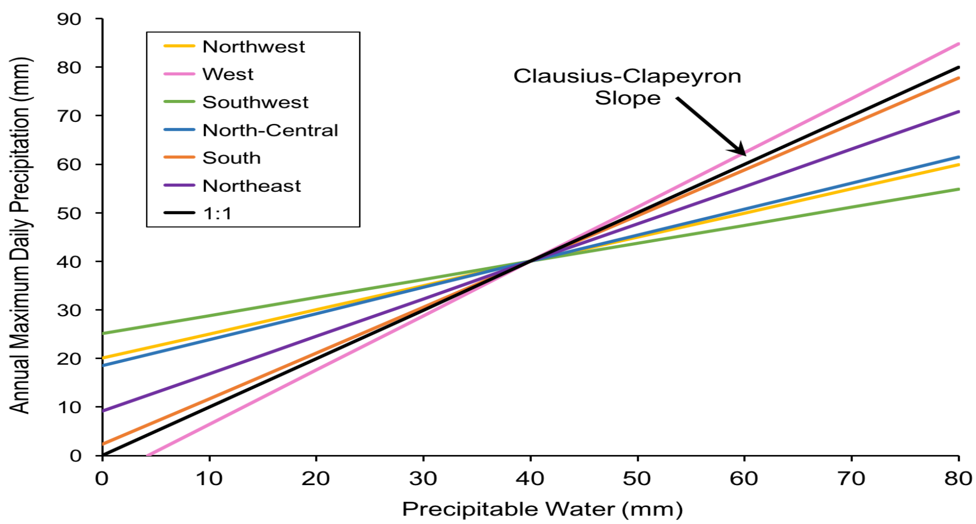


Figure 1. *Average slope of the regression between annual maximum daily precipitation and the precipitable water in the vicinity of each event, averaged over six regions. The 1:1 line represents the expectation if the Clausius-Clapeyron relationship were the sole determinant.*

The other major component proposed for IDF adjustments is weather system changes. We have implemented automated software to identify relevant weather system types in climate model simulation data. A major technical challenge that confronted us was the automated detection of fronts. Existing algorithms did not perform as well as desired. We collaborated with Lawrence Berkeley National Laboratory to apply Deep Learning methods to this issue. A 2-dimensional convolutional neural network algorithm was developed and validated against a dataset of manually-drawn fronts. This algorithm can reproduce the observed spatial pattern of the frequency of fronts. The number of automatically-detected fronts is somewhat lower than observed, by about 20%. However, when comparing with a manual dataset of fronts associated with extreme precipitation events, the automated algorithm detects near 100% of these. Thus, the algorithm appears to be suitable for the objectives of this project, which is to detect all or almost all significant weather-producing fronts when extreme precipitation is being produced.

Summer fronts are the dominant cause of extreme events in the interior north-central part of the U.S. There has been a statistically-significant upward trend in such events and the number of such events by season is correlated with the Palmer Z-score, indicating that they preferentially occur in seasons that are wet overall.

Future changes in relevant atmospheric systems as simulated by the CMIP5 suite of models were analyzed for certain atmospheric characteristics. Future changes in maximum values of PW are very large by the end of the century under a high emissions scenario, exceeding 25% in most parts of the U.S.

This represents potentially very large upward adjustments to IDF values. Analysis of CMIP5 extratropical cyclones (ETCs) generally show decreases in the number, and this could have important implications.

A GEV analysis of precipitation from a new dataset which has been statistically downscaled from the CMIP5 models indicates future increases in IDF values. The largest increases are for the longest recurrence intervals. At the longest recurrence intervals examined (100 years), the increases in IDF values are close to what would be expected from a simple water vapor adjustment.

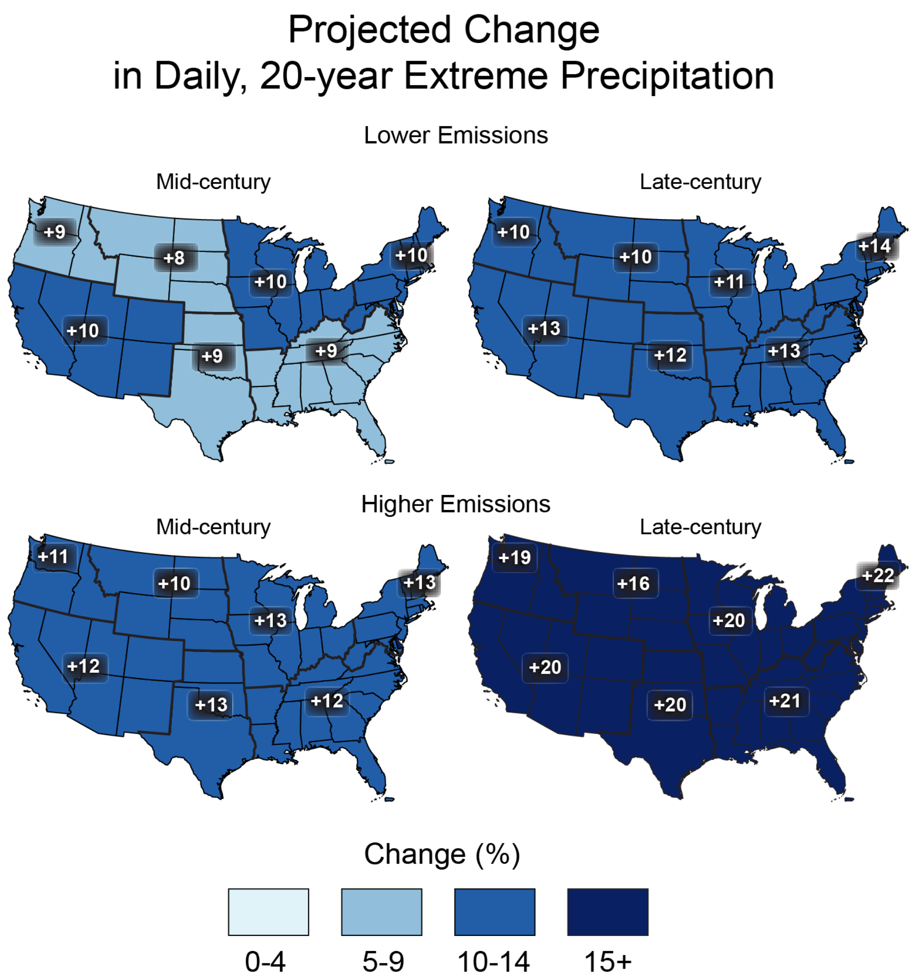


Figure 2. *Projected changes (%) in the daily, 20-yr return period design value.*

Analysis of extreme daily precipitation in the North American Monsoon found that nearly all of the heavy precipitation events are associated with low level moisture flux convergence in Arizona and New Mexico. By comparison, the climatological distribution of moisture flux convergence is centered around zero with the distribution skewed toward moisture flux divergence. Both extreme precipitation events and occurrence of moderate-to-strong moisture flux convergence are projected to increase over Arizona and New Mexico in the late 21st century for lower and higher scenarios (RCP4.5 and RCP8.5). This indicates that moisture flux convergence is a suitable metric for identifying extreme event conditions in climate models.

Statistical analysis of the GHCN-D stations for the coastal states along the Gulf of Mexico and the Atlantic Seaboard from TX to ME used both conventional (C-moments) and linear (L-moments) approaches to analyze extreme events. L-moment analysis seems to provide a greater variability in the optimal distribution than a conventional moment approach. Since a distinction was made between TC/non-TC (Tropical Cyclone) related events, it is possible to account for any future expected change in precipitation associated with TC/non-TC events.

Planned work

- Complete analysis of CMIP5 and CAM5 climate model simulations with regard to future changes in the weather systems that cause extreme precipitation.
- Expand the analysis to Alaska, Hawaii, and Guam.
- Develop factors for adjusting current IDF values for future climate change.
- Construct a beta version of an online system for access to adjusted IDF values.
- Determine optimal statistical distributions for extreme event statistics and determine homogeneous groups of stations.

Presentations

Biard, J., and **K. E. Kunkel**, 2017: Use of a Deep Learning Neural Network to detect weather front boundaries. *NASA Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) Applications Workshop*, Greenbelt, MD, June 19, 2017.

Biard, J., 2017: Automated Detection of Fronts using a Deep Learning Convolutional Neural Network. *CICS Science Conference*, College Park, MD, November 6, 2017.

Biard, J., **K. E. Kunkel**, and E. Racah, 2017: IN11A-0024: Automated Detection of Fronts using a Deep Learning Convolutional Neural Network. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 11, 2017.

Champion, S., 2017: The Importance of Summer Season Fronts in Extreme Precipitation Events. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 27, 2017.

Kunkel, K. E., 2017: Understanding the Physical Causes of Observed Trends in Extreme Precipitation: How Can Statistics Help? *SAMSI Opening Climate Workshop*, Asheville, NC, August 21, 2017.

Kunkel, K. E., 2017: DoD Needs: Memories of the Past and a Look to the Future. *White Sands Missile Range Army Research Laboratory,* White Sands Missile Range, New Mexico, September 25, 2017.

Kunkel, K. E., 2017: Effect of Global Warming on Extreme Precipitation Design Values. *2017 SERDP/ESTCP Symposium*, Washington, DC, November 28, 2017.

Kunkel, K. E., 2017: Precipitation Intensity-Duration-Frequency (IDF) Relationships and Climate Change. *Inter-agency Forum on Climate Risks, Impacts & Adaptation: Special Session*, Washington, DC, December 1, 2017.

Kunkel, K. E., and D. R. Easterling, 2017: H22B-04: An approach toward incorporation of global warming effects into Intensity-Duration-Frequency values. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.

Kunkel, K. E., and **S. Champion**, 2018: 6.4: The Meteorology of Extreme Precipitation and Implications for Future Planning. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

Kunkel, K. E., **J. C. Biard**, and E. Racah, 2018: TJ7.4: Automated Detection of Fronts Using a Deep Learning Algorithm. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.

Stevens, L. E., **K. E. Kunkel**, and **S. Stevens**, 2018: 531: The Role of Atmospheric Water Vapor in the Observed Upward Trend in Extreme Precipitation. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

Other

Sarah Champion is a project scientist and North Carolina State University Ph.D. graduate student advised by Kenneth Kunkel and her research supports the objectives of this project.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**12**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Climate Model Data Support to the Assistant Secretary of Air Force Climate Projection Engineering Weather Data (EWD) Project	
Task Leader/Task Team:	Kenneth Kunkel (Leader), Sarah Champion, Liqiang Sun, and Jared Rennie
Task Code	NC-OTH-05-NCICS-KK
Other Sponsor	Dignitas/US Department of Defense (DOD)
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	**Goal 1:** Climate Adaptation and Mitigation 100%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: Future engineering design values were estimated for Air Force bases at Langley, VA and Thule, Greenland, based on two scenarios for future climate change. Substantial future increases were calculated for temperature and humidity variables.

Background

The goal of this study was to provide 50-year climate projection information for Langley and Thule Air Force Bases in order to facilitate MILCON cost-savings determinations for recently completed construction projects at each location. The climate projection information was developed for climate variables included in the Air Force Climate Projection Engineering Weather Data (EWD) Project documents for these two locations.

The Air Force 14th Weather Squadron produces EWD values for Air Force installations by applying established methods to their extensive archive of observational data. For many of the EWD values, these methods require observational data at hourly time resolution, which is generally available in their archive. The estimation of future changes in EWD values due to anthropogenically-forced climate change cannot use these established methods for several reasons. First, future estimates are derived from analysis using data from global climate model simulations and hourly data from these models has not generally been stored in data archives. Second, these model simulations are performed at rather coarse spatial resolutions (approximately 100 km grid box spacing) and the data do not translate directly to the in situ point observations on which EWDs are based. Third, the data from these models must be adjusted for biases in simulating the current climate. Fourth, while there are general approaches for using climate model data to estimate future climate conditions, methods for estimating extreme conditions are not established but remain an active area of research. This project required research and development to choose appropriate methods and, as needed, develop them for project application.

Accomplishments

Three datasets were employed in this study:

- Daily and hourly observational weather data for Thule AFB and Langley AFB via the Integrated Surface Database (ISD).
- The Coupled Model Intercomparison Project Phase 5 (CMIP5) suite of climate model simulations used in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). This is the most recent globally-coordinated set of simulations and a gridded dataset. The data from the nearest grid point to each site was used for calculating projection information.
- The Localized Constructed Analogs (LOCA) dataset. This is a new, statistically-downscaled dataset based on the CMIP5 data. LOCA covers the continental United States, includes the period of 1950-2100, has data for 32 models, is of daily resolution and 1/16th degree spatial resolution, and

includes maximum temperature, minimum temperature, and precipitation. It is being used as projection information for graphics and analysis in the upcoming Fourth National Climate Assessment. This is a gridded dataset. The data from the nearest grid point to Langley AFB was used for calculating projection information. Thule AFB is not in the domain of this dataset.

The future estimates of EWD values were obtained using general approaches developed in the climate science research community to estimate future changes in climate for local sites. The specific methods were developed from the general approaches and adapted as needed to the specific EWD value. Future EWD values were derived using two established emissions scenarios: Representative Concentration Pathway (RCP)4.5, a moderate emissions future, and RCP8.5, a high emissions future.

Substantial future increases are projected for temperature and humidity design values. These arise from direct effects of the increase in atmospheric concentrations of greenhouse gases (GHGs). The direct radiative effect of GHG increases results in a rise in temperatures. This in turn directly influences the atmospheric concentration of water vapor due to the fundamental and strong relationship between temperature and saturation water vapor pressure (which increases 6-7% per °C). These combined effects are quite evident for some of the design metrics. For example, the combined Ventilation Cooling Load Index for Langley AFB increases by 91% under the high scenario. This occurs not only because summer days are hotter and more humid, but also because the length of the cooling season expands in the spring and fall. In contrast, the cold design values warm substantially more at Thule AFB than at Langley AFB because of the enhanced polar winter warming that is simulated by all climate models.

Uncertainty estimates were included in the future design value estimates. The primary sources of uncertainty are differences in scenarios of future anthropogenic emissions of greenhouse gases and differences in climate model sensitivity (the amount of warming from a set amount of increased greenhouse gas concentrations).

Publications (*Non-peer-reviewed)*

Kunkel, K.E., S. M. Champion, L. Sun, and **J. Rennie**. 2017: *Climate Model Data Support to the Assistant Secretary of Air Force (ASAF) Climate Projection Engineering Weather Data (EWD) Project*. Final Report, Contract N61340-14-C-6103 P00013, 53pp.

Presentations

Kunkel, K. E., 2017: DoD Needs: Memories of the Past and a Look to the Future. *White Sands Missile Range Army Research Laboratory,* White Sands Missile Range, New Mexico, September 25, 2017.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**1**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Water Sustainability and Climate Change: A Cross-Regional Perspective	
Task Leader/Task Team:	Kenneth Kunkel (leader), Steve Stegall, and Andrew Ballinger
Task Code	NC-OTH-06-NCICS-KK
Other Sponsor	National Science Foundation (NSF)
Contribution to CICS Research Themes	Theme 3: Climate Research and Modeling 100%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Goal 1: 75%; Goal 2: 25%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: Analysis of CMIP5 decadal experiment simulations indicate that future projections of extreme precipitation for 2006-2035 reflect increases in all regions with respect to 1981-2010. This suggests that there is merit in incorporating future extreme precipitation increases in planning in this near-term future time horizon.

Background

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 are revisiting how freshwater sustainability could have been better achieved over the past five decades across the Sunbelt. To couple the hydroclimatic 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 de/centralized adaptive strategies that have been employed independently and collectively to maintain flows, increase supplies, or reduce demands. Utilizing the near-term hydroclimatic 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

Two metrics of extreme precipitation from CMIP5 hindcast and predictive data were analyzed: the annual daily maximum precipitation and the total precipitation exceeding the 99.5^{th} percentile of daily precipitation. The results were aggregated into six U.S. regions. Future projections indicate increases in all regions for this near-term future window, indicating that the increases in anthropogenic forcing are sufficient to produce a systematic response in the climate system at the regional scale (Figure 1). This suggests that there is merit in incorporating future extreme precipitation increases in planning, even for situations in which only this relatively short future time horizon needs to be considered. Other studies found limited skill for precipitation forecasts for a 2-9 year time horizon; any predictive skill for such a time horizon is likely to arise from the initial and boundary conditions. The 30-yr time horizon evaluated here includes overall larger levels of anthropogenic forcing changes over the hindcast evaluation period and even larger forcing changes between the hindcast and predictive periods; this combined with the longer period to average out internal variability appears to be sufficient to produce a detectable signal.

This conclusion should be considered in the context of two other outcomes of this study. One, there is generally good qualitative agreement between the observations and model simulations with regard to the direction of recent trends; both indicate generally upward trends in the historical 1981-2010 period. But the model trends are generally smaller in magnitude than the observed trends. This may indicate either that the models are not sensitive enough to anthropogenic forcing of extreme precipitation or that the observed trends are also being forced by other (natural) factors that could reverse in the future. In fact, other studies suggest that forcing by sea surface temperature (SST) variability was a more important factor over this period. Two, there are a few ensemble members that indicate small future decreases in extreme precipitation, presumably the result of internal natural variability. Thus, in this near-term window, natural variability could temporarily negate the increases that are forced by greenhouse gas forcing. Both of these outcomes increase the uncertainties about the magnitude of near-term future changes. However, we are now already a decade into the "future" predictive period. Extreme precipitation has continued to increase, partially confirming the predictive results. Incorporation of increases in planning would appear to be a prudential approach.

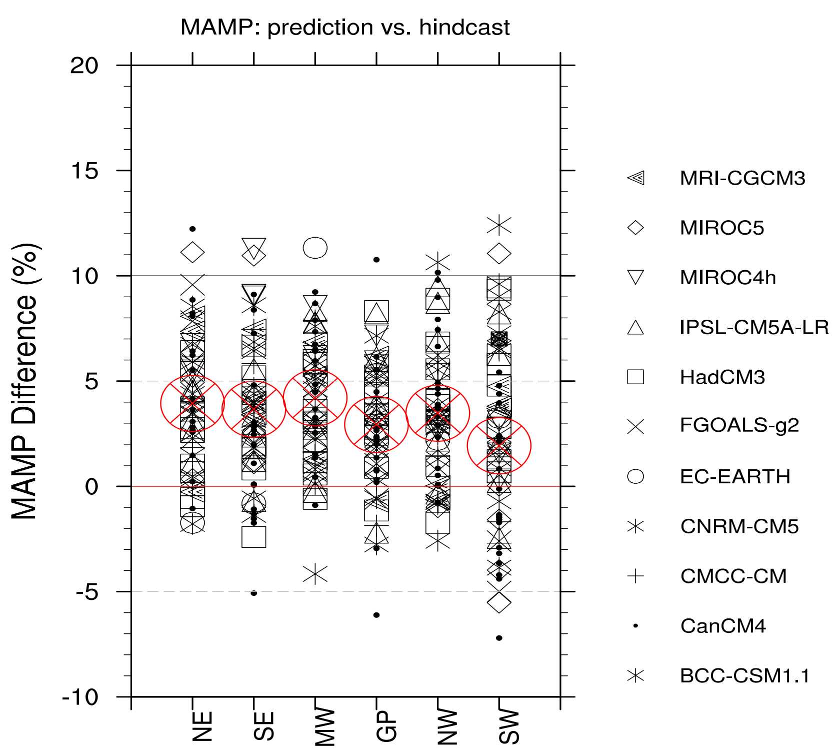


Figure 1. *The difference (%) in the magnitude of the mean annual maximum daily precipitation (MAMP) between the 2006-2035 prediction and the 1981-2010 hindcast [(prediction-hindcast)/hindcast] for each ensemble member (black circles) and the multi-model mean (large red circles).*

Planned work

- Complete an analysis of predictability of drought conditions for a 30-yr time horizon.

Publications (all peer-reviewed)

Das Bhowmik, R., A. Sankarasubramanian, T. Sinha, J. Patskoski, G. Mahinthakumar, and **K. E. Kunkel**, 2017: Multivariate downscaling approach preserving cross-correlations across climate variables for projecting hydrologic fluxes. *Journal of Hydrometeorology*. http://dx.doi.org/10.1175/jhm-d-16-0160.1

Sankarasubramanian, A., J. L. Sabo, K. L. Larson, S. B. Seo, T. Sinha, R. Bhowmik, A. R. Vidal, **K. Kunkel**, G. Mahinthakumar, E. Z. Berglund, and J. Kominoski, 2017: Synthesis of Public Water Supply Use in the U.S.: Spatio-temporal Patterns and Socio-Economic Controls. *Earth's Future*, **5,** 771-788. http://dx.doi.org/10.1002/2016EF000511

Other

Kenneth Kunkel served on the Ph.D. committee of Rajarshi Das Bhowmik, North Carolina State University, Civil Engineering.

Performance Metrics	
# of peer reviewed papers	**2**
# of presentations	**0**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Climate indicators to track the seasonal evolution of the Arctic sea ice cover	
Task Leader:	Ge Peng
Task Code	NC-OTH-07-NCICS-GP
Other Sponsor	National Aeronautics and Space Administration (NASA)
Contribution to CICS Research Themes	Climate and Satellite Observations and Monitoring: 100%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	Goal 1: 75%; Goal 4: 25%
NOAA Strategic Research Priorities:	Arctic

Highlight: The NOAA/NSIDC (National Snow and Ice Data Center) Sea Ice Concentration Climate Data Record (CDR) was used 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 and examine long-term average and temporal variability of the new sea ice climate indicators.

Background

Since 1979, the 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 seasonally and inter-annually.

This 3-year project started in July 2016 is aiming 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). NCSU/NCICS PI, Ge Peng, contributes to this effort by assisting with the CDR fields and integration of the fields with the melt/freeze and advance/retreat parameters.

Accomplishments

- Examined temporal variability of Arctic sea ice climate indicators.
- Examined the impact of non-stationarity of regional and temporal means (see more details below).

Sea ice retreat has been extreme in recent years, but this was not the case in earlier years of the satellite era. Long-term trends of dates also vary spatially. This creates a quandary for generating time series of regional mean parameters for the area over which to average. There are two choices: (i) average in each year only over the area for which a parameter is valid for ALL years (i.e., the minimal intersection of all years), referred to Case core or (ii) average in each year over the full area valid for that parameter in that year, referred to Case allv. The linear trend can be computed from the regional averages of valid dates or of departure from spatially varied long-term time means. An analysis is carried out to examine both strategies and both trends using the snow melt onset date data (Figure 1). The results from this analysis and temporal variability of melt onset dates, retreat, and freeze-up dates for the whole Arctic region will be described in a manuscript to be submitted to a peer-reviewed journal.

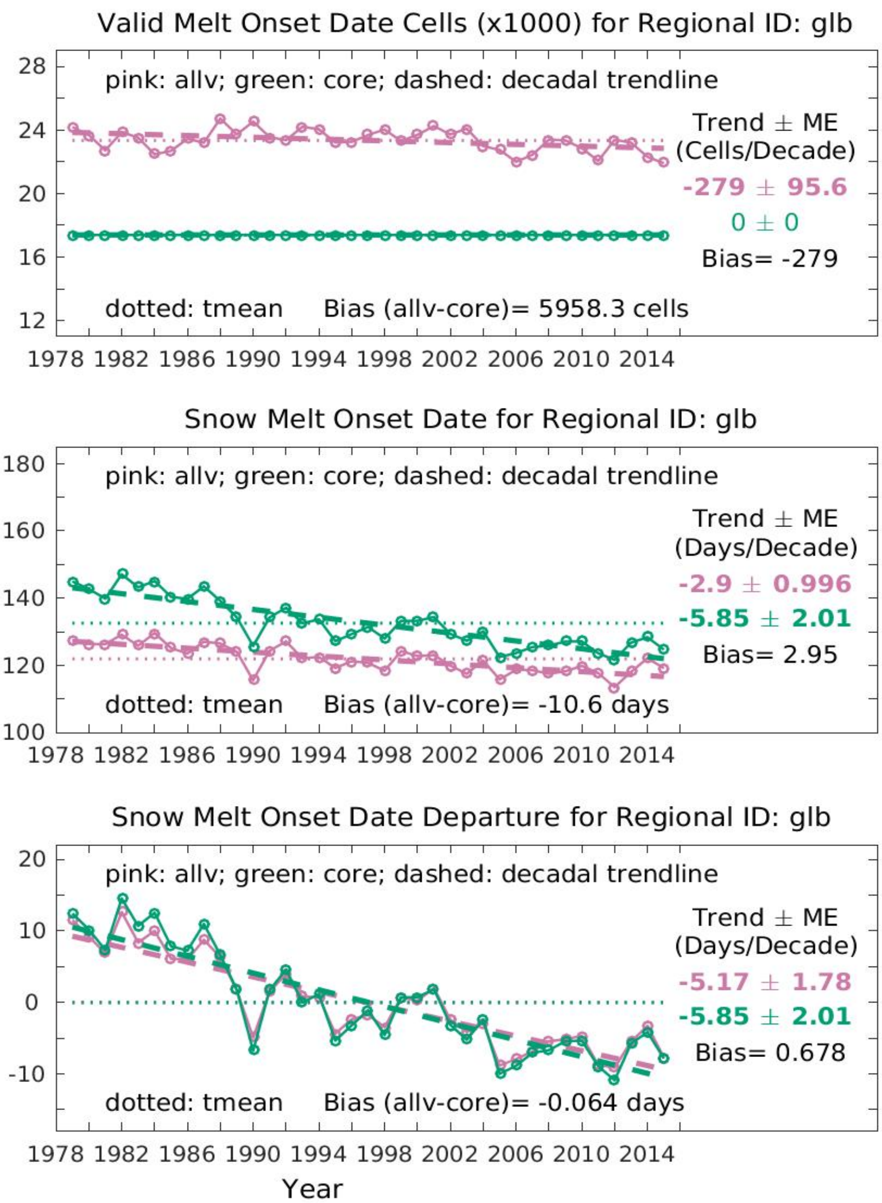


Figure 1. *The number of valid snow melt onset date grid cells (x1000) (top), snow melt onset date (middle), and the departure (bottom) for the whole Arctic. Pink denotes Case allv where all the valid date cells are included in the averaging. Green denotes Case core where only the cells have a valid date for the whole record period of (1979–2015). The solid lines with circles are the time series of the variable. The thin dotted lines are for the time means. The bias between the time means of Case allv and core is denoted below the curves. The thick dashed lines denote the decadal linear trend lines. The values of decadal trends and their margin of error at the 95% confidence level are denoted on the right within the figure along with the bias of the decadal trends between the two cases.*

Planned work

- Continue to examine temporal and regional variability of new sea ice climate indicators, preparing a paper to be submitted to a peer-review journal.
- Continue to seek input and feedback from stakeholders and provide feedback to the PI and Co-PI of this project to improve the scientific quality of the derived indicator products.

Presentations

Peng, G., W.N. Meier, A. Bliss, M. Steele, and S. Dickinson, 2017: Spatial and Temporal Means and Variability of Arctic Sea Ice Climate Indicators from Satellite Data. Poster. C21G-1187. 2017 AGU Fall Meeting, December 12, 2017, New Orleans, LA, USA. https://doi.org/10.6084/m9.figshare.5613613

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**1**
# of graduate students supported by this project	**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-08-NCICS-OP
Other Sponsor	Columbia University /US Department of Energy (DOE)
Contribution to CICS Research Themes	Theme 1: 50%; Theme 3: 50%
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA Goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

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

Background

Rain microphysical processes exert a critical control on the evolution and impact of weather systems, including deep convection. In particular, the microphysical characteristics of rain determine evaporation and hydrometeor loading that, in turn, control downdraft characteristics and subsequent cold pool formation and convective structure and organization. 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 the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) polarimetric and zenith-pointing radars, allow for unprecedented information on rain microphysical processes. However, the current state of microphysical parameterization schemes renders problematic the assimilation of observational insights into models. In this work, we are investigating the uncertainties in the representation of microphysical processes in climate models with the goal of developing a novel warm rain microphysics scheme that uses Bayesian inference to estimate parameter uncertainties and reduce unnecessary assumptions. The Bayesian statistical approach combines real rainfall dual-pol radar data from ARM field campaigns, bin microphysical modeling, and a new bulk parameterization. This is a collaborative project with partners: Dr. Marcus van Lier-Walqui (Columbia University), Dr. Matthew Kumjian (Penn. State University), and Dr. Hughbert Morrison (NCAR).

Accomplishments

Our contribution to the project consisted of providing one-dimensional bin-model simulations (Prat et al. 2012) covering the totality of realistic DSDs encountered in nature. From approximately 10.000 initial conditions imposed at the top of the one-dimensional model, we have generated about 199 million DSDs. From this ensemble, and for a given moment combination Mx-My, we investigated how uncertainties propagate to the integral properties (Liquid Water Content: LWC; Rain Rate: RNT, Reflectivity: Z) and to the microphysical processes (coalescence, breakup, evaporation). Figure 1 displays an example of results for the pair of moments M0-M3: $46 < M0$ (dBz) <48 and $44 < M3$ (dBz) < 46.

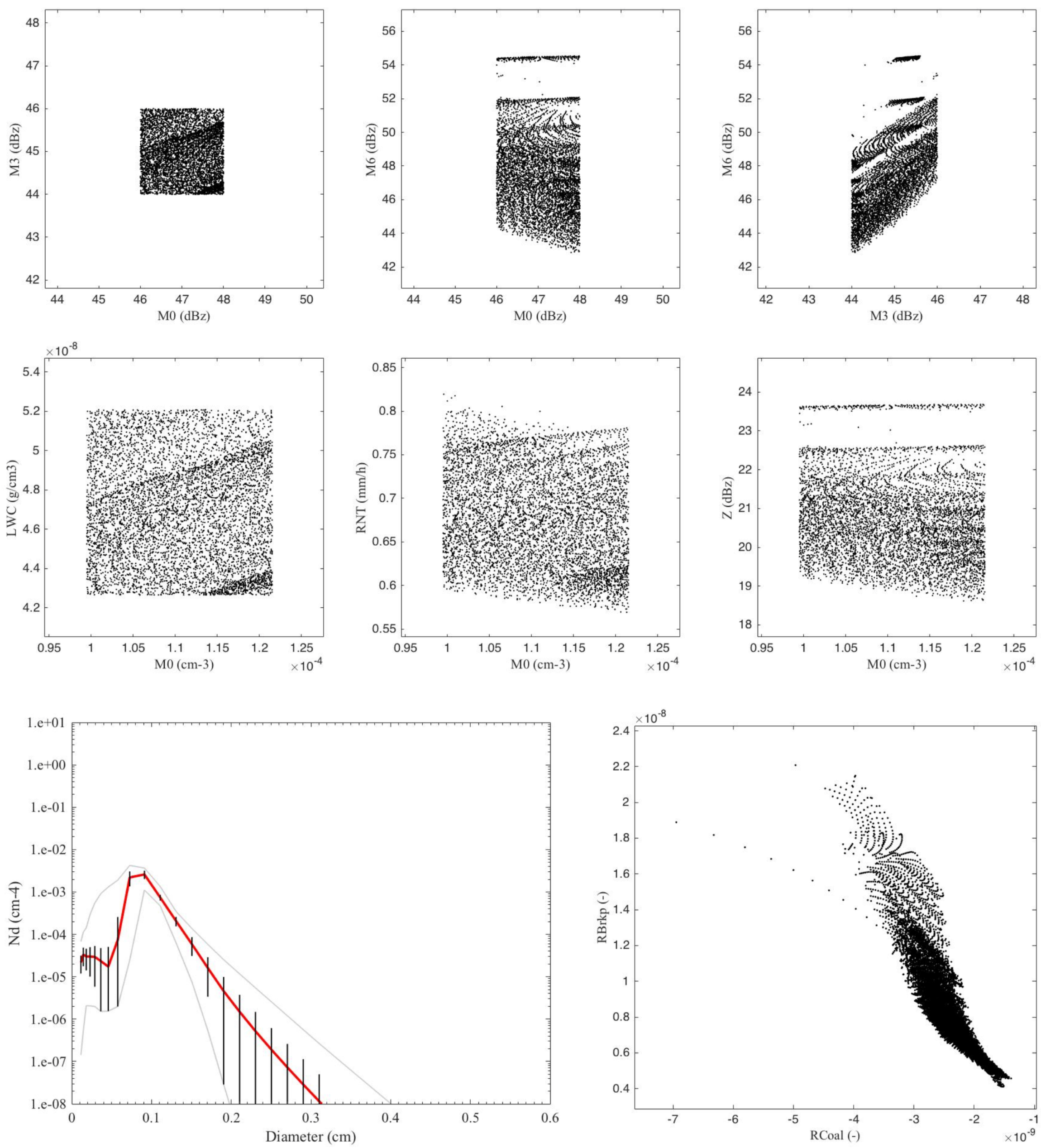


Figure 1: *Top row: Moments M0-M3 (left panel), M0-M6 (center panel), and M3-M6 (right panel). Each dot represents a DSD. Middle row: Corresponding domain of variation of the integral properties (LWC, RNT, Z). Bottom row: The left panel of the lower row displays the mean (red line) and the envelop (grey lines) of the DSDs. The right panel of the lower row displays the variations for the coalescence (RCoal) and breakup (RBrkp) contributions.*

The synthetic DSDs, in addition to DSDs obtained from disdrometer measurements collected during field campaigns, have been used to develop the N-moment normalization method for deriving raindrop size distribution scaling relationships (Morrison et al. 2018). To avoid having the combined dataset strongly dominated by the bin simulations, we sampled according to a climatology of rain rates obtained from 10 years of in situ measurements from the US Climate Reference Network (USCRN). The 5-min rain rate probability density function (PDF) and associated statistics are computed for observed rain events when the near surface air temperature was above 5°C. Figure 2 displays the CDF and PDFs of 5-min rain rate derived from USCRN stations and used the full record of disdrometer and bin model DSDs, which were reduced to random subsets of equal size, so that neither source dominates the combined sample (Morrison et al. 2018).

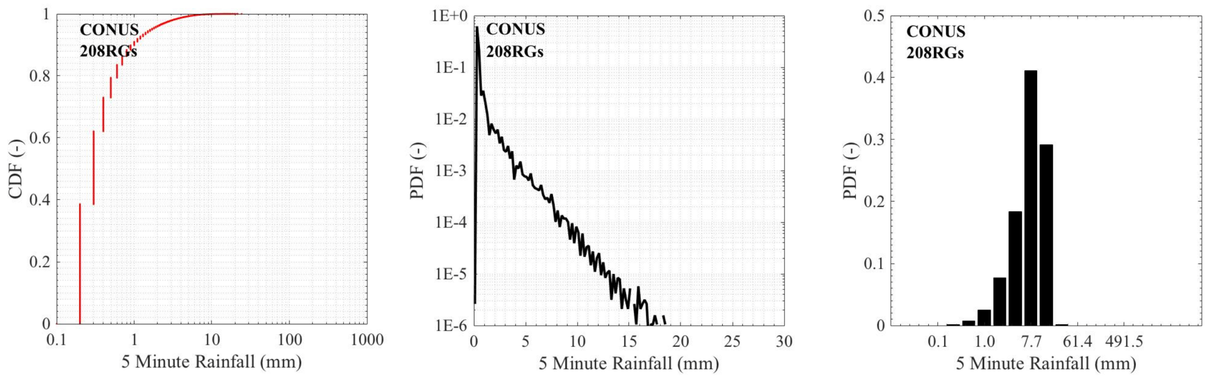


Figure 2: *CDF and PDFs of the 5-min rain rate derived from USCRN stations CONUS wide.*

One paper describing the general N-moment normalization method developed has been submitted for publication (Morrison et al. 2018). One paper describing the moment-based polarimetric radar forward operator is being finalized for submission and two other manuscripts are in preparation.

Planned work

- Finalize the implementation of evaporation processes in the bin microphysical model.
- Compute uncertainties in bin parameterizations for coalescence, breakup, and evaporation processes for any combination of moments M0-M3, M0-M6 M3-M6.
- 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.
- Draft a manuscript for the bin microphysical component of the project.
- Revise Journal of Applied Meteorology and Climatology manuscript if necessary.

Presentations

Kumjian M., C. Martinkus, **O.P. Prat**, M. van Lier-Walqui, H. Morrison, and S. Collis, 2018. General moment-based methods for DSD normalization and a polarimetric radar forward operator. 2018 ARM/ASR Joint User Facility and PI Meeting, Vienna, VA, March 20 2018.

van Lier-Walqui, H. Morrison, M. Kumjian, M., C. Martinkus, **O.P. Prat**, and K.J. Reime, 2018. Probabilistic observational constraint of a microphysics scheme with flexible structural complexity. 2018 ARM/ASR Joint User Facility and PI Meeting, Vienna, VA, March 20, 2018.

Kumjian, M.R., C. Martinkus, **O.P. Prat**, S.M Collis, H. Morrison, and M. van Lier-Walqui, 2017. A moment-based polarimetric radar forward operator for rain microphysics. 2017 AGU Fall Meeting, New Orleans, LA, December 12, 2017.

Morrison, H., M.R. Kumjian, **O.P. Prat**, M. van Lier-Walqui, and C. Martinkus, 2017. A Generalized drop size distribution normalization method for bulk microphysics schemes. 2017 AGU Fall Meeting, New Orleans, LA, December 12, 2017.

Martinkus, C., M.R. Kumjian, **O.P. Prat**, S. Collis, M. van Lier-Walqui, and H. Morrison, 2017. Development of a moment-based polarimetric radar forward operator, 38th Conference on Radar Meteorology, Chicago, IL, August 29, 2017.

van Lier-Walqui, M., M.R. Kumjian, C. Martinkus, H. Morrison, and **O.P. Prat**, 2017. Constraining and estimating microphysical parameterization uncertainty using polarimetric radar observations and the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS), a novel probabilistic microphysics framework. 30th AMS Conference on Climate Variability and Change, 24th AMS Conference on Probability and Statistics in the Atmospheric Sciences, and the 16th AMS Conference on Artificial Intelligence and its Applications to the Environmental Sciences, Baltimore, MD, July 28, 2017.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**5**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Continuous Monitoring of Individual Exposure to Cold Work Environment: A Participatory Sensing Study	
Task Leader	Jennifer Runkle
Task Code	NC-OTH-09-NCICS-JR
Other Sponsor	University of South Florida / National Institute for Occupational Safety and Health (NIOSH)
Contribution to CICS Research Themes	Theme 2: 10%; Theme 3: 90%;
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Climate Adaptation and Mitigation: 100%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: This pilot study utilizes new wearable sensor technology to test and implement more sensitive means of evaluating cold temperatures as an occupational hazard and develop effective report-back strategies as a means to communicate with participants about harmful occupational exposures and their associated health risks.

Background

The National Institute for Occupational Safety and Health (NIOSH) acknowledges the dangers of working in “moderately cold environments,” and the associated negative impacts on worker performance and increased injury risk. The effect of a cold environment for both indoor and outdoor workers is an understudied health and safety concern, and there is a need for updated guidelines and educational materials tailored to employees working in both cold and moderately cold environments. Fixed-site monitoring of ambient temperatures provides a large amount of temporal data; however, these data are constrained to one location with limited spatial availability. New technology exists to supplement these weather station networks, allowing for individual monitoring of actual temperature experience. This study leverages the new sensor technology in an effort to test and implement more sensitive means of evaluating cold temperatures as an occupational hazard, develop effective data report-back strategies as a means to communicate with participants about harmful occupational exposures and their associated health risks, and help targeted vulnerable exposure groups move from understanding environmental health risks to acting upon these risks by engaging in workplace prevention strategies. The larger objective is to apply a sensor-based approach to develop an early warning temperature-health system to be used in the surveillance of illness, injury, and behavioral modification in the workplace.

Accomplishments

Project PIs conducted preliminary research in the summer of 2016 to evaluate individual experienced temperature in a warm environment to establish the feasibility of wearing temperature sensors, heart rate monitors, and GPS-enabled Garmin watches to monitor high temperature exposure in an outdoor environment. Grounds management workers at two public universities in two geographic locations, were recruited to participate in the study. Through this pilot work, the PIs found that workers were more concerned with exposure to cold temperatures than warmer temperatures.

For the cold environment study, the PIs recruited grounds management workers at the same two geographic locations as the pilot high temperature study, North Carolina State University in Raleigh, NC, and Appalachian State University in Boone, NC. Three data collection periods were completed during the months of January and February and analysis of the data is currently underway.

Planned work

- Completion of data analysis.
- Report back sessions with the project participants.
- Draft and submit project results manuscript tp peer reviewed journal.

Presentations

Fuhrmann, C.M., M.M. Sugg, and **J.R. Runkle**, 2017: Temporal and Spatial Variations in Personal Ambient Temperatures (PATs) for Outdoor Working Populations in the Southeast U.S., *International Congress of Biometeorology,* Durham, England, UK, September 4, 2017.

Fuhrmann, C.M., M.M. Sugg, and **J.R. Runkle**, 2017: Assessment of Personal Heat Exposure among Grounds Management Workers In The Southeast USA. *Southeastern Division of the Association of American Geographers,* Starkville, MS, November 20, 2017.

Runkle, J.R., L.C. Thompson, and M.M. Sugg, 2017: Report-Back for Location-based Personal Monitoring Data on Individual Experienced Temperature in Outdoor Workers, *Integrating Exposure Science Across Diverse Communities,* Raleigh, NC, October 17, 2017.

Runkle, J.R., M.M. Sugg, and C.M. Fuhrmann, 2017: Personal Monitoring of Individual Temperature Experience in Outdoor Workers using Wearable Sensors, *Integrating Exposure Science Across Diverse Communities,* Raleigh, NC, October 18, 2017.

Runkle, J.R., M.M. Sugg, D. Boase, S. Galvin, and C. Coulson, 2017: Wearable sensors for continuous pregnancy health and environmental monitoring: From a patient and provider perspectives. *American Public Health Association,* Atlanta, GA, November 7, 2017.

Runkle, J.R., M.M. Sugg, C.M. Fuhrmann, and S. Sevens, 2017: Use of Wearable Sensor Technology as a Surveillance Tool to Measure Climate-related Changes in Heat Exposure among Outdoor Workers. *American Public Health Association,* Atlanta, GA, November 7, 2017.

Thompson, L.C., M.M. Sugg, **J.R. Runkle,** and C.M. Fuhrmann, 2017: Reporting Back Environmental Exposures: A Case Study of Environmental Health Literacy and Individual Experienced Temperature among Ground Maintenance Workers, *Celebration of Student Research and Creative Endeavors,* Boone, NC, April 25, 2017.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**7**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**5**
# of undergraduate students mentored during the year	**2**

Multiscale convection and the Maritime Continent	
Task Leader:	Carl Schreck
Task Code	NC-OTH-10-NCICS-CS
Other Sponsor	National Aeronautics and Space Administration (NASA)
Contribution to CICS Research Themes	Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Climate Data and Information Record and Scientific Data Stewardship
Contribution to NOAA goals	A Climate Ready Nation: 100%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: This multi-institutional team is examining the strong diurnal cycle of convection over the Maritime Continent and demonstrating how it impacts subseasonal-to-seasonal forecasts.
NCICS.org/mjo

Background

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

Many studies have examined the interactions between the MJO and convection over the MC. Far fewer have looked at the role of convectively 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 complement a major international field campaign, the Year of Maritime Convection, proposed for 2017-2019.

Accomplishments

This project continues to progress as anticipated towards its Year 2 goals, consistent with the proposal. As before, it is split into two main projects. One is led by Co-I Mekonnen (NC A&T) investigating the diurnal cycle of convection over the Maritime Continent using a variety of TRMM and ISCCP datasets. The other is led by PI Schreck and Co-I Aiyyer (NCSU). They are exploring the skill of novel Fourier filtering of combined observations and CFSv2 hindcasts in the region.

Figure 1 highlights some of the results from the first branch of the project. Diurnal cycles are compared between land (black), ocean (green), and coastal (red) portions of Maritime Continent using ISCCP weather states (WS type 1 and 3), TRMM TMPA rainfall, and radar-based TRMM precipitation features (PFs). Consistent with other studies, the diurnal cycle is much stronger over land than ocean with rainfall peaking around 1800 LST. Over land/coastal areas, ISCCP WS type 1 (composed of large scale and well-organized convection) and TMPA peak later in the afternoon, consistent with past work over the tropics. However, WS type 3 (small scale and less well-organized convection) and TMPA earlier in the day. The PF data show peaks a little earlier than TMPA total rainfall, probably due to differences in the retrieval mechanisms.

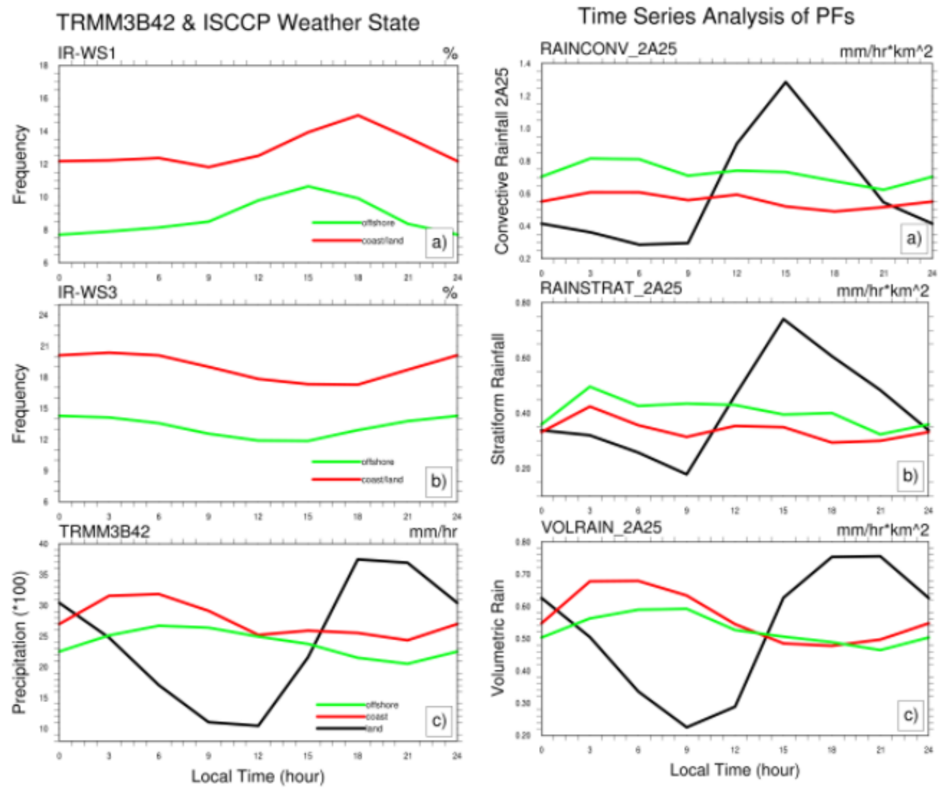


Figure 1. *Diurnal cycles of (upper-left): IR-WS1 (MCSs), (middle-left): IR-WS3, disorganized deep convection, (lower-left): TRMM TMPA, (upper-right) Convective rain from PFs, (middle-right) stratiform rain from PFs, and (lower-right) total PF rain. Lines indicate off-shore (red), coastal (green), and land (black) regions.*

Figure 2 highlights the key results of the other branch of this research. It verifies some of the forecast diagnostics from ncics.org/mjo. The novel methodology uses 1+ years of observed TRMM TMPA rainfall and appends it with CFSv2 hindcasts for 45 days and then climatology thereafter. These combined data are filtered for the MJO and key equatorial waves. It is a novel improvement upon the Wheeler–Weickmann (2001, *Mon. Wea. Rev.*) method, which used the Fourier filtering to extrapolate the observe wave propagations. Figure 2 shows that the new method (solid lines) significantly improves upon Wheeler–Weickmann (dashed lines) for all wave modes.

It is worth noting that this figure shows the anomaly correlations dropping below the 0.60 level often considered skillful at 9 days for the MJO. The CFSv2 is often purported to have skill out to about 21 days based on the Wheeler–Hendon Real-time Multivariate MJO (RMM) index. However, that index is heavily weighted towards the circulation, esp. at upper levels, which is likely to be more predictable. The analysis in Fig. 2 is focused on rainfall, which is harder to predict but more impactful. Other preliminary results from this project are that the skill is generally better during December–February and also when the MJO is active in RMM phases 6/7. Some of these results are being included in a recently submitted publication:

Janiga, M. A., **C. J. Schreck**, J. A. Ridout, M. Flatau, B. Barton, J. Metzger, and C. A. Reynolds, 2017: Subseasonal Forecasts of Convectively Coupled Equatorial Waves and the MJO: Activity and Predictive Skill. *Mon. Wea. Rev.*, Submitted.

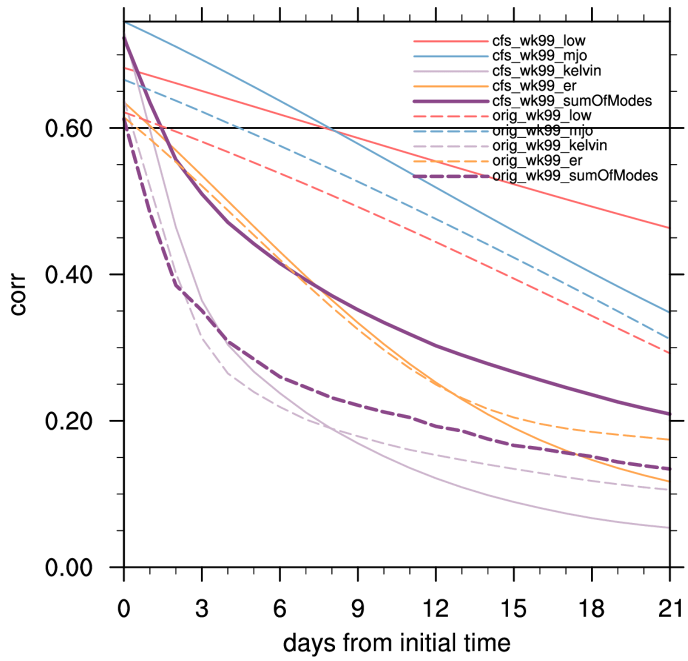


Figure 2. *Anomaly-correlations for various wave modes using either the original Wheeler–Weickmann (2001, Mon. Wea. Rev.) method (dashed), or the novel CFSv2 filtered hindcasts (solid).*

Planned work

- Submit a publication on the initial comparisons of the diurnal cycles between ISCCP, TRMM rainfall, and TRMM precipitation features.
- Examine variations in that diurnal cycle by phase of the MJO and Kelvin waves.
- Submit the above findings for publication.
- Submit a publication on the skill of the MJO and equatorial wave projections in the CFS.
- Revise submitted manuscript as needed for publication.

Presentations

Janiga, M., J. A. Ridout, **C. J. Schreck, III**, M. K. Flatau, N. P. Barton, W. Komaromi, and C. A. Reynolds, 2017: OS43A-1403: Convectively Coupled Equatorial Waves and the MJO in Subseasonal Forecasts from Global Coupled Atmosphere-Ocean Models: Activity and Predictive Skill. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 14, 2017.

Janiga, M. A., **C. J. Schreck, III**, J. Ridout, M. Flatau, N. Barton, W. A. Komaromi, and C. Reynolds, 2018: 311: Influence of Convectively Coupled Equatorial Waves, the MJO, and ENSO on the Environment of Tropical Cyclones in Coupled Atmosphere–Ocean Subseasonal Prediction Systems. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.

Janiga, M. A., **C. J. Schreck, III**, J. Ridout, M. Flatau, N. Barton, W. A. Komaromi, and C. Reynolds, 2018: 421: Convectively Coupled Equatorial Waves and the MJO in Subseasonal Forecasts from Global Coupled Atmosphere–Ocean Models: Activity and Predictive Skill. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

Schreck, C. J., III, 2017: CFS Hindcast Skill and MJO Propagation across the Maritime Continent. *NASA Precipitation Measuring Mission (PMM) Science Team Meeting*, San Diego, CA, October 17, 2017.

Schreck, C. J., III, 2017: Diurnal Cycle of Precipitation over the Maritime Continent: Using TRMM3B42, TRMM PFs and ISCCP Weather State Datasets. *NASA Precipitation Measuring Mission (PMM) Science Team Meeting*, San Diego, CA, October 17, 2017.

Schreck, C. J., III, 2017: CFS hindcast skill and MJO propagation across the Maritime Continent. *42nd NOAA Climate Diagnostics and Prediction Workshop*, Norman, OK, October 25, 2017.

Schreck, C. J., III, A. R. Aiyyer, M. A. Janiga, and C. W. Yeary, 2018: J28.3: CFS Hindcast Skill and MJO Propagation across the Maritime Continent. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

Other
Advising PhD students Lakemarium Worku at NC A&T University and Cody Yeary at NCSU.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**7**
# of graduate students supported by this project	**2**
# of graduate students formally advised	**2**
# of undergraduate students mentored during the year	**0**

Investigations between Kelvin waves and Easterly waves using CYGNSS data	
Task Leader:	Carl Schreck
Task Code	NC-OTH-11-NCICS-CS
Other Sponsor	National Aeronautics and Space Administration (NASA)
Contribution to CICS Research Themes	Climate and Satellite Observations and Modeling
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals	A weather-ready nation: 100%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions

Highlight: This team is using NASA's new Cyclone Global Navigation Satellite System (CYGNSS) retrievals to investigate the surface interactions between Kelvin waves and easterly waves.

Background

Kelvin waves and easterly waves are among the most prominent modes of synoptic-scale convective variability in the tropics. Recent studies suggest that interactions between these waves can lead to tropical cyclogenesis; however, many questions remain regarding how these waves affect one another and how cyclogenesis ensues. Two of the most significant ways that Kelvin waves might affect easterly waves relate to their modulation of low-level winds, which may alter the background shear and gradient of vorticity and enhance wave-mean flow interaction. The Kelvin wave westerlies could also enhance surface enthalpy fluxes within the easterly wave, which would lead to intensification through diabatic heating. While the kinematic view of the interaction appears simple, the inherent dynamics are expected to be complex and nonlinear. The recent launch of NASA's Cyclone Global Navigation Satellite System (CYGNSS) provides an unprecedented opportunity to observe and model these interactions. The high spatial and temporal resolution of CYGNSS is ideally suited for studying Kelvin waves and easterly waves, which have a phase speed of ~20 m s^{-1} relative to one another and each have wavelengths of just 2000–4000 km.

Accomplishments

Ph.D. student Sridhar Mantripragada began climatological analysis of the interactions between easterly waves and Kelvin waves in reanalysis datasets. He is identifying Kelvin waves in filtered outgoing longwave radiation (OLR) and correlating them with 700-hPa eddy kinetic energy to identify the easterly wave activity. We have also identified three Kelvin waves during the 2017 hurricane season that could be candidate case studies (Fig. 1). Each of these occurred during the CYGNSS era and each has at least one tropical cyclone forming in its wake. The second of these may have played a role in the development of Hurricane Harvey. Mantripragada has completed control simulations in WRF of this event.

Planned work

- Perform experiments on Hurricane Harvey in WRF.
- Examine Harvey and the other two 2017 cases with CYGNSS wind data.
- Present results at the AMS's 33rd Conference on Hurricanes and Tropical Meteorology, and a publication will follow.

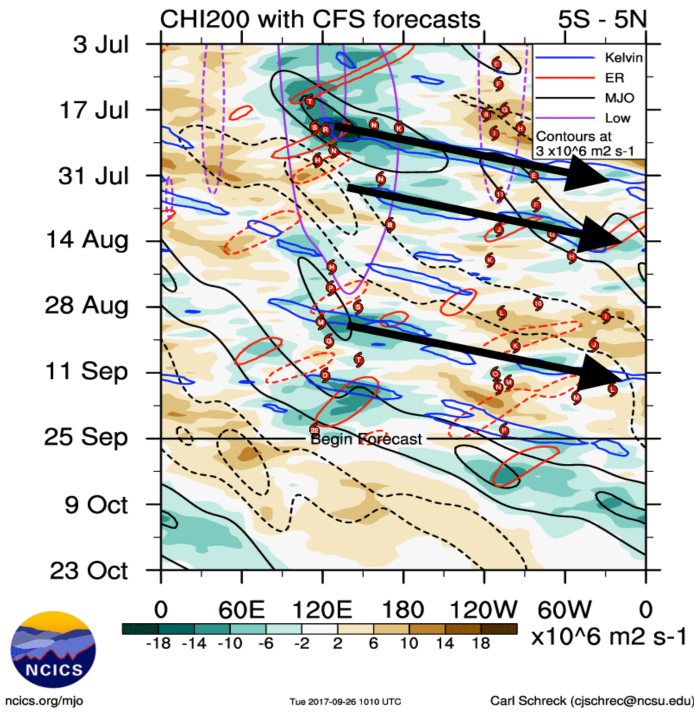


Figure 1: *Time–longitude Hovmöller of 200-hPa velocity potential from CFSv2 analyses and forecasts. Daily anomalies from climatology are shaded while filtered anomalies from various tropical modes are contoured. Hurricane symbols denote tropical cyclogenesis locations. Thick arrows highlight three potential Kelvin wave cases from the CYGNSS era that could serve as testbeds for our research.*

Presentations

Schreck, C. J., 2017: Interactions between Kelvin waves and easterly waves in CYGNSS. *NASA CYGNSS Science Team Meeting,* Miami, FL, December 18, 2017.

S**chreck, C. J.,** 2017: Kelvin waves and Subseasonal Hurricane Activity. National Hurricane Center. Miami, FL, December 19, 2017.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**2**
# of graduate students supported by this project	**1**
# of graduate students formally advised	**1**
# of undergraduate students mentored during the year	**0**

Developing New Forecast Tools for the USAF 14th Weather Squadron's Tropical Pacific Convective Outlook	
Task Leader/Task Team:	Carl Schreck and Jared Rennie
Task Code	NC-OTH-12-NCICS-CS/JR
Other Sponsor	Dignitas/DoD
Contribution to CICS Research Themes	Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA goals	Goal 2: 100%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions
Highlight: Key tropical subseasonal metrics from CICS-NC's Madden–Julian Oscillation (MJO) monitoring page (*NCICS.org/mjo)* are being transitioned into operations in the USAF 14th Weather Squadron.	

Background

A unique approach to the challenge of subseasonal-to-seasonal (S2S) atmospheric predictability has been developed and implemented on NCICS.org/mjo. The website takes recent observations and appends them with 45-day forecasts from the NOAA Climate Forecast System version 2 (CFSv2). The combined data are then Fourier filtered in space and time for some of the dominant modes of S2S variability in the tropics: the MJO, convectively coupled equatorial waves, and low-frequency variability such as the El Niño–Southern Oscillation (ENSO). This filtering highlights the most predictable aspects of the S2S system. The website includes numerous maps, Hovmöller diagrams, and indices for identifying and predicting these modes. It has been updated daily since 2011 with several upgrades and iterations over the years.

The variables and diagnostics on NCICS.org/mjo are specifically tailored for predicting tropical convection and cyclogenesis. They show the evolution over the last few weeks along with the CFS forecasts for the coming four weeks. These forecast aids are now routine inputs for the USAF 14th Weather Squadron's (14WS) Tropical Hazards and Benefits Outlook which provides actionable forecasts to end users throughout the Air Force and Department of Defense and are at a level of maturity where they can now be successfully transitioned into operations at the 14WS.

Accomplishments

All of the NCICS.org/mjo input datasets are publicly available operational products. The website currently includes eight different atmospheric variables and tracks six different tropical modes providing multiple options for diagnostics. Products were prioritized by 14WS, including Outgoing Longwave Radiation, and Precipitable Water. Requirements for libraries and ingest data formats were delivered to the 14WS. The 14WS also needs the diagnostic code in Python version 3, while ncics.org/mjo currently runs in the NCAR Command Language (NCL). Code refactoring has begun, and the key portion of that code, the Fourier filtering, has been converted. Figure 1 shows an overview of the full workflow that will be transferred.

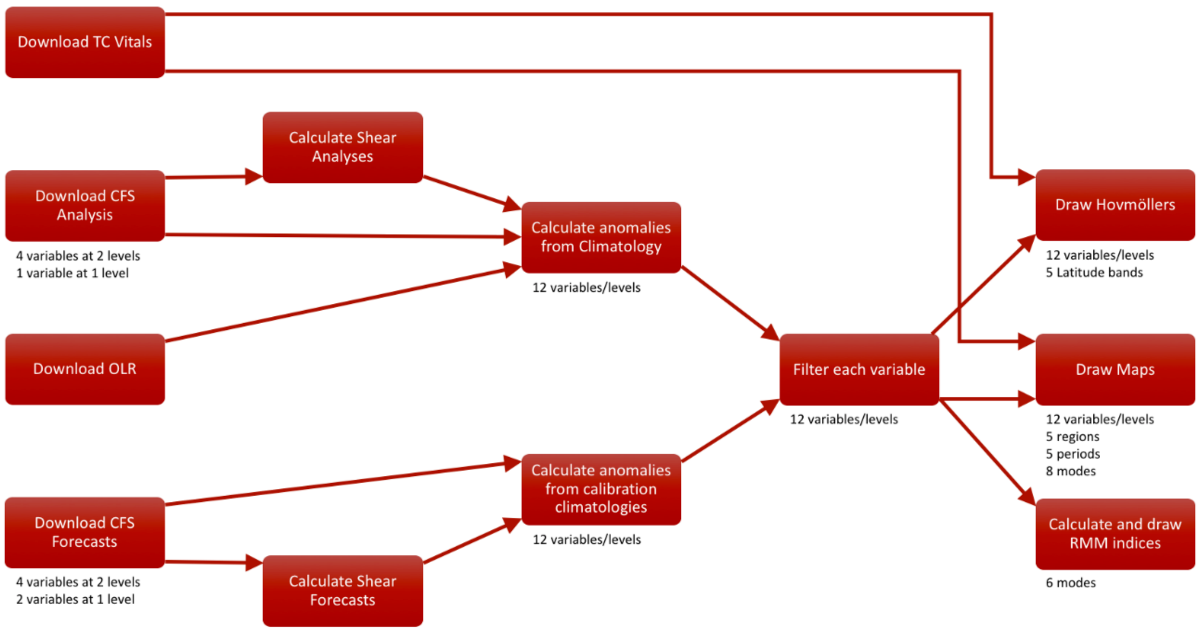


***Figure 1**. Flow chart of primary processes involved in producing the ncics.org/mjo diagnostics.*

Planned work

- Complete transition of code to Python version 3.6.
- Testing and verification of results to ensure reproducibility.
- Deliver code to 14WS and support implementation.
- Prepare technical report.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**0**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Investigation of Trends in Airport Weather Conditions	
Task Leader:	Scott Stevens
Task Code	NC-OTH-13-NCICS-SS
Contribution to CICS Research Themes	Climate and Satellite Research and Applications: 100%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA goals	Climate Adaptation and Mitigation: 100%
NOAA Strategic Research Priorities:	Decision Science, Risk Assessment and Risk Communication

Highlight: Several decades of surface observations were assessed to quantify a trend in the frequency of low-visibility conditions at the nation's busiest airports.

Background

Aviation is profoundly impacted by weather, which causes billions of dollars in lost revenue each year. One such avenue by which flights can be delayed or canceled is through reduced visibility and low cloud ceilings, which force aircraft to rely on separation provided by radar, referred to as Instrument Flight Rules (IFR), causing a need for greater spacing and therefore diminished capacity for an airport to land aircraft. Given that these conditions are very often tied to atmospheric moisture content, specifically saturation in the form of fog, mist, and clouds, one may hypothesize that a trend exists in the frequency of IFR conditions over recent decades, as the changing climate includes changes in moisture. This study aims to quantify these trends, if any exist, and examine the characteristics of IFR events in space and time.

Accomplishments

A study of 45 years of hourly weather observations has been completed for the 30 busiest airports in the United States, showing a marked decrease in the frequency of IFR conditions at 29 of 30 airports in all seasons, driven primarily by a decreasing frequency of hours in which visibility is low (Figure 1).

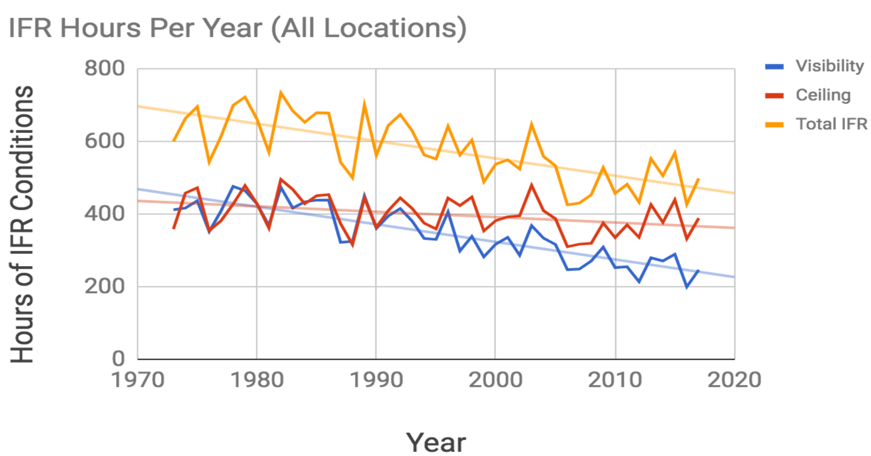


Figure 1. *Annual hours of IFR conditions across all locations*

Planned work

- Complete and submit manuscript for publication.

Collaborative Support for the Development of the Quantitative Urban-Scale Microclimatic Modeling Tool (QUEST)	
Task Leader:	Liqiang Sun
Task Code	NC-OTH-14-NCICS - LS
Other Sponsor	Urban Redevelopment Authority of Singapore
Contribution to CICS Research Themes	Theme 3: 100%.
Main CICS Research Topic	Climate Research and Modeling
Contribution to NOAA goals	Goal 1: 50%; Goal 2: 50%
NOAA Strategic Research Priorities:	Integrated Earth System Processes and Predictions Decision Science, Risk Assessment and Risk Communication

Highlight: In collaboration with the Urban Redevelopment Authority of Singapore, CICS-NC is providing climate modeling and customized global/regional datasets to support the development of a climate information system for urban heat island effect for Singapore urban planning.

Background

The frequency, severity, and duration of heat waves associated with urban heat island (UHI) effects are increasing in Singapore with climate change. As such, Singapore is likely to experience more climate-related health threats. The availability of high-resolution geospatial data, monitoring of land, coastal, and water resources and high-resolution environmental modelling at local scales is able to support timely and reliable climate-sensitive urban planning. A well-formulated cyber-infrastructure design, incorporating recent advances in informatics and geographic information systems (GIS), is essential for the success of climate-sensitive urban planning efforts to track and adapt to a changing climate and changing environments. The project's overarching objective is to develop a climate information system for urban heat island effect for urban planning in Singapore. This system consists of:
1) Environmental information, including oceanic, atmospheric, and geophysical data archives from surface and satellite measurements for 1979 onwards,
2) Customization of coupled global/regional climate models with an urban canopy model in Singapore,
3) Analytical and 3D visualization tools and services to support planners and managers in understanding the complex nature of urban development, and
4) Intelligent Disaster Decision Support System (IDDSS) for urban planning, integrating a smart geospatial information platform with an advanced optimization and simulation engine.

The system will enable visualization of geo-located/geo-referenced climate change information with layers that contain important infrastructure location and demographic data such as transport infrastructure. The overlay information will include highly specific and high-resolution data to help government agencies plan ahead and make informed decisions for mitigation planning for UHI and environmental changes due to further intensification of urban developments in Singapore.

CICS-NC scientist Liqiang Sun is providing support for sourcing and customization of the global/ regional environmental data sets, helping optimize the integration of the global/regional climate data with various urban models to support the modelling and simulation requirements for urban planning.

Accomplishments

Collected a number of reanalysis datasets:
NCEP/NCAR Reanalysis I
NCEP/DOE Reanalysis II

NCEP Climate Forecast System Reanalysis (CFSR)
NOAA-CIRES 20th Century Reanalysis version 2 (20CRv2)
NOAA-CIRES 20th Century Reanalysis version 2c (20CRv2c)
NASA Modern Era Reanalysis for Research and Applications (MERRA)
NASA Modern Era Reanalysis for Research and Applications Version-2 (MERRA-2)
Japanese 55-year Reanalysis (JRA-55)
ECMWF Interim Reanalysis (ERA-Interim)
ECMWF CERA-20C
ECMWF ERA-20C

Completed the analysis and comparison of these reanalysis datasets over Southeast Asia and chose the NCEP/DOE Reanalysis dataset to drive the high-resolution integrated urban model, mainly based on the performance of wind and temperature fields, and the consistency of model physical parameterizations between reanalysis model and the microclimate model.

Planned work

- Develop an interface package between global dataset and the high-resolution regional model and perform validation experiments with the high-resolution model driven by the global dataset identified earlier.
- Generate the climatic baselines using the high-resolution model forced by the global climate data.

Performance Metrics	
# of peer reviewed papers	**0**
# of presentations	**0**
# of graduate students supported by this project	**0**
# of graduate students formally advised	**0**
# of undergraduate students mentored during the year	**0**

Appendix 1: CICS-NC Personnel and Performance Metrics

CICS-NC Personnel	Numbers*		CICS-NC Subcontractors	Numbers**
Scientists working ≥ 50% time	**28**		Scientists working ≥ 50% time	**0**
Scientists working < 50% time	**0**		Scientists working < 50% time	**22**
Scientists working at no cost	**1**		Scientists working at no cost	**3**
Total Scientists	**29**		**Total Scientists**	**25**
Administrative/technical staff	**8**		**Administrative/technical staff**	**27**
Graduate Students	**0**		Graduate Students	**1**
Undergraduate Students	**0**		Undergraduate Students	**4**
High School Students	**0**		High School Students	**0**
Total Students	**0**		**Total Students**	**5**
Total Personnel	**37**		**Total Personnel**	**57**

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

***Based on NOAA/CICS-NC budgeted support effort for current subcontractor projects*

Performance Metrics	
# of new or improved products developed that became operational (please identify below the table)	**71**
# of products or techniques submitted to NOAA for consideration in operations use	**52**
# of peer reviewed papers	**32**
# of NOAA technical reports	**3**
# of presentations	**174*** **
# of graduate students supported by your CICS task	**6**
# of graduate students formally advised	**17**
# of undergraduate students mentored during the year	**17**

****Presentations: 149 science presentations; 25 outreach and engagement presentations.*

Appendix 2: CICS-NC Publications 2017–2018

Chen, Y., W. Ju, **P. Groisman**, J. Li, P. Propastin, X. Xu, W. Zhou, and H. Ruan, 2017: Quantitative assessment of carbon sequestration reduction induced by disturbances in temperate Eurasian steppe. *Environmental Research Letters*, **12,** 115005. http://dx.doi.org/10.1088/1748-9326/aa849b

Coopersmith, E. J., **J. E. Bell**, K. Benedict, J. Shriber, O. McCotter, and M. H. Cosh, 2017: Relating coccidioidomycosis (valley fever) incidence to soil moisture conditions. *GeoHealth*, **1,** 51-63. http://dx.doi.org/10.1002/2016GH000033

Das Bhowmik, R., A. Sankarasubramanian, T. Sinha, J. Patskoski, G. Mahinthakumar, and **K. E. Kunkel**, 2017: Multivariate downscaling approach preserving cross-correlations across climate variables for projecting hydrologic fluxes. *Journal of Hydrometeorology*. http://dx.doi.org/10.1175/jhm-d-16-0160.1

Diamond, H. J., and **C. J. Schreck**, eds., 2017: The tropics [in "State of the Climate in 2016"]. *Bulletin of the American Meteorological Society*, **98**, S93-S128. https://doi.org/10.1175/2017BAMSStateoftheClimate.1

Easterling, D. R., **K. E. Kunkel**, J. R. Arnold, T. Knutson, A. N. LeGrande, L. R. Leung, R. S. Vose, D. E. Waliser, and M. F. Wehner (lead authors), **S. M. Champion, L. Sun** (contributing authors), 2017: Precipitation change in the United States. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 207-230. http://dx.doi.org/10.7930/J0H993CC

Emanuel, K., P. Caroff, S. Delgado, C. C. Guard, M. Guishard, C. Hennon, J. Knaff, K. R. Knapp, J. Kossin, **C. Schreck**, C. Velden, and J. Vigh, 2017: On the Desirability and Feasibility of a Global Reanalysis of Tropical Cyclones. Bull. Amer. Meteor. Soc., **99,** 427-429. https://doi.org/10.1175/BAMS-D-17-0226.1

Groisman, P., H. Shugart, D. Kicklighter, G. Henebry, N. Tchebakova, S. Maksyutov, E. Monier, G. Gutman, S. Gulev, J. Qi, A. Prishchepov, E. Kukavskaya, B. Porfiriev, A. Shiklomanov, T. Loboda, N. Shiklomanov, S. Nghiem, K. Bergen, J. Albrechtová, J. Chen, M. Shahgedanova, A. Shvidenko, N. Speranskaya, A. Soja, K. de Beurs, O. Bulygina, J. McCarty, Q. Zhuang, and O. Zolina, 2017: Northern Eurasia Future Initiative (NEFI): facing the challenges and pathways of global change in the twenty-first century. *Progress in Earth and Planetary Science*, **4,** 41. http://dx.doi.org/10.1186/s40645-017-0154-5

Herring, S. C., N. Christadis, A. Hoell, **C. J. Schreck**, and P. A. Stott, eds., 2018: Explaining Extreme Events of 2016 from a Climate Perspective. *Bull. Amer. Meteor. Soc.*, **99**, S1-S157. https://doi.org/10.1175/BAMS-ExplainingExtremeEvents2016.1

Jing, Z., **S. T. Stegall**, and X. Zhang, 2018: Wind–sea surface temperature–sea ice relationship in the Chukchi–Beaufort Seas during autumn. *Environmental Research Letters*, **13,** 034008. http://dx.doi.org/10.1088/1748-9326/aa9adb

Kopp, R. E., D. R. Easterling, T. Hall, K. Hayhoe, R. Horton, **K. E. Kunkel**, and A. N. LeGrande, 2017: Potential surprises — compound extremes and tipping elements. *Climate Science Special Report:*

Fourth National Climate Assessment, Volume I. D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 411-429. http://dx.doi.org/10.7930/J0GB227J

Kossin, J. P., T. Hall, T. Knutson, **K. E. Kunkel**, R. J. Trapp, D. E. Waliser, and M. F. Wehner, 2017: Extreme storms. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 257-276. http://dx.doi.org/10.7930/J07S7KXX

***Kunkel, K.E., S. M. Champion, L. Sun,** and **J. Rennie**. 2017: *Climate Model Data Support to the Assistant Secretary of Air Force (ASAF) Climate Projection Engineering Weather Data (EWD) Project*. Final Report, Contract N61340-14-C-6103 P00013, 53pp.

*Lemieux, P., **G. Peng**, D.J. Scott, Donna J, 2017: Data Stewardship Maturity Report for NOAA Climate Data Record (CDR) of Passive Microwave Sea Ice Concentration, Version 2. *Figshare*. Version: 8 July 2017. https://doi.org/10.6084/m9.figshare.5279932

Liu, X., Q. Tang, X. Zhang, **P. Y. Groisman**, S. Sun, H. Lu, and Z. Li, 2017: Spatially distinct effects of preceding precipitation on heat stress over eastern China. *Environmental Research Letters*. http://dx.doi.org/10.1088/1748-9326/aa88f8

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

Monier, E., D. W. Kicklighter, A. P. Sokolov, Q. Zhuang, I. N. Sokolik, R. Lawford, M. Kappas, S. V. Paltsev, and **P. Y. Groisman**, 2017: A review of and perspectives on global change modeling for Northern Eurasia. *Environmental Research Letters*, **12,** 083001. http://stacks.iop.org/1748-9326/12/i=8/a=083001

Parmentier, B., N. Neeti, **E. Nickl**, and M. Millones, 2017: Multichannel Empirical Orthogonal Teleconnection Analysis: A Method for Space–Time Decomposition of Climate Variability. *Journal of Applied Meteorology and Climatology*, **56,** 1897-1919. http://dx.doi.org/10.1175/jamc-d-16-0072.1

Partasenok, S., S. V. Povajnaya, E. V. Kamarouskaya, and **P. Y. Groisman**, 2017: Peculiarities of precipitation near 0°C regime and freezing events occurrence over the territory of Belarus. *Natural Resources***,** 69-76.

***Peng, G.,** 2017a: Getting to know and to use DSMM. *Figshare*. Version: 25 August 2017. https://doi.org/10.6084/m9.figshare.5346343

Peng, G., 2018: The State of Assessing Data Stewardship Maturity – An Overview. *Data Science Journal*. **17**. http://doi.org/10.5334/dsj-2018-007

Peng, G., J. Matthews, and J. Yu, 2018: Sensitivity analysis of Arctic sea ice extent trends and statistical projections using satellite data. *Remote Sensing*, **10**. http://dx.doi.org/doi:10.3390/rs10020230

Peng, G., and W. N. Meier, 2017: Temporal and regional variability of Arctic sea-ice coverage from satellite data. *Annals of Glaciology***,** 1-10. http://dx.doi.org/10.1017/aog.2017.32

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*, **9**. https://doi.org/10.1142/S2424922X17500061

Qi, J., X. Xin, R. John, **P. Groisman**, and J. Chen, 2017: Understanding livestock production and sustainability of grassland ecosystems in the Asian Dryland Belt. *Ecological Processes*, **6,** 22. http://dx.doi.org/10.1186/s13717-017-0087-3

Ramapriyan, H., **G. Peng**, D. Moroni, and C.-L. Shie, 2017: Ensuring and Improving Information Quality for Earth Science Data and Products. *D-Lib Magazine*, **23**. http://dx.doi.org/10.1045/july2017-ramapriyan

Sankarasubramanian, A., J. L. Sabo, K. L. Larson, S. B. Seo, T. Sinha, R. Bhowmik, A. R. Vidal, **K. Kunkel**, G. Mahinthakumar, E. Z. Berglund, and J. Kominoski, 2017: Synthesis of Public Water Supply Use in the U.S.: Spatio-temporal Patterns and Socio-Economic Controls. *Earth's Future*, **5,** 771-788. http://dx.doi.org/10.1002/2016EF000511

Schröder, M., and Coauthors [including **C. J. Schreck**], 2017: GEWEX water vapor assessment (G-VAP). WCRP Report 16/2017; World Climate Research Programme (WCRP), Geneva, Switzerland, 216 pp. https://www.wcrp-climate.org/WCRP-publications/2017/WCRP-Report-16-2017-GVAP-v1.3_HiRes.pdf

Semunegus, H., A. Mekonnen, and **C. J. Schreck, III**, 2017: Characterization of convective systems and their association with African easterly waves. *International Journal of Climatology*, **37,** 4486-4492. http://dx.doi.org/10.1002/joc.5085

***Shen, S.S.P.,** 2017: R Programming for Climate Data Analysis and Visualization: Computing and plotting for NOAA data applications. The first revised edition. San Diego State University, San Diego, USA, 152pp.

Shriber, J., K. Conlon, K. Benedict, O. McCotter, and **J. Bell**, 2017: Assessment of Vulnerability to Coccidioidomycosis in Arizona and California. *International Journal of Environmental Research and Public Health*, **14,** 680. http://www.mdpi.com/1660-4601/14/7/680

Thorne, P. W., R. J. Allan, L. Ashcroft, P. Brohan, R. J. H. Dunn, M. J. Menne, P. R. Pearce, J. Picas, K. M. Willett, M. Benoy, S. Bronnimann, P. O. Canziani, J. Coll, R. Crouthamel, G. P. Compo, D. Cuppett, M. Curley, C. Duffy, I. Gillespie, J. Guijarro, S. Jourdain, E. C. Kent, H. Kubota, T. P. Legg, Q. Li, J. Matsumoto, C. Murphy, N. A. Rayner, **J. J. Rennie**, E. Rustemeier, L. C. Slivinski, V. Slonosky, A. Squintu, B. Tinz, M. A. Valente, S. Walsh, X. L. Wang, N. Westcott, K. Wood, S. D. Woodruff, and S. J. Worley, 2017: Toward an Integrated Set of Surface Meteorological Observations for Climate Science and Applications. *Bulletin of the American Meteorological Society*, **98,** 2689-2702. http://dx.doi.org/10.1175/BAMS-D-16-0165.1

USGCRP, 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I.* D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 470 pp. http://dx.doi.org/10.7930/J0J964J6

Vose, R. S., D. R. Easterling, **K. E. Kunkel**, A. N. LeGrande, and M. F. Wehner (lead authors), **L. Sun** (contributing author),2017: Temperature changes in the United States. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. D. J. Wuebbles, D. W. Fahey, K. A.

Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 185-206. http://dx.doi.org/10.7930/J0N29V45

Wehner, M. F., J. R. Arnold, T. Knutson, **K. E. Kunkel**, and A. N. LeGrande (lead authors), **L. Sun** (contributing author), 2017: Droughts, floods, and wildfires. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 231-256. http://dx.doi.org/10.7930/J0CJ8BNN

Wuebbles, D. J., D. R. Easterling, K. Hayhoe, T. Knutson, R. E. Kopp, J. P. Kossin, **K. E. Kunkel**, A. N. LeGrande, C. Mears, W. V. Sweet, P. C. Taylor, R. S. Vose, and M. F. Wehner (lead authors), **L. E. Stevens** (contributing author), 2017: Our globally changing climate. *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, **B. C. Stewart**, and **T. K. Maycock**, Eds., U.S. Global Change Research Program, 35-72. http://dx.doi.org/10.7930/J08S4N35

Young, A. H., Knapp, K. R., **Inamdar, A.,** Hankins, W., and Rossow, W. B., 2018: The International Satellite Cloud Climatology Project H-Series climate data record product, *Earth Syst. Sci. Data*, **10,** 583-593. https://doi.org/10.5194/essd-10-583-2018

*Non-peer-reviewed

Appendix 3: CICS-NC Presentations 2017–2018

Science / Project Presentations

- **Appadurai, N.**, 2017: Resilience Efforts and Activities in India, *U.S.-India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*. Pune, India, March 9, 2017.
- Arndt, D. S., J. Blunden, **L. E. Stevens**, and **S. M. Champion**, 2018: 6.8: Managing a Multi-Agency Set of Climate Indicators. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Ballinger, A. P.**, 2017: Partnering with Cities to Build Resilience to Future Climate and Hydrological Extreme Events. *Climate Predictions Applications Science Workshop (CPASW)*, Anchorage, AK, May 2, 2017.
- **Ballinger, A. P.,** and **K. E. Kunkel**, 2018: TJ8.2: Communicating Projections of Weather and Climate Extremes for Urban Decision-Makers. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.
- **Bell, J. E.**, 2017: Drought Impacts on Health. *NIDIS Upper Missouri Basin User Forum: Drought Early Warning for the Upper Basin*, Rapid City, SD, May 24, 2017.
- **Bell, J. E.**, 2017: Using extreme event attribution to determine the health impacts of climate change. *American Public Health Association (APHA) Annual Meeting*, Atlanta, GA, November 6, 2017.
- **Bell, J.**, and **R. Leeper**, 2017: CRN Manual Quality Control. *USCRN meeting with NOAA Air Resources Lab Atmospheric Turbulence Diffusion Division (ATDD) Partners*, Oak Ridge, TN, November 15, 2017.
- **Bell, J.**, and **R. Leeper**, 2017: Standardizing USCRN Soil Moisture. *USCRN meeting with NOAA Air Resources Lab Atmospheric Turbulence Diffusion Division (ATDD) Partners*, Oak Ridge, TN, November 15, 2017.
- **Bell, J.**, 2017: Analysis of Drought Conditions in the United States: 1895-2016. *Centers for Disease Control and Prevention* (CDC) webinar, December 4, 2017.
- **Bell, J.**, **J. Rennie**, **K. Kunkel**, S. Herring, and H. M. Cullen, 2017: GC23E-01: Assessment of the Long Term Trends in Extreme Heat Events and the Associated Health Impacts in the United States. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.
- **Bhadwal,** Suruchi, 2017. Disaster Risk Reduction (DRR), Sendai Framework. *UCHAI Webinar*, August 18, 2017.
- **Biard, J.**, and **K. E. Kunkel**, 2017: Use of a Deep Learning Neural Network to detect weather front boundaries. *NASA Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) Applications Workshop*, Greenbelt, MD, June 19, 2017.
- **Biard, J.**, 2017: String and char. *2017 NETCDF-CF Workshop*, Boulder, CO, September 6, 2017.
- **Biard, J.**, 2017: Linked Data and netCDF. *2017 NETCDF-CF Workshop*, Boulder, CO, September 7, 2017.
- **Biard, J.**, 2017: Automated Detection of Fronts using a Deep Learning Convolutional Neural Network. *CICS Science Conference*, College Park, MD, November 6, 2017.
- **Biard, J.**, **K. E. Kunkel**, and E. Racah, 2017: IN11A-0024: Automated Detection of Fronts using a Deep Learning Convolutional Neural Network. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 11, 2017.

- Brewer, M., T. Houston, A. Hollingshead, N. Jones, **J. Dissen**, and N. A. Ritchey, 2017: IN42C-04: Customer Use Cases and Analytics for Climate Data at NOAA's National Centers for Environmental Information. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 14, 2017.
- Brewer, M. J., T. G. Houston, A. Hollingshead, **J. Dissen**, and N. Jones, 2018: 5B.2: Customer Use Cases and Analytics for Climate Data at NOAA's National Centers for Environmental Information. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Brown, O.**, 2017: 10 years of SECOORA: Panel Discussion. *Southeast Coastal Observing Regional Association (SECOORA) Annual Meeting*, Melbourne, FL, May 17, 2017.
- **Brown, O.**, 2017: CICS research in North Carolina (CICS-NC). *CICS Science Conference*, College Park, MD, November 6, 2017.
- Bulygina, O., N. Korshunova, V. Razuvaev, and **P. Y. Groisman**, 2017: GC33F-1136: Characterization of freezing precipitation events through other meteorological variables and their recent changes over Northern Extratropics. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.
- **Burke, L**., 2017: WRI and the Partnership for Resilience and Preparedness (PREP) – An Overview. *U.S.-India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 9, 2017.
- **Burke, L**. and Appadurai, N., 2017: Development of Dashboards and its Utilization in State Action Planning. *U.S.-India Partnership for Climate Resilience Workshop on Development and Applications of Downscaling Climate Projections*, Pune, India, March 9, 2017.
- **Champion, S.**, 2017: The Importance of Summer Season Fronts in Extreme Precipitation Events. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 27, 2017.
- **Champion, S.**, 2017: Metadata and the Sustained Assessment: Data Transparency as Climate Science Communication. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 28, 2017.
- **Champion, S.**, and **K. E. Kunkel**, 2017: IN52A-08: Sustained Assessment Metadata as a Pathway to Trustworthiness of Climate Science Information. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.
- Collins, W., M. Prabhat, E. Racah, Y. Liu, K. Kashinath, C. Pal, **J. C. Biard**, **K. E. Kunkel**, M. Wehner, and T. O'Brien, 2018: TJ7.1: Deep Learning for Detecting Extreme Weather and Climate Patterns. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.
- **Datta**, Arindam, 2017. Critical Climate Science and Pathways that Increase Risks to Health. *UCHAI Webinar*, August 18, 2017.
- **Dissen, J.**, 2017: The Role of Environmental Intelligence for the Energy Industry. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 26, 2017.
- **Dissen, J.**, D. R. Easterling, **K. Kunkel**, A. Kulkarni, F. H. Akhtar, K. Hayhoe, A. M. K. Stoner, R. Swaminathan, and B. L. Thrasher, 2017: GC31H-04: Key Findings from the U.S.-India Partnership for Climate Resilience Workshop on Development and Application of Downscaling Climate Projections. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.
- Easterling, D. R., **K. E. Kunkel**, R. S. Vose, and M. F. Wehner, 2017: U23A-03: Observed and Projected Changes in Climate Extremes in the United States. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.
- **Fox, J.**, E. P. Gardiner, D. Herring, D. Kreeger, 2017: Using the U.S. Climate Resilience Toolkit's 'Steps to Resilience' Workshop. *National Adaptation Forum 2017*, Saint Paul, MN, May 11, 2017.

- Fuhrmann, C. M., Sugg, M. M., and **Runkle, J. R.**, Temporal and Spatial Variations in Personal Ambient Temperatures (PATs) for Outdoor Working Populations in the Southeast U.S. *International Congress of Biometeorology*, Durham, England, UK, September 4, 2017.
- Fuhrmann, C. M., Sugg, M. M., and **J. R. Runkle**, Assessment of Personal Heat Exposure Among Grounds Management Workers In The Southeast USA. *Southeastern Division of the Association of American Geographers*, Starkville, MS, November 20, 2017.
- Fulford, J., G. Hammer, **R. D. Leeper**, and **J. Rennie**, 2018: August Eclipse; A public engagement opportunity. *NCEI Tuesday Seminar Series*, Asheville, NC, June 20, 2017.
- Georgiadi, A., E. Kashutina, I. Milyukova, and **P. Y. Groisman**, 2017: GC33F-1140: Changes of Geo-Runoff Components in Russian Arctic Rivers. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.
- **Ginoya, N.**, 2018: PREP India – An overview of Madhya Pradesh and Uttarakhand. *Quarterly PREP Partners meeting*, Washington, DC, January 17, 2018.
- **Groisman, P.**, 2017: Freezing Precipitation and Freezing Events over High Latitudes of the Northern Hemisphere: Climatology and the Last Decade Changes. *Arctic Monitoring and Assessment Programme (AMAP) International Conference on Arctic Science: Bringing Knowledge to Action*, Reston, VA, April 26, 2017.
- **Groisman, P.**, 2017: A Review of the Perspectives on Global Change Modeling for Northern Eurasia (poster). *Japan Geoscience Union (JpGU) – American Geophysical Union (AGU) Joint Meeting*, Makuhari, Japan, May 20, 2017.
- **Groisman, P.**, 2017: Northern Eurasia Future Initiative (NEFI): Nine Science Foci of Research. *Japan Geoscience Union (JpGU) – American Geophysical Union (AGU) Joint Meeting*, Makuhari, Japan, May 20, 2017.
- **Groisman, P.**, 2017: Transition from the Northern Eurasia Earth Science Partnership (NEESPI) to the Northern Eurasia Future Initiative (NEFI). *Japan Geoscience Union (JpGU) – American Geophysical Union (AGU) Joint Meeting*, Makuhari, Japan, May 20, 2017.
- **Groisman, P.**, 2017: Virtual research environment for analysis, evaluation and prediction of global climate change impacts on the Northern Eurasia environment. *Japan Geoscience Union (JpGU) – American Geophysical Union (AGU) Joint Meeting*, Makuhari, Japan, May 20, 2017.
- **Groisman, P.**, 2017: Contemporary global climatic changes and their manifestation in the Dry Land Belt (DLB) of Northern Eurasia. *International Synthesis Workshop on Environmental and Socio-economic Changes in East Asia*, Ulaanbaatar, Mongolia, June 4, 2017.
- **Groisman, P.**, 2017: Dry land belt of Northern Eurasia: contemporary climate changes and their consequences (panel discussion). *International Synthesis Workshop on Environmental and Socio-economic Changes in East Asia*, Ulaanbaatar, Mongolia, June 4, 2017.
- **Groisman, P.**, 2017: Northern Eurasia Future Initiative (NEFI): Nine Science Foci of Research. *International Synthesis Workshop on Environmental and Socio-economic Changes in East Asia*, Ulaanbaatar, Mongolia, June 4, 2017.
- **Groisman, P.**, 2017: Understanding of Freezing Precipitation Processes and their Changes. *International Conference and Young Scientists School on Computational Information Technologies for Environmental Sciences: CITES-2017*, Zvenigorod, Russia, September3-7, 2017.
- **Groisman, P.**, 2017: Freezing Precipitation, Characterization of Weather Conditions Associated with it, and Changes of the Frequency of its Occurrence. *CICS Science Conference*, College Park, MD, November 7, 2017.

- **Groisman, P.**, 2017: Freezing Precipitation, Characterization of Weather Conditions Associated with it, and Changes of the Frequency of its Occurrence. *Annual Meeting of the Institute for Climate and Satellite Studies,* Washington, DC, November 7, 2017.
- **Groisman, P. Y.**, X. Yin, and O. Bulygina, 2017: GC33F-1136: Characterization of freezing precipitation events through other meteorological variables and their recent changes over Northern Extratropics. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.
- **Hayhoe, K.**, 2018: High Resolution Climate Projection: How to Select and Use. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Delhi, India, February 9, 2018.
- **Hayhoe, K. and Scott-Fleming, I.**, 2018: Downscaling Exercise and Discussion. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Delhi, India, February 9, 2018.
- **Hayhoe, K.**, 2018: High Resolution Climate Projection: How to Select and Use. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 12, 2018.
- **Hayhoe, K.**, 2018: Introduction to Asynchronous Regional Regression Model (ARRM). *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 12, 2018.
- **Hayhoe, K. and Scott-Fleming, I.**, 2018: Downscaling Exercise and Discussion. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 12-13, 2018.
- **Hayhoe, K.**, 2018: Applications of High Resolution Climate Projections – Agriculture, Water and Energy. *U.S.-India Partnership for Climate Resilience Workshop on High-Resolution Climate Projections and Analysis for India*, Hyderabad, India, February 13, 2018.
- Hollingshead, A., M. J. Brewer, **J. Dissen**, N. Jones, and T. Owen, 2018: 727: Exploring and Advancing Customer Engagement at NOAA's National Centers for Environmental Information. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- Hollingshead, A., M. J. Brewer, **J. Dissen**, and T. Owen, 2018: Environmental Information for Resilience in Infrastructure. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Inamdar, A. K.**, and **R. D. Leeper**, 2018: 484: Reconstructing Diurnal Cycle of Land Surface Temperature from Daily Max/Min Temperatures. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- Janiga, M., J. A. Ridout, **C. J. Schreck, III**, M. K. Flatau, N. P. Barton, W. Komaromi, and C. A. Reynolds, 2017: OS43A-1403: Convectively Coupled Equatorial Waves and the MJO in Subseasonal Forecasts from Global Coupled Atmosphere-Ocean Models: Activity and Predictive Skill. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 14, 2017.
- Janiga, M. A., **C. J. Schreck, III**, J. Ridout, M. Flatau, N. Barton, W. A. Komaromi, and C. Reynolds, 2018: 311: Influence of Convectively Coupled Equatorial Waves, the MJO, and ENSO on the Environment of Tropical Cyclones in Coupled Atmosphere–Ocean Subseasonal Prediction Systems. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.
- Janiga, M. A., **C. J. Schreck, III**, J. Ridout, M. Flatau, N. Barton, W. A. Komaromi, and C. Reynolds, 2018: 421: Convectively Coupled Equatorial Waves and the MJO in Subseasonal Forecasts from Global Coupled Atmosphere–Ocean Models: Activity and Predictive Skill. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.

- Kearns, E. J., S. Glass, **O. Brown**, **J. Brannock**, A. Simonson, and J. O'Neil, 2018: 2B.1: Making Data Available on the Cloud for Decision Support Applications through NOAA's Big Data Project. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.
- Knapp, K. R., A. H. Young, **A. K. Inamdar**, W. Hankins, and W. B. Rossow, 2018: 6B.2: Reprocessing 30 Years of ISCCP: Introducing New ISCCP H Data. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 11, 2018.
- Kumjian, M., C. Martinkus, **O. P. Prat**, S. M. Collis, H. Morrison, and M. van Lier-Walqui, 2017: A moment-based polarimetric radar forward operator for rain microphysics. *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.
- Kumjian M., C. Martinkus, **O. P. Prat**, M. van Lier-Walqui, H. Morrison, and S. Collis, 2018: General moment-based methods for DSD normalization and a polarimetric radar forward operator. *2018 ARM/ASR Joint User Facility and PI Meeting*, Vienna, VA, March 20, 2018.
- **Kunkel, K. E.**, 2017: Tools for Climate Change Adaptation: State Climate Summaries and New Climate Scenarios. *National Adaptation Forum*, St. Paul, MN, May 9, 2017.
- **Kunkel, K. E.**, 2017: The Switch to MMTS Has Changed Extreme Temperature Trends. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 27, 2017.
- **Kunkel, K. E.**, 2017: CICS-NC / NCICS Overview. *American Association of State Climatologists (AASC) Annual Meeting*, Asheville, NC, June 30, 2017.
- **Kunkel, K. E.**, 2017: Understanding the Physical Causes of Observed Trends in Extreme Precipitation: How Can Statistics Help? *SAMSI Opening Climate Workshop*, Asheville, NC, August 21, 2017.
- **Kunkel, K. E.**, 2017: DoD Needs: Memories of the Past and a Look to the Future. *White Sands Missile Range Army Research Laboratory, Invited Seminar*, White Sands Missile Range, New Mexico, September 25, 2017.
- **Kunkel, K. E.**, 2017: Effect of Global Warming on Extreme Precipitation Design Values. *2017 SERDP/ESTCP Symposium*, Washington, DC, November 28, 2017.
- **Kunkel, K. E.**, 2017: Precipitation Intensity-Duration-Frequency (IDF) Relationships and Climate Change. *Inter-agency Forum on Climate Risks, Impacts & Adaptation: Special Session*, Washington, DC, December 1, 2017.
- **Kunkel, K. E.**, and D. R. Easterling, 2017: H22B-04: An approach toward incorporation of global warming effects into Intensity-Duration-Frequency values. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.
- **Kunkel, K. E.**, and S. Champion, 2018: 6.4: The Meteorology of Extreme Precipitation and Implications for Future Planning. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Kunkel, K. E.**, **J. C. Biard**, and E. Racah, 2018: TJ7.4: Automated Detection of Fronts Using a Deep Learning Algorithm. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.
- **Kunkel, K. E.**, 2018: Climate Science in the National Climate Assessment. *NCSU Department of Marine, Earth, and Atmospheric Sciences*, Raleigh, NC, January 22, 2018.
- Lawrimore, J. H., D. Wuertz, M. A. Palecki, D. Kim, **S. E. Stevens**, **R. Leeper**, and B. Korzeniewski, 2017: H53Q-05: Improved Hourly and Sub-Hourly Gauge Data for Assessing Precipitation Extremes in the U.S. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.
- Lee, J., D. E. Waliser, H. Lee, P. C. Loikith, and **K. E. Kunkel**, 2017: GC33E-1118: Evaluation of CMIP5 Ability to Reproduce 20th Century Regional Trends in Surface Air Temperature and

Precipitation over CONUS. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.

- **Leeper, R.**, 2017: Standardizing In-Situ Soil Moisture Observations to Improve Hydrological Monitoring. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 26, 2017.
- **Leeper, R.**, 2018: 20: An Evaluation of Recent U.S. Drought Events Using a Newly Available Standardized Soil Moisture Dataset. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.
- **Leeper, R. D.**, **Bell, E. J.**, and Palecki, M. 2018, Standardizing USCRN Soil Moisture Observations. *USCRN meeting with Drought.gov Partners*, Asheville, NC, February 19, 2018.
- Liu, X., Q. Tang, X. Zhang, **P. Y. Groisman**, S. Sun, H. Lu, and Z. Li, 2017: GC33F-1140: Changes of Geo-Runoff Components in Russian Arctic Rivers. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.
- Martinkus, C., M. R. Kumjian, **O. P. Prat**, S. Collis, M. van Lier-Walqui, and H. Morrison, 2017: Development of a moment-based polarimetric radar forward operator. *38th Conference on Radar Meteorology*, Chicago, IL, August 29, 2017.
- **Matthews, J.**, 2017: Next-generation Environmental Intelligence for the Solar Industry. *The Climate Resilient Grid: A Forum on Energy, Climate, and the Grid*, Asheville, NC, June 15, 2017.
- **Matthews, J.**, 2017: Fusing Data from Multiple Remote Sensing Instruments. *Joint Statistical Meeting*, Baltimore, MD, July 30, 2017.
- **Matthews, J.**, 2018: Earth Science Data Uncertainty from the Application Perspective. *Earth Science Information Partner (ESIP) Winter Meeting*, Bethesda, MD, January 11, 2018.
- **Matthews, J.**, 2018: Optimization methods in Remote Sensing. *Remote Sensing, Uncertainty Quantification, and a Theory of Data Systems Workshop*, Pasadena, CA, February 12, 2018.
- Matthews, K. V., D. S. Arndt, J. Crouch, J. F. Fox, G. Hammer, and **T. Maycock**, 2017: Communicating Climate with Media - Tactics and Strategies. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 28, 2017.
- Matthews, K. V., G. Hammer, S. Osborne, J. Fulford, and **T. Maycock**, 2018: 6.3: Climate Science and Social Media: Success Reaching the Masses. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- McGuirk, M., **J. Dissen**, and S. Herring, 2018: 8.2: The Climate Resilient Grid: A Report on the Forum on Energy, Climate, and the Grid. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.
- **Miller, D.**, L. Stewart, D. Hotz, J. Winton, A. Barros, J. Forsythe, A. P. Biazar, and G. Wick, 2017: Atmospheric Rivers and the Great Smoky Mountains National Park; Fact and Fiction. *Oconaluftee Visitor Center, Great Smoky Mountains National Park*, October 5, 2017.
- Moroni, D., H. Ramapriyan, and **G. Peng**, 2017: A Platform to provide international and inter-agency support for data and information quality solutions and best practices. *International Ocean Vector Winds Science Team Meeting*, San Diego, CA, May 3, 2017.
- Moroni, D., H. Ramapriyan, **G. Peng**, and Y. Wei, 2017: IN52A-06: Information Quality as a Foundation for User Trustworthiness of Earth Science Data. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.
- Moroni, D., H. Ramapriyan, **G. Peng**, and Y. Wei, 2017: OD24A–2726: The multi-dimensionality of oceanographic data's information quality: Prompting transparency, reproducibility and scientific integrity. *2018 Ocean Sciences Meeting*, Portland, Oregon, February 13, 2018.

- Morrison, H., M. R. Kumjian, **O. P. Prat**, M. van Lier-Walqui, and C. Martinkus, 2017. A Generalized drop size distribution normalization method for bulk microphysics schemes. *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.
- Nelson, B. R., **O. P. Prat**, and **R. Leeper**, 2017: Use of NEXRAD radar-based observations for quality control of in-situ rain gauge measurements. *2017 American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.
- Osborne, S., K. V. Matthews, G. Hammer, J. Fulford, H. McCullough, K. Boseo, A. Sallis, and **T. Maycock**, 2018: 6.2: Communicating Science on Social Media: Strategic Keys to Success. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Pandey, P.**, 2018: PREP Demo – An Introduction to PREP Platform. *Stakeholder mapping meeting*, Dehradun, India, January 4, 2018.
- **Pandey, P.**, 2018: PREP Demo – An Introduction to PREP Platform. *Stakeholder mapping meeting*, Bhopal, India, February 26, 2018.
- **Pandey, P.**, 2018: PREP Demo – PREP Platform for Uttarakhand. *Stakeholder meeting*, Dehradun, India, March 7, 2018.
- **Pandey, P.**, 2018: PREP Demo – PREP Platform for Madhya Pradesh. *Stakeholder meeting,* Dehradun, India, March 22, 2018.
- **Peng, G.**, N. Ritchey, An. Milan, S. Zinn, K.S. Casey, D. Neufeld, P. Lemieux, R. Ionin, R. Partee, D. Collins, J. Shapiro, A. Rosenberg, T. Jaensch, and P. Jones, 2017: Towards Consistent and Citable Data Quality Descriptive Information for End-Users. *2017 DataONE User Group Meeting*, Bloomington, IN, July 24, 2017.
- **Peng, G.**, 2017: Towards consistent and citable data quality descriptive information for end-users. *2017 Earth Science Information Partners (ESIP) Federation Summer Meeting*, Bloomington, IN, July 26, 2017.
- **Peng, G.**, 2017: Data Stewardship Maturity Matrix – Introduction and Application. *Library of Congress Annual Digital Preservation - DSA Meeting*, Washington, DC, September 18, 2017.
- **Peng, G.**, 2017: Temporal and Regional Variability of Arctic Sea Ice Extent from Satellite Data. *CICS Science Conference*, College Park, MD, November 7, 2017.
- **Peng, G.**, W. Meier, A. C. Bliss, M. Steele, and S. Dickinson, 2017: C21G-1187: Spatial and Temporal Means and Variability of Arctic Sea Ice Climate Indicators from Satellite Data. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 12, 2017.
- **Peng, G.**, 2018: Data Stewardship Maturity Matrix - Application Update. *Earth Science Information Partner (ESIP) Winter Meeting*, Bethesda, MD, January 11, 2018.
- **Peng, G.**, 2018: ESIP Information Quality Cluster - Fostering collaborations in managing Earth Science Data Quality. *Research Data Alliance (RDA) Europe*, January 15, 2018.
- Phinney, R. M., and **J. Rennie**, 2018: 730: Visualizing Extreme Precipitation for Climate Storytelling. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- Prabhat, M., E. Racah, **J. Biard**, Y. Liu, M. Mudigonda, K. Kashinath, C. Beckham, T. Maharaj, S. Kahou, C. Pal, T. A. O'Brien, M. F. Wehner, **K. Kunkel**, and W. D. Collins, 2017: IN11A-0022: Deep Learning for Extreme Weather Detection. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 11, 2017.
- Prabhat, M., **J. Biard**, S. Ganguly, S. Ames, K. Kashinath, S. K. Kim, S. Kahou, T. Maharaj, C. Beckham, T. A. O'Brien, M. F. Wehner, D. N. Williams, **K. Kunkel**, and W. D. Collins, 2017: IN13E-01: ClimateNet: A Machine Learning dataset for Climate Science Research. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 11, 2017.

- **Prat, O. P.**, 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,* Asheville, NC, June 26, 2017.
- **Prat, O. P.**, B. R. Nelson, E. Nickl, and R. R. Ferraro, 2017: Evaluation of daily extreme precipitation derived from long-term global satellite Quantitative Precipitation Estimates (QPEs). *American Geophysical Union Fall Meeting*, New Orleans, LA, December 15, 2017.
- **Rennie, J.**, 2017: Multivariate Analysis of Drought Conditions in the United States: 1895-2016. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 26, 2017.
- **Rennie, J.**, **J. E. Bell**, **K. E. Kunkel**, S. Herring, and H. Cullen, 2018: 4.1: Using a Daily Homogenized Temperature Product to Assess Long-Term Trends in Extreme Heat Events and Associated Health Impacts in the United States. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 10, 2018.
- Rogers, K., **J. Fox**, M. Hutchins, N. Hall, 2017: Moving Toward Resilience: A Structured Resilience Planning Process in Asheville, North Carolina. *National Adaptation Forum 2017*, Saint Paul, MN, May 9, 2017.
- **Runkle, J. R.**, M.M. Sugg, and C.M. Fuhrmann, 2017: Personal Monitoring of Individual Temperature Experience in Outdoor Workers using Wearable Sensors, *Integrating Exposure Science Across Diverse Communities*, Raleigh, NC, October 18, 2017.
- **Runkle, J.R.,** L.C. Thompson, and M.M. Sugg, 2017: Report-Back for Location-based Personal Monitoring Data on Individual Experienced Temperature in Outdoor Workers. *Integrating Exposure Science Across Diverse Communities,* Raleigh, NC, October 2017.
- **Runkle, J.**, 2017: Roundtable Discussion: Use of Wearable Sensor Technology as a Surveillance Tool to Measure Climate-related Changes in Heat Exposure among Outdoor Workers. *American Public Health Association (APHA) Annual Meeting*, Atlanta, GA, November 7, 2017.
- **Runkle, J.**, 2017: Wearable sensors for continuous pregnancy health and environmental monitoring: From a patient and provider perspective. *American Public Health Association (APHA) Annual Meeting*, Atlanta, GA, November 7, 2017.
- **Schlie-Janssen, E.,** 2017: A Historical Analysis of Severe Hail Outbreaks over the CONUS. *2nd European Hail Workshop*, Bern, Switzerland, April 19, 2017.
- **Schlie-Janssen, E.,** 2017: Observed U.S. Trends in Extreme Precipitation. *Hampton Roads Adaptation Forum: Modeling and Managing Extreme Precipitation*, Suffolk, VA, May 19, 2017.
- **Schlie-Janssen, E.,** 2017: A radar-based analysis of severe hail outbreaks over the contiguous United States for 2000-2011. *University of Maryland Earth System Science Interdisciplinary Center*, College Park, MD, June 26, 2017.
- **Schlie-Janssen, E.,** 2017: A radar-based Assessment of Historical severe hail outbreaks and outbreak environments over the contiguous United States. *Cooperative Institute for Climate and Satellites North Carolina (CICS-NC) and National Centers for Environmental Information (NCEI)*, Asheville, NC, October 30, 2017.
- **Schreck, C. J.**, 2017: Impacts of Western Pacific Uncertainties on the Global Climatology. *Workshop on Global Tropical Cyclone Reanalysis.* Asheville, NC, May 22, 2017.
- **Schreck, C. J., III**, 2017: Different Flavors of Normals: Accounting for ENSO and Climate Change. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 27, 2017.

- **Schreck, C. J., III**, 2017: CFS Hindcast Skill and MJO Propagation across the Maritime Continent. *NASA Precipitation Measuring Mission (PMM) Science Team Meeting*, San Diego, CA, October 17, 2017.
- **Schreck, C. J., III**, 2017: Diurnal Cycle of Precipitation over the Maritime Continent: Using TRMM3B42, TRMM PFs and ISCCP Weather State Datasets. *NASA Precipitation Measuring Mission (PMM) Science Team Meeting*, San Diego, CA, October 17, 2017.
- **Schreck, C. J., III**, 2017: Different flavors of normals: Accounting for ENSO and climate change. *42nd NOAA Climate Diagnostics and Prediction Workshop*, Norman, OK, October 24, 2017.
- **Schreck, C. J., III**, 2017: CFS hindcast skill and MJO propagation across the Maritime Continent. *42nd NOAA Climate Diagnostics and Prediction Workshop*, Norman, OK, October 25, 2017.
- **Schreck, C. J.**, 2017: Interactions between Kelvin waves and easterly waves in CYGNSS. *NASA CYGNSS Science Team Meeting,* Miami, FL, December 18, 2017.
- **Schreck, C. J.**, 2017: Kelvin waves and Subseasonal Hurricane Activity. National Hurricane Center, Miami, FL. December 19, 2017.
- **Schreck, C. J., III**, A. Arguez, **A. K. Inamdar**, A. H. Young, and M. Palecki, 2018: 118: Different Flavors of Normals: Accounting for ENSO and Climate Change. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.
- **Schreck, C. J., III**, A. R. Aiyyer, M. A. Janiga, and C. W. Yeary, 2018: J28.3: CFS Hindcast Skill and MJO Propagation across the Maritime Continent. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Shen, S.S.;** Behm, G.P.; Song, Y.T.; Qu, T.; Pierret, J.; Tucker, T.; and Knapp, S., 2018: Dynamically Consistent Reconstruction and Visualization of Monthly Ocean Temperature with 1-Degree Resolution since January 1950 by the Spectral Optimal Gridding Method. *2018 Ocean Sciences Meeting*, Portland, OR, February 15, 2018.
- **Stegall, S.**, 2018: 442: A Monthly Near-Real-Time Night Marine Air Temperature Dataset. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Stevens, L. E.**, **K. E. Kunkel**, D. R. Easterling, **J. C. Biard**, **L. Sun**, and T. R. Thompson, 2017: Climate Scenarios Development for the Fourth National Climate Assessment. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 27, 2017.
- **Stevens, L. E.**, **K. E. Kunkel**, and **S. Stevens**, 2018: 531: The Role of Atmospheric Water Vapor in the Observed Upward Trend in Extreme Precipitation. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 9, 2018.
- **Stevens, S.**, 2017: A 1-km Climatology of Subhourly Rain Rates for the Contiguous United States from NOAA's NEXRAD Reanalysis. *American Meteorological Society 23rd Conference on Applied Climatology*, Asheville, NC, June 26, 2017.
- **Sun, L.**, 2017: Climate downscaling for the National Climate Assessment: practices and challenges. *International Workshop on Climate Downscaling Studies*, Tsukuba, Japan, October 2, 2017.
- **Sun, L**., 2017: Downscaling climate change information for the United States. International Research Institute for Climate and Society. *Columbia University*, New York, NY, November 30, 2017.
- **Swaminathan, R.**, 2018: US-Indian Collaborations on Analysis of Observational Climate Data and Future Projections, 98th Annual American Meteorological Society Annual Meeting, Austin, TX, January 8, 2018.
- Thompson, L.C., M.M. Sugg, **J.R. Runkle,** and C.M. Fuhrmann, 2017: Reporting Back Environmental Exposures: A Case Study of Environmental Health Literacy and Individual

Experienced Temperature among Ground Maintenance Workers. *Celebration of Student Research and Creative Endeavors,* Boone, NC, April 25, 2017.

- **Thompson, T. R.**, **K. E. Kunkel**, **L. E. Stevens**, D. R. Easterling, **J. C. Biard**, and **L. Sun**, 2017: Localized Trend Analysis of Multi-Model Extremes Metrics for the Fourth National Climate Assessment, *American Meteorological Society (AMS) Applied Climatology Conference*, Asheville, NC, June 26, 2017.
- **Thompson, T. R.**, **K. Kunkel**, **L. E. Stevens**, D. R. Easterling, **J. Biard**, and **L. Sun**, 2017: GC33E-1117: Localized Multi-Model Extremes Metrics for the Fourth National Climate Assessment. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 13, 2017.
- Van Lier-Walqui, M., M. R. Kumjian, C. Martinkus, H. Morrison, and **O. P. Prat**, 2017: Constraining and estimating microphysical parameterization uncertainty using polarimetric radar observations and the Bayesian Observationally-constrained Statistical-physical Scheme (BOSS), a novel probabilistic microphysics framework. *30th AMS Conference on Climate Variability and Change, 24th AMS Conference on Probability and Statistics in the Atmospheric Sciences, and the 16th AMS Conference on Artificial Intelligence and its Applications to the Environmental Sciences*, Baltimore, MD, July 28, 2017.
- Van Lier-Walqui, M. Kumjian, M., H. Morrison, and **O. P. Prat**, 2018: Probabilistic observational constraint of a microphysics scheme with flexible structural complexity. *2018 ARM/ASR Joint User Facility and PI Meeting*, Vienna, VA, March 20, 2018.
- Vose, R., D. R. Easterling, and **K. E. Kunkel**, 2018: 3A.7: Extremes and Attribution. *American Meteorological Society 2018 Annual Meeting*, Austin, TX, January 8, 2018.
- Young, A. H., K. R. Knapp, **A. Inamdar**, W. B. Hankins, and W. B. Rossow, 2017: A11A-1856: Reprocessing 30 years of ISCCP: Addressing satellite intercalibration for deriving a long-term cloud climatology. *American Geophysical Union Fall Meeting*, New Orleans, LA, December 11, 2017.

Outreach and Engagement Presentations

- **Bell, J.**, 2017: Climate Data and Climate Science, *Global Climate Change: Health Impacts and Responses graduate course, Emory University Rollins School of Public Health*, Atlanta, GA, September 18, 2017.
- **Bell, J.**, 2017: Climate Change and the Global Health Response (panel discussion), *American Mock World Health Organization (AMWHO) International Conference, Emory University*, Atlanta, GA, November 14, 2017.
- **Bell, J.**, 2018: Careers in Water Resources (panel discussion), *NC State University Water Resources Research Institute* (WRRI), Raleigh, NC, March 14, 2018.
- **Dissen, J.,** 2017: STEM Teachers: From Western NC to India and Back into the Classroom, *Application of India STEM education findings panel discussion, The Collider*, Asheville, NC, October 17, 2017.
- **Kunkel, K.**, 2017: Climate Science in the National Climate Assessment, *Perspectives on Western Hydroclimate graduate class webinar, University of Nevada-Reno*, October 5, 2017.
- **Matthews, J.**, 2017: What to Expect in a Nonacademic Career, *Association for Women in Mathematics (AWM), Clemson University*, Clemson, SC, November 20, 2017.
- **Maycock, T.**, 2018: Climate Change and Human Health, visiting *East Tennessee State University* faculty and graduate students, *The Collider*, Asheville, NC, February 16, 2018.
- **Rennie, J.**, 2017: Weather and Climate, *Owen Middle School*, Swannanoa, NC, October 13, 2017.

- **Rennie, J.**, 2017: Panelist, Career Opportunities. *Statistical and Applied Mathematical Sciences Institute (SAMSI) Undergraduate Workshop*, Durham, NC, October 23, 2017.
- **Rennie, J. and Stevens, S.**, 2017: How was this Made?: Making Dirty Data into Something Usable at NCEI, *Statistical and Applied Mathematical Sciences Institute (SAMSI) Undergraduate Workshop*, Research Triangle Park, NC, October 24, 2017.
- **Rennie, J.**, 2017: Weather, Climate, and Coding, *Waynesville Middle School*, Waynesville, NC, November 11, 2017.
- **Rennie, J.**, 2017: Weather Instruments and CICS-NC, *North Buncombe Elementary* Career Day, Weaverville, NC, November 21, 2017.
- **Rennie, J.**, 2018: Coding Weather and Climate Data, *Christ School*, Arden, NC, January 22, 2018.
- **Schreck, C.**, 2017: Hurricanes, the Jet Stream, the Gulf Stream, and ENSO, *Black Mountain Elementary School*, Black Mountain, NC, April 3, 2017.
- **Schreck, C.**, 2017: Weather and Climate, *Claxton Elementary School* Science Inquiry Symposium, Asheville, NC, May 18, 2017.
- **Schreck, C.**, 2017: Hurricane Formation (interview), Seven Minutes of Science podcast, *Asheville Museum of Science* (AMOS), Asheville, NC, September 26, 2017.
- **Schreck, C.**, 2017: Climate Change Communication (panel discussion), *Citizens' Climate Lobby* Workshop, University of North Carolina-Asheville, Asheville, NC. September 30, 2017.
- **Schreck, C.**, 2017: Climate Change: Causes, Impacts, & Solutions (panel discussion), *WLOS Climate Change Round Table*, Asheville, NC, October 5, 2017.
- **Schreck, C.**, 2017: Climate Change Science for Educators, *Buncombe County* Professional Development Day, AC Reynolds High School, Asheville, NC, October 9, 2017.
- **Schreck, C.**, 2017: Climate Change, Hurricanes, and North Carolina, *Trinity Presbyterian Church*, Hendersonville, NC, November 29, 2017.
- **Schreck, C.**, 2018: Hurricanes, the Jet Stream, and El Niño, *Black Mountain Elementary School*, Black Mountain, NC, March 23, 2018.
- **Schreck, C.**, 2018: Climate Change, Zombies, and the Southeast, *Citizens' Climate Lobby Southeast Regional Conference*, Asheville, NC, March 23, 2018.
- **Stevens, L.**, 2017: Weather and Climate, *North Carolina Arboretum ecoEXPLORE Lunch with a Scientist* , Asheville, NC, September 23, 2017.
- **Stevens, S.**, 2017: Climate Change Effects on Cacao Harvesting and Chocolate Production (panel discussion), *The Collider*, Asheville, NC, October 24, 2017.
- **Stevens, S.**, 2018: No Wrong Path, *ClimateCon Summit for Emerging Climate Leaders*, Asheville, NC, March 19, 2018.