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

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

CICS' scientific vision centers on the observation, using instruments on Earth-orbiting satellites and surface networks, and prediction using realistic mathematical models of the present and future behavior of the Earth System. 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 of these activities is the fundamental goal of enhancing our collective interdisciplinary understanding of the state and evolution of the full Earth System. This vision is consistent with NOAA's Goals and CICS scientists work on projects that advance NOAA objectives. CICS conducts collaborative research with NOAA scientists in three principal Themes: Satellite Applications, Observations and Modeling, and Modeling and Prediction.

CICS-NC's mission focuses on collaborative research into the use of in situ and remotely sensed observations in climate research and applications that is led by NCEI; innovation of new products and creation of new methods to understand the state and evolution of the full Earth System through cutting-edge research; preparation of the workforce needed to address climate science and its applications; engagement with corporate leaders to develop climate-literate citizens and a climate-adaptive society; and the facilitation of regional economic development through its Engagement activities.

CICS-NC activities primarily support NCEI activities and enterprise climate services. Main collaborative activities are currently organized into 8 task streams:

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

These streams are 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. CICS-NC is structured thematically by these streams.

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 activities are also funded by NWS and OAR's Climate Program Office (CPO), ARL's Atmospheric Turbulence and Diffusion Division (ATDD), and the Earth System Research Laboratory (ESRL). While CICS-NC activities remain primary, NCICS scientists are also engaged in research projects supported by non-NOAA sponsors that currently include: The National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Department of Defense (DoD), and *EarthRisk/Riskpulse*.

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

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

NCEI Website Information Architecture Development and User Interface Design Support: The new NCEI website, launched in April 2015 following the merger of NOAA's three data centers, provides 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. CICS-NC web development and program staff are working to identify the best research partner to support the development of an updated information architecture, redesigned user interface, and an implementation plan for the NCEI website.

Assessment Activities [NCEI/CPO]
Building on the support provided for the Third U.S. National Climate Assessment (NCA3) released in May 2014, the NOAA Assessment Technical Support Unit (TSU), staffed largely by CICS-NC personnel, is providing the same level of scientific, editorial, graphic design, metadata, project management, programming, and web design support for the U.S. Global Change Research Program's report on the impacts of climate change on human health. The TSU delivered two major review drafts of the report, with the final report due to be released in April 2016.

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

Web Development for Assessments: Planned, designed, and built the Climate and Human Health Assessment (http://health2016.globalchange.gov) and began redevelopment/redesign work of the USGCRP Resources/Collaboration websites.

National Climate Assessment Scientific Support Activities: A NOAA Technical Report comparing CMIP3 and CMIP5 model simulations and the implications for the National Climate Assessment was published, and draft climate assessment summaries on an individual U.S. state scale have been completed for all 50 states.

Sustained Assessment Data Processes: Information Quality Act compliance and assessment production support: Continued development and operation of a unique Product Suite and production processes to collect, curate, and display the metadata for five assessments products. The efforts remain compliant with the Information Quality Act and include traceability of data, contributors, and scientific analysis methods across graphics, visualizations, references, and photos at a level of detail to satisfy a requirement to also be reproducible.

An investigation into current and future trends in severe thunderstorms and their environments: An 11-year (2000–2011) MRMS radar based hail climatology using variables such as Maximum Expected Size of Hail (MESH) and Severe Hail Index (SHI) was developed, with subsequent analysis comparing the hail based climatology to a hail day climatology using NARR, developed based on environmental parameters which signify hail. Detection of long-term trends in the NARR hail day climatology looking for similarities in hail day frequency, the observed decrease in the number of tornado days in the U.S., and any subsequent increase in hail and tornado outbreaks.

Climate Data Records and Scientific Data Stewardship [NCEI]

Expansion of CDR User Base (e.g., Obs4MIPs): 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 Phase 5 (CMIP5). Results from analyses from CMIP5 were used for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

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

High-resolution Infrared Radiation Sounder (HIRS) Monthly Outgoing Long-wave Radiation (OLR) Climate Data Record (CDR) Software Refactoring: The HIRS Monthly OLR software refactoring effort has produced noticeable improvements in data and software quality.
https://www.ncdc.noaa.gov/cdr/atmospheric/outgoing-longwave-radiation-monthly

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

Reanalyzing Tropical Cyclone Imagery with Citizen Scientists: CycloneCenter.org has collected more than 500,000 tropical cyclone classifications from citizen scientists, and results published in the *Bulletin of the American Meteorological Society* show that this crowdsourced data can help address uncertainties in the historical record of these storms.

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

Broadband radiation budget at TOA and surface at high Spatial and Temporal Resolution from Multi-Sensor Data Fusion: Techniques are being developed to estimate broadband top-of-atmosphere (TOA) and surface radiation components, at high spatial and temporal resolution, in the short wave and long wave from geostationary imagers.

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

Transitioning the International Satellite Cloud Climatology Project (ISCCP) Process to NCEI: The transfer of the ISCCP Cloud products processing from the ISCCP team (at CCNY and NASA-GISS) to NOAA/NCEI, is nearly complete with delivery of code, ancillary data and necessary documentation. This will result in a higher resolution ISCCP product (so-called H-series), an extended period of record, and an expanded user-base, with easier data access and availability.

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 High-resolution Infrared Radiation Sounder (HIRS) observations to produce the global dataset.

Evaluation and Characterization of Satellite Data Products: This effort focused on the evaluation and characterization of satellite climate data records (CDRs) in various stages of development and application. The accuracy of the NCEI High-resolution Infrared Radiation Sounder (HIRS) near-surface temperature product was evaluated in the Arctic using the quality-controlled SHEBA dataset. Analysis lays the foundation for a long-term remote sensing near-surface air temperature product in the Arctic.

Scientific data stewardship for digital environmental data products: This effort focuses on research in scientific stewardship of individual digital environmental data products. Leading, coordinating, and participating in NCEI and across-agency DSMM (data stewardship maturity matrix) use-case studies and development of tools for integrating DSMM results for enhanced data discovery and decision-making support. Introducing roles of data, scientific, and technology stewards and their responsibilities and other major stakeholders for effectively ensuring and improving data quality and usability.

Merging long-term high-resolution quantitative precipitation estimates Quantitative Precipitation Estimates from the high-resolution NEXRAD reanalysis over CONUS with rain-gauge observations: The objective of this work is to provide long-term high-temporal and spatial resolution quantitative precipitation estimates (QPEs) suitable for hydrological, meteorological, and climatological applications. The radar-only National Mosaic and Multi-sensor QPE (NMQ/Q2) Precipitation Reanalysis is adjusted using a suite of in situ datasets at various temporal resolutions (GHCN-D, HADS, ASOS, CRN).

Toward the development of Reference Environmental Data Records (REDRs) for precipitation: Global evaluation of satellite based Quantitative Precipitation Estimates (QPEs): This project uses a suite of quantitative precipitation estimates (QPEs) derived from satellite observations to derive long-term global precipitation characteristics at high spatial and temporal resolution. The work is part of a broader effort to evaluate long-term multi-sensor QPEs, with the goal of developing Reference Environmental Data Records (REDRs) for precipitation.

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

Hydrometerological Automated Data System (HADS): Effort to recreate and automate quality control processes for in situ rain gauge data: This project works to port algorithms developed at NCEI into a more operational framework. This involves streamlining, debugging, and automating code to run in a more autonomous way.

Reanalysis of archived NEXRAD data using NMQ/Q2 algorithms to create a high-resolution precipitation dataset for the continental U.S.: The reanalysis product is in the process of being entered into the NCEI archive. Project lead worked closely with Big Data partners to make raw data available.

Ingest Archive System Agile Development Team: Provided modifications to NCEI ingest system in support of new center needs, system stability, and operational issues.

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

CICS-NC is currently co-hosting a webinar series on impacts of a changing climate and opportunities in adaptation and resilience with the Research Triangle Foundation (RTF) that will culminate in the next Executive Forum on Business and Climate (EFBC) focused on resiliency and adaptation for RTF's member companies.

In collaboration with the Economic Development Coalition for Asheville-Buncombe County Coalition (Asheville EDC), CICS-NC co-sponsored the *2016 AMS Annual Meeting* Asheville information booth, which showcased climate activities and companies advancing climate services in Western North Carolina.

CICS-NC also helped design and host an NCEI engagement forum, "Moving from Environmental Data to Resilience: Forging Public-Private Partnerships in the Energy Sector" in New Orleans with energy industry participants following the AMS Annual Meeting.

Engagement capacity in the energy sector was enhanced through service on the NOAA Energy Team and the Executive Advisory Council (EAC) for the *Utility Analytics Institute*, a membership-based group for energy industry professionals looking at strategic analytics issues. CICS-NC staff are building industry partner collaborations on uses and applications of environmental data for decision making.

Worked with the Asheville-Buncombe Sustainable Community Initiative to develop the *Collider*—an event and business center in downtown Asheville intended to advance climate/environmental literacy and development of climate services business. The Collider opened March 2016. http://www.thecollider.org/

CICS-NC staff participated in K–12 educational outreach events in conjunction with the celebration of the state-wide 2015 and 2016 North Carolina Science Festival by providing information about the Cyclone Center citizen science project and the Third National Climate Assessment at the *Mountain Science Expo* at the North Carolina Arboretum and at Isothermal Community College's *Science and Technology Expo.* CICS-NC also coordinated numerous outreach events in Fall 2015 and Winter 2016.

Communications activities serve to highlight CICS-NC/NCICS research activities and facilitate distribution of relevant information to CICS-NC/NCICS' various stakeholders. Past year activities included thirteen press releases/website stories, development of a new institute brochure, issuance of the 3rd edition of the institute newsletter, *Trends*, and initiation of a redesign of the institute website to improve navigation and incorporate updated NCSU branding.

Surface Observing Networks [NCEI/ATDD]

Evaluation of U.S. Climate Reference Network (USCRN) Soil Moisture and Temperature Observations: This research focuses on an analysis of USCRN soil observations to develop an understanding of spatial and temporal variability of soil moisture and temperature. The goal of this project is to determine the changes in soil observations to improve USCRN for drought monitoring and satellite calibration.

Expansion and Development of U.S. Climate Reference Network (USCRN) Soil Moisture Observations: The addition of soil instrumentation to the United States Climate Reference Network (USCRN) provides an opportunity to evaluate national signals for changes in soil climate. This research involves modeling of the USCRN soil observations to develop a historical soil moisture record for improved drought monitoring.

Climate Monitoring and Research Support for NOAA's Air Resources Laboratory (ARL) Atmospheric Turbulence and Diffusion Division (ATDD): Oak Ridge Associated Universities (ORAU) contractor personnel completed two additional USCRN station installations in Alaska and 16 annual station maintenance visits, surveyed 5 sites for future installations, and tested a small Unmanned Aerial System platform in support of the VORTEX SE research program. http://www.arl.noaa.gov/sUAS_CIstudy.php

Development and verification of U.S. Climate Reference Network (USCRN) Quality Assurance Method: A new revised precipitation algorithm was accepted by the USCRN configuration management and NCEI science council and deployed operationally. The National Ecological Observatory Network was provided help to adopt a variant of the precipitation algorithm for their quality control needs.

Development of an Extra-Tropical Cyclone Track dataset: Extra-tropical cyclone (ETC) tracks were generated from a 56-member ensemble of the 20th century reanalysis. Ensemble mean and member ETC tracks were placed within a database for public dissemination. ETC track densities since 1950 were

analyzed by MJO phase, which revealed tracks favoring heavier Northeast snowfall were more likely in MJO phases 7-8.

Analysis of hydrological extremes from the U.S. Climate Reference Network (USCRN): Analyzed changes to USCRN precipitation patterns over the 2012 drought and compared USCRN soil conditions to a commonly used reanalysis model; the North American Regional Reanalysis (NARR). These two studies highlighted the severity of the 2012 drought and the model's capacity to simulate the evolution of hydrological extremes. The development of a soil product for the USCRN that can monitor both sides of hydrological extremes (droughts and floods) is currently underway.

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

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

Building a Climatology of Extreme Snowfall Events in the United States: A joint NOAA/FEMA project is underway to validate snowfall extremes for every county in the United States. This will help mitigate future snowfall events and build better spatial quality algorithms for weather station data products.

Workforce Development [NCEI]

CICS-NC 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. High school, undergraduate and graduate level students and recent post-docs support projects across the CICS-NC task streams.

Evaluation of a new spatial interpolator to estimate land surface precipitation over the contiguous U.S. region: Estimations of land surface precipitation climatologies at 2.5-minute resolution using a new spatial interpolator were evaluated and compared with estimations from Cressman's traditional interpolator, NCEI/NOAA, and PRISM.

Estimation of topographic variables at different resolutions: DEM information from GTOPO30 is being used to estimate topographic variables (elevation, latitudinal and longitudinal components of slope and exposure to orography) at different resolutions for contiguous U.S. and global scale.

Global Surface Temperature Portfolio: Land Surface Temperature Analysis and Assessment of HIRS Surface Temperature Collocated with USCRN Observed Surface Temperature and Global Land Surface Temperature Datasets: The goal of this task is to provide a detailed assessment of HIRS surface temperature with high-quality USCRN observed surface temperatures. Bias and RMSE were calculated for HIRS surface temperatures vs. the USCRN observation network from 2006–2013 for the N17 and M02 satellites. This effort applies a calibration scheme that results in improved and reduced bias and RMSE when compared to USCRN, especially for the western United States.

Global Surface Temperature Portfolio: Evaluation of NOAA Temp/MLOST Land Surface Temperature using ERA Interim: The purpose of this task is to use ERA Interim as a benchmark for NOAATemp/MLOST land surface temperature evaluation. A comparison of the spatial and temporal variability of global surface temperature trends for different datasets (*e.g.* University of York, GISTEMP, and NOAATemp/MLOST), identifying regions, and periods of discrepancies was completed.

Other CICS PI Projects

Research dealing with the impacts of climate on health: This report illustrates current collaboration and interaction with the Centers for Disease Control and Prevention on issues related to climate and health. The goal of this interaction is to increase the understanding of climate on human health and assist with projects that can further this knowledge. **[NCEI/CDC]**

The Partnership for Resilience: A public–private partnership consortia organization was instituted to foster collaborative activities and a dynamic environmental change solution-provider industry for environmental analytics and adaptation strategies. http://www.partnershipforresilience.org/ **[NCSU]**

Water Sustainability and Climate Change: A Cross-Regional Perspective: Model simulations from the CMIP5 hindcast/predictive experiment were found to reproduce observed temperature trends for six regions of the U.S. for the period 1981–2010 and 2006–2035. Trends in the number of extreme monthly temperatures are simulated well for most regions, but not for the northwest. The very large-scale features of historical trends in extreme daily precipitation are simulated moderately well. **[NSF]**

Incorporation of climate change into Intensity-Duration-Frequency Design Values: A comprehensive analysis of historical trends in extreme precipitation found larger increasing trends for the shortest durations and longest return periods. A candidate metric for identifying North American Monsoon heavy rainfall events has been identified. **[DOD / SERDP]**

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

German Wind Power Model Development Support: Wind power generation over Germany can be statistically forecast out to 30 days using teleconnections, including tropical diagnostics of outgoing longwave radiation. **[EarthRisk/Riskpulse]**

Relationship between occurrence of precipitation and incidence of traffic fatalities using high-resolution NEXRAD reanalysis: This project is using the recently completed NMQ/Q2 NEXRAD reanalysis to study the impact of precipitation on the frequency of fatal auto accidents across the United States. The new product has the ability to determine the intensity of precipitation (if any) within five minutes and one kilometer of a crash. **[NCEI/CDC]**

Trends and Projections of Northern Hemisphere Blocking Highs: Analysis of 20th Century Reanalysis data provides a 141-year climatology of blocking high events—a period longer than any previous analysis. **[NOAA/CPO]**

Trends and Projections of Northern Hemisphere Extratropical Cyclones: Analysis of CMIP5 future projections indicates a decrease in weak ETCs and an increase in strong ETCs. A northward shift in the mean track is also projected. **[NOAA/CPO]**

Administration

Administrative or Task I activities provide a central suite of shared resources for the CICS-NC staff and partners. Primary Task I activities include institute administration, 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.

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

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

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

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

Information Technology Systems Improvement, Management and Maintenance

Task Leader	Jonathan Brannock, Scott Wilkins
Task Code	NC-ADM-01
NOAA Sponsor	Ed Kearns, David Easterling (partial)
NOAA Office	NESDIC/NCEI (partial)
Contribution to CICS Themes (%)	Theme 1: 33%; Theme 2: 33%; Theme 3: 33%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%, Goal 4: 0 %, Goal 5: 0%

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

BACKGROUND

CICS-NC IT staff support a well-rounded set of IT resources and services as well as maintain the necessary infrastructure required to do so. CICS-NC services can be organized into 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 and the *headnode*. *headnode* is a powerful server where users can prototype ideas and perform light work tasks including coding and testing. *headnode* can then queue heavy workloads onto the cluster where a number of different queues are available to suit computing requirements. Last, there is the network and storage network (SAN) which supports the former with high-speed access to network resources, high speed storage, and tape resources.

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

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

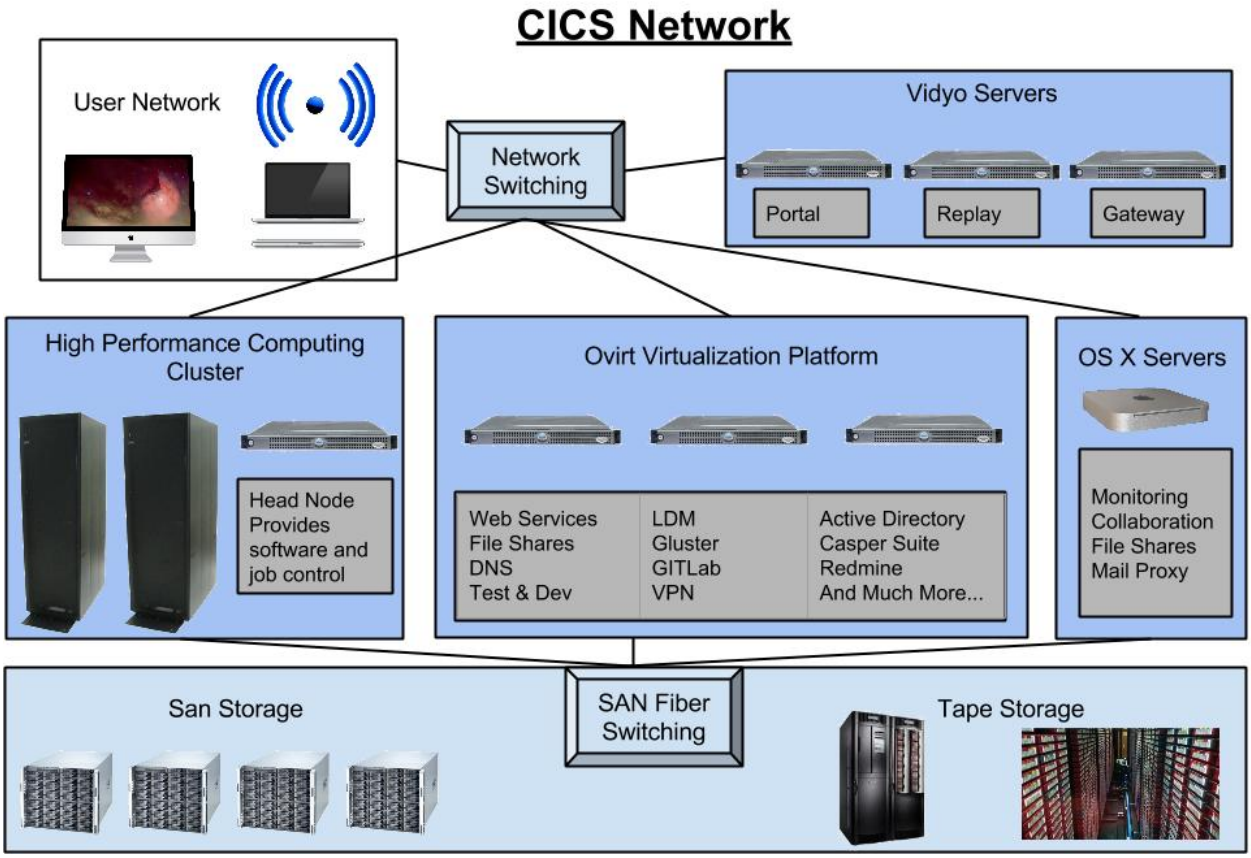


Figure 1: Network, and system diagram.

A building-wide wireless network was created to provide both CICS-NC and 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 32 access points covering areas on the 1st floor through 3rd floors, fitness center, and NCDC archive and full coverage on 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.

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

A video conferencing solution by *Vidyo* has been made widely available. This provides users with the ability to quickly and easily set up virtual meetings where they can share video, audio, and desktop content. It provides a method to effectively work with offsite employees, teleworkers, and people on travel. It also provides a means to collaborate and attend meetings hosted by other organizations including NCSU and NOAA. The *Vidyo* system also provides recording and webcasting services. *VidyoVoice* allows for integration with existing telephone systems.

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

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

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

CICS-NC utilizes *Microsoft Active Directory*. This provides a stable and sustainable infrastructure for centralized authentication services. This provides group and role based access controls to CICS resources.

ACCOMPLISHMENTS

We transitioned from the traditional Linux/KVM virtualization implementation to *oVirt* 3.6. *oVirt* is the upstream Fedora project from the *RedHat Enterprise Virtualization Solution*. This provides better interface with simplified provisioning of both hosts and guests. *oVirt* supports a variety of technologies including live migration, storage migration, failover, high availability, and load balancing. *oVirt* also support a variety of storage options including *Gluster*, *Ceph*, Fiber Channel, and iSCSI. These improve our stability and reliability while reducing the amount of time needed to manage these resources.

CICS-NC moved from our OS X Server mail system to our own *Google Apps* instance. This provides Mail, Hangouts, Calendar, and all of the other Google services to CICS-NC staff while integrating with our existing authentication and mail configurations, and also eases our integration with NOAA and NCSU which both utilize *Google Apps*.

IPv6 support was revamped and rolled out to all CICS-NC networks, providing native dual-stack IPv4 and IPv6 end-to-end connectivity with the internet, on-site services, and wireless endpoints.

CICS-NC IT is working on executing a transition from *Redhat* 6.5 to *Redhat* 7.1, keeping our Linux environment up to date. This update will roll out to both our computing cluster and virtualization environment. The additional benefits include newer compilers and libraries, better service management with *Systemd*, and support for cutting-edge technologies like *Ceph* and *Docker*.

We migrated our cluster resource management software from *Torque* and *Maui* to *Openlava*. This *LSF*-compatible open source platform combines both functions into a single package with many more features than our previous software. *Openlava* provides users with greater control over job resources and scheduling flow using job dependencies.

We participated in the NOAA Big Data Initiative by hosting and transferring 24 years of NEXRAD Level 2 RADAR data to *Microsoft Azure, Amazon S3*, and *Google Cloud Services*. One year of data was

transferred to *Open Commons Consortium* (OCC) *Griffin*. Implemented processes to feed the latest data received from NCEI onward to *Azure*, *Google*, and *Griffin.*

We purchased a vaulting license from *Quantum* that allows us to move tapes in and out of the library. Our 500-slot library now manages 1200 tapes. We reorganized the project data holdings to split the input data that is primarily archived at NCEI and output data that is only stored at CICS-NC until repatriation to NCEI, giving us greater flexibility and control over long-term project storage.

PLANNED WORK

- Continuous tasks (monitoring and maintenance)
- Planning for expected end of life equipment
- Research cloud technologies and potential benefits to CICS-NC and NCEI
- Investigate storage alternatives for both software and hardware architectures

PERFORMANCE METRICS

	FY16
# of new or improved products developed	7
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

CICS-NC IT is primarily in a support role for scientists and their research.

Access and Services Development

Access and services development activities support improvements to access mechanisms for NOAA's National Centers for Environmental Information (NCEI)'s data and product holdings. NCEI has a continuing number of requirements to improve conveyance of data products and services to its stakeholders and clients. NCEI services include interaction with data users, providing data products to users, and communicating unmet user needs to the science and stewardship components of NCEI. This requires the input and guidance of scientific data management staff, user-interface development, and integration of user-end needs into data products—the goal is to provide tools and information to facilitate improvement of society resilience to climate change. The new NCEI website, launched in April 2015 following the merger of NOAA's three data centers, also offers the opportunity to update and enhance current services to customers with a more user friendly design and interface to enable current and future users to more easily identify, locate, and access specific data products and services. To meet this demand, CICS-NC will provide highly skilled staff in data architecture, management, web services, and user interface design and development. While consistent support remains a challenge, CICS-NC will nevertheless work to identify prospective future skilled practitioners, broaden its software engineering staff and utilize partner expertise as needed, and continue to nurture community interest in climate applications to provide opportunities for improvement of NCEI's user experience.

CICS-NC initiated work on the climate model portal during the first five-year cooperative agreement. Activities under this task identified the need for a much broader approach to accession models and services. This task provides a broader set of skills to address needs across NCEI services. CICS has initiated interactions with NCSU computer science and database faculty to broaden its skill matrix in these areas and will utilize consortium/UNC system members to complete projects and tasks as needed when new tasks are identified.

Programming and Applications Development for Climate Portal

Task Leader	Jim Fox
Task Code	NC-ACD-01-UNCA
NOAA Sponsor	David Herring; David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

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

BACKGROUND

There is a continuing need within NOAA's online climate services for greater collaboration to incorporate climate services across NOAA and enhance NOAA's web presence in response to customer requirements. NOAA's Climate Services Portal (NCSP) is envisioned to be the "go-to" website for NOAA's climate data, products, and services for all users. Toward this end, the NCSP has a need for expertise and resources to support programming work for applications development and data visualization in support of: 1) Drupal Content Management System for Climate.gov; 2) U.S Climate Resilience Toolkit; 3) Global Climate Dashboard; 4) Climate Explorer and online Map Viewers; 5) Climate Interactive tools; and 6) Maps and Data Section Leadership. Supplemental development and integration tasks were also identified for: a) Graphics for Indicators and NCA; b) GIS/climate projections for NCA; c) Regional, state, local products; d) Internal management portals; and e) Decision support. CICS consortium partner, UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC), is uniquely situated to address these needs through its expertise in visualization, geographic information systems (GIS), programming, multimedia, and environmental science.

ACCOMPLISHMENTS

Drupal Content Management System for Climate.gov: NEMAC provided maintenance and development support for the Climate.gov team including Data Snapshots maintenance support and initial stage feedback on the climate.gov redesign.

U.S Climate Resilience Toolkit: The CRT provides scientific tools, information, and expertise to help people manage their climate-related risks and opportunities, and improve their resilience to extreme events. The site is designed to serve interested citizens, communities, businesses, resource managers, planners, and policy leaders at all levels of government. The CRT was initially launched in November 2014 with fully developed content for two topics, Coastal Flood Risk and Food Resilience, including over 20 Taking Action case studies, and short narratives for two other topics, Ecosystem Vulnerability and Human Health. As of May 21, 2015, the CRT included 155 published tools and 64 published case studies.

During the current project period, NEMAC worked with NOAA personnel to accomplish the following tasks:
New CRT content including: four new fully developed and published Topics (Arctic, Energy, Transportation, and Tribal Nations) with a fifth topic under development (Marine) as well as new case studies and tools for both new and existing topic areas. As of March 17, 2016, there are 98 published case studies and 222 published tools in the CRT. In addition, the Steps to Resilience were completely re-imagined, re-conceptualized, and re-written. The edits for the new Steps to Resilience will be published in the CRT's design refresh, discussed below, which is expected to launch in April 2016. NEMAC also provided updates and maintenance expertise for the Find Experts map, facilitated the review, approval, and ingestion of nine new training courses, and facilitated the creation of a new Federal Agency Cooperation page.

Redesign of homepage and navigation including: an update of the CRT's home page slideshow to provide new featured content and completion of several prototype site designs to "refresh" and update the CRT's initial design and navigation structure, incorporating feedback from the editorial team. NEMAC prepared the new designs for implementation by NCEI and is currently working on mobile responsive layouts. It is expected that the design refresh will be published in April 2016.

Development of new sections including: the development and hosting of a *Sustainable and Climate Resilience Health Care Facilities Toolkit* which required the creation and implementation of a new content type and changes to the navigational structure; conceptualization and development guidelines for a new *Regions* section, based on National Climate Assessment regions (content now under development by editorial and Regional teams); and development of new content types and implementation of a *Water Resources Dashboard launched March 16, 2016,* for the Water Resources section. NEMAC also conceptualized, developed, designed, and produced a suite of resources for contributors, consisting of 13 guidance documents and templates, in order to more effectively manage the development of content.

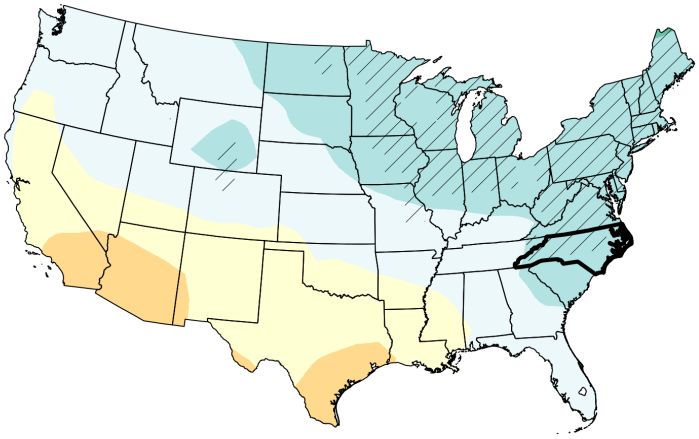
Climate Explorer and Online Map Viewers: In the early part of the year, a decision was made to create a second iteration of the Climate Explorer, dubbed Climate Explorer 2 (CE2), to support current functionality as well as new climate projection maps. The work of developing CE2 was awarded to Habitat Seven (H7), and NEMAC has collaborated with H7 on the transition. CE2 is expected to launch in June 2016; NEMAC is maintaining the original Climate Explorer in the interim. NEMAC has added map layers to the Climate Explorer to support the new CRT topics as needed throughout the year.

Jim Fox was invited to participate as a member of the planning committee for incorporation of climate projection information into the CRT. This has required his attendance at weekly webinars beginning in April 2015. NEMAC has been responsible for implementing action items from this committee through a new web application called the Climate Widget. The Widget will be incorporated into CE2 by H7.
NEMAC subcontracted JMH Consulting for data ingest and digital design of the Widget.
NEMAC worked with Dave Blodgett to get the data (BCCA CMIP5), created the ingest API, designed the interface, worked through multiple prototypes of the graph designs, and worked with H7 on the data and application transfer.

Supplemental Task Areas:
Graphics for Indicators and NCA: NEMAC supported the Health Assessment team for the National Climate Assessment including design and development of static graphics using SigmaPlot and Adobe Photoshop and interactive online versions of the same graphics using page sliders, radial buttons, and

similar functions) for the Climate and Health Assessment website. See example below of a three-map comparison using two tabs (in red) of higher and and moderate emissions.

National Climate Assessment Regional Map Products: In previous years NEMAC supported the National Climate Assessment (NCA) mapping needs through the creation of various CONUS and regional maps displaying different climate models, time periods, and variables. This period, NEMAC supported the development of NCA state-focused products by producing maps of individual states displaying the same information and recreated some of the same CONUS and regional map displays to highlight individual states within CONUS and within each region to provide focused context, yet be able to show the highlighted state in relation to the rest of that region or country. This work was completed for CMIP5 data and using only the RCP 8.5 (high emissions) output, for just the mid- and late-century scenarios (2041–2070 and 2071–2099), for annual and seasonal time periods, and just for the precipitation variable. The processing mapping led to the creation of a total of 1,030 new maps.



CONUS Region (North Carolina), CMIP5 RCP 8.5, 2041–2070, Annual, Precipitation

Regional, state, local products: NEMAC collaborated and contributed to the development of several NCA products at different scales (regional, state, county).

Internal Management Portals: NEMAC supported the CICS-NC TSU and NCEI with developing and maintaining several internal management portals using Drupal.

Decision Support: NEMAC lead several local and regional efforts in the decision support arena focused on the Steps to Resilience within the CRT and identifying ways of transferring this process to different scales. This included:

- Working with the Southeast Sustainability Directors Network (SSDN), led two structured workshops (in Charleston, SC, and Atlanta, GA) to interact with SSDN members from the 30 representative cities to determine their true needs linked to the Steps to Resilience in the CRT. Based on their feedback, updated the Steps to Resilience.
- Matt Hutchins worked with the City of Asheville, using the Steps to Resilience, to help them create a more detailed vulnerability analysis for the city.
- Working with David Herring and Nancy Beller-Simms, designed and ran a three-day workshop in Marquette, Michigan that interacted with multiple townships, utilities, and conservation planners to use the CRT to help them build resilience in their location.

PLANNED WORK

Work will continue on the Climate Widget, Climate Resilience Toolkit, and other interactive tools under Year 3 of the project. Currently anticipated tasks include:

- launch of the Climate Resilience Toolkit (CRT) design "refresh"
- additional CRT content development and implementation
- launch of new Regions section of CRT
- maintenance of original Climate Explorer and support for transition to CE2
- possible redesign or redeployment of the Global Climate Dashboard

PERFORMANCE METRICS

	FY16
# of new or improved products developed	6
# of products or techniques submitted to NOAA for consideration in operations use	7
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	6
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	3

Invited Presentations: AGU, AMS, EPA in Raleigh, SENRLG in Atlanta, Charleston
Products: The U.S Climate Resilience Toolkit, the Climate Explorer v2.0 (CE2), and the Climate Widget (3). Products were generated including graphics (static and interactive) for the Climate and Health Assessment, regional, and local products for the National Climate Assessment, and internal management portals for the CICS TSU and NCEI (3). Several workshops were also held for the purpose of decision support and transfer of the CRT Steps to Resilience (1).

- U.S Climate Resilience Toolkit: www.toolkit.climate.gov
- Climate Explorer: http://toolkit.climate.gov/climate-explorer
- http://www.climate.gov/maps-data/data-snapshots/start

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 will include ongoing engagement with public and private partners and targeted, scientifically rigorous reports as well as participation in the high-level, visible, and legally mandated National Climate Assessment (NCA) process, which is responsive to greater emphasis on user-driven science needs under the auspices of the U.S. Global Change Research Program (USGCRP). USGCRP is a confederation 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 many 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. The agency also plans to invest 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 that significantly contributed to virtually all aspects of the report by providing scientific, editorial, graphics, project management, metadata, software engineering, and web design expertise, and CICS-NC has been a strong partner with NCEI in building partnerships with private, academic, and non-governmental organizations to promote societal resilience. CICS and its consortium partners continue to address assessment priorities, including the sustained assessment process, interim assessments, and technical and special reports, development of enduring partnerships through the Partnership for Resilience, and continuing support of USGCRP activities, including the USGCRP Climate and Human Health Assessment, a Climate Science Special Report, and the next (Fourth) National Climate Assessment.

National Climate Assessment Scientific Support Activities

Task Leader	Kenneth Kunkel, Liqiang Sun, Laura Stevens, Sarah Champion, and Andrew Buddenberg
Task Code	NC-ASSESS-01-NCICS-KK
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%, Goal 5: 0%

Highlight: A report on the CMIP5 model simulations was published. Scientific support contributions to the climate and human health report, including contributing authorship of Chapter 1 and the appendix, were completed. Draft state summaries have been completed for all 50 states.

BACKGROUND

NOAA is participating in the high-level, visible, and legally mandated National Climate Assessment (NCA) process, which will be responsive to greater emphasis on user-driven science needs under the auspices of the U.S. Global Change Research Program (USGCRP). National climate assessments are intended to advance the understanding of climate science in the larger social, ecological, and policy systems to provide integrated analyses of impacts and vulnerability. NOAA's National Climatic Data Center (NCDC) and many 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 has formed a technical support unit (TSU). Within the TSU, a group focused on scientific support has been assembled, consisting of a lead senior scientist (Kenneth Kunkel), a deputy scientist (Liqiang Sun), support scientists (Laura Stevens and Sarah Champion), and a software engineer (Andrew Buddenberg). The Lead Senior Scientist provides scientific oversight for the development of NOAA's assessment services, focusing on a contribution to the National Climate Assessment and, in support of the National Climate Assessment and in conjunction with NOAA and other agency expertise, providing scientific oversight and guidance to coordinate and implement distributed and centralized high-resolution modeling capabilities.

ACCOMPLISHMENTS

A technical report comparing climate projections from the CMIP3 and CMIP5 projects was completed and published as NOAA Technical Report NESDIS TR144. This is a follow-up to NOAA Technical Report NESDIS TR142, which was produced to support the development of NCA3. This technical report includes a thorough analysis and comparison of temperature and precipitation projections. Time periods include early, mid, and late 21st Century. Climate variables include mean temperature (seasonal and annual), mean precipitation (seasonal and annual), and selected CLIMDEX metrics (annual). Historical simulations are compared with observations.

Scientific support was provided for the USGCRP climate change and human health report. Climate scenarios based on the CMIP5 simulations were produced for two of the author groups. In addition, Kunkel is one of the contributing authors on Chapter 1, "Climate Change and Human Health", and Appendix 1, "Technical Support Document: Modeling Future Climate Impacts on Human Health".

The development of "NOAA's State Summaries for the National Climate Assessment" was continued, coordinated by Champion. These state summaries are intended to be 2–6 pages in length and summarize historical climate trends and CMIP5 projections of temperature and precipitation. The project includes development, editing, and informal/formal review of climate text, graphics, metadata, and web for all 50 U.S. states with TSU staff, as well as climate experts in all states and other climate science centers. Drafts of 50 states have been completed. Twenty-six have been sent out for the formal NOAA anonymous external review process. Express interest exists already in these summaries for future updated versions and dissemination at climate-related conferences.

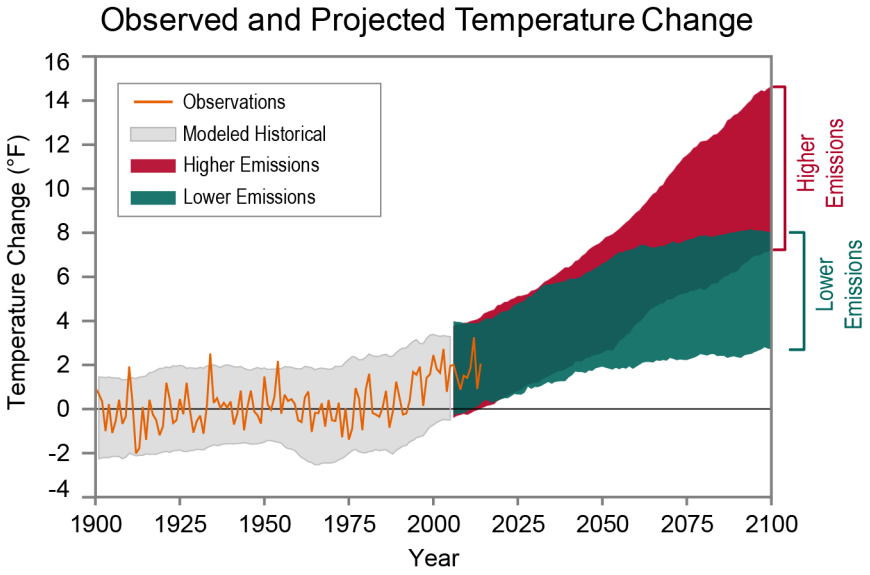


Figure 1: Observed and projected changes in near-surface air temperature for New Mexico. This is an example of a graphic that will be included in each state summary. Observed data are for 1900-2014. Projected changes for 2015-2100 are from global climate models for two future scenarios: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in New Mexico (orange line) have risen almost 2°F since the beginning of the 20th century. Observed temperatures are within the envelope of model simulations of the historical period (gray shading). Further warming is projected through the 21st century with smaller warming under a low emissions future (green shading) and greater (and very large) warming under a high emissions future (red shading). Under a low emissions scenario, some mid-21st century model projections are not too much warmer than current conditions.

In support of the upcoming Climate Science Special Report and the Fourth National Climate Assessment, the Localized Constructed Analogs (LOCA) data set was obtained. This is a new statistically-downscaled daily data set based on CMIP5 simulations and at 1/16-degree spatial resolution for the conterminous United States. Computer programs to process these data were developed and an initial set of 23 derived climate variables were calculated.

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

PLANNED WORK

- Complete and publish 50 NOAA state summaries
- Complete papers on the effect of the changeover to MMTS on extreme temperature trends, a global review of snow extremes, and use of CoCoRaHS data.
- Complete development of an initial set of climate scenarios products based on LOCA, a new statistically-downscaled data set, in support of the Fourth National Climate Assessment

PUBLICATIONS

Peer-Reviewed

- Easterling, D.R., K.E. Kunkel, and M.F. Wehner, 2016: Detection and attribution of climate extremes in the observed record. *Weather and Climate Extremes*, doi:10.1016/j.wace.2016.01.001.
- Kibler, S.R., P.A. Tester, K.E. Kunkel, S.K. Moore, and R.W. Litaker, 2015: Effects of ocean warming on growth and distribution of dinoflagellates associated with ciguatera fish poisoning in the Caribbean. *Ecological Modeling*, 316, 194-210.
- Kunkel, K.E. and R.M. Frankson, 2015: Global land surface extremes of precipitation: Data limitations and trends. *Journal of Extreme Events*, 2, 1550004-1 to 1550004-19, doi: 10.1142/S2345737615500049.
- Frei, A., K.E. Kunkel, and A. Matonse, 2015: The seasonal nature of extreme hydrological events in the Northeastern United States. *J. Hydrometeorol.*, 16, 2065-2085.
- Kunkel, K.E., R. Moss, and A. Parris, 2015: Innovations in science and scenarios for assessment. *Climatic Change*, doi:10.1007/s10584-015-1494-z.
- Kossin, J.P., T.R. Karl, T.R. Knutson, K.A. Emanuel, K.E. Kunkel, J.J. O'Brien, 2015: Reply to "Comments on 'Monitoring and understanding trends in extreme storms: state of knowledge'". *Bull. Amer. Meteor. Soc*., 96, 1177-1179.
- Jacobs, J., S. Moore, K. Kunkel, and L. Sun, 2015: A framework for examining climate driven changes to the seasonality and geographic range of coastal pathogens. *Climate Risk Management*, 8, 16-27.
- Sun, L., K.E. Kunkel, L.E. Stevens, A. Buddenberg, J.G. Dobson, and D.R. Easterling, 2015: Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment, *NOAA Technical Report NESDIS 144,* 111 pp.

PRODUCTS

- Publication of papers on lessons learned from the Third National Climate Assessment
- Publication of papers on climate extremes
- Publication of papers examining impacts of climate change on health risks
- Completion of external review drafts of NOAA state summaries for 26 states
- Publication of CMIP3/CMIP5 comparison report
- Completion of two chapters of climate change and health report as contributing author

PRESENTATIONS

- Banzon, V., G. Liu, K. Fornry, E.A. Becker, L. Sun, K. Arzayus, 2016: Use of a Blended Satellite and In situ Sea Surface Temperature Climate Data Record for Evaluating Long-term Impacts on Coral and Marine Mammal Communities, 2016 Ocean Sciences Meeting, New Orleans, LA, Feb. 21-26, 2016.
- Kunkel, K.E., 2016: Climate Resilience for the Southeast U.S., Research Triangle Park Foundation webinar, (22 February).
- Kunkel, K.E., 2016: The Development of Climate Scenarios for the National Climate Assessment, Annual Meeting of the American Meteorological Society, New Orleans, LA, (13 January).
- Kunkel, K.E., 2016: Precipitation Extremes and Anthropogenically-forced Warming: Considerations for Future Changes in Design Values, Annual Meeting of the American Meteorological Society, New Orleans, LA, (13 January).
- Kunkel, K.E., 2016: Communicating Uncertainty in Weather and Climate-From PoPs to Beyond CO2, invited talk, Town Hall Panel, Annual Meeting of the American Meteorological Society, New Orleans, LA, (12 January).
- Kunkel, K.E., 2015: Precipitation Extremes: Considerations for Anthropogenically-Forced Future Changes, Invited talk, Fall Meeting of the American Geophysical Union, San Francisco, CA, (18 December).
- Kunkel, K.E., 2015: A New Look at Precipitation Extremes in the central U.S., Invited talk, Workshop-Implications of a Changing Arctic on Water Resources and Agriculture in the Central U.S., Lincoln, NE, (10 November).
- Kunkel, K.E., 2015: Climate Resilience for the Southeast U.S., Invited talk, "Climate Resilient Design in the Southeast", Asheville chapter of The American Institute of Architects and The Collider, Asheville, NC, (6 November).
- Kunkel, K.E., 2015: Precipitation and Temperature Extremes in the U.S.: Trends and Causes, Invited talk, 40th Climate Diagnostics and Prediction Workshop, Denver CO, (26 October).
- Kunkel, K.E., 2015: Attribution of Heat and Cold Events, Invited talk, National Academy of Sciences Extreme Weather Events and Climate Change Attribution Workshop, Washington, DC, (22 October).
- Kunkel, K.E., 2015: Extreme Climate Trends and Projections for the Southeast U.S., invited keynote, Annual Meeting of the Southeast Climate Consortium, Athens, GA, (20 October).
- Kunkel, K.E., 2015: Downscaling of Global Climate Models, U.S.-India Joint Working Group on Combating Climate Change, Washington, DC, (21 September 21).
- Kunkel, K.E., 2015: Opportunities in Climate Analytics for Utilities, Summer Meeting of the Utility Analytics Institute Executive Advisory Council, Atlanta, GA, (11 August).
- Kunkel, K.E., 2015: NOAA State Summaries for the National Climate Assessment, Annual meeting of the American Association of State Climatologists, invited talk, Cape May, NJ, (25 June).

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	8
# of non-peered reviewed papers	0
# of invited presentations	8
# of graduate students supported by a CICS task	0
# of graduate students formally advised	2
# of undergraduate students mentored during the year	0

The TSU published a report comparing CMIP5 climate model simulations with CMIP3 simulations and also completed scientific support contributions to the Climate and Human Health report, including contributing authorship of Chapter 1 and the appendix. Draft state summaries were completed for all 50 states and 26 have been sent out for the formal anonymous external NOAA review. Eight scientific journal papers were published or accepted. Numerous invited talks were given.

Software engineering for scientific workflow

Task Leader	Andrew Buddenberg
Task Code	NC-ASSESS-02-NCICS-AB
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: CICS technical support staff applied the best practices of software engineering to the scientific research workflow.

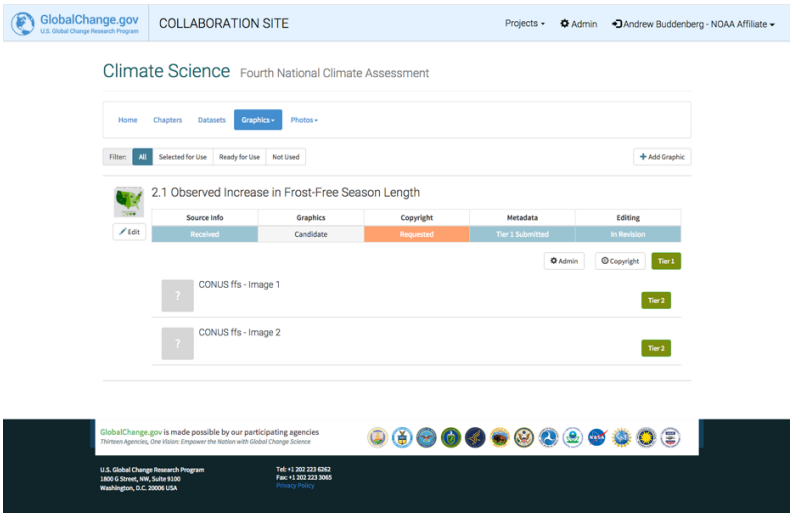
BACKGROUND

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

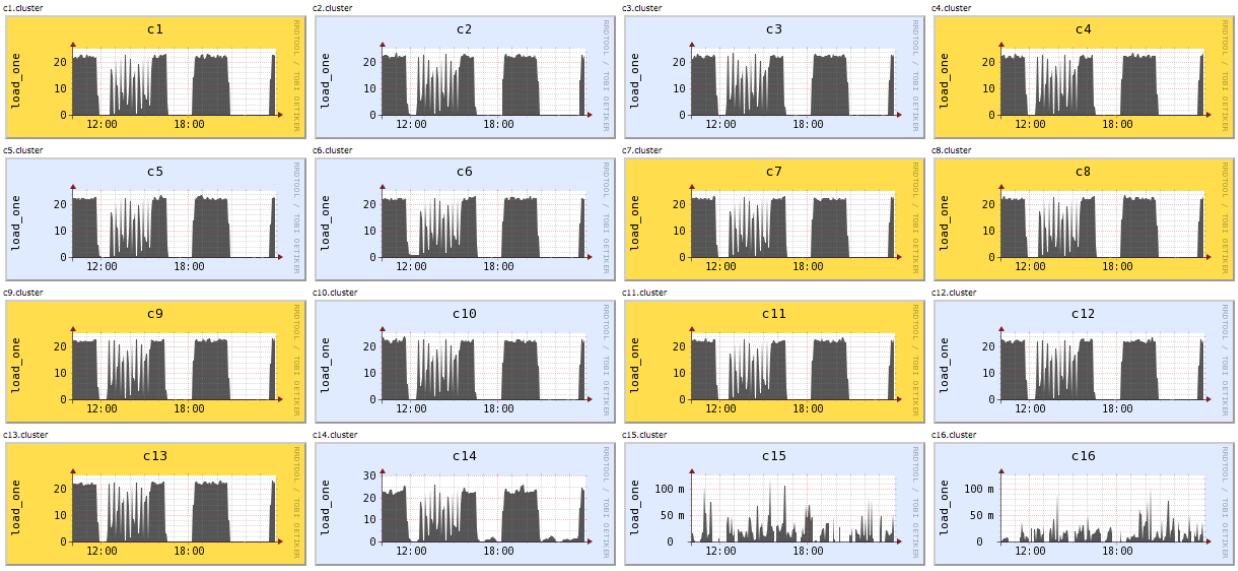
Given that almost all of these analyses are implemented with computer software, this task focuses on ensuring the integrity and portability of the programs developed for the NCA and assisting the lead scientist in their creation and development. In addition, to facilitate the overall business of the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

ACCOMPLISHMENTS

Continued development of TSU's software portfolio supporting the impending release of the Climate and Human Health Assessment and commencement of the Fourth National Climate Assessment. Improvements to these tools greatly enhance our ability to gather, process, and disseminate climate science metadata to ensure the highest levels of traceability and reproducibility. The figure below depicts our next-generation, real-time metadata collaboration tool:



In anticipation of the Fourth National Climate Assessment, a processing framework for the LOCA (Localized Climate Analogs) dataset was developed. This dataset is relatively large (11 TB) and requires an HPC (High Performance Computing) cluster to deliver results in a timely fashion. The eponymous processing framework can seamlessly scale to any number of CPUs and runs modular, arbitrary functions against the data to accommodate unforeseen requirements.



PLANNED WORK

- Continue development of metadata collection system and supporting technologies.
- Continue performance analysis and enhancement of Big Data processing.
- Continue assisting lead scientist and associates with scientific programming tasks.
- Continue to mentor undergraduate interns.

PRODUCTS

- GCIS Data Acquisition System (GDAS): real-time metadata collaboration tool.
- Deployed Docker automated container management tool.
- loca-proc: flexible, scalable processing framework for LOCA dataset.
- gcis-py-client 1.2: latest iteration of Global Change Information System tools.
- ECV Database: Essential Climate Variables analysis and visualization for international satellite community.
- blocking-highs: software in support of Extra-Tropical Cyclone research.
- CMIP3-Downscaled: processing datasets for Rutgers University, Centers for Disease Control, and Environmental Protection Agency.

OTHER

Mentored 2 undergraduate and 1 high school intern.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	7
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	3

See product list above. Demonstrated GDAS real-time metadata collaboration tool and Docker DevOps tool to NOAA.

Sustained Assessment Data Processes: Information Quality Act compliance and assessment production support

Task Leader	Sarah Champion
Task Code	NC-ASSESS-03-NCICS-SC
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Continued development and operation of a unique Product Suite and production processes in order to collect, curate, and display the metadata for five assessments products. The efforts remain compliant with the Information Quality Act and include traceability of data, contributors, and scientific analysis methods across graphics, visualizations, references, and photos at a level of detail to satisfy a requirement to also be reproducible.

BACKGROUND

The Technical Support Unit continued management of data and metadata collection, documentation, and delivery processes and applications for five major Sustained Assessment products:

- The Third National Climate Assessment (post 2014 release)
- Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities (released July 2015)
- Implications for the U.S. National Climate Assessment, and Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (Release set for April 2016)
- NOAA's State Climate Summaries (Release set for Summer 2016)
- Climate Science Special Report (In Development, release set for 2017)

The TSU also facilitated re-design and updates of the metadata, graphics, and collaborative websites used to support Sustained Assessment activities.

ACCOMPLISHMENTS

Across the above-named Sustained Assessment products, Champion successfully engineered and executed the end-to-end process to collect, document, and deliver assessments metadata in accordance with the Information Quality Act guidelines. This is a first-ever process of its kind, which included personally authored web surveys, designed for optimal user experience and matched against ISO 19115 documentation standards; improvements, updates, and revisions to the surveys and process were developed in-house and collaboratively with other TSU technical teams in conjunction with each report supported. The success of these efforts resulted in interest of duplication from other groups such as the International Panel on Climate Change (for future IPCC products) and the Oak Ridge National Laboratory (in support of the next Carbon Cycle Report). Specifically, for each Sustained Assessment product:

- The Third National Climate Assessment: documentation of data and methods for 88% of nearly 300 graphics, 600 image panels, and approximately 83 data sources used across as many as 235 instances in the entire assessment
- Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment: 78 figures, 275 image panels, and 4 datasets

- Impacts from Climate Change on Human Health in the United States: A Scientific Assessment: 62 figures, 110 image panels, and 7 datasets (including data specific to human health/Centers for Disease Control statistics, previously undocumented)
- NOAA'S State Climate Summaries (Ongoing): Anticipating as many as 1500 figures, an unprecedented TSU metadata effort

The metadata survey and collection process was redesigned and updated with each report, and is undergoing a major update in advance of the next National Climate Assessment and associated products. This will be an even better, more streamlined, most efficient collection survey to best facilitate collection from any contributor to a Sustained Assessment product. This work is ongoing, but is already leaps and bounds beyond the initial survey used with the Third National Climate Assessment, which serves to stand as its own accomplishment.

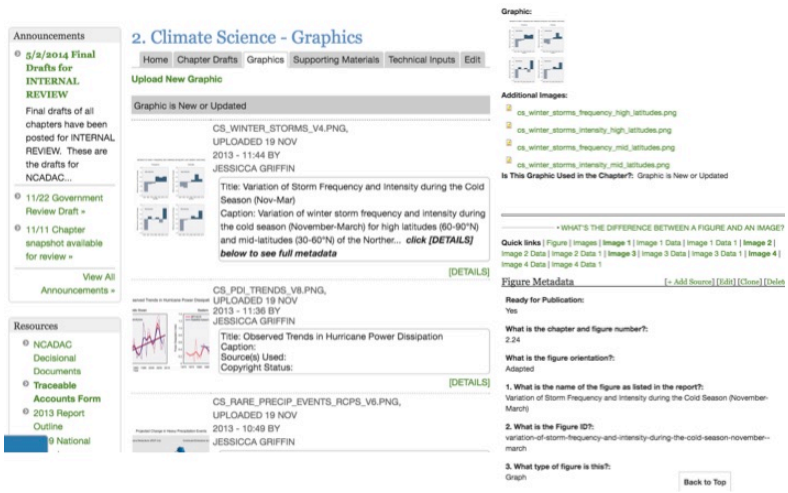


Figure 1: Metadata organization and survey access/collection survey for the Third National Climate Assessment. This was an ad-hoc solution, built after development and production of the Report had been initiated; this provided a means to an end, but was far from ideal. Feedback included negative experiences on account of survey length and difficulty understanding the requirements.

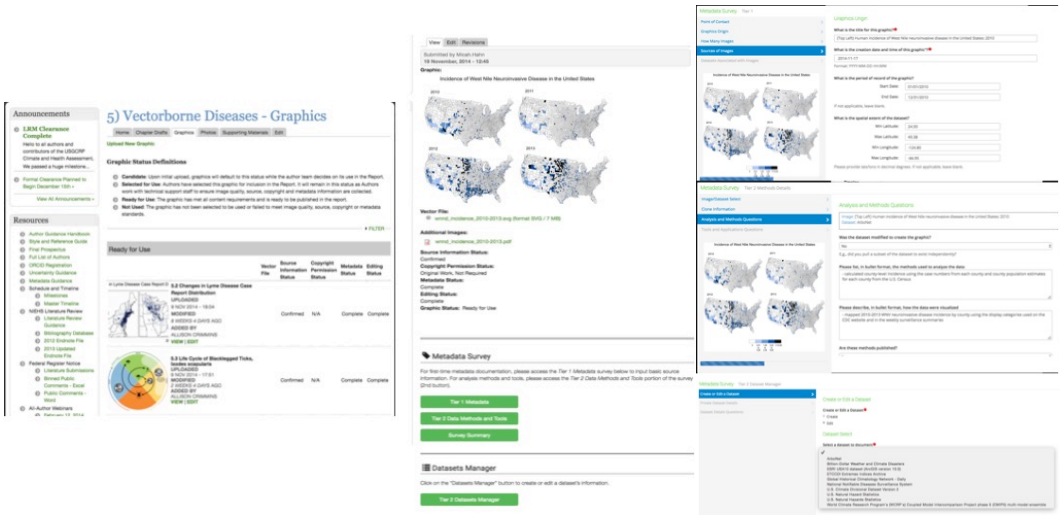


Figure 2: Revised metadata organization and survey access/collection, used in the CMIP comparison technical report, Health Report, and State Summaries. Metadata collection was separated into to collection batches, or tiers, and was built around the user-experience, vs. the collection/documentation requirement; survey questions were presented in sections and grouped accordingly. Metadata were collected in conjunction with report development and released alongside the reports themselves, vs. after-the-fact. A separate dataset collection survey was used to allow duplication of dataset information across figures, and also served as the foundation for building a Sustained Assessment climate metadata dataset repository.

PLANNED WORK

- Coordinate to completion all 50 State Climate Summaries
- Continue revisions, updates, and corrections to revised metadata, graphics, and collaborative tools and applications, with a targeted release of next major version in the summer of 2016
- Collect, document, and deliver all metadata for all Sustained Assessment products (NOAA's State Climate Summaries, the Climate Science Special Report, and The Fourth National Climate Assessment)

PUBLICATIONS

- Waple, A.M., S.M. Champion, K.E. Kunkel, C. Tilmes, 2016: Innovations in information management and access for assessments. *Climatic Change*, doi:10.1007/s10584-015-1588-7.

PRODUCTS

- The Technical Support Unit Metadata Collection Survey

PRESENTATIONS

- Champion, S. and Kunkel, K.E., 2015: Data Management and the National Climate Assessment: A Data Quality Solution, Invited talk, Fall Meeting of the American Geophysical Union, San Francisco, CA, (14 December).

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

TSU Metadata Web Collection Surveys have undergone almost continuous updates and development since their initial version with the Third National Climate Assessment

National Climate Assessment Technical Support Unit Graphical Services

Task Leader	Jessicca Griffin
Task Code	NC-ASSESS-04-NCICS-JG
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: CICS staff provided editorial, graphics, and production support for the Climate and Human Health Assessment.

BACKGROUND

The National Climate Assessment (NCA) is intended to provide the President, Congress, other stakeholders, and the general public with a report on the current state of climate change science, the impacts of climate change, and the effectiveness of mitigation and adaptation efforts. Given the intended audience, it is essential that the report is written and graphically represented in clear language that is easily understood by a broad audience while maintaining the highest possible standards of accuracy and transparency.

ACCOMPLISHMENTS

Graphic design support services were provided for the development of the Climate and Human Health Assessment. Tasks included basic image editing, as well as more extensive editing and new creations to improve readability and ensure accuracy, and layout design of the report and its companion pieces. Production services included preparing graphics for various pre-release and final drafts as well the implementation of creating the print and PDF pieces of the report. With tight deadlines and short turnaround times, delivery of that report also required successful integration of the functions of multiple staff members within the TSU and effective coordination between the TSU staff and the USGCRP office in Washington, D.C. The final report is scheduled for release in April 2016.

Graphic design support services were provided for the development of the NOAA NCEI State Summary Fact Sheets. Tasks included basic image editing, as well as more extensive editing and new creations to improve readability and ensure accuracy, and layout design of the report. Production services included preparing graphics for various pre-release drafts as well the implementation of creating the print and PDF pieces of the report. With tight deadlines and short turnaround times, delivery of that report also required successful integration of the functions of multiple staff members within the TSU and effective coordination between the TSU staff and state and regional climatologists. The final report is scheduled for release in Summer 2016.

PLANNED WORK

- Continued layout for the Climate and Human Health Assessment Report expected in April 2016
- Continued development of graphics and layout for the NOAA National Centers for Environmental Information State Summary Fact Sheets expected in Summer 2016
- Begin development of graphics for the Climate Science Special Report expected in 2017
- Continue providing graphical support as a Visual Communications team member in the Communications and Outreach Branch of NCEI.
    - BAMS State of the Climate

- Explaining Extreme Events
- Conference posters and briefings

PRODUCTS

- Explaining Extreme Events (Summer 2015)
- BAMS State of the Climate (Fall 2015)
- Climate and Human Health Assessment Report (Spring 2016)
- NOAA National Centers for Environmental Information State Summary Fact Sheets (Summer 2016)

OTHER

- Project Management Principles–Certificate of Training
- NOAA National Centers for Environmental Information 2015 Employee's Choice Award–For Team Excellence (Visual Communications Team in the Communications and Outreach Branch)

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Web Development for Assessments

Task Leader	Angel Li
Task Code	NC-ASSESS-05-NCICS-AL
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: %; Goal 3: %; Goal 4: 0%; Goal 5: 0%

Highlight: Planned, designed, and built the Climate and Health Assessment and USGCRP Resources/Collaboration websites. http://health2016.globalchange.gov

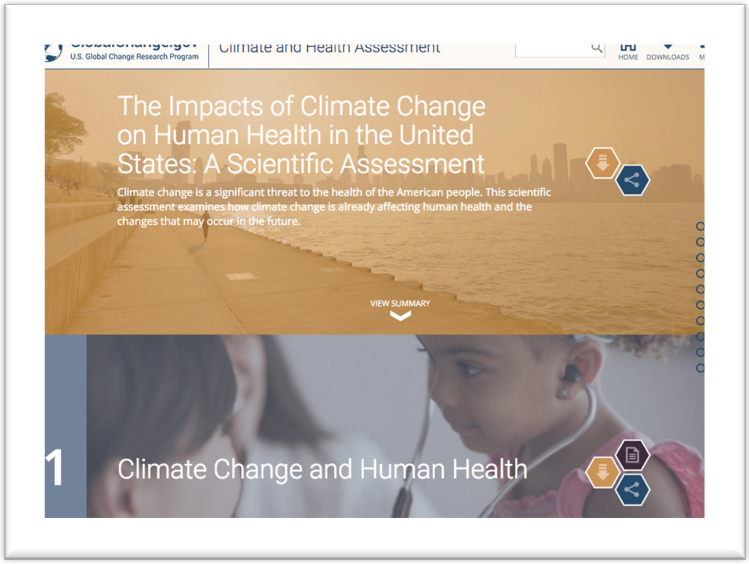
BACKGROUND

The National Climate Assessment integrates, evaluates, and interprets the findings of the U.S. Global Change Research Program (USGCRP) into a single cohesive report for policymakers and private entities to inform their decision-making and planning for the future. As print media is being phased out, the web is now a much more vital resource for reports such as the National Climate Assessment report. As tablet sales continue to outpace personal computer sales, the e-Book version of the report proves to be an important addition to the NCA products.

ACCOMPLISHMENTS

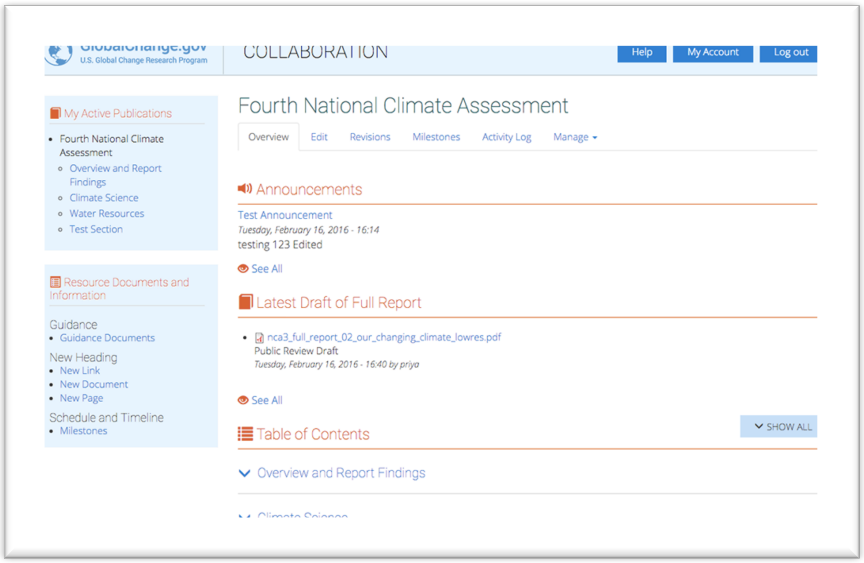
2015 was a very busy year for the CICS-NC web development team. The team continued the maintenance and support of the USGCRP websites. As USGCRP transitioned to a new contract, all their associated websites had to be moved to new hosting providers and new security concerns had to be addressed.

The Climate and Human Health Assessment Website: A website for the Climate and Human Health Assessment was designed in-house and implemented in Drupal. Final content will be added in early 2016 with an anticipated launch date of early April 2016. This site is fully responsive, *i.e.*, the site adjusts to the current screen width be it on a phone, a tablet, or a desktop display (see next page). Metadata has been collected for every figure in the report and is easily viewable on the website.



The 50 State Fact Sheets: In preparation for the completion of the 50 states fact sheets, a new site was designed and implemented in Drupal. There is a prototype of the home page, a clickable map of the 50 states, and fact sheets rendered as HTML pages. The project team will be dealing with over 1000 figures later this year.

Author Collaboration Site: For the Climate and Human Health Assessment, its authors used an outdated collaboration site. The subsystem for collecting metadata for figures was replaced by a more user-friendly procedure, but it had limitations that hampered its usability, *e.g.* the lack of autocomplete for many fields. April Sides re-implemented the collaboration site after much input from TSU editors and authors. Andrew Buddenberg also implemented a new metadata collection, with the same questions as the old system but with new and innovative technology. These two systems needed to communicate with each other so they were styled to look similar in order to facilitate going back and forth between them. Some work still remains to be done, especially in the area of single sign-on.



PLANNED WORK

- Launch of the 2016 Climate and Health website
- Launch of the 50 State Fact Sheets
- Launch of the TSU Collaboration Site
- Launch of a new CICS-NC web site

PRODUCTS

- http://health2016.globalchange.gov
- http://contribute.globalchange.gov
- https://kollab.cicsnc.org
- https://monitor.cicsnc.org
- https://www.cicsnc.org

OTHER

- Participation in the Asheville Drupal group

PERFORMANCE METRICS

	FY16
# of new or improved products developed	5
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

http://health2016.globalchange.gov; http://contribute.globalchange.gov; https://kollab.cicsnc.org; https://monitor.cicsnc.org; https://www.cicsnc.org

Assessments: Editorial and Project Management Support

Task Leader	Tom Maycock
Task Code	NC-ASSESS-06-NCICS-TM
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Provided project management, editorial, and technical support for USGCRP Climate and Health Assessment, which is scheduled to be released in April 2016.
Link to a research web page: health2016.globalchange.gov

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

Efforts this year focused on the USGCRP assessment report entitled "The Impacts of Climate Change on Human Health: A Scientific Assessment."

ACCOMPLISHMENTS
Maycock coordinated the activities of the TSU editorial, graphics, metadata, software engineering, and web teams in support of the development and production of the Climate and Human Health Assessment. Maycock also served as the TSU editorial lead for the project.

Tasks performed by the TSU included significant science editing and copyediting; development and refinement of scientific figures; metadata collection; ongoing support for web-based collaboration tools; layout and production of the final PDF version of the report; production of a printed 24-page Executive Summary and several other communications materials; and development, testing, and deployment of the report website.

The editorial team provided developmental and copyediting support for each draft of the report and the final product. The team also worked with author teams and project leads in revising the text and figures in response to comments, managed the selection of photos for the report, and worked with the graphics team to develop the 24-page print version of the Executive Summary.

The TSU successfully delivered three draft versions of the report: a draft for review by the public and the National Research Council in April 2015, a draft for review by the USGCRP agencies in October of 2015, and a draft for final Legislative Referral Memorandum review by the Office of Management and Budget in December 2015.

The final report is expected to be released by the White House in early April 2016.

Maycock also provided editorial and science communication support for the State Fact Sheet project.

PLANNED WORK

- Post-release support of the Climate and Human Health Assessment
- Development of several supplemental communication products supporting the report, including a 4-page brochure and a set of 2-page fact sheets.

PRODUCTS

- Three draft versions of the Climate and Human Health Assessment
- The final version of the report, in both PDF and web format
- A 24-page print version of the Executive Summary of the assessment

PRESENTATIONS

- NCEI Branch Seminar on the Climate and Human Health Assessment and related TSU activities. July 28, 2015. National Centers for Environmental Information, Asheville, North Carolina. (Tom Maycock and Jennifer Runkle)
- "Climate Change and the 2014 National Climate Assessment." September 12, 2015, Omaha, NE. Presentation to a book club.
- "Asheville, Climate, and Climate Change." November 16, 2015. Ardenwoods Senior Living Center, Arden, North Carolina.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	5
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	3
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Products include 3 separate drafts of the USGCRP Climate and Human Health Assessment, the final report, and a 24-page print version of the Executive Summary of the report.

Web Development for Assessments

Task Leader	April Sides
Task Code	NC-ASSESS-07-NCICS-AS
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Planned, designed, and built the Climate and Human Health Assessment and USGCRP Resources/Collaboration websites.

BACKGROUND

The National Climate Assessment integrates, evaluates, and interprets the findings of the U.S. Global Change Research Program (USGCRP) into a single cohesive report for policymakers and private entities to inform their decision-making and planning for the future. As print media is being phased out, the web is now a much more vital resource for reports such as the National Climate Assessment report. As tablet sales continue to outpace personal computer sales, the e-Book version of the report proves to be an important addition to the NCA products.

ACCOMPLISHMENTS

- Designed and built the Climate and Human Health Assessment website.
- Planned and built the USGCRP Resources/Collaboration website.
- Deployed five code releases with new or modified features to GlobalChange.gov.
- Deployed modifications to the Scenarios website to expand its use for future assessment scenarios content.
- Obtained an NCSU Invention Disclosure for the Global Change Information System Metadata Looker.
- Archived two Legacy Resources websites for offline access.

PLANNED WORK

- Launch the Climate and Human Health Assessment website.
- Complete development and launch the USGCRP Resources/Collaboration website.
- Begin planning for the 4th National Climate Assessment website.

DELIVERABLES

The following products were delivered:

- Project charters and requirements documents for the Climate and Human Health Assessment and USGCRP Resources/Collaboration websites.
- USGCRP Public Contribution and Climate and Human Health Assessment websites.

OTHER

- Certificate of Appreciation from the United States Department of State: In recognition of outstanding contributions and teamwork exhibited as a member of the U.S. Interagency World Ocean Assessment Team in supporting the Department of State's commitment to the United Nation's Regular Process. Between December 2014 and March 2015, representatives from

across the USG contributed their time and expertise to review the draft chapters of the first World Ocean Assessment.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	9
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Products: GlobalChange.gov, USGCRP Review and Comment System, Third National Climate Assessment, Legacy Resources, Scenarios, State of the Climate Portal, USGCRP Public Contribution, Climate and Human Health Assessment, USGCRP Resources/Collaboration websites.

Science Editor for the Climate and Human Health Assessment and State Summaries Documents / Project Lead for Climate Science Special Report / Project Coordination for Fourth National Climate Assessment

Task Leader	Brooke Stewart
Task Code	NC-NCA-08-NCICS-BS
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: CICS staff provided editorial, graphics, and production support for NOAA's Technical Support Unit to the National Climate Assessment, making significant contributions to the development of the full report and accompanying Highlights document.

BACKGROUND

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

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

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

The NCA4, which again is being undertaken due to congressional mandate by the U.S. Global Change Research Act of 1990, is already underway. The Steering Committee is being formed, author groups are being chosen, and a timeline has been formulated. The writing of the report is scheduled to begin in July 2016. Public and Peer review are slated for April 2017, with the final report scheduled for release in March 2018.

ACCOMPLISHMENTS

Extensive editing was performed to help ensure scientific accuracy and consistency throughout the Climate and Human Health Assessment and the State Summaries documents. Stewart served as lead author for the Alaska state summary and contributing author on many others. For State Summaries, Stewart served as science editor, copy editor, and technical editor, performing extensive work to ensure accurate and credible information. Stewart also assisted with the review process, providing initial responses to comments from Regional Climate Center directors as well as State Climatologists. Stewart worked with the project coordinator to formulate the formal review process and tracking methods and also worked with the entire production team (scientists, authors, coordinators, and graphic designers) to develop a workflow and production process for the final product.

Stewart worked with senior staff at the U.S. Global Change Research Program (USGCRP) in the planning phases of the Climate Science Special Report. Working with USGCRP staff, Stewart led the development of the timeline for the CSSR as well as the NCA4. For the CSSR, Stewart also developed the initial guidelines to authors for page limits and graphic limits for their individual sections and assisted USGCRP with the development of content for the first author meeting to be held in Washington, DC in April 2016.

PLANNED WORK

- Continued editorial and production work with the State Summaries project. Stewart will assist with responding to comments received as part of the formal review process and will help with the final editorial and production steps.
- Continue to serve as the Technical Support Unit's (TSU) Project Lead for USGCRP's Climate Science Special Report. In this role, Stewart will be responsible for keeping TSU management updated on the progress of the report and ensuring the team has adequate resources to meet expectations and deliverables in a timely manner.

PERFORMANCE METRICS

Performance Metrics	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# 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-ASSESS-09-UIUC
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: An 11 year (2000-2011) MRMS radar based hail climatology using variables such as Maximum Expected Size of Hail (MESH) and Severe Hail Index (SHI) was developed with subsequent analysis comparing the hail based climatology to a hail day climatology using NARR, developed based on environmental parameters which signify hail. Detection of long term trends in the NARR hail day climatology looking for similarities in hail day frequency, the observed decrease in the number of tornado days in the U.S. and any subsequent increase in hail and tornado outbreaks.

BACKGROUND

Hail climatology efforts primarily rely on storm reports from national databases such as the NCEI *Storm Data* database (Doswell et al. 2005, Changnon and Changnon 2000, Kelly et al 1985). Cintineo et al. (2012) shows that a hail climatology, with superior coverage and resolution, is possible through Next-Generation Weather Radar (NEXRAD) data. Using 42 months of data from the Multiyear Reanalysis of Remotely Sensed Storms (MYRORSS) dataset, they apply multi-radar multisensory (MRMS) algorithms such as the Severe Hail Index (SHI) and Maximum Expected Size of Hail (MESH) (Witt et al., 1998) to create a short hail climatology and examine the presence and severity of hail. Through verification with SHAVE and comparisons to other report based methods, the MRMS approach to hail climatology has proven to be a useful tool for studying historical hail events.

Our primary goal is to analyze climatological trends in hail over the U.S., and their supporting environments, using a radar based hail climatology in combination with the NARR. A climatology of hail events over the past decade in the U.S. will be developed using pre-calculated variables such as MESH (Witt et al. 1998). Any correlations between the frequency and number of severe hail events and the observed decrease in the number of tornado days in the U.S. will be identified (Brooks et al. 2014). Using reanalysis, a comparison between the severe hail climatology and parameters signifying environments supportive of severe hail will be performed.

ACCOMPLISHMENTS

This project applied two basic methodologies for examining historical hail events over the United States. The any-hail threshold for MESH is set at 21 mm and the severe hail threshold is set at 29 mm. These thresholds were chosen based on the analysis done by Cintineo et al. (2012) who test for optimal MESH thresholds using the Heidke Skill Score comparing MESH values to the SHAVE database of reports (Ortega et al. 2009). Applying automated quality control (QC) to the MESH data is necessary for the development of the hail climatology. These methods are in development and will be applied before any analysis takes place.

The first method of analyzing MESH involves finding maximum values of MESH over various time periods. *Figure 1* is a plot of maximum MESH (greater or equal to 21 mm, the any-hail threshold) for the year

2009. MESH is plotted on the original grid of 0.01° by 0.01°. For every grid point we find the greatest MESH value over the threshold, which is then recorded. If we find a greater MESH value for a given grid point, the smaller value is replaced and the larger recorded. *Figure 2* shows a single day of maximum MESH events (07-06-2009) over the any-hail threshold. A noteworthy hail event occurred on this day and we have zoomed in on the area of interest. The corresponding map of hail reports from the SPC archives is shown for reference.

Method 2 utilizes counts of hail events to be applied to both the any-hail and severe hail thresholds. A count method is applied for every year of data as well as single days and various months of interest. Any 5-minute interval with a MESH value higher than a given threshold is counted. This is repeated over the entire period (ex: 1 year, 1 month, 1 day) for each grid point. This method can be altered to count just hail days. For example, if a single grid point had 3 reports of MESH greater than threshold, during various 5 minute intervals, that day would count as one hail day. Similarly, only one occurrence of hail over a day could also count as one hail day. This could prove to be a more robust way of comparing MESH to archived storm reports.

The project also theorized other potential methods that may be useful for analyzing MESH. For example, by recording the number of hail producing storms on a given day we could investigate trends in hail outbreaks (*e.g.* greater than 30 events in a day). If a given location records MESH values above threshold multiple times a day, with an acceptable time period between events, it is possible to count the number of events in a given day.

Figures 1 and *2* both show results of MESH that are not filtered/smoothed nor undergone any further quality control outside of what was done during the processing and creation of the MESH dataset. The project team plans to implement further quality control to eliminate erroneous hail signatures, such as those observed off the Atlantic and Gulf coasts of the U.S., southeastern Texas and southern Arizona and also to re-grid the data to be more comparable with the 32km NARR grid by utilizing a Barnes' weighting scheme (Barnes 1964) to interpolate to the larger grid. Temporal filters may also be applied as necessary to compensate for any oversampling issues given the very high temporal resolution (5 minutes) of the original data. Once these filters and quality control measures have been properly applied we will use methods 1 and 2 to analyze the entire data set (approximately 11 years) on yearly, monthly and daily time scales. This will allow for detection of any short term climatological trends in hail. Ultimately a comparison of this hail climatology to parameters in the NARR dataset which signify environments supportive of hail will be conducted.

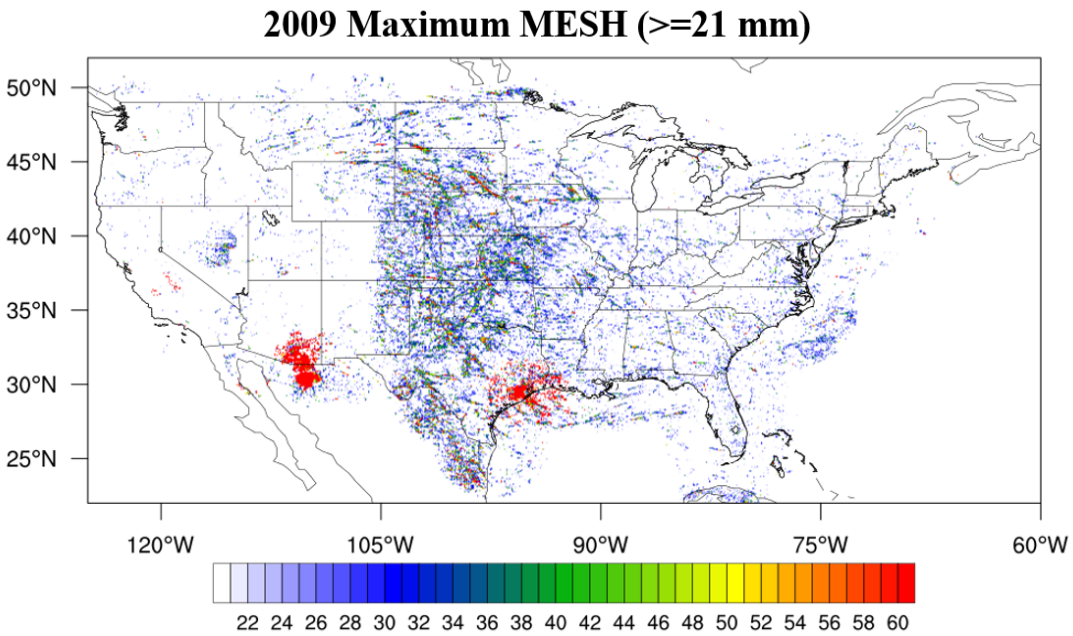


Figure 1: Maximum recorded MESH values greater than or equal to the any-hail threshold (21mm) for the year 2009. Each grid point at 5 minute intervals is checked and the highest MESH value for the entire year is recorded and plotted.

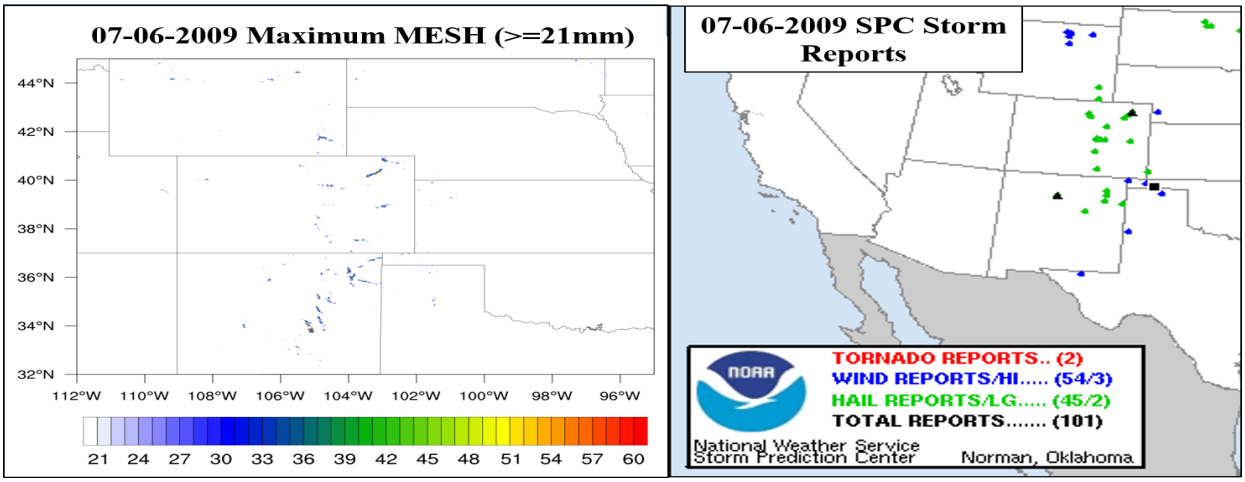


Figure 2: The maximum MESH values meeting the any-hail threshold are plotted for one day (07-09-2009) on which a noteworthy hail event occurred, based on SPC storm reports. The area of interest has been enlarged for easy viewing and the subsequent SPC storm reports are shown on the right for comparison.

PLANNED WORK

- Develop a climatology of hail and severe hail events over the past decade in the U.S. using MESH from the MRMS dataset
- Develop a hail day climatology using reanalysis data (NARR) of environments supportive of hail and tornadoes
- Compare MESH hail climatology to the reanalysis hail day climatology to verify that a reanalysis climatology is a useful tool to study historical hail events
- Investigate the spatial extent of environments supportive of hail and tornadoes using reanalysis hail day and tornado day climatologies and tornado reports
- Identify any trends or correlations between the frequency and number of hail events and the observed decrease in the number of tornado days in the U.S.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	1
# of graduate students formally advised	1
# of undergraduate students mentored during the year	0

The radar based hail climatology with automated quality control will be a new product developed from the NEXRAD MRMS reprocessed hail data.

Climate Data Records and Scientific Data Stewardship

Climate Data Records (CDRs) 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.

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

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

CDR Name Here

maturity level as of mm/dd/yyyy

Climate Data Record (CDR) Maturity Matrix

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

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

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

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

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

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

- Expertise needed to coordinate the development of calibration and validation activities and approaches for high-quality baseline climate data sets from satellite and in situ observations relevant to documentation and detection of climate change in the land, ocean, and atmosphere.
- Expertise needed to develop, refine, and implement algorithms for daily, global, multi-sensor, optimally interpolated Climate Data Records (CDRs); to characterize the sources and magnitudes of errors and biases in the CDRs; and to develop methodologies for the reduction of these errors and biases.
- Expertise needed to develop high-quality baseline climate data sets from satellite and in situ climate data and develop the relationship(s) between the observed tropospheric and stratospheric trends from the ground-based network with those observed from satellite.
- Software engineering expertise to support coding, code refactoring, code review, database development, and the transition of scientific codes into operationally executable and maintainable processes.
- Development of scientifically-based quality control algorithms for in situ climate data of various time scales (hourly, daily, monthly, annually), methods to detect and adjust for inhomogeneities due to issues such as instrumentation changes or observing station relocations, and scientific analyses of structural uncertainty due to these methods.
- Expertise needed to ensure that research to operation transitions occur between data set development activities and the operational use of these data sets in activities such as climate monitoring and climate research, as well as performing research documenting climate variability and change using the observed record and climate model simulations.
- Expertise to provide “transitions management” of various externally developed CDRs to NCEI.
- Expertise to develop and implement interim CDRs for early use of climate-relevant observations.
- Expertise needed to support the stewardship of archival and current climate observations

Climate Data Record (CDR) Integrated Product Team (IPT) Support

Task Leader	Anand Inamdar, Jessica Matthews, Ge Peng, Olivier Prat
Task Code	NC-CDR/SDS-01-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50 %; Theme 3: 0%.
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Several CICS-NC scientists have served as Products and Operations Branch representatives on multiple CDR IPTs.

BACKGROUND

Climate Data Record (CDR) 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.

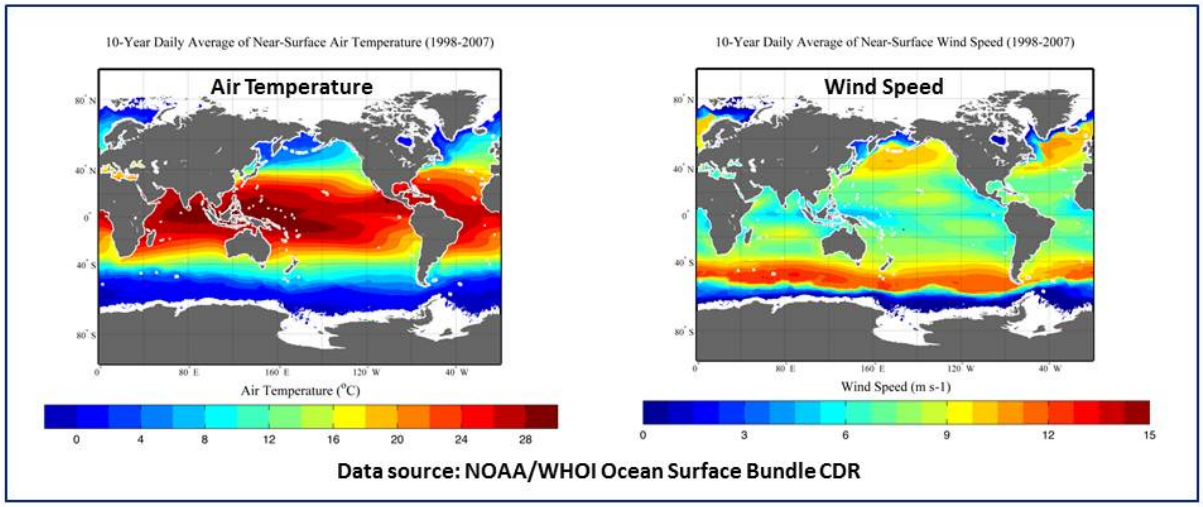


Figure 1: Ten-year daily averages of near-surface air temperature and near-surface wind speed from the Ocean Surface Bundle CDR.

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 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
- Delivering presentation to the NCEI User Engagement Branch on the CDR.

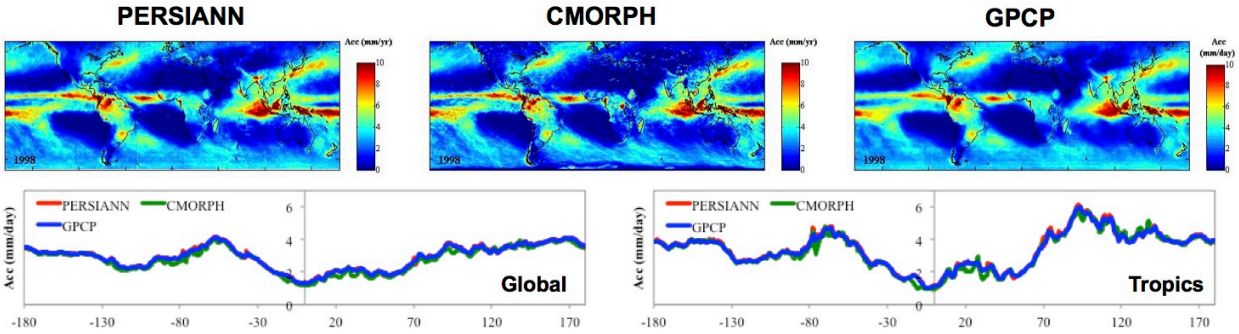


Figure 2: Annual rainfall accumulation for 1998 as derived from existing (PERSIANN) or in transition (CMORPH, GPCP) Reference Environmental Data Records (REDRs) (top row). REDs inter-comparison as a function of the latitude for the entire globe (50N-50S) and for the tropics (23N-23S).

PLANNED WORK

- Continue participating on CDR IPTs as requested to transition CDRs to initial operational capability status

PRESENTATIONS

- Prat, O.P., B.R. Nelson, S.E. Stevens, E. Nickl, and L. Vasquez, 2015. Toward the development of an evaluation framework of climate data records for precipitation. *2015 NOAA Climate Data Record (CDR) Program Annual Meeting*, August 3-7 2015, Asheville, NC, USA.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

The Precipitation-CMORPH CDR has been transitioned to IOC status.

Expansion of CDR User Base (Obs4MIPs)

Task Leader	Jim Biard, Jessica Matthews, Olivier Prat
Task Code	NC-CDR/SDS-02-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%.
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Several CICS-NC scientists have worked on a project to make observational products more accessible for climate model intercomparisons.

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 Phase 5 (CMIP5). Results from analyses from CMIP5 were used for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report. In order for NOAA CDRs to be used for comparison with CMIP5 model output, there are some key specific requirements that need to be met such as format, temporal/spatial resolution, documentation, and data access support.

CMIP5 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). The Observations for Model Intercomparison Projects (obs4MIPs) program is an effort to reformat observational datasets into the standard form used by the CMIP5 community for their model outputs, allowing the 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 CMIP5 model outputs for addressing critical climate questions.

ACCOMPLISHMENTS

The pilot study portion of this project, which involved conversion of three operational CDRs to obs4MIPs form, was completed by March 2015. A key accomplishment of the pilot study was development of a configurable software tool for this purpose. Given the success of the pilot study another 6 CDRs have been proposed for conversion to obs4MIPs form (*see Table 1*).

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°)

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

PLANNED WORK

- Work with NCEI Subject Matter Experts to determine inputs needed for converting the six CDRs to obs4MIPs form.
- Convert samples from the six CDRs to obs4MIPs form using the software tool.
- Verify sample outputs from the tool against the original CDRs.
- Validate the metadata contained in the obs4MIPs datasets that were produced.
- Convert full periods of record for the six CDRs to obs4MIPs form using the software tool.
- Verify the full outputs from the tool against the original CDRs.
- Compose the required Technical Note documentation to accompany each obs4MIPs CDR.

OTHER

- Jim Biard spent a week in March 2016 at Lawrence Livermore National Laboratory to strengthen the collaboration with the team that provides governance to the obs4MIPs effort.

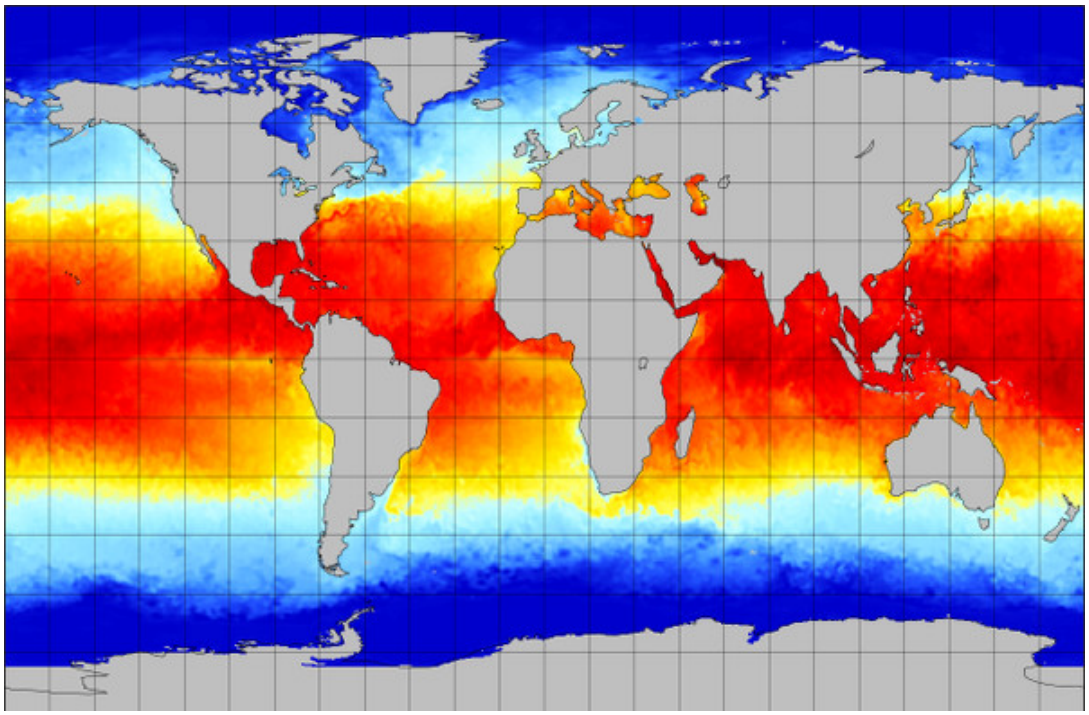


Figure 1: A sample image of the Optimal Interpolation Sea Surface Temperature CDR prepared for Obs4MIPs in the pilot study completed in FY14.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Optimum Interpolation Sea Surface Temperature (OISST) Transition to Operations

Task Leader	Jim Biard
Task Code	NC-CDR/SDS-03-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%, Theme 2: 100%, Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%, Goal 2: 0%, Goal 3: 0%, Goal 4: 0%, Goal 5: 0%

Highlight: The OISST production software is being refactored to meet Climate Data Record Program requirements for operation readiness. https://www.ncdc.noaa.gov/cdr/oceanic/sea-surface-temperature-optimum-interpolation

BACKGROUND

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

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

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

ACCOMPLISHMENTS

FY 2016 tasks included:

- Development of a robust and configurable replacement for the refactored control scripts,
- Development of an application to update the format of one of the current production software outputs, and
- Assistance in performing an analysis of differences between the current production outputs and the refactored software outputs.

The motivation behind the first task – replacing the refactored control scripts, was a desire on the part of NCEI Software Engineering Support Branch (SESB) management to improve on the set of custom shell scripts that had been produced to that point. This was intended to be the prototype for a general-purpose processing executive that could handle many different production application suites. Design

and development of an automated rules-based service written in Python and using a graph database for knowledge persistence and performance analysis was begun, but uncertainties about the ability of the NCEI production computing environment to support the needed software packages led to the postponement of this effort.

The second task grew from a need to update one of the current OISST production outputs to meet a changed format requirement. The particular OISST output is the sea surface temperatures written to files using the format specified by the Group for High Resolution Sea Surface Temperature (GHRSST). The files are sent on a regular, ongoing basis to servers at the NASA Jet Propulsion Lab (JPL), where they are made available to the public alongside sea surface temperature datasets from other researchers and organizations. The format accepted by the GHRSST servers was changed, going from GHRSST Data Specification (GDS) 1.0 to GDS 2.0, and SESB management determined that it would be simpler to add a processing step to produce GDS 2.0 – compliant files from the GDS 1.0 – compliant outputs. The refactored production software will produce GDS 2.0 – compliant outputs.

An application was developed and was added to the regular operational OISST production sequence so that the GHRSST output file produced each day and sent to JPL is now GDS 2.0 – compliant. The application was also used to produce GDS 2.0 compliant files for the entire period of record for the OISST product, and those files were sent to JPL as well.

The third task, analyzing the differences between the current OISST production outputs and the outputs from the refactored software, was begun because changes in the NCEI production environment make it likely that the outputs from the refactored software will not match the outputs from the historical OISST production environment. The current production software is running on a server with a 32-bit hardware architecture. All new NCEI production environments run on servers with a 64-bit hardware architecture. This fundamental difference is likely to produce some amount of difference in the results obtained when using the same inputs. It is important to be able to identify the sources of those differences, make sure that those differences aren't due to errors introduced during the refactoring process, and verify that the quality of the product is not affected.

A fixed input dataset covering a slightly larger than one-year span from August 26, 2012 through August 31, 2013 was processed with the current production software on the 32-bit production server, and with the refactored software on the 64-bit development server. The results were then compared to identify the differences and their magnitudes. *Figures 1* and *2* show some of the results from this analysis.

While the bulk of the differences seen in *Figure 1* are less than the associated uncertainties (values less than 1), there are numerous localized areas where the differences are up to 10 times larger than the uncertainties. *Figure 2* shows that these differences are also localized in time. These differences were large enough that further investigations were undertaken to locate their origins.

Those investigations revealed that the current 32-bit production output is suffering from a calculation error introduced by a bug in the compiler used on the 32-bit server. The bug was corrected in the later-version compiler used on the 64-bit server. Efforts continue to determine if any differences are due to algorithm or architecture differences apart from the compiler problem.

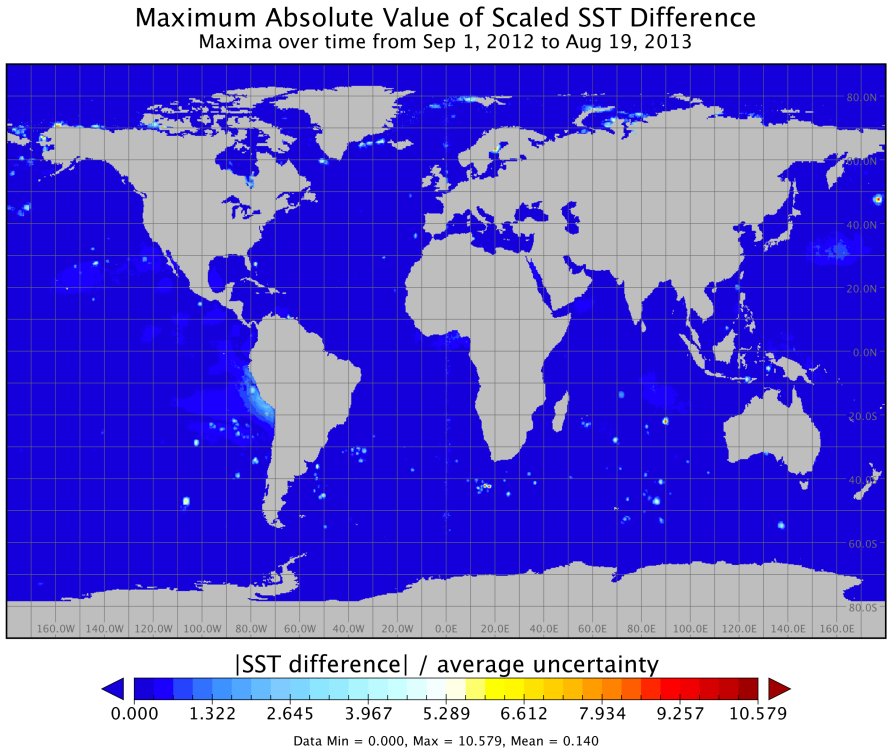


Figure 1: The maximum over time of the absolute value of the difference between the 32-bit productions and 64-bit refactored OISST outputs scaled by the mean uncertainties for the time span Sep 1, 2012 to Aug 19, 2013.

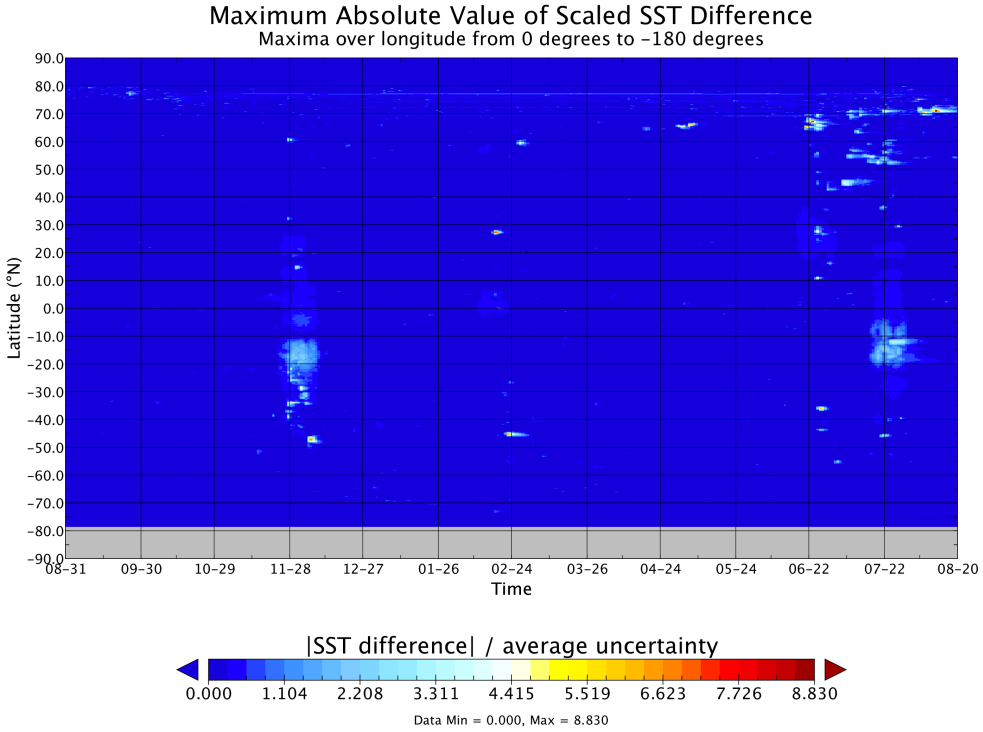


Figure 2: The maximum over western hemisphere longitudes of the absolute value of the difference between the 32-bit production and 64-bit refactored OISST outputs scaled by the mean uncertainties for the time span Sep 1, 2012 to Aug 19, 2013.

PLANNED WORK

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

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

The GDS 1.0 to 2.0 conversion application was developed. This was integrated into the OISST production environment and used to produce a GDS 2.0 – compliant version of the GHRSST OISST dataset for the full period of record.

High-resolution Infrared Radiation Sounder (HIRS) Monthly Outgoing Long-wave Radiation (OLR) Climate Data Record (CDR) Software Refactoring

Task Leader	Jim Biard
Task Code	NC-CDR/SDS-04-JB
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%, Theme 2: 100%, Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA goals (%)	Goal 1: 100%, Goal 2: 0%, Goal 3: 0%, Goal 4: 0%, Goal 5: 0%

Highlight: The HIRS Monthly OLR software refactoring effort has produced noticeable improvements in data and software quality. https://www.ncdc.noaa.gov/cdr/atmospheric/outgoing-longwave-radiation-monthly

BACKGROUND

A major goal of the Climate Data Records (CDR) Program (CDRP) is to adapt the software being used to produce a CDR dataset so that ongoing production of that dataset can be done on NCEI operational systems. This ensures that valuable CDRs will continue to be produced regardless of changes in the ability of the current Principal Investigator (PI) or the PI's organization to continue that effort. The CDRP defines CDR production software that has undergone such changes as reaching Full Operational Capability (FOC).

In order to reach FOC, the software used to produce the CDR dataset must meet a set of coding standards defined by the CDRP. Among other things, this involves refactoring the code to make it more maintainable and understandable by ensuring that it is well documented internally, has low algorithmic complexity, and has high modularity. Previous efforts to have teams of NCEI software engineers perform this refactoring in-house has proven to be difficult and slow due to the need to develop intimate knowledge of the algorithms before modifying them. In an attempt to find a more efficient way to perform this task, the CDRP decided to try a new approach in which the PI performed the refactoring with the guidance and support of a professional software developer. The High-resolution Infrared Radiation Sounder (HIRS) Monthly Outgoing Long-wave Radiation (OLR) CDR was selected for this effort.

Dr. Hai-Tien Lee, of NOAA's Center for Satellite Applications and Research (STAR) and the Cooperative Institute for Climate and Satellites – Maryland (CICS-MD), is the author of the current HIRS MONTHLY OLR CDR software, and is responsible for its production. Jim Biard was chosen to work with Dr. Lee on the FOC software refactoring.

ACCOMPLISHMENTS

FY 2016 tasks included:

1) Development and implementation of a process for the effort
2) Refactoring the software
3) Verification of the refactored software

The first task was to develop a process for working as a geographically distributed team to refactor the software. Dr. Lee was given the coding standards document to read and become familiar with, and Mr. Biard traveled to Dr. Lee's location so that they could develop a working relationship. During this visit Dr.

Lee familiarized Biard with the algorithms involved, and they decided on the process to follow. They decided to use cyclic, incremental reviews of the source code. The basic process agreed on was:

1) Dr. Lee modifies a group of source code files to address the CDRP coding standard requirements and submits them to Mr. Biard.
2) Mr. Biard places those modified files in a folder shared with Dr. Lee and attaches comments noting deficiencies relative to the CDRP coding standard and possible errors that were noticed. Each comment is numbered and recorded in a shared spreadsheet.
3) Dr. Lee is notified of the comments and considers them.
4) A teleconference is held to resolve any questions about the comments.
5) Dr. Lee modifies the source code files to address the comments.
6) Dr. Lee performs regression testing to verify that the changes have not introduced problems.
7) Dr. Lee resubmits the modified files to Mr. Biard for review.
8) Mr. Biard reviews the modifications to verify that they address the comments and marks the comment as resolved.
9) If Mr. Biard determines that further changes are required, the process continues at step 2). If no further changes are required, the process for that group of source code files is complete.

This cycle would be repeated until the process had been completed for all the source code files. In the course of this refactoring process, Dr. Lee could ask for a requested change to be waived. If Mr. Biard and his NCEI management agreed, the waiver would be noted in the spreadsheet and marked as resolved.

The review process was started, and all of the HIRS Monthly OLR CDR source code was successfully refactored. Mr. Biard was performing the first round of reviews of the core OLR retrieval subroutine source code when he realized that the number of comments needed to note all of the changes that would be required would be unmanageable. He decided to rewrite the subroutine himself as a way of showing Dr. Lee what sort of changes to make, marking a departure from the planned process, but it proving to be beneficial.

In the course of the rewrite of the subroutine, Mr. Biard discovered that some input measurements were being missed and others were being included multiple times. He devised a different approach to ingesting the data that resolved both of these problems. He and Dr. Lee worked in close collaboration in a tighter and informal cycle to implement the new ingest algorithm. The result was a more accurate daily OLR outputs with ~5% more measurements than before the refactoring. The final Monthly OLR CDR output is produced from the daily OLR outputs, so the final product benefitted as well. *Figure 1* shows the improvement in coverage for the dayside and nightside passes on a sample day.

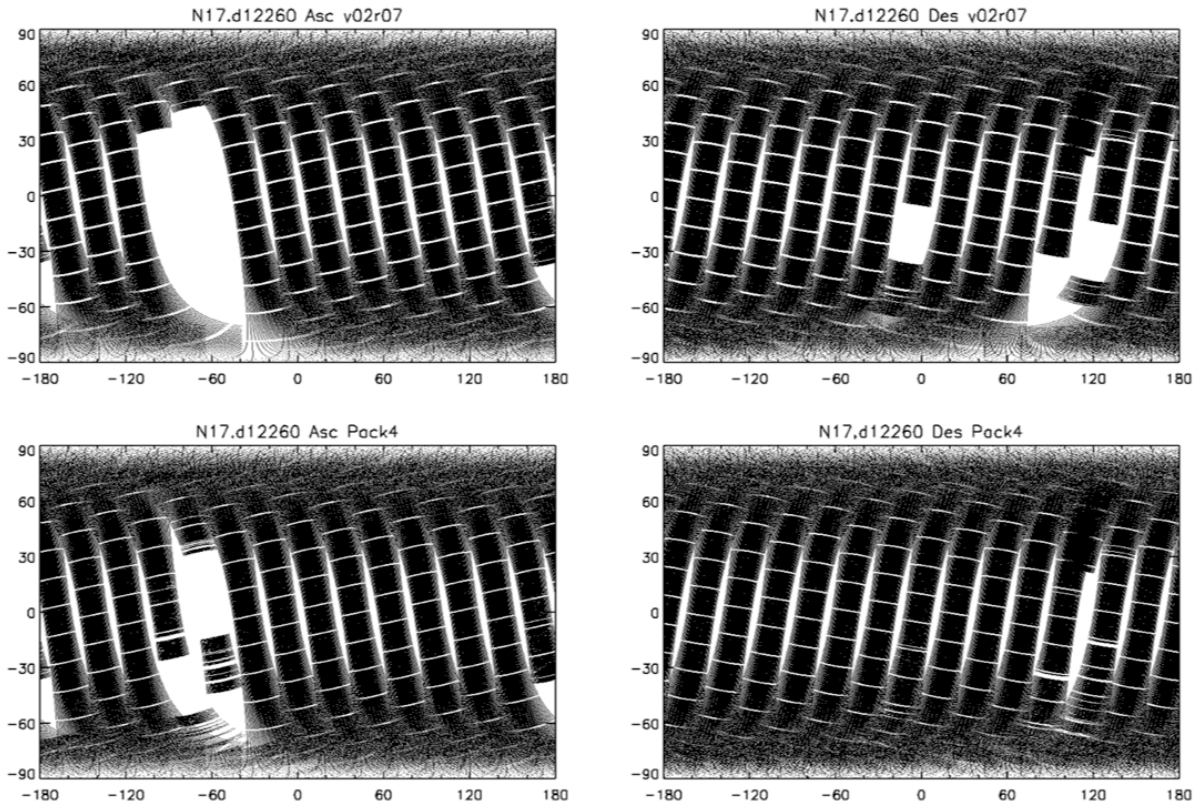


Figure 1: Global coverage for the dayside (left) and nightside (right) portions of one day of HIRS OLR measurements on Sept 16, 2012 (day 260). The upper pair of images represents the coverage before refactoring the ingest algorithm. The lower pair of images represents the coverage after refactoring. Black denotes the presence of measurements. The regularly spaced narrow bands represent normal periodic shifts of the HIRS instrument from earth observing mode to calibration mode.

The refactoring cycle was completed for all of the HIRS Monthly OLR CDR production software, and Dr. Lee verified that the final refactored code performed correctly.

PLANNED WORK

- Assist NCEI personnel with installing and running the HIRS Monthly OLR CDR production software in-house.
- Assist NCEI personnel as needed with getting the software to the point where it is in operational production within NCEI.

PRODUCTS

- Refactored HIRS Monthly OLR CDR production software
- Comments and their resolution as recorded in the documents and spreadsheet on Google Drive

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Common Ingest Agile Development Team

Task Leader	Linda Copley
Task Code	NC-CDR/SDS-05-NCICS-LC
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Completed evaluation and testing of the NCEI-CO Common Ingest software for use at NCEI-NC. Currently engaged in implementing the software at NCEI-NC.

BACKGROUND

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

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

ACCOMPLISHMENTS

Demonstration of the CI software by NCEI-CO led the NCEI-NC team to investigate the potential for its use at NCEI-NC. Evaluation of the CI architecture revealed its many advantages over the current system. The CI architecture was found to employ industry best practices; is modular, flexible and extensible; is deployable within a continuous integration/continuous deployment environment; employs asynchronous tasks; provides complete file provenance tracking; and deploys a simple-to-use, browser-based Graphical User Interface.

We derived the requirements for an ingest and archive system at NCEI-NC based on the current operational scenario, and compared these to the functional capabilities of the CI system. The capabilities required for ingesting submitted data into an archive are well understood and defined in in the Open Archival Information System (OAIS) Reference Model. As such, although the systems at NCEI-CO and NCEI-NC were built to satisfy the requirements of the respective data centers, the core functionality is inherently the same. In each system data submissions are collected from providers, Submission Information Packages (SIPs) undergo various transformations to create Archive Information Packages (AIPs), and AIPs are submitted for archive.

Although the CI system does not currently satisfy all of the functional requirements of NCEI-NC, the well-designed software architecture allows for the ready addition and modification of software components to satisfy the missing requirements, without adversely affecting already implemented functionality.

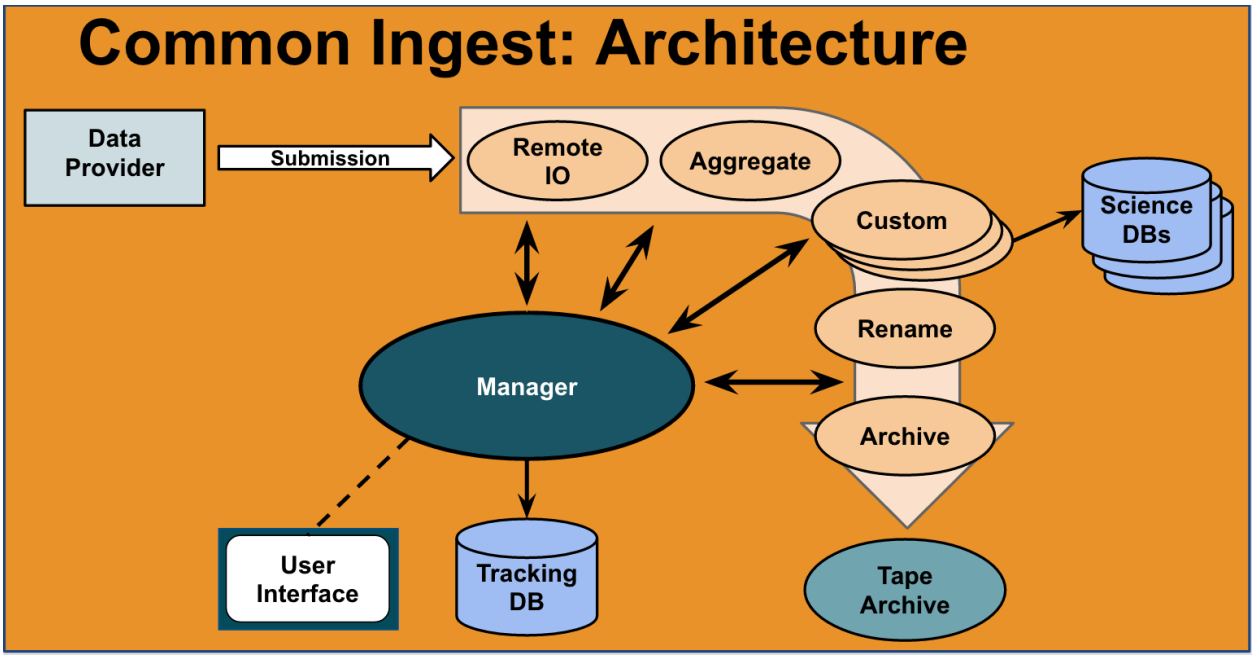


Figure 1: Common Ingest Architecture

Since the functional requirements and architecture met our needs, we built a CI instance on a CICS-NC server to investigate its operations and functionality, and also to execute a performance test. The performance test was designed to evaluate the speed of the CI software, the central queuing system, and the central database in relation to the anticipated NCEI-NC load. The current NCEI-NC load comprises approximately 39,000 files/day, with a maximum of 80,000 files/day, ingested in 1000 unique data streams. For the load test we simulated 1008 data streams, and achieved ingest of over 887,000 files in a 24-hour test – demonstrating more that 10 times the current maximum rate of ingest. In a separate test, we achieved a test run of 80,000 files in 50 minutes, without any observed bottlenecks, which equates to 2.3 million files per day.

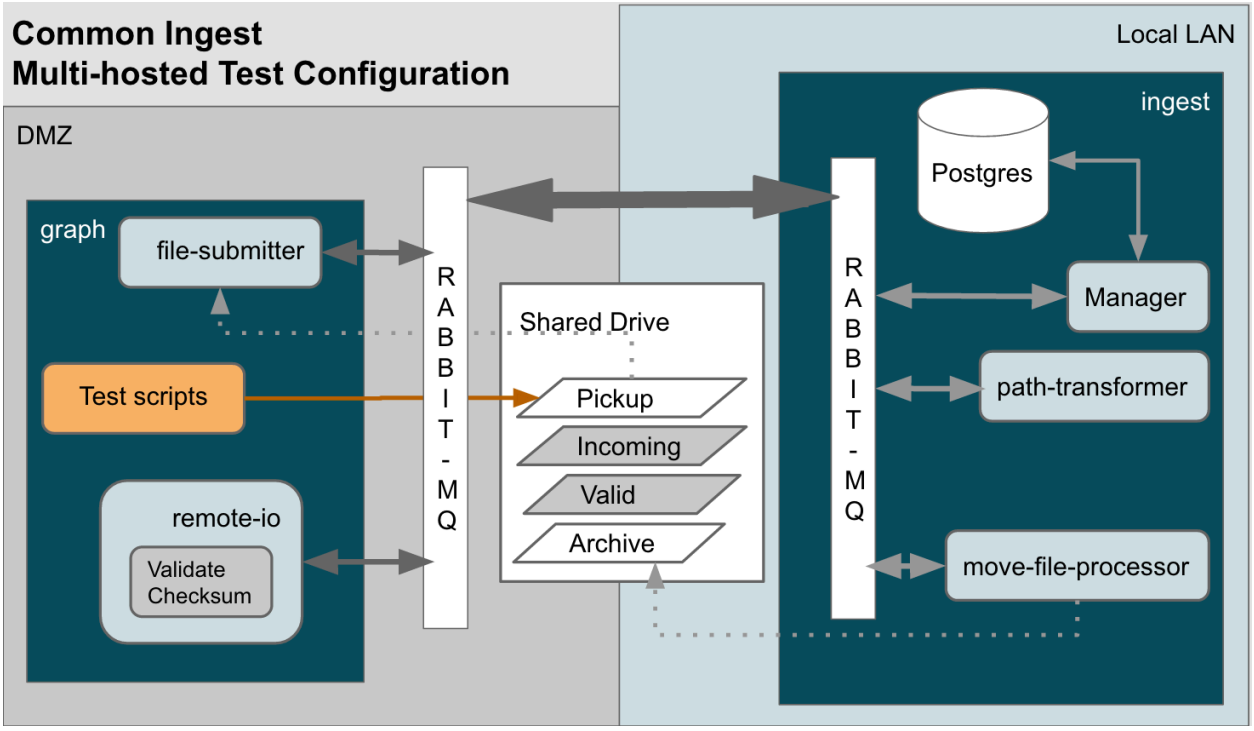


Figure 2: Common Ingest Multi-Hosted Test Configuration

Through the functional analysis, operation testing, and load testing we identified the enhancements required to implement CI at NCEI-NC. After presenting the results of our analysis and our recommendation to NCEI-NC management, we defined the scope of the project to include several of these enhancements in order to accomplish implementation of an initial dataset at NCEI-NC. We built a workflow engine that creates the specific manifest used for archive of data at NCEI-NC, added filters and pagination to the user interface to support the greater volume of data, and created a dynamic file feeder that supports dynamic streaming of data sets from providers.

The entirety of this project has been performed under the construct of an Agile Scrum development team. The Scrum development methodology provides a rapid feedback cycle to stakeholders in conjunction with small, incremental product delivery. Continuously updated requirements are provided as a prioritized input to the team's development cycle. The self-organized Scrum team works towards a common goal to satisfy the highest priority requirements at any given time.

We began using the Scrum methodology in January of 2014, and as a self-organized team much process refinement has been accomplished over this year. The move to managing our work by 'Epic Stories' has allowed us to concentrate on a single functional area as a team, greatly improving the team's productivity by providing team focus and a platform for teamwork. The improvements to our process have also enabled us to determine a relative measure of the work we can accomplish in a 2-week period and allowed us to create a tool for management that provides a reasonable estimation of completion dates for work that is in our backlog.

PLANNED WORK

- Complete security enhancements for Common Ingest
- Modify Common Ingest time aggregation of files for the streaming file model

- Extend Common Ingest for archive to the NOAA Comprehensive Large Array-data Stewardship System (CLASS)
- Implement initial data set in production at NCEI-NC

DELIVERABLES

- Common Ingest Load Test Results
- Common Ingest Recommendation
- Common Ingest User Interface enhancements
- Common Ingest HPSS-Manifestor engine

PERFORMANCE METRICS

	FY16
# of new or improved products developed	4
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Reanalyzing Tropical Cyclone Imagery with Citizen Scientists

Task Leader	Chris Hennon, Jessica Matthews, Carl Schreck, Scott Stevens, Theresa Stone
Task Code	NC-CDR/SDS-06-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: CycloneCenter.org has collected more than 500,000 tropical cyclone classifications from citizen scientists. A manuscript published in the *Bulletin of the American Meteorological Society* shows that they can help address uncertainties in the historical record of these storms.

BACKGROUND

The global record of tropical cyclones contains uncertainties caused by differences in analysis procedures around the world and through time. Patterns in storm imagery are best recognized by the human eye, so we have enlisted the public. Interested volunteers are shown one of nearly 300,000 satellite images. They answer questions about that image as part of a simplified technique for estimating the maximum surface wind speed of tropical cyclones.

ACCOMPLISHMENTS

Since its inception in 2012, Cyclone Center has collected more than 11,000 citizen scientists who have produced over 500,000 classifications. Even though the current data is just a fraction of our target of about 2 million classifications, the site has already produced promising results and gained wider acceptance from the scientific community. These results have been published in the *Bulletin of the American Meteorological Society* and *Monthly Weather Review* and have been presented at major conferences. Additionally, a number of CICS-NC outreach events have featured the Cyclone Center project as a tool to engage the public.

Having a substantial number of classifications, we began exploring statistical methodologies for interpreting the citizen scientist input. In particular, we focused on how to provide probabilities of a particular image's "type" (*e.g.*, curved band, eye, shear, *etc.*) based on multiple classifications of a single image. An expectation-maximization (EM) algorithm was used which is capable of characterizing classifiers with varying levels of expertise. Analysis suggests that about 200 classifications are needed to quantify an individual's precision, and each image needs about 10 classifications to adequately determine image type. An example of storm image typing is shown in *Figure 1* for 2005 Katrina in the North Atlantic Ocean. The EM algorithm converts the individual classifications—using the tendencies of each classifier—to estimate the probabilities of each image storm type. The EM algorithm reduces the noisiness of the numerous individual storm type selections in the bottom panel into a smooth, inter-consistent set of storm types in the top panel. This is an important first step towards the ultimate goal of this effort: to provide temporally homogenous information on tropical cyclone intensity.

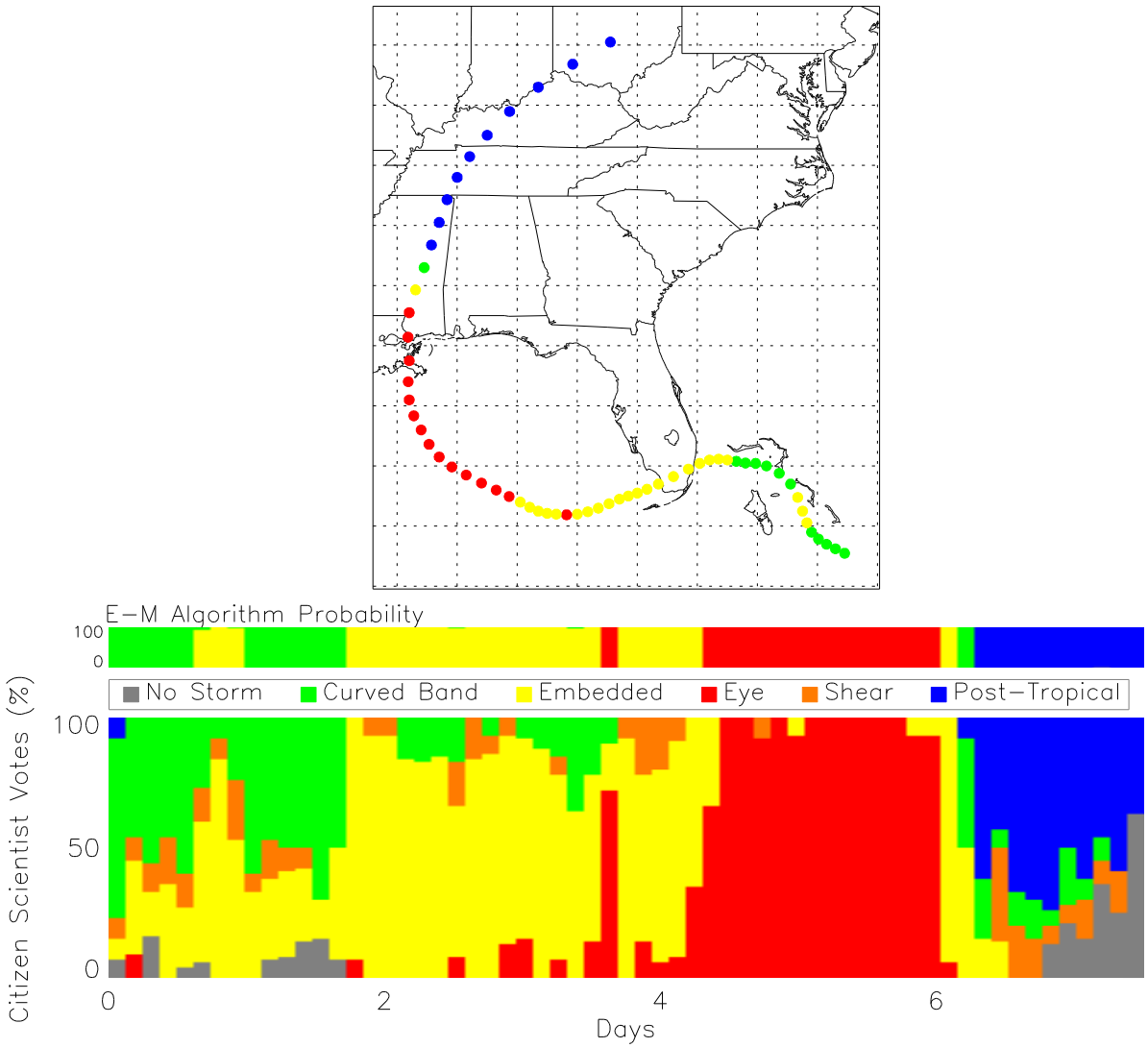


Figure 1: EM algorithm results for storm types of imagery from Hurricane Katrina (2005) in the North Atlantic. The bottom graph shows the percentages of the raw votes with the EM resulting probabilities above it. The map plots the storm type along the track of the system at approximately 3h intervals.

PLANNED WORK

- Continue promoting this project through a variety of media outlets, particularly during the 2016 Atlantic Hurricane Season
- An undergraduate NOAA Hollings scholar will be working on analysis activities during the summer of 2016
- Develop method for applying the full Dvorak analysis to the data collected, including the "Data T-Number"

PUBLICATIONS

- Hennon, C. C., K. R. Knapp, C. J. Schreck III, S. E. Stevens, J. P. Kossin, P. W. Thorne, P. A. Hennon, M. C. Kruk, J. Rennie, J-M Gadea, M. Striegl, and I. Carley, 2015: Cyclone Center: Can Citizen

Scientists Improve Tropical Cyclone Intensity Records? *Bulletin of the American Meteorological Society,* 96, 591-607, doi:10.1175/BAMS-D-13-00152.1.

- Knapp, K. R., J. L. Matthews, J. P. Kossin, and C. C. Hennon, 2016: Identification of tropical cyclone "storm types" using crowd-sourcing. *Mon. Wea. Rev.,* In revision.

PRESENTATIONS

- Thorne, P., C. C. Hennon, K. R. Knapp, C. J. Schreck, S. E. Stevens, J. P. Kossin, J. Rennie, P. A. Hennon, and M. C. Kruk, 2015: Cyclone Center: Insights on historical tropical cyclones from citizen volunteers. *2015 AGU Fall Meeting*, December 14 -18, December 2015, San Francisco, CA.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

NOAA PERSIANN-CDR Support for Hydrologic and Water Resource Planning and Management

Task Leader	Kuolin Hsu
Task Code	NC-CDR/SDS-07-UCI
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CISC Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 75%; Goal 2: 25%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: The PERSIANN Precipitation Climate Data Record (PERSIANN-CDR) processed precipitation dataset at daily 0.25^0 lat-long scale covering from 60^oS to 60^oN and 0° to 360° longitude from 1983 to June 2015. Application of PERSIANN-CDR to hydro-climatological studies is demonstrated.

BACKGROUND

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

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

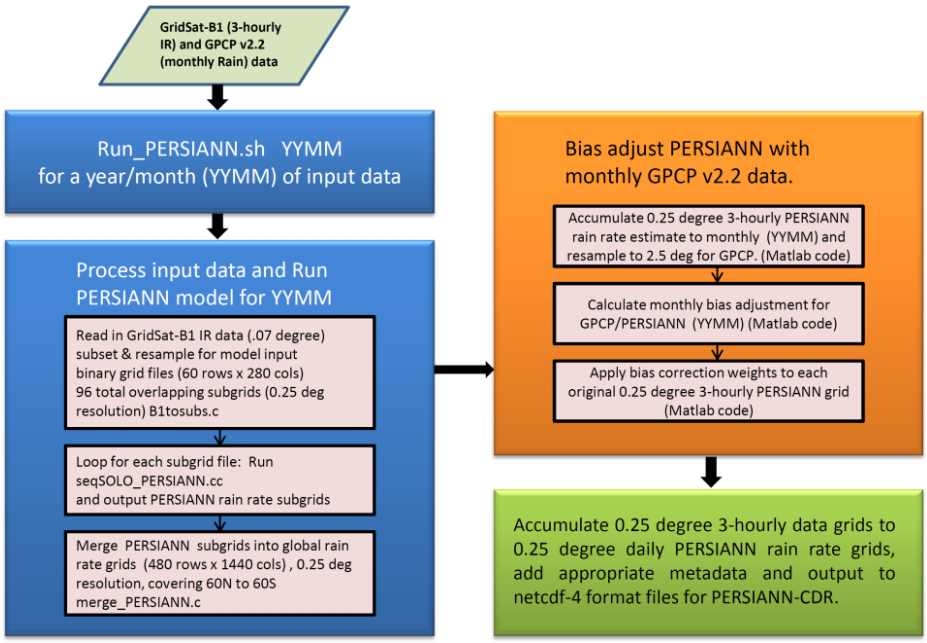


Figure 1: The PERSIANN-CDR flowchart

ACCOMPLISHMENTS

PERSIANN-CDR daily data is processed up to June 2015. During this report period, PERSIANN-CDR data is applied for the evaluation of CMIP5 model and extreme event analysis in California.

Analyze extreme events (Atmospheric Rivers) in California: PERSIANN-CDR data is used to analyze extreme precipitation events over California and adjacent states. We have been working with The California Department of Water Resources (DWR) to process and analyze extreme precipitation (atmospheric river) events causing heavy floods in the Western United States, and particularly California. An object-based algorithm named CHRS CONNECT has been developed by CHRS to extract and store all global extreme precipitation events estimated from satellite information in a searchable database system (Sellars et al., 2013). CHRS CONNECT algorithm is being applied to the PERSIANN-CDR historical archive of 33+ years to produce a global extreme precipitation event database named PERSIANN-CDR-CONNECT for analyzing extreme precipitation events in climatic studies and hydrologic prediction. *Figure 2* shows a case investigation of using CDR-CONNECT data for an atmospheric river event developed and evolved during 6-10 November 1983 over Pacific Ocean to Western U.S.

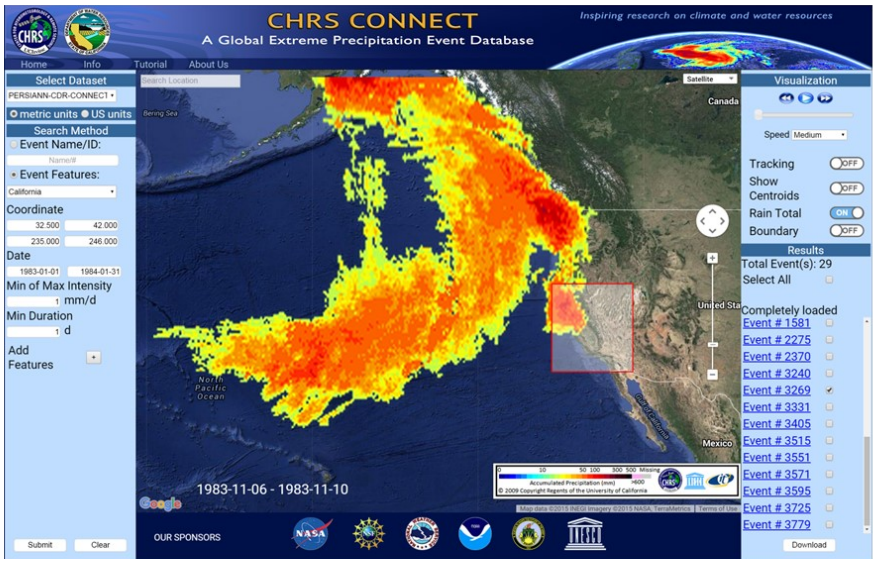


Figure 2: A demonstration of an atmospheric river event, developed during 6-10 November 1983, over Pacific Ocean and western U.S through the CHRS CONNECT graphic-user interface.

Evaluate climate models' simulations (CMIP5) using PERSIANN-CDR: Our experiment covers the comparison of precipitation estimation from PERSIANN-CDR and the archive of CMIP5 climate model simulations. PERSIANN-CDR data over the time period after 1983 to June 2015 have been made available. The CMIP5 model data were processed and experiments have been in progress. *Figure 3* shows the evaluation of CMIP-5 climate models' historical simulation over China. Both Climate Research Unit (CRU) and PERSIANN-CDR data are listed as references for model evaluation. Detailed evaluation is ongoing and will be provided in the upcoming report.

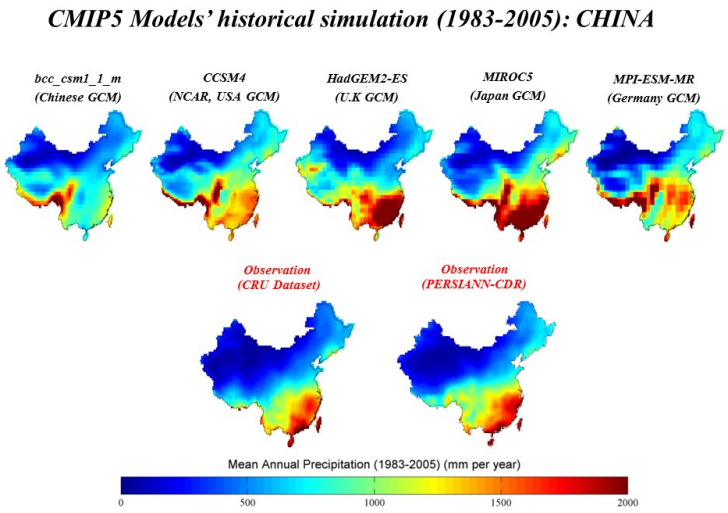


Figure 3: An evaluation of some CMIP5 model's historical simulation using CRU and PERSIANN-CDR estimation over China

Apply PERSIANN-CDR data in the hydrologic modeling of flood events: PERSIANN-CDR is applied to the stream flow simulation over experimental watersheds. The runoff simulation from other high-resolution precipitation products (Stage IV & TMPA-V7), and the USGS stream flow gauge observation are included in the evaluation.

The study is conducted in two steps:
The first step is applied for the period from 2000 to 2010 where several high-resolution precipitation products are available.
The second step of the simulation is extended back to 1983 where PERSIANN-CDR starts providing daily precipitation data. Three river basins documented in NOAA's NWS Distributed Hydrologic Model Intercomparison Project - Phase 2 (DMIP2) experiments are selected for this experiment. The National Weather Service (NWS) Office of Hydrologic Development (OHD) Hydrology Laboratory-Research Distributed Hydrologic Model (HL-RDHM) with calibrated parameters provided by OHD is used in the stream flow simulation of those test basins.
Stream flow simulation for the gauge point at Illinois River South of Siloam Spring Arkansas (SOLA4) from precipitation products (Stage IV, TMPA-V7, and PERSIANN-CDR) is evaluated. The results (*Table 1*) show stream flow simulation from daily PERSIANN-CDR is consistent with the simulation outputs from Stage IV and TMPA-V7 products. The flow simulation experiment at SOLA4 has extended to cover the 30-year period (1983—2012) using daily PERSIANN-CDR precipitation data. Stream flow simulation data from PERSIANN-CDR extends beyond the period of the USGS flow record (See *Figure 4.*).

Table 1. Bias, Correlation Coefficient, and RMSE statistics for simulated stream flow (2003-2010) from stage IV radar data, PERSIANN-CDR, and TMPA against USGS stream flow gauge observations

Statistics	**Stage IV**	**PERSIANN-CDR**	**TMPA**
Bias (%)	-26.34	9.91	8.08
Correlation Coefficient	0.73	0.68	0.72
Root Mean Square Error (m^3/s)	23.60	24.40	23.84

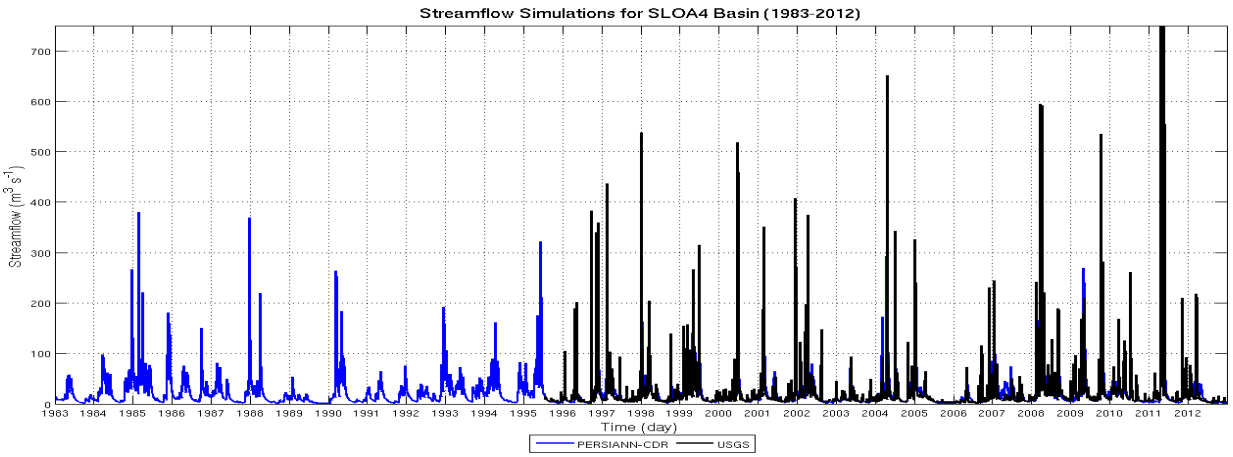


Figure 4: Long-term (1983-2012) historical simulated streamflow from PERSIANN-CDR daily precipitation data (blue) versus USGS streamflow observations (black) for SLOA4 basin.

DELIVERABLES

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

PUBLICATIONS

- Miao, C, H. Ashouri, K. Hsu, S. Sorooshian, and Q. Duan, Evaluation of the PERSIANN-CDR Daily Rainfall Estimates in Capturing the Behavior of Extreme Precipitation Events over China, *Journal of Hydrometeorology*, 16(3), 1387-1396, 2015. doi: http://dx.doi.org/10.1175/JHM-D-14-0174.1.
- Nasrollahi, N., A. AghaKouchak, L. Cheng, L. Damberg, T.J., Phillips, C. Miao, K. Hsu, and S. Sorooshian, How Well do CMIP5 climate simulations replicate historical trends and patterns of meteorological droughts, *Water Resources Research*, 10.1002/2014WR16318, 2847-2864, 2015. doi: 10.1002/2014WR016318
- Nguyen, P., A. Thorstensen, S. Sorooshian, K. Hsu, and A. AghaKouchak, Flood Forecasting and Inundation Mapping Using HiResFlood-UCI and Near-Real-Time Satellite Precipitation Data: The 2008 Iowa Flood, *Journal of Hydrometeorology*, 16, 1171-1183. doi: 10.1175/JHM-D-14-0212.1
- Thorstensen, A., P. Nguyen, K. Hsu, and S. Sorooshian, Using Densely Distributed Soil Moisture Observations for Calibration of a Hydrologic Model, *Journal of Hydrometeorology*, 17, 571-590. DOI: 10.1175/JHM-D-15-0071.1

PRESENTATIONS

- Nguyen, P., A. Thorstensen, H. Liu, S. Sellars, H. Ashouri, D. Braithwaite, K. Hsu, X. Gao, and S. Sorooshian. CHRS CONNECT – A global extreme precipitation event database using object-oriented approach. Poster session at the Fifth annual workshop on Understanding Climate Change from Data; 2015 Aug 4-5; University of Minnesota, Minneapolis, Minnesota, USA.
- Sorooshian, S., P. Nguyen, H. Liu, and H. Ashouri. Building an Atmospheric Rivers Catalog using Big Data Approach – CHRS CONNECT and PERSIANN CDR. Oral presentation at "Improving Sub-Seasonal & Seasonal Precipitation Forecast for Drought Preparedness" at DWR-WSWC Workshop; 2015 May 28; San Diego, California, USA.

- Sorooshian, S. (Invited) PERSIANN-CDR daily precipitation for hydrologic application, AGU Fall Meeting, 14-18 December, 2015. San Francisco, 2015.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	4
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	2
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Broadband radiation budget at TOA and surface at high Spatial and Temporal Resolution from Multi-Sensor Data Fusion

Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-08-NCICS-AI
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Techniques are being developed to estimate broadband top-of-atmosphere (TOA) and surface radiation components, at high spatial and temporal resolution, in the short wave and long wave from geostationary imagers.

BACKGROUND

The ability to better monitor each of the shortwave and long wave radiative components at the TOA and the surface at high spatial and temporal resolution is essential in many applications, such as the estimation of surface energy balance and its interaction with the hydrological cycle, analysis of fire plumes in wild fire events, *etc.* NASA-operated Clouds and Earth's Radiant Energy System (CERES) instrument on board the EOS platform is the only instrument making measurements of broadband TOA and surface radiative components, but the spatial and temporal resolution is inadequate for the afore-mentioned applications. However, with a wide array of sensors (like Moderate Resolution Imaging Spectroradiometer (MODIS), the suite of geostationary orbit meteorological satellites, etc.), there is potential for filling in the spatial and temporal gaps through optimized data fusion techniques.

ACCOMPLISHMENTS

- The technique developed to derive net surface radiation in the shortwave domain at high spatial (1 km) and temporal resolution (hourly) has been successfully deployed for GOES-10 and GOES-12 visible imagery for the years 2003 and 2007 and the study has been published. The method does not require characterization of cloud optical properties and relies on adaptation of a standard algorithm developed for the CERES scanner on board the EOS platform. Comparison of results with ground measurements at all eight of NOAA's surface radiation network (SURFRAD) sites has yielded excellent agreement. An advantage of this product is a significantly extended spatial and temporal coverage than that offered by the CERES instrument;
- The study done in collaboration with John Augustine (NOAA ESRL, Boulder) on the impact of fire on the radiative forcing at the top, middle atmosphere, and surface has been submitted to JGR-Atmospheres;
- Plans have been made to extend the LW model developed for the above-mentioned study to retrieve the downward LW radiation at the surface under clear skies, and when combined with the SW model, can be made to yield net surface radiation (SW+LW) balance at high spatial and temporal resolution under all-sky conditions, through the use of appropriate techniques.

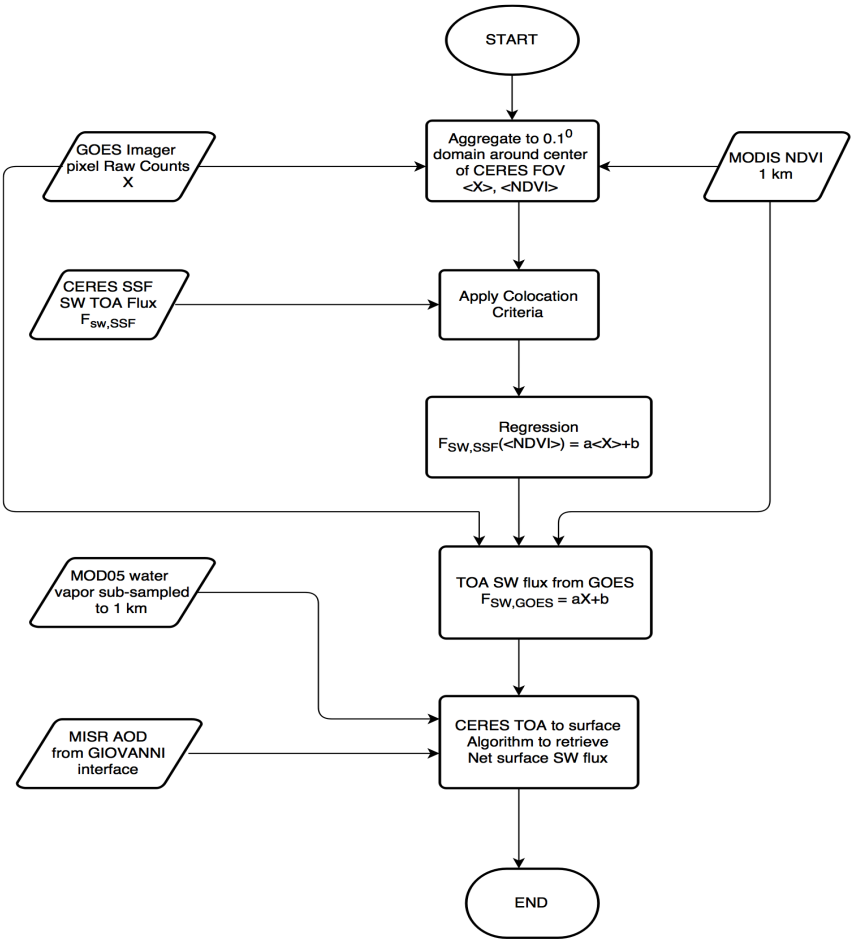


Figure 1: Schematic of net surface radiation estimation from geostationary imagery.

PLANNED WORK

- Extension of work to other meteorological satellites around the globe;
- The SW scheme described here will be extended to the long wave through employing the GOES imagery;
- Use of high resolution OLR in improving precipitation estimates.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	1
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

New product:

- The net surface SW radiation over the CONUS U.S. region for years 2003 and 2007 for the months of Jan, Apr, Jul and Oct.

Peer-Reviewed Publications:

- Anand K. Inamdar and Pierre Guillevic, 2015: Net Surface Shortwave Radiation from GOES Imagery—Product Evaluation Using Ground-Based Measurements from SURFRAD. *Remote Sens.* 2015, *7*(8), 10788-10814; doi:10.3390/rs70810788.
- John Augustine, Robert Stone, David Rutan, and Anand Inamdar, 2016: Radiative forcing by wildfire smoke at the surface, within the atmosphere and at the top of the atmosphere. Submitted to Journal of Geophysical Research – Atmospheres.

Calibration of the Visible Channel of the International Satellite Cloud Climatology Project (ISCCP) B1 data for the extended period (2010-2015)

Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-09-NCICS-AI
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 70%; Theme 3: 30%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Calibration of the Geostationary Earth Orbit (GEO) visible channel in the ISCCP B1 data stream, completed for all meteorological satellites for the period 1979-2009, is being revised for use in the Geostationary Surface Albedo (GSA) project, and also extended for years beyond 2009.

BACKGROUND

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

ACCOMPLISHMENTS

Calibration for the GOES series for the extended period of 2010–2015 (see attached *Figure 1*) has been completed. Results from the new approach compared favorably with the ISCCP and previous calibration (as reported in the cited journal paper). The ISCCP series of calibrations are also being developed for the extended period in a separate effort under "ISCCP Transition to NCEI" task.

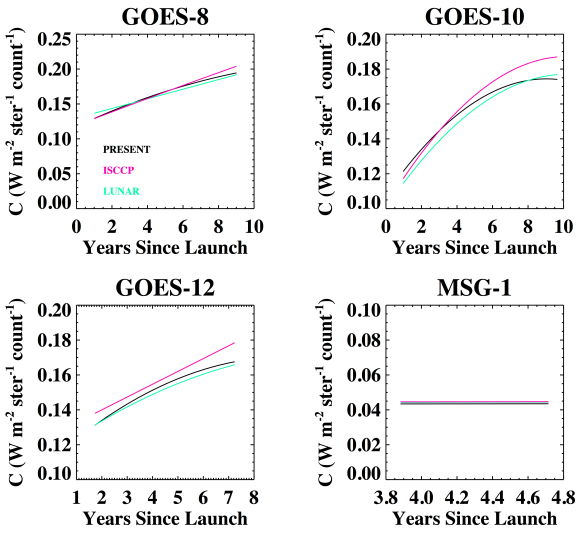


Figure 1: Time variation of the calibration coefficient derived from ISCCP and present scheme for a sampling of satellites, with additional results from the lunar calibration overlaid for comparison.

PLANNED WORK

- Process calibration with PATMOS-x reference for the 2010-2015 period for MET, GMS series of satellites;
- Complete similar calibration as above using the ISCCP calibration package and compare;

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Peer-reviewed list of publications:

- Anand K. Inamdar and Kenneth R. Knapp, 2015: Intercomparison of Independent Calibration Techniques Applied to the Visible Channel of the ISCCP B1 Data. *J. Atmos. Oceanic Technol.*, **32**, 1225–1240. doi: http://dx.doi.org/10.1175/JTECH-D-14-00040.1
- Anand K. Inamdar and Ken Knapp, 2015: Updates to the calibration of the visible channel of the ISCCP B1U data in the production of the H-series ISCCP cloud products. GSICS Quarterly Newsletter [DOI: 10.7289/V54J0C3R].

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

Transitioning the International Satellite Cloud Climatology Project (ISCCP) Process to NCEI-NC

Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-10-NCICS-AI
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 70%; Theme 3: 30%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: The transfer of the ISCCP Cloud products processing from the ISCCP team (at CCNY and NASA-GISS) to NOAA/NCEI-NC, is nearly complete with delivery of all codes, newer ancillary data and necessary documentation. This processing will result in a higher resolution ISCCP product (so-called H-series), extended period of record and an expanded user-base owing to the availability and ease of access of data.

BACKGROUND

The International Satellite Cloud Climatology Project (ISCCP) began in 1983 under the leadership of Dr. William Rossow (CCNY and GISS) with the objective of pooling the radiance from the suite of meteorological satellites around the globe and the polar-orbiting AVHRR sensors to derive a cloud climatology of the Earth. It is one of the most 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.

However, the D-series ISCCP cloud product has not been updated since 2009. Its current resolution is somewhat antiquated at 2.5 degrees latitude. NCEI routinely received requests for updated ISCCP data from customers, so the launch of the H-series production at NOAA/NCEI fulfills this long-awaited need.

ACCOMPLISHMENTS

The latest version of the ISCCP processing code, Build 5, was delivered and implemented in Sep 2015, and has undergone several modifications and upgrades over the past year. These pertain to the Quality Control (QC) processing of the ISCCP B1U (3 hourly geostationary imagery-GEO), Global Area Coverage (GAC) AVHRR data, and production of H-series cloud climatology. Extensive QC processing of GEO and GAC imagery for the base period (1983-2009) was completed for a second time employing the latest build, and bad-quality images were identified through both automated and manual visual inspection, and quarantined. Several data gaps were also identified and attempts were made to fill in those gaps. Inspection of the results from the production runs by the entire team for the base period also unearthed several additional issues like missing scan line times in GEO imagery, inverted counts in GEO images, Earth's radius value used in map projections, *etc.* These issues were fixed either through recreating the affected data or appropriate code changes. Several automated scripts were developed for inspection of post-production results. These activities are being coordinated and guided by Bill Rossow's ISCCP team.

Recently an additional package for including new satellites and developing calibration tables for the extended period of 2010-2015 was delivered and implemented. The generation of an initial version of HBT (H-series calibration tables) and subsequent QC processing were also completed.

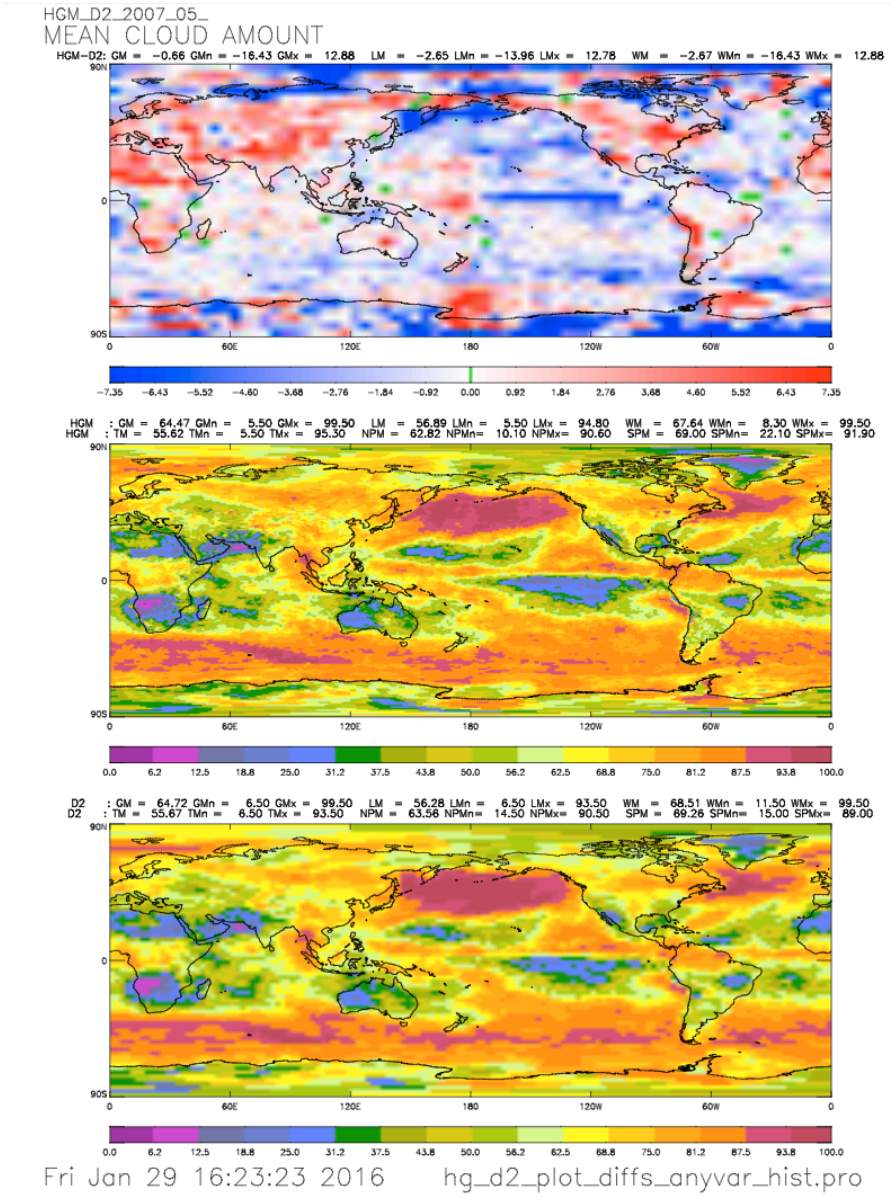


Figure 1: Map of monthly mean cloud amount for 2007 May derived from the ISCCP H-series run (middle panel), its predecessor D-series (bottom panel), and the difference (top panel).

PLANNED WORK:

- Continue inspection of production results for the base period and fix outstanding problems;
- Fill in data gaps in the B1U stream;
- Complete calibration processing for the extended period of record (2010-2015);
- Complete production and evaluation for the extended period;
- Share H-series cloud products among diverse scientific community and receive feedback;
- We are targeting IOC transition of the ISCCP cloud products CDR for summer 2016;

- Planning 3 presentations by our team during the Satellite Meteorology Conference hosted by AMS in Aug 2016 at Madison, Wisconsin,
- A series of papers including a BAMS article are planned.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	2
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	1
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

The improved products:

- List of quarantined GEO and AVHRR GAC imagery from the QC runs and visual inspections;
- The H-series cloud products for the base period (1983-2009).

Non-peer-reviewed paper:

- Young, Ken Knapp, A. Inamdar, and W. Hankins, 2015: International Satellite Cloud Climatology (ISCCP) project H-series CDR. Poster presented at NOAA CDR Conference Aug 2015.

Implementation of Geostationary Surface Albedo (GSA) Algorithm with GOES data

Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-11-NCICS-JM
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: 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 climate data record.

BACKGROUND

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

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

ACCOMPLISHMENTS

This project is one of only 10 selected by the SCOPE-CM Executive Panel from open competition. We proposed to extend the international collaboration into Phase 2, which is planned to last 5 years and includes activities such as, a common cloud mask approach, a common inter-calibration method, exploration of different temporal resolutions and formats of output, and validation of Level 2 products. We are now in year 3 (2016) of this 5-year plan.

Progress has been made towards processing the 1995-2014 GOES-GVAR data. To date we have:

- Obtained ancillary ECMWF data
- Updated acceptor code to handle 5 additional satellites
- Implemented a new calibration approach
- Devised a methodology to handle duplicate GOES imagery in an automated way
- Processed 8 years of data

During the processing a number of important lessons learned have been shared with stakeholders, most notably:

1) CLASS provides GOES AREA files with both big and little endianness. This must be tested for prior to processing.
2) The code is structured such that there must be data present on the 10th day of the processed period for correct execution, otherwise runtime errors occur.

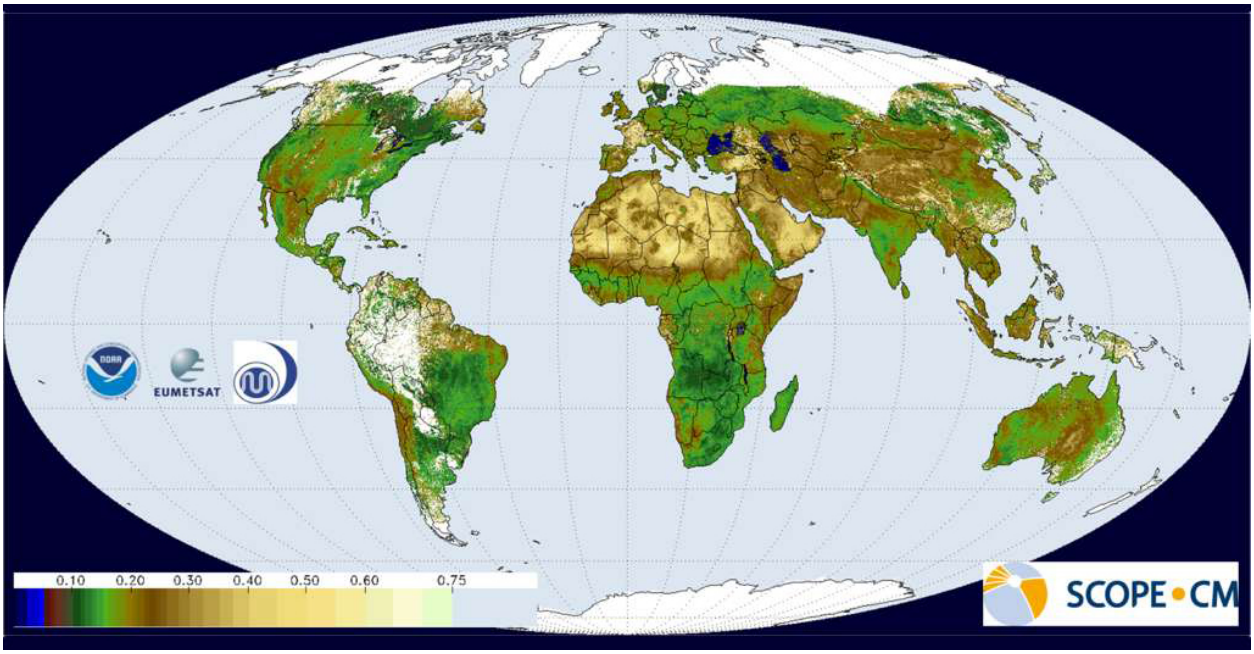


Figure 1: Broadband black sky albedo spatial composite product for the period 1-10 May 2001.

Collaboration with Brian Reich and Elizabeth Mannshardt of the Statistics Department at North Carolina State University continues to develop a validation framework for this data set. To date we have selected a methodology capable of comparing the geostationary-based GSA albedo data to both the polar-orbiting MODIS albedo data and ground-based Ameriflux albedo data. This methodology is flexible to account for issues such as spectral, spatial footprint, and temporal compositing differences between the datasets.

PLANNED WORK

- Process GOES-E and GOES-W data for all of 1995-2014 with updated calibration coefficients and using the unified approach to NWP inputs.
- Perform validation of GSA products with MODIS and in situ observational data
- Implement and test cloud mask as developed by the Satellite Application Facility on Climate Monitoring

PRESENTATIONS

- Lattanzio, A., J. Matthews, M. Takahasi, K. Knapp, J. Schulz, R. Roebeling, R. Stoeckli. 2014. 30 years of land surface albedo from GEO satellites. *QA4ECV Review Meeting*, 5-6 February 2015, Mainz, Germany.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a 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-12-NCICS-JM
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: %.
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

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

BACKGROUND

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

For the temperature profiles HIRS, Channels 2-12 were used, while for the humidity profiles, HIRS Channels 4-8 and 10-12 were used as inputs. These selections were based on the known relations of the channel information to the different physical variables. The HIRS data coupled with CO2 data were used as inputs to a neural network. The neural networks were calibrated according to surface pressure bins. There were three different neural nets, one each for: surface pressures less than 700 mb, greater than 850 mb, and those in between 700 and 850 mb. Radiative Transfer for Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) (RTTOV) data were used as inputs of profile data for calibration purposes.

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

ACCOMPLISHMENTS

The previous version of the temperature and specific humidity data sets were processed through 2014. Several independent datasets were compared to the HIRS profile data. Algorithms were developed to co-locate measurements within 0.1 degrees latitude and longitude and within 1 hr. of overpass. To date comparisons have been done with Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) and Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC2013) observations, which are both largely based on radiosonde measurements.

As a result of analyzing these comparisons, a bias correction methodology was developed. It is a two-tier approach. We first leverage information from the AVHRR Reflectance – PATMOS-x CDR to identify cloud coverage of the HIRS pixels. We then optimized a bias correction method based on COSMIC2013 observations, RS92 radiosonde observations, latitude, and measured values.

The full PATMOS-x CDR was staged, approximately 10 TB of data, and matchups were performed to find coincident cloud fraction and cloud probability values to the HIRS measurements. To identify thresholds for these two variables that indicate "cloudy sky" conditions, optimizations were performed to minimize the difference between the HIRS and RS92 measurements for two years of data through excluding HIRS data associated with cloud probability and fraction above the thresholds. Then, two years of these clear-sky HIRS data were used to formulate bias correction equations via comparisons with COSMIC observations (for stratospheric temperatures) and RS92 (for temperature and humidity in the troposphere). The mean bias errors after bias correction, for the 2011-2012 data used for calibration, are shown in *Figure 1.*

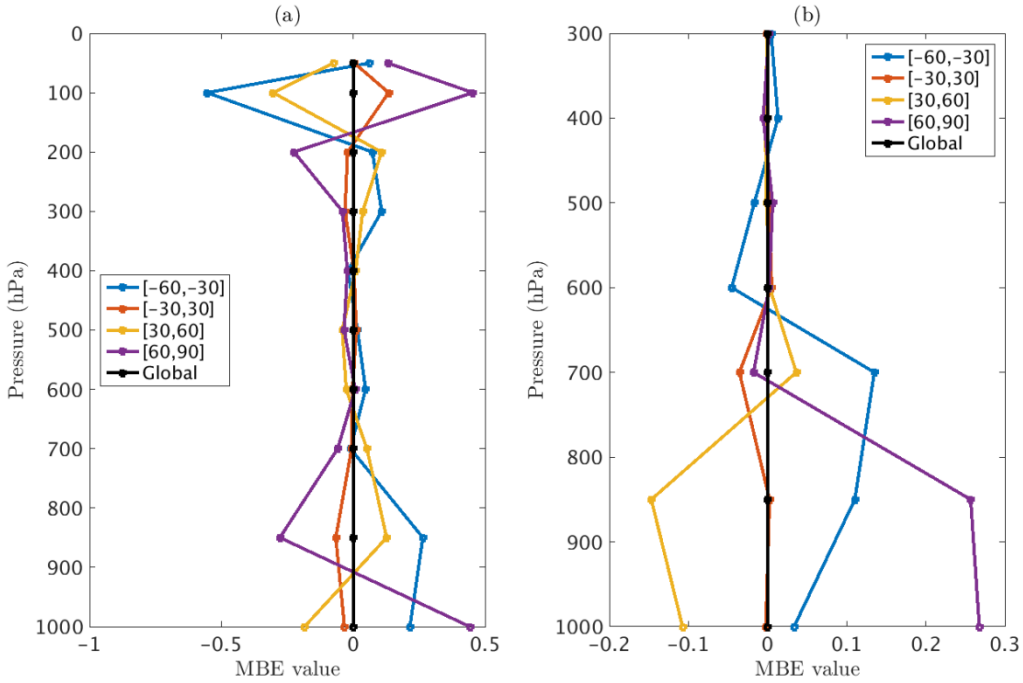


Figure 1: The mean bias error (MBE) of HIRS retrievals compared to 2011-2012 radiosonde observations for global and latitude bands (HIRS values minus radiosonde values) for (a) temperature (ºC) and (b) specific humidity (g/kg).

These cloud-clearing and bias correction procedures were applied to the time series of 1978-2015, including twelve separate satellites. Additionally, quality flags were included with each observation indicating:

- 0 = Both PATMOS-x cloud probability and fraction are less than 10% (likely clear-sky)
- 1 = Either PATMOS-x cloud probability or fraction is larger than 10% but both are less than the thresholds set for likely cloudy pixel (possibly cloudy)
- 2 = Likely cloudy
- 3 = No matching PATMOS-x data available

PLANNED WORK

- 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

PUBLICATIONS

- Peng, G., L. Shi, S. T. Stegall, J.L. Matthews, C. W. Fairall, 2016: An evaluation of HIRS near-surface air temperature product in the arctic with SHEBA data. Journal of Atmospheric and Oceanic Technology, 33(3), 453-460, doi:10.1175/JTECH-D-15-0217.1.
- Shi, L., J.L. Matthews, S.-P. Ho, Q. Yang, J. J. Bates, 2016: Algorithm development of temperature and humidity profile retrievals for long-term HIRS observations. *Remote Sensing*, In revision.

DELIVERABLES

- Quality-flagged, temperature and specific humidity profile data through 2015

PRESENTATIONS

- Shi, L., J.L. Matthews, S. Stegall, G. Peng. 2015. Deriving long-term global dataset of temperature and humidity profiles from HIRS. The 20th International TOVS Study Conference, 28 October-3 November 2015, Lake Geneva, Wisconsin, USA.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	2
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

This year we developed new, quality-flagged, temperature and humidity profile data sets through 2015 (2).

Evaluation and Characterization of Satellite Data Products

Task Leader	Ge Peng
Task Code	NC-CDR/SDS-13-NCICS-GP
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 10%; Theme 2: 85%; Theme 3: 5%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 80%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 20%

Highlight: This effort focused on the evaluation and characterization of satellite climate data records (CDRs) that are in various stages of development and application. For this period, the accuracy of the NCEI High-resolution Infrared Radiation Sounder (HIRS) near-surface temperature product was evaluated in the Arctic using the quality-controlled SHEBA dataset. This analysis lays the groundwork for a long-term remote sensing near-surface air temperature product in the Arctic. Lead-authored a manuscript published by a peer-review journal. Co-authored a manuscript to be submitted to a peer-reviewed journal.

BACKGROUND

The primary object of this task is to evaluate, validate, and characterize satellite-based climate data products that have been or in the process of being transitioned to operation from research or being developed at NOAA's NCEI.

The evaluation and characterization of the satellite product will improve data quality maturity of the product and provide a baseline and additional quality information for users and identify areas for product improvement.

ACCOMPLISHMENTS

An ocean near-surface air temperatures product derived from inter-satellite-calibrated High-resolution Infrared Radiation Sounder (HIRS) measurements onboard NOAA's polar-orbiting satellite series is under development at NCEI. Built on previous evaluations, the latest and improved version of along-swath air temperature profiles was produced by the NCEI HIRS product team. The accuracy and uncertainty sources of the temperature retrievals at 2-meter height (T2m) are evaluated in the Arctic region, using high-quality observations from the integrated Surface Heat Budget of the Arctic Ocean (SHEBA) dataset (*Fig. 1*), to lay the groundwork for a long-term remote sensing near-surface air temperature product in the Arctic. Lead-authored a peer-reviewed paper describing the analysis results (Peng et al., 2016), published by AMS Journal of Atmospheric and Oceanic Technology.

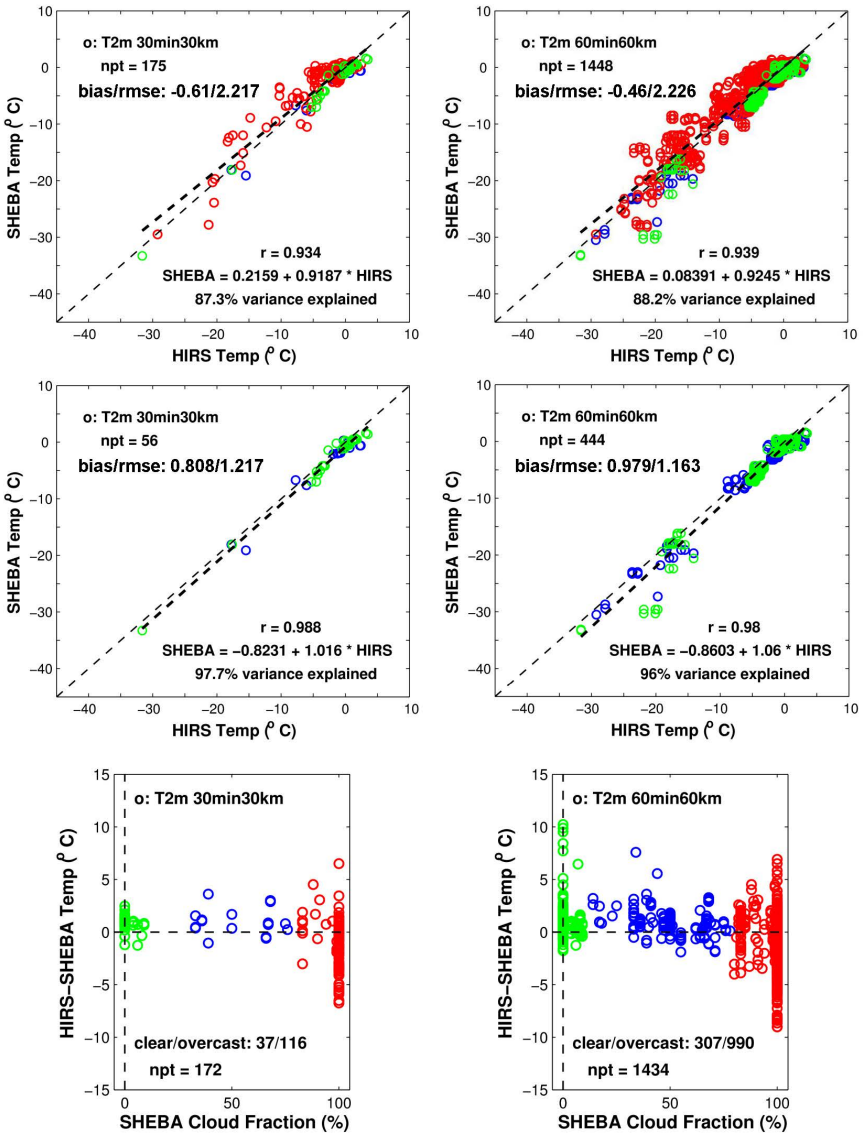


Figure 1: The scatter-diagram of HIRS and SHEBA T2m (top 4 panels) and their temperature differences as a function of SHEBA cloud fraction (bottom 2 panels) for the 30min30km case (left 3 panels), i.e., a temporal radius of 30 minutes and a spatial radius of 30 km for co-location, and for the 60min60km case (right 3 panels), i.e., a temporal radius of 60 minutes and a spatial radius of 60 km for co-location, respectively. The color code denotes clear, cloudy, and overcast conditions when the SHEBA could fractions are less than 10%, between 10% and 80%, and more than 80%. This figure shows the accuracy of HIRS T2m compared to SHEBA T2m in terms of mean, i.e., bias, and RMSE (root-mean-square error) of HIRS-SHEBA T2m differences, and the robustness of statistical characteristic to spatial and temporal co-location radius and cloud conditions.

PLANNED WORK

- Present the evaluation results of the long-term Arctic data products at a national or international conference if travel is permitted.
- Compute and examine the regional sea ice normal and variability, laying ground for a sea ice climate indicator-monitoring project.

- Participate in developing new sea ice climate indicators – a NASA funded project (Co-PI).

PUBLICATIONS

- Peng, G., L. Shi, S. Stegall, J. Matthews, and C. Fairall, 2016: An Evaluation of HIRS Near-Surface Air Temperature Product in the Arctic with SHEBA data. *J. Atmos. Oceanic. Technol*., 33, 453–460. doi: 10.1175/JTECH-D-15-0217.1.
- Stegall, S. T., L. Shi, and G. Peng, 2016: Arctic Spatial Variability of HIRS Surface Temperatures Collocated to LSAT Datasets for 2009. *In prep*.

PRESENTATIONS

- Shi, l., J. L. Matthews, S. Stegall, and G. Peng, 2015: Deriving long-term global dataset of temperature and humidity profiles from HIRS. Poster. 20th International TOVS Study Conference. Lake Geneva, Wisconsin, 28 October – 3 November 2015.

OTHER

- Received the NCEI Group Gold Award.
- Served as Scientific Steward for NOAA Sea Ice Concentration and Ocean Surface Bundle CDRs - reviewed work statements, revised data flow diagrams, sample data, and documents.
- Co-PI for the NASA sea ice climate indicator project.
- Served as an internal reviewer for the NCEI manuscript central.
- Served as an external reviewer for the Remote Sensing Journal.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a 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-14-NCICS-GP
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 10%; Theme 2: 85%; Theme 3: 5%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 80%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 20%

Highlight: This effort focuses on cutting-edge research in scientific stewardship of individual digital environmental data products. Leading, coordinating, and participating in NCEI and across-agency DSMM (data stewardship maturity matrix) use case studies and development of tools for integrating DSMM results for enhanced data discovery and decision-making support. Co-authored conference presentations. Lead-authored a manuscript to be submitted to a peer-review journal. Introducing roles of data, scientific, and technology stewards and their responsibilities and other major stakeholders for effectively ensuring and improving data quality and usability. Lead-authored a conference presentation and a paper submitted to a peer-review journal.

BACKGROUND

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

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

Any improvement process requires the knowledge of the current stage and what needs to be done to improve if necessary. Currently, there is no systematic framework for assessing the quality of stewardship practices applied to digital environmental datasets and providing consistent information such as data integrity and usability information to users and stakeholders.

ACCOMPLISHMENTS

- Led, coordinated, and participated in DSMM use-case studies, collaborating with the NOAA CDR Program, NCEI Data Stewardship Division, and ESIP Data Stewardship Committee. *Table 1* outlines the datasets selected and the current status of their stewardship maturity assessments.
- Coordinated and participated in the development of a data use/service maturity matrix.
- Selected by NOAA OneStop Program to lead the stewardship maturity assessment of selected NOAA core datasets.
- Lead-authored a manuscript submitted to a peer-review journal on roles and responsibilities of product key players for ensuring quality and usability of digital environmental data products (Peng et al., 2016).

Data Type	Dataset Title	Sponsors & Collaborators	Assessment Status*
Satellite – polar ocean	NOAA/NSIDC Sea Ice Concentration CDR	NCEI; NSIDC; ESIP	Baselined
Satellite – global ocean	NOAA Optimum Interpolation Sea Surface Temperature (OISST) CDR	NCEI	Final assessment draft under review
GIS - regional	NCEI Digital Elevation Model (DEM)	NCEI	Revised assessment draft to be reviewed
Station – in situ - land	Global Historical Climatology Network (GHCN)-Monthly	NCEI	Baselined
Station – gridded - land	National Climate Division (nCliDiv)	NCEI	Not yet assessed
Physical records – in situ	Local Climatological Data	NCEI	Initial assessment draft to be reviewed
Paleo – tree rings	International Tree-Ring Data Bank (ITRDB)	NCEI	Final assessment draft under review
Model - Reanalysis	NCAR Global Climate Four Dimensional Data Assimilation (CFDDA) Hourly 40 km Reanalysis	ESIP	Final assessment draft under review
Ecological – DataOne member	Santa Barbara Coastal Long Term Ecological Research Network (SBC LTER)	ESIP; DataOne	Revised assessment draft under review
Long tail – Arctic	NSF Advanced Cooperative Arctic Data & Information Service (ACADIS)	ESIP	Initial assessment draft
Socioeconomic	Socioeconomic dataset	ESIP; CIESIN	Preliminary assessment
Paleo - borehole	Borehole dataset	CSIRO; ESIP	Not yet assessed

Table 1: Summary of selected datasets and assessment status for the NCEI and ESIP use case studies of utilizing the NCEI/CICS-NC Scientific Data Stewardship Maturity Matrix (DSMM).
The status levels progress in the order of: Not yet assessed; Preliminary assessment; Initial, Revised, and Final assessment draft; and Basedlined. The review is currently done by an assessment team for each product including a DSMM Subject Matter Expert (SME), data product SME or data manager, metadata and technology specialists assigned for the data product.

PLANNED WORK

- Continue with the use case study for selected IOC CDRs – towards potentially baseline stewardship maturity rating for all IOC CDRs, which will help the CDR program with informed and efficient stewardship management and improvement process, pending task allocation and prioritization.

- Lead the stewardship maturity assessment of selected NOAA datasets for the NOAA OneStop Program.
- Continue to refine the consistency of and to expand the scope of the data stewardship maturity matrix, collaborating with NCEI Data Stewardship Division, ESIP Data Stewardship Committee, DataOne members, and the EUMETSAT CORE-CLIMAX project.
- Continue to promote improving data quality and usability to scientific and data management community and encourage a consistent way to measure and convey data product maturity in the Earth Science data community.

PUBLICATIONS

- Peng, G., Nancy A. Ritchey, Kenneth S. Casey, Edward J. Kearns, Jeffrey L. Privette, Drew Saunders, Philip Jones, T. Maycock, and Steve Ansari, 2016: Scientific Stewardship in the Open Data and Big Data Era - Roles and Responsibilities of Stewards and Other Major Product Stakeholders. *Submitted to D.-Lib Magazine.*
- Peng, G. and T. Maycock, 2015: Increasing sharing, expanding user base, and estimating impact of your research data using service tools and social media - a use case study. *Data Stories Blog*. Published June 29, 2015. http://datastories.jiscinvolve.org/wp/?p=159.
- Peng, G., J. Lawrimore, V. Toner, C. Lief, R. Baldwin, and N. Ritchey, 2016: Assessment of Stewardship Maturity of the Global Historical Climatology Network-Monthly (GHCN-M) Dataset and Lessons Learned. *In prep.*

PRESENTATIONS

- Privette, J. L., G. Peng, and K. Casey, 2015: Stewardship Frameworks in the National Centers for Environmental Information. NCEI/CICS-NC Branch Seminar Series. June 30, 2015, Asheville, NC, USA.
- Peng, G., 2015: A new paradigm for ensuring and improving data quality and usability – Roles and responsibilities of key players and stakeholders. 2015 ESIP Summer Meeting, Jul 14 – 17, 2015, Pacific Cove, CA, USA.
- Peng, G., 2015: Towards a consistent measure of stewardship practices applied to individual digital Earth Science datasets. 2015 ESIP Summer Meeting, Jul 14 – 17, 2015, Pacific Cove, CA, USA.
- Peng, G., 2015: Stewardship maturity assessment of GHCN-Monthly v3 and lessons learned. NCEI stakeholders and management briefing. September 28, 2015. Asheville, NC, USA.
- Ramapriyan, H., D. Moroni, and G. Peng, 2015: Improving information quality for Earth Science data and products – overview. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Downs, R., G. Peng, Y. Wei, H. Ramapriyan, and D. Moroni, 2015: Enabling the usability of Earth Science data products and services by evaluating, describing, and improving data quality throughout the data lifecycle (invited). 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Ritchey, N. and G. Peng, 2015: Assessing stewardship maturity: use case study results and lessons learned. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Hou, C.-Y., M. Mayermik, G. Peng, R. Duerr, and A. Rosati, 2015: Assessing formation quality: Use case studies for the data stewardship maturity matrix. Poster. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.

- Austin, M. and G. Peng, 2015: A Prototype for content-rich decision-making support in NOAA using data as an asset. Poster. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Ritchey, N., A. Milan, P. Jones, D. Collins, Y. Li, J. Mize, and G. Peng, 2016: NOAA OneStop: Metadata Plans and Progress. 4 – 5 January 2016, NOAA's Environmental Data Management Workshop, Washington, D.C., USA.

OTHER

- 2015 Employees' Choice Award for NCEI Paper of the year – lead author.
- Co-chaired, participated or led monthly telecons of ESIP information quality cluster.
- Participated when time permit monthly telecons of NOAA metadata and catalog working groups and ESIP data stewardship committee.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	1
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Merging long-term high-resolution quantitative precipitation estimates Quantitative Precipitation Estimates from the high-resolution NEXRAD reanalysis over CONUS with rain-gauge observations

Task Leader	Olivier Prat
Task Code	NC-CDR/SDS-15-NCICS-OP
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 35%; Theme 2: 55%; Theme 3: 10%.
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 60%; Goal 2: 40%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: The objective of this work is to provide long-term high-temporal and spatial resolution quantitative precipitation estimates (QPEs) suitable for hydrological, meteorological, and climatological applications. The radar-only National Mosaic and Multi-sensor QPE (NMQ/Q2) Precipitation Reanalysis is adjusted using a suite of in situ datasets at various temporal resolution (GHCN-D, HADS, ASOS, CRN).

BACKGROUND

The processing of radar-only precipitation via the reanalysis from the National Mosaic and Multi-Sensor Quantitative (NMQ/Q2) based on the WSR-88D Next-generation Radar (NEXRAD) network over Continental United States (CONUS) was completed for the period covering from 2002 to 2011. While this constitutes a unique opportunity to study precipitation processes at higher resolution than conventionally possible (1-km, 5-min), the long-term radar-only product needed to be merged with in situ information in order to be suitable for hydrological, meteorological, and climatological applications. The radar-gauge merging was performed by using rain gauge information at daily (Global Historical Climatology Network–Daily: GHCN-D), hourly (Hydrometeorological Automated Data System: HADS), and 5-min (Automated Surface Observing Systems: ASOS; Climate Reference Network: CRN) resolution. The challenges related to incorporating differing resolution and quality networks to generate long-term large-scale gridded estimates of precipitation are enormous. Among the challenges faced are the difficulties incorporating differing resolutions and quality surface measurements to adjust gridded estimates of precipitation. Another challenge is the type of adjustment technique.

ACCOMPLISHMENTS

The bias-assessment of the radar-only product was performed using surface datasets at the daily (GHCN-D) and hourly (HADS) scales for the period 2002-2011. *Figure 1* displays the radar-only and bias-adjusted QPEs using an Inverse Distance Weighting (IDW) approach at the daily and hourly scale. The visual comparison between the radar-only and the bias-adjusted QPEs shows that the merging of in situ data improves considerably the precipitation patterns over the Western United States. Local differences in the average rainfall are observed between daily and hourly bias-adjusted QPEs, but precipitation patterns are comparable with Stage IV estimates.

At the hourly scale, the basic QA/QC (large errors, stuck gauges) of the HADS data was found insufficient as can be seen in *Figure 2* (first column). While using a condition on the radar-only estimate (NMQ>0) allows removing a large number of the erroneous gauges (third column), this also decreases significantly (one order of magnitude) the bias-adjusted rainfall accumulation over the Western U.S. due to beam blockage by the topography (third column). The use of a reprocessed HADS dataset that include additional levels of QC drastically reduces the number of erroneous gauges (second column). The

remaining problematic gauge locations vanish when combined with the condition on the radar-only estimate greater than zero (fourth column).

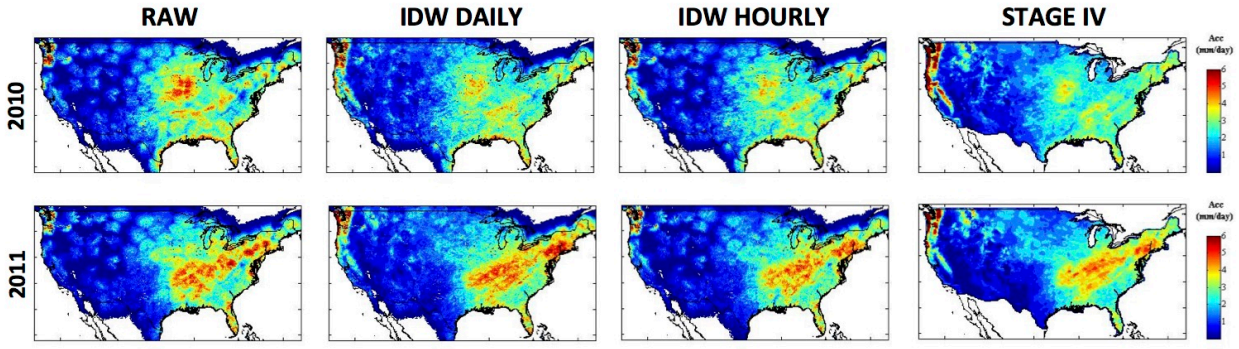


Figure 1: Average daily rainfall from the radar-only (first column) and bias-adjusted QPEs from the NMQ/Q2 using in situ GHCN-D at the daily scale (second column) and HADS at the hourly scale (third column). Average daily rainfall derived from Stage IV is reported for comparison (fourth column). Results are presented form the years 2010-2011.

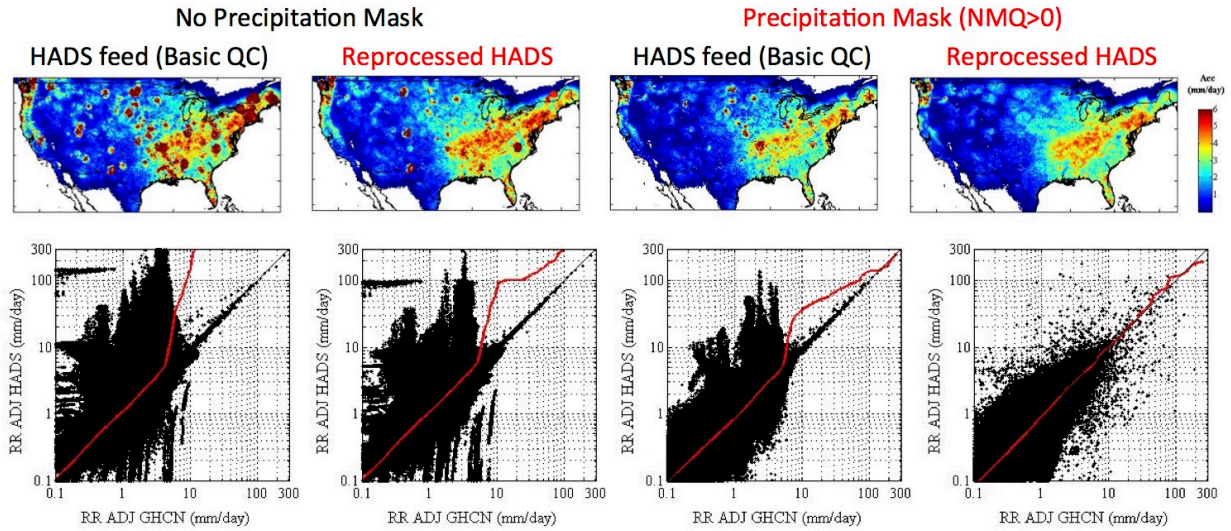


Figure 2: Bias-adjustment of radar-only QPE using the IDW technique at the hourly scale for 2011. Results show the importance of in situ HADS data QA/QC when comparing bias-adjusted estimates obtained with the basic HADS QA/QC (first and third columns) or with the reprocessed HADS dataset (second and fourth columns) and the impact of IDW variants with (third and fourth columns) or without (first and second columns) condition on the radar-only QPE (NMQ>0). The scatterplots display a comparison of the hourly bias-adjusted (HADS) QPE (y-axis) with respect to the daily bias-adjusted (GHCN-D) QPE (x-axis).

While a beta version of the bias-adjusted NMQ that filters the erroneous HADS gauges based on the radar-only QPE is available at the hourly scale for the entire period of record, the current work has issues remaining to be addressed. The entire HADS dataset used in the merging procedure is currently being reprocessed using a more careful QA/QC. The reprocessed dataset will be used for the final version of the bias-adjusted QPE. In addition, additional merging methods (Kriging and variants) are currently being tested. Preliminary results obtained for a pilot domain over Texas showed that an

advanced bias-adjustment technique such as the Conditional Bias-Penalized Co-Kriging (CBPCK), improves significantly the precipitation estimates for extreme events.

PLANNED WORK

- Complete the QA/QC reprocessing of in situ HADS for the full period of record (2002-2011).
- Finalize the Kriging bias-adjustment procedure.
- Fix/address remaining issues: *i.e.* perform mean field bias-adjustment prior to IDW or Kriging bias-adjustments, improve rainfall patterns over the West due to mountain blockage, fill gaps for missing HADS data for particular years.
- Test of alternative merging techniques (OCK: Ordinary Co-Kriging; CBPCK: Conditional Bias Penalized Co-Kriging) over a selected domain in Texas (collaboration with D.-J. Seo at UTA).

PUBLICATIONS

- Kim, B., D.-J. Seo, S.J. Noh, O.P Prat, and B.R. Nelson, 2016. Improving multisensor estimation of heavy-to-extreme precipitation via conditional bias-penalized optimal estimation. *Journal of Hydrology. Submitted.*

DELIVERABLES

- A complete long-term large-scale bias-adjusted precipitation estimates at high spatial and temporal resolution over CONUS at the hourly scale (2002-2011). While a beta version is currently available, the final version will address the issues mentioned above.
- A measure of uncertainty associated with the bias-adjusted QPE over CONUS.
- A manuscript presenting the final long-term high-resolution bias-adjusted QPE.

PRESENTATIONS

- Prat, O.P., B.R. Nelson, S.E. Stevens, E. Nickl, D.-J. Seo, B. Kim, J. Zhang, and Y. Qi, 2015. Merging radar Quantitative Precipitation Estimates (QPEs) from the high-resolution NEXRAD reanalysis over CONUS with rain-gauge observations. *2015 AGU fall meeting*, December 14-18 2015, San Francisco, CA, USA.
- Nelson, B.R., D. Kim, O.P. Prat, S.E. Stevens, J. Zhang, and K. Howard, 2015. NOAA's NEXRAD Reprocessing Effort - Bias assessment and adjustment of a long-term high-resolution quantitative precipitation estimates. *37th AMS conference on radar meteorology*, September 13-18 2015, Norman, OK, USA.
- Zhang, J, Y. Qi, S.E. Stevens, B. Kaney, C. Langston, K.L. Ortega, B.R. Nelson, K. Howard, and O.P. Prat, 2015. Multiple Year Reanalysis of Remotely Sensed Storms-Precipitation (MYRORSS-P). *37th AMS conference on radar meteorology*, September 13-18 2015, Norman, OK, USA.
- Kim, B., D.-J. Seo, B.R. Nelson, and O.P. Prat 2015. Improving Multisensor Precipitation Estimation via Conditional Bias-Penalized Optimal Estimation. *2015 EWRI World Environmental & Water Resources Congress*, May 17-21 2015, Austin, TX, USA. (O)

OTHER

- NOAA National Centers for Environmental Information (NCEI) employee's choice award (2015) – *Innovative product of the year* (shared with B. Nelson and S. Stevens)

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	4
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

The radar-only NMQ precipitations estimates at the daily scale were bias-adjusted with in situ rain gauge data using an Inverse Distance Weighting approach. The bias-adjustment procedure has been extended at the hourly scale (1). One presentation was made on the product bias-adjustment procedure at the AGU Fall Meeting (1). Three other presentations have been co-authored on different aspects of the project (3) including project overview (1), IDW bias-adjusted product (1), and implementation of state of the art bias-adjustment techniques (1).

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-16-NCICS-OP
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 20%; Theme 2: 75%; Theme 3: 5%.
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 80%; Goal 2: 20%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: This project uses a suite of quantitative precipitation estimates (QPEs) derived from satellite observations to derive 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 in the perspective of developing Reference Environmental Data Records (REDRs) for precipitation.

BACKGROUND

Four satellite based precipitation Reference Environmental Data Records (REDRs: previously Climate Data Records) are currently or will be transitioned to the REDR program (PERSIANN-CDR; GPCP; CMORPH; AMSU-A, B, Hydrologic bundle). PERSIANN-CDR is a 30-year record of daily-adjusted global precipitation. GPCP is an approximately 30-year record of monthly and pentad adjusted global precipitation and 17-year record of daily-adjusted global precipitation. CMORPH is a 17-year record of daily and sub-daily adjusted global precipitation. AMSU-A, B, Hydro-bundle is an 11-year record of a bundle of perceptible water, cloud water, and ice water among others. The different satellite based QPEs are evaluated over the concurrent period. The product inter-comparisons are performed at various temporal (annual, seasonal, daily, or sub-daily when possible) and spatial scales (global, overland and over ocean, tropics or higher latitudes, high elevation). The evaluation of the different products will include trend analysis and comparison with in situ data sets from the Global Historical Climatology Network (GHCN-Daily).

ACCOMPLISHMENTS

The comparison was conducted for the globe over the full period of record of each product. *Figure 1* displays the annual precipitation derived from the PERSIANN CDR and from the CDR in transition CMORPH and GPCP for the selected years 1998 and 2005. All products display similar precipitation patterns with area of higher precipitation such as the Inter-Tropical Convergence Zone (ITCZ) over the tropics, the Gulf Stream over the Atlantic Ocean, and the Kuroshio Current over the Pacific Ocean near Japan. The precipitation anomalies displayed for 1998 and 2005 give an illustration of the inter-annual variability with important differences between a strong El Nino year (1998) and a neutral year (2005).

Figure 2 displays the zonal averaged precipitation estimates for the different products over the globe (50S-50N) and over the tropical band (23S-23N), and shows comparable results for the three satellite QPE products.

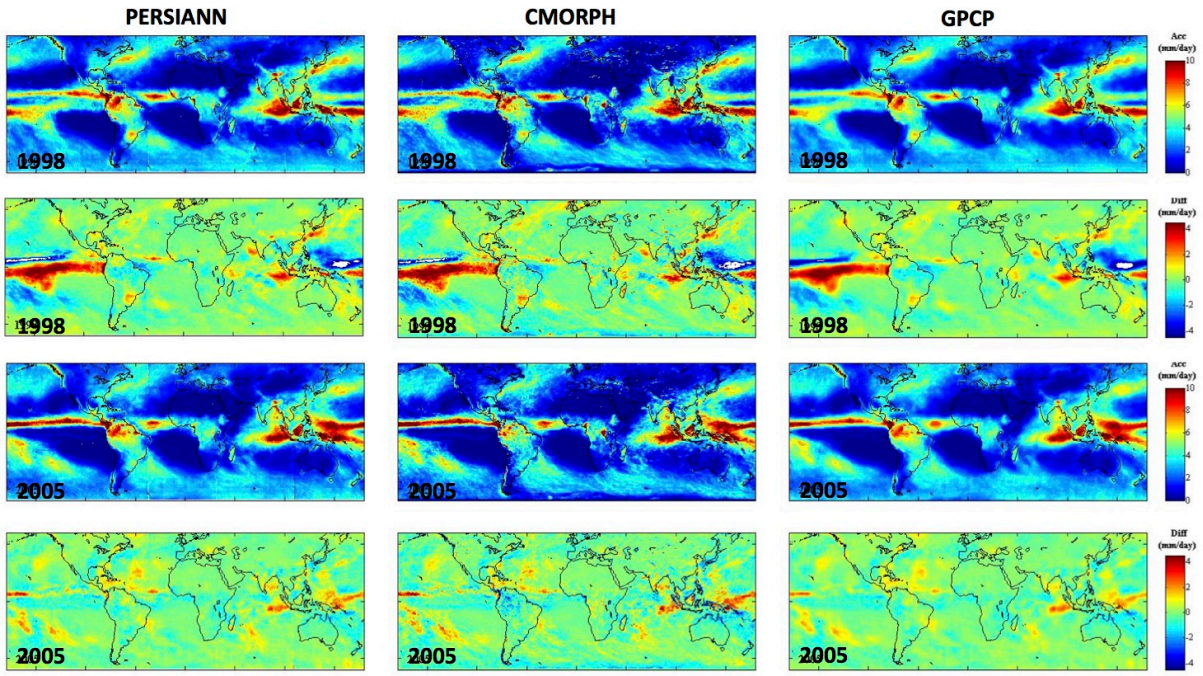


Figure 1: Annual rainfall derived from current or in-transition Reference Environmental Data Records (REDRs) PERSIANN, CMORPH, and GPCP for the year 1998 (upper row) and 2005 (third row) and corresponding anomalies for 1998 (third row) and 2005 (lower row).

A comparison of the different satellite QPE daily products over their respective period of record shows that PERSIANN and GPCP are quasi identical over their concurrent period of record (*Fig. 2*: lower row). This is somewhat expected since PERSIANN uses GPCP for monthly precipitation total calibration. With respect to the other products, CMORPH presents slightly lower precipitation averages.

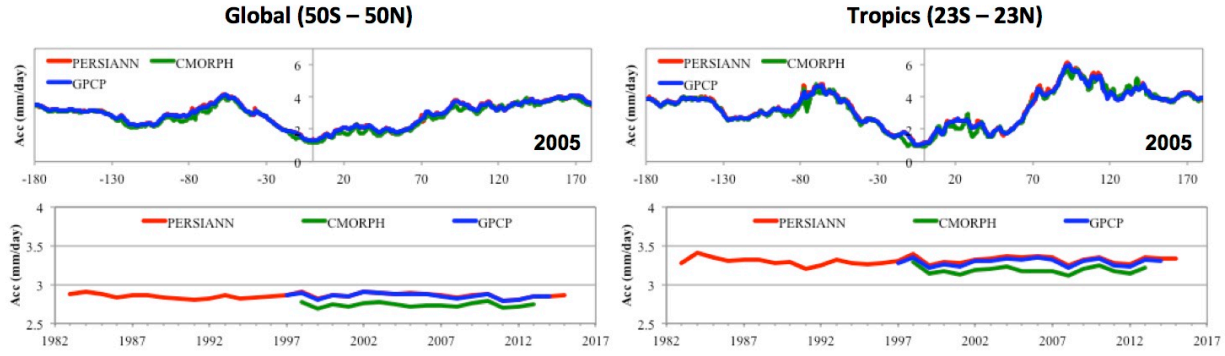


Figure 2: Satellite QPE products comparison of the zonal averaged precipitation estimates for the globe (50S-50N) and the tropical band (23S-23N) for the year 2005 (upper row). Evolution of the zonal averaged rainfall for the globe and the tropics presented for the period of record and for each product (lower row).

Current work consists of extending the comparison to other CDRs in transition such as the AMSU-A, B-Hydrologic bundle. The comparison with other gridded with other multi-sensor satellite precipitation products (TMPA, GPM) and in situ data (GHCN-D) is also considered. The different satellite precipitation REDRs are being evaluated at various temporal (annual, seasonal, daily) and spatial scales (global, over

land and over ocean, tropics or higher latitudes, high elevation). Conditional analysis will be conducted to evaluate the ability of the different products to capture extreme precipitation (storms, tropical cyclones, *etc.*).

PLANNED WORK

- Continue the inter-comparison of the different satellite precipitation current and in-transition REDRs. The evaluation will be performed at the global and local (geography type, elevation, climatic regimes) scales and for various time scales.
- Extend this work by including other gridded precipitation QPEs (GPM, GPCC, TMPA); and
- Summarize the finding of the satellite precipitation REDRs evaluation into a publication.
- Other possible directions include the development of new functionalities for the Satellite Product Evaluation Center (SPEC) to help with QPE products comparison (L. Vasquez). For the upcoming year, this task is still pending funding and time availability.

PUBLICATIONS

- Prat, O.P., and B.R. Nelson, 2015. Evaluation of precipitation estimates over CONUS derived from satellite, radar, and rain gauge data sets at daily to annual scales. *Hydrology and Earth System Sciences.* 19, 2037-2056.
- Nelson, B.R., O.P Prat, D.-J. Seo, and E. Habib, 2016. Assessment and implications of Stage IV QPE for product inter-comparisons. *Weather and Forecasting.* 31, 371-394.
- Prat, O.P., and B.R. Nelson, 2016. On the link between tropical cyclones and daily rainfall extremes derived from global satellite quantitative precipitation estimates. *Journal of Climate. Submitted.*

DELIVERABLES

- Global evaluation of the different satellite precipitation REDRs differences. Comparison with in situ data (GHCN-D) for the entire period of record at the annual, seasonal, and daily scale;
- Manuscript summarizing the results of this comparison effort at the global scale; and
- Software (SPEC) tailored for comparison of precipitation datasets with differing formats, spatial and temporal resolution. Pending resources and time availability.

PRESENTATIONS

- Prat, O.P., B.R. Nelson, E. Nickl, R. Adler, R. Ferraro, S. Sorooshian, and P. Xie, 2016. Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs) from the Reference Environmental Data Records (REDRs). *2016 EGU General Assembly*, April 17-22 2016, Vienna, Austria.
- Nelson, B.R., O.P. Prat, and L. Vasquez, 2015. Precipitation Climate Data Records. *2015 AGU fall meeting*, December 14-18 2015, San Francisco, CA, USA.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	3
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

One journal article on the evaluation of multi-sensor QPE products was published in April 2015 (1). One coauthored journal article on Stage IV evaluation was published in April 2016 (1). One manuscript on the contribution of tropical cyclones to extreme rainfall was submitted for publication (1). One presentation has been accepted for the EGU General Assembly (1). One presentation was coauthored at the AGU Fall Meeting (1).

Identifying Tropical Variability with CDRs

Task Leader	Carl Schreck
Task Code	NC-CDR/SDS-17-NCICS-CS
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Tropical variability identified through Climate Data Records can be leveraged for numerous end users, including the climate monitoring, the energy sector, and the U.S. Military.

BACKGROUND

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

ACCOMPLISHMENTS

Since 2011, monitor.cicsnc.org/mjo has been serving CDR-based diagnostics of tropical variability to about 300 users per month. This year, those diagnostics were significantly overhauled to include the new interim CDR of outgoing longwave radiation (OLR) and interim tropical cyclone tracks. The latter spawned development of a potential new interim version of NCEI's IBTrACS dataset.

Figure 1 shows an example of one of the new diagnostics, which includes observed OLR anomalies from the interim CDR along with NCEP Climate Forecast System (CFS) forecasts of those anomalies. The contours identify prominent modes of tropical variability, and the hurricane symbols denote tropical cyclone formations. NOAA's Climate Prediction Center and the Air Force's 14th Weather Squadron routinely use these diagnostics for making forecasts of tropical variability from 1–4 weeks.

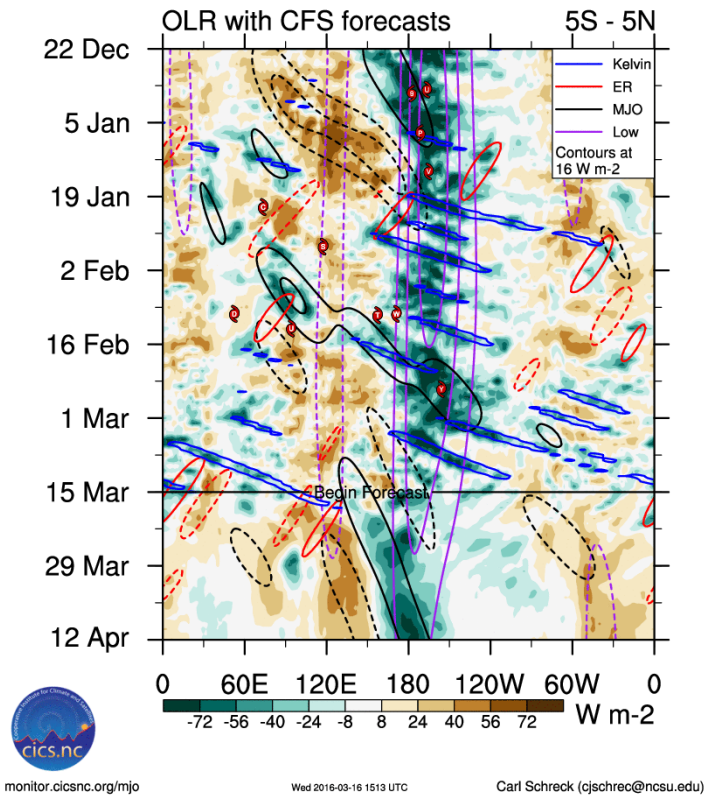


Figure 1: Time–longitude Hovmöller of observed and forecast OLR anomalies (shading). Contours identify primary modes of tropical variability and hurricane symbols denote tropical cyclogenesis.

In the previous year, a team of NASA DEVELOP interns used the outgoing longwave radiation (OLR) daily CDR along with GHCN-Daily to identify the impacts of various teleconnections on temperatures in the northeast quadrant of the U.S., a high-impact region for natural gas prices. The results showed that the MJO and the West Pacific Oscillation were the two most dominant signals on intra-seasonal time scales. Furthermore, the impact of other extratropical teleconnections was modulated by the phase of the MJO. In the current year, these results were confirmed and expanded to cover the contiguous United States. In addition, it was found that the dominant teleconnection varies by region and by time scale.

CDRs play a critical role in climate monitoring. As co-editor of the Tropic chapter of the annual State of the Climate Report in the *Bulletin of the AMS*, Schreck has encouraged expanded use of several CDRs, particularly OISST and OLR. Schreck is also co-advisor for Hilawe Semunegus, a PhD student at NC Agricultural and Technical University. This dissertation research relies on data from the ISCCP CDR for identifying modes of convection within African Easterly Waves.

PLANNED WORK

- Add new MJO indices to monitor.cicsnc.org/mjo
- Prepare manuscript comparing the new OLR-daily CDR with the previous dataset.
- Present relationships between satellite-derived tropical cyclone imagery and central pressure at the AMS Tropical Conference
- Investigate the sources and causes of cold air outbreaks over the United States
- Complete advising of Semunegus's PhD dissertation and publish results

PUBLICATIONS

Peer-reviewed

- Klotzbach, P. J., E. C. J. Oliver, R. D. Leeper, and C. J. Schreck, 2016: The Relationship between the Madden-Julian Oscillation (MJO) and Southeastern New England Snowfall. *Mon. Wea. Rev.*, In Press, doi:10.1175/MWR-D-15-0434.1.
- Schreck, C. J., and Coauthors, 2015: Natural Gas Prices and the Extreme Winters of 2011/12 and 2013/14: Causes, Indicators, and Interactions. *Bull. Amer. Meteor. Soc.*, 96, 1879–1894, doi:10.1175/BAMS-D-13-00237.1.

Other publications

- Baxter, S., C. J. Schreck, and G. D. Bell, 2015: [The Tropics] Tropical intraseasonal activity [in "State of the Climate in 2014"]. *Bull. Amer. Meteor. Soc.*, 96, S93–S96, doi:10.1175/2015BAMSStateoftheClimate.1.
- Kruk, M. C., C. J. Schreck, and T. Evans, 2015a: [The Tropics] Eastern North Pacific basin [in "State of the Climate in 2014"]. *Bull. Amer. Meteor. Soc.*, 96, S107–S112, doi:10.1175/2015BAMSStateoftheClimate.1.
- Kruk, M. C., C. J. Schreck, and K. S. Griffin, 2015b: [The Tropics] Remnant eastern Pacific storms drive wacky weather across the U.S. [in "State of the Climate in 2014"]. *Bull. Amer. Meteor. Soc.*, 96, S108–S109, doi:10.1175/2015BAMSStateoftheClimate.1.

DELIVERABLES

- monitor.cicsnc.org/mjo served CDR-based diagnostics to about 300 unique visitors every month

PRESENTATIONS

- Schreck, C. J., J. Rennie, L. Watkins, K. Dobeck, and D. Podowitz, 2016: Scale-Dependent Relationships Between U.S. Temperatures and Teleconnections. *Fourth Symposium on the Madden–Julian Oscillation*, 10-14 January 2016, New Orleans, LA.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	2
# of peer reviewed papers	2
# of non-peered reviewed papers	3
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	1
# of undergraduate students mentored during the year	0

Hydrometerological Automated Data System (HADS): Effort to recreate and automate quality control processes for in situ rain gauge data

Task Leader	Scott Stevens
Task Code	NC-CDR/SDS-18-SS
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 10%; Goal 2: 60%; Goal 3: 0%; Goal 4: 30%; Goal 5: 0%

Highlight: This project works to port algorithms developed at NCEI into a more operational framework. This involves streamlining, debugging, and automating code to run in a more autonomous way.

BACKGROUND

This report summarizes the early stages of a project working toward moving the quality control of Hydrometerological Automated Data System (HADS) data from research to operations. The CICS-NC project focus is on streamlining and automating existing algorithms so that they can be run autonomously and in an archive mode on archived data.

ACCOMPLISHMENTS

Stevens has successfully developed a decoder to read incoming HADS data in Standard Hydrometeorological Exchange Format (SHEF) and replicated metadata checks put in place by NCEI scientists. The metadata checks have been streamlined and rewritten in a more portable way so that they can run on a variety of machines.

PLANNED WORK

- Become familiar with algorithms developed at NCEI to perform quality control on incoming HADS data
- Work toward automating this process and the ability to reprocess data in bulk

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Reanalysis of archived NEXRAD data using NMQ/Q2 algorithms to create a high-resolution precipitation dataset for the continental U.S.

Task Leader	Scott Stevens
Task Code	NC-CDR/SDS-19-NCICS-SS
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 10%; Goal 2: 60%; Goal 3: 0%; Goal 4: 30%; Goal 5: 0%

Highlight: The reanalysis product is in the process of being entered into the NCEI archive. Stevens worked closely with Big Data partners to make raw data available.

BACKGROUND

This report summarizes the year-6 work toward the National Mosaic and Multisensor Quantitative Precipitation Estimate (NMQ/Q2) NEXRAD Reanalysis, an ongoing effort at CICS-NC. An improved precipitation estimate algorithm has been developed at NOAA's National Severe Storms Laboratory (NSSL) and adapted for reprocessing at CICS-NC. The algorithm represents a significant step forward in both spatial and temporal resolution of gridded precipitation products, providing 1-km gridded precipitation information at an interval of only five minutes. *Figure 1* shows the improvement in spatial resolution over the operational Stage IV precipitation product.

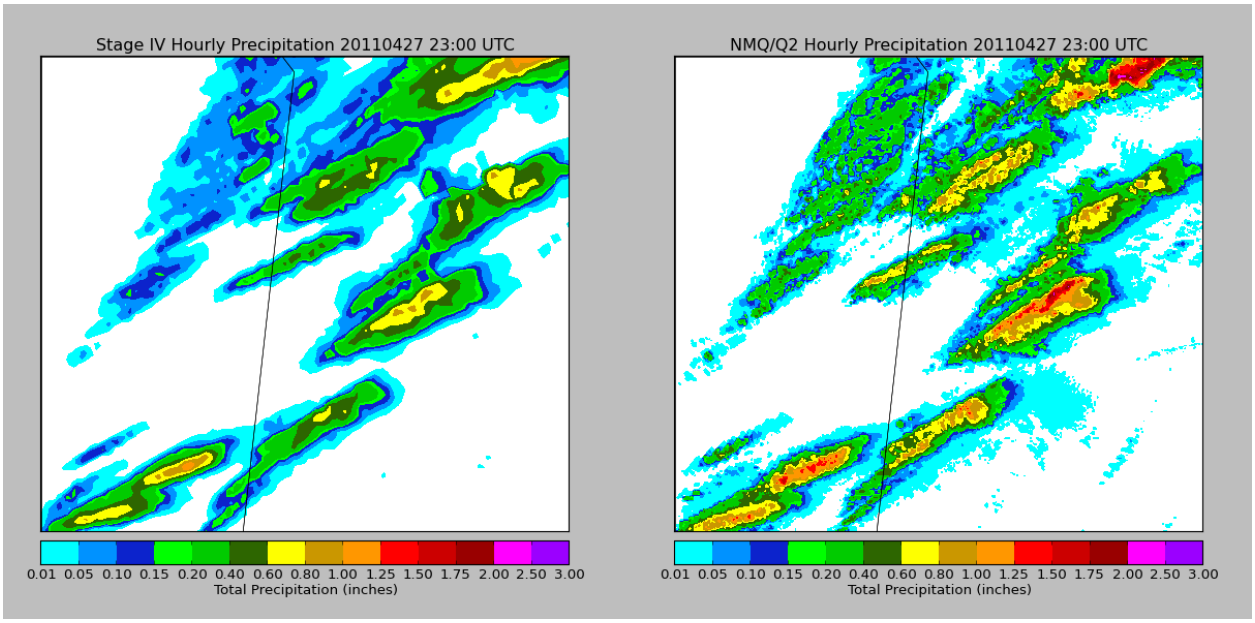


Figure 1: Comparison of spatial resolution in the operational Stage IV gridded precipitation product (left), and the NMQ/Q2 reanalysis product (right).

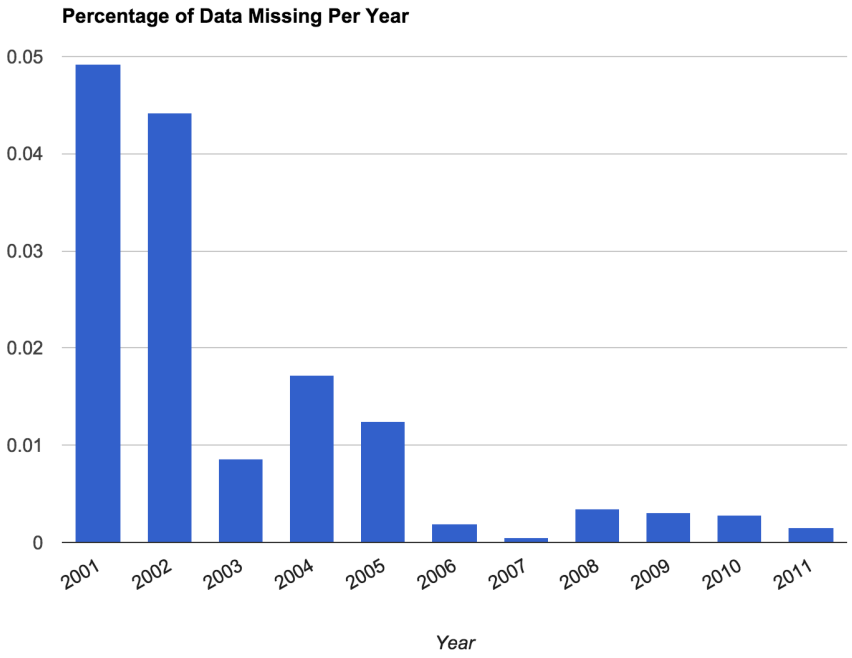


Figure 2: Fraction of sub-hourly data missing per year.

ACCOMPLISHMENTS

During Year 6, efforts began to introduce the completed dataset into the NCEI archive. Because of the large scale of the dataset, as well as the data center consolidation that took place during the year, progress has only recently begun on this front. A process is being finalized which will attempt to fill in the few remaining gaps in the record. At present, the record is 98.6% complete, with most gaps occurring during the first two years in the record (*Figure 2*).

In addition, the dataset is now being used in some applied science. The sub-hourly rain rates are being used in a study to investigate fatal traffic accidents, and also being integrated into the SERDP project.

PLANNED WORK

- Fill as many gaps as possible in the completed record
- Complete transition into NCEI archive

DELIVERABLES

- Archived dataset

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Ingest Archive System Agile Development Team

Task Leader	Lou Vasquez
Task Code	NC-CDR/SDS-20-NCICS-LV
NOAA Sponsor	Ed Kearns
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Provided modifications to NCEI ingest system in support of new center needs, system stability, and operational issues.

BACKGROUND

The NCEI Ingest Archive System is utilized at NCEI-NC for ingest and archive of weather and climate data from multiple internal and external sites. It is configurable to allow data to be pushed to the local system and to pull data from remote systems. The operational system archives up to 6.7 terabytes per day, packaged into as many as 39,000 archive-information packages. Ingested data is variously checked for soundness and packaged for archive prior to submission to the NCEI High-Performance Storage System (HPSS) or the NOAA Comprehensive Large-Array Storage System (CLASS) archive. The system in place at the beginning of this project was built over time to satisfy needs as they arose. The patchwork nature of the development without clear direction led to a system that, while functional, was rather fragile in nature.

A charter now exists to replace this outdated system with a significantly more modern solution. Following a rejuvenation/stabilization effort by the Data Stewardship Division agile software development team in the prior annual cycle, work performed this year has been geared towards limiting the scope of work on this system to allow focus on the up and coming Common Ingest system. All development has also used the Agile Scrum 'Epic Story' approach which joins smaller tasks into larger stories, to avoid team division and constant task switching which reduces the productivity of the development team.

Work discussed here was performed as part of a collaborative development team including Cooperative Institute and non-institutional contractor members. This approach benefits the Center by consolidating a wider knowledge base, more thorough code reviews, and the ability to complete larger projects in a shorter cycle.

ACCOMPLISHMENTS

While an effort was made to reduce development on the existing NCEI Ingest Archive System to maintain system stability and allow focus on new system development, it was necessary to perform changes while the new approach was undergoing load testing and modifications for deployment. These changes included Deterministic Archive, LDM Monitoring, HTTP Retrieval, FTPS Retrieval and Transmission, Server Pair Synchronization, Regression and Unit Tests.

A deterministic archive approach was required to prevent the re-sending of previously archived packages. Given the existing IAS polling approach to managing ingest, this was a regular occurrence. The provided solution placed hooks in the system to track packages deterministically, record their metadata

in persistent storage, and through comparison, detect and eliminate attempts by the system to re-archive.

Monitoring of the Local Data Manager (LDM) service was recommended following significant undetected failures of upstream data providers for National Weather Service (NWS) data. A monitoring solution was created which connects to the live LDM application event stream, tracks state to deduce processing metadata, and reports that through the existing IAS monitoring system *(Figure 1)*.

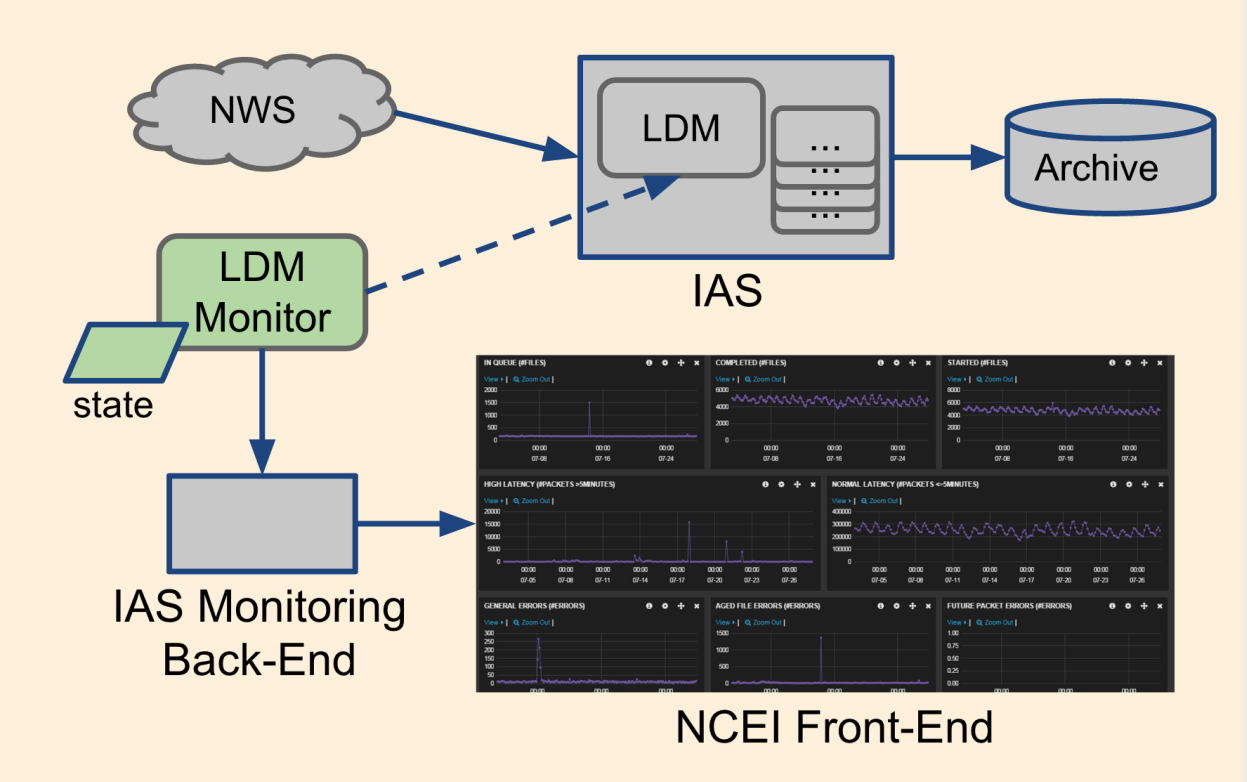


Figure 1: LDM Monitoring

The development team worked with National Centers for Environmental Prediction (NCEP) to provide recommendations, IAS modules, and feedback for transition of data provider service from File Transfer Protocol (FTP) to Hypertext Transfer Protocol (HTTP). For this task, software modules *(Figure 2 – light green)* were designed, and integrated into the IAS system to reuse the existing infrastructure, but allow for package discovery and retrieval via HTTP.

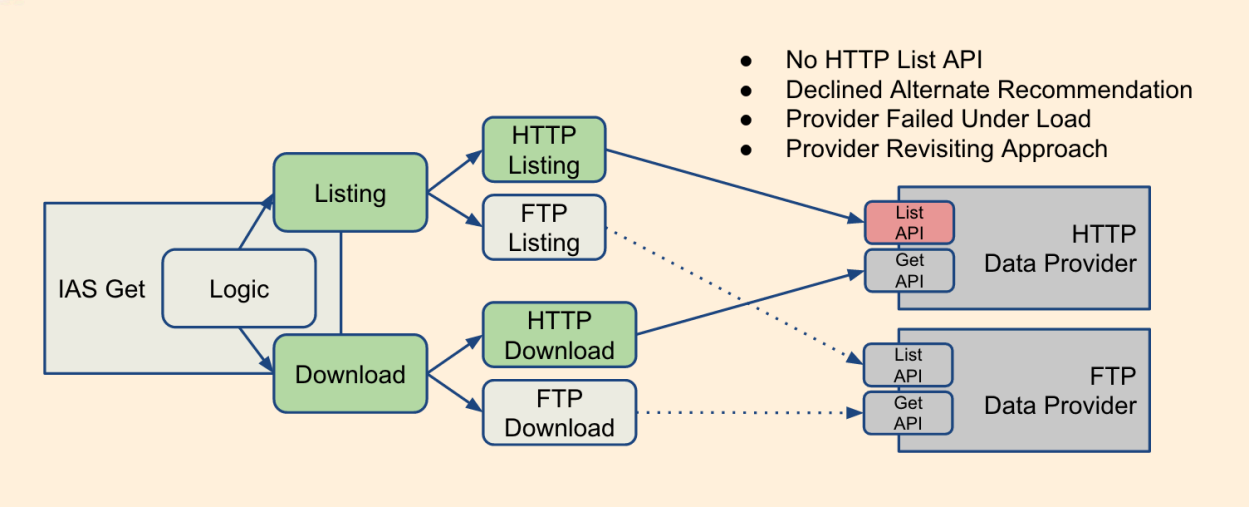


Figure 2: HTTP Retrieval

Following the approach implemented for HTTP retrieval, this team successfully designed, built, and deployed modules for FTP Secure (FTPS) data retrieval and transmission, minimal authentication services, and the required Python cross version libraries. This project supported the Comprehensive Large Array-data Stewardship (CLASS) transition from FTP to FTPS for increased security of data transfers. As one of the center's two archive endpoints this was crucial in supporting continued, secure archive.

The polling nature of the IAS system results in occasional file state inconsistencies as packages travel through the system, locking up the file synchronization system. As management of file synchronization by IAS is performed centrally, such a situation typically stops the flow of ingest of data on all IAS systems. The development team designed and modified this subcomponent of IAS to separate file synchronization based on the server pair involved. Such an approach allows any server file synchronization lockup to occur without impeding any unrelated server pair. In a failure scenario this means that system issues only affect the failing system, not the entire IAS.

Resilience of the IAS system to modification has been problematic due to the many interacting components and special case tuning it has obtained over its long lifespan. Deployment of new feature releases often introduces unexpected issues, an unacceptable side effect in a core center service. To mitigate this risk, a regression test was developed to verify end-to-end data flow for well-understood cases, and unit/deployment tests were developed to validate component operation.

The team provided significant support of the operational IAS system. This was important given its long lifecycle, code complexity, and legacy oriented components. System issues that impacted NCEI data ingest were not uncommon, and this list is not complete, but representative of the larger cases handled.

- A conversion of the Kibana graphical monitoring display to a new version was performed following a complete loss of data and configuration by the center.
- Packet header metadata parsing for Service Records Retention System (SRRS) were modified to automatically handle corrupt and missing segments.
- File system corruption, center tape library failure, extended network outage and repeated disk failures were supported through live ingest system management, debugging, and recovery.

- Repeated configuration file losses were handled with an overhaul of the installation process to exclude configuration metadata.
- Corruption of Next-Generation Radar (NEXRAD) data packages were investigated to manage data loss, determine cause, and propose stabilizing changes.
- Load tests were performed to confirm recommended replacement storage solution would meet IAS system demands.

PLANNED WORK

- Continued support of operational issues.
- Transition support to Common Ingest system.

DELIVERABLES

- Deterministic Archive Capability
- LDM Monitoring
- HTTP Retrieval
- FTPS Retrieval and Transmission
- Server Pair Synchronization
- Regression and Unit-Deploy Tests

PERFORMANCE METRICS

	FY16
# of new or improved products developed	6
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a 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, understanding, and access to climate information in various areas such as advancement in science, data, impacts, and engagement with users of the information. In addition, CICS-NC supports NCEI's strategic plan for engagement 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 or so, understanding changes in our climate has emerged as one of the most important areas of scientific endeavor. There is a rapidly increasing realization that profound changes in the Earth climate system are already occurring and the consequent impacts are already being experienced, either directly or indirectly. It is well recognized globally that there is a need to mitigate the effects of climate change by reducing greenhouse emissions. The magnitude and scale of climate change and its impacts are unpredictable, arguably underestimated, and certain to intensify as past emission levels impact the weather patterns today and into the future. As the discussion on reducing emissions shifts into mainstream awareness, considered as climate mitigation pathways, the question still remains on understanding the inevitable impacts that are already occurring and how we can strategically adapt to adverse conditions.

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

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

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

Research Activities in Advancing Climate Literacy, Outreach, Engagement, and Communications across Public, Private, and Academic Institutions

Task Leader	Jenny Dissen
Task Code	NC-CLOEC-05-NCICS
NOAA Sponsor	Tim Owen
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Climate Literacy, Education, Outreach, and Engagement
Contribution to NOAA goals (%)	Goal 1: 40%; Goal 2: 0%; Goal 3: 0%; Goal 4: 40%; Goal 5: 20%

Highlight: Climate literacy, outreach, engagement and communication are all important elements of the broader CICS mission. CICS-NC engages in the improvement of both formal and informal approaches to a variety of stakeholders and the public, ultimately to advance climate information and activities in adaptation and resilience. These activities are broadly grouped within K-12 Education, undergraduate and graduate education, business and industry engagement, non-profits and foundations, the general public and other interdisciplinary stakeholder groups.
Link to a research web page: https://www.cicsnc.org/events/

BACKGROUND

There is a need to advance climate science information for decision-makers as they explore practical and cost-effective approaches to leverage available resources. However, the provision of climate data for applications and decision support capabilities, which can factor into strategic, planning, and operational decisions, requires partnerships across public, private, and academic organization. CICS-NC engages in several meaningful climate literacy, engagement, and outreach activities for business and industry, academia, non-profits, and other stakeholders through various modes, which includes presentations, lectures, development science, and active engagement initiatives. These activities are often in conjunction with CICS-NC partners, which include the NCEI Information Services Division, NOAA's Climate Program Office, and other cooperative institutes.

Key topics or themes for discussion when engaging with the stakeholders include the following:

- Increase awareness and extend current research information in climate science, variability, and changes in the climate system
- Grow the understanding of how climate data is collected, observed, analyzed, and used for research purposes in academia and by legislative staff and the general public
- Increase awareness of climate datasets and products and discuss areas of uses and applications of these climate data products
- Increase business and industry sector understanding and use of climate data and information for their strategic planning and operations
- Demonstrate capacity building on the various impacts of climate change across public, private, and academic arenas

The various engagement 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 organizations. Coordination responsibilities internally are split with Jenny Dissen as the lead, with emphasis on literacy, engagement, and outreach; Theresa Stone

coordinating K-12 and community outreach events; and Thomas Maycock leading media, print, and inter-campus communications efforts.

ACCOMPLISHMENTS

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

- Providing operational support to the NOAA NCEI Center for Weather and Climate 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 general public

Outreach Activities in Education and General Public

CICS-NC conducted outreach activities across K-12, higher education, and the general public to advance environmental information and increase climate literacy throughout the year:

- 4/11/2015: NC Science Week Mountain Science Expo, NC Arboretum, Asheville, NC. Theresa Stone, Laura Stevens, Jared Rennie manned a booth with NCEI and showcased Cyclone Center and the Third National Climate Assessment.
- 4/17/2015: NC Science Week ICC Science and Technology Expo, Isothermal Community College, Spindale, NC. Theresa Stone and Scott Stevens gave presentations to elementary school groups demonstrating the Cyclone Center and the National Climate Assessment.
- 6/29/2015: Montreat College Myles of Science (middle school) summer camp, Purchase Knob, NC. Scott Stevens presented, "What is Climate Change, and How Do We Know It's Real?".
- 7/24/2015: Asheville Science Tavern, Asheville, NC. Jenn Runkle and Jim Fox presented, “Report on the Impacts of Climate Change on Human Health in the United States: At a Glance.”
- 9/12/2015: Immanuel Village retirement community, Omaha, NE. Tom Maycock gave a presentation on climate change and the National Climate Assessment.
- 11/3/2015: Mitchell County High School STEM Expo, Bakerville, NC. Scott Stevens presented, "Climate Change: What is it, and how do we know it's real?"
- 11/4/2015: Sand Hill-Venable Elementary School Career Day, Asheville, NC. Jared Rennie and Carl Schreck gave a presentation on Tropical Cyclones and other CICS-NC activities.
- 11/13/2015: Jenny Dissen served as a panelist at the Lenoir Rhyne University Sustainability Program Asheville Bioneers conference, addressing topics in “Adaptation and Resilience,” “Food, Race, and Justice,” and “Climate Change and Clean Energy.”
- 11/16/2015: Apple Valley Middle School, Hendersonville, NC. Jared Rennie discussed software coding and how it is used at NCEI on a video chat with science club students.
- 11/16/2015: Heather Glen at Ardenwoods, assisted living facility, Arden, NC. Tom Maycock gave a presentation on NOAA NCEI and a 2014 National Climate Assessment overview.
- 12/01/2015 - 12/04/2015: Hour of Code week, Isaac Dickson Elementary School, Asheville, NC. Jared Rennie and Jim Biard talked with students about how CICS-NC and software developers use code, and assisted students with exercises to help them learn about developing software.
- 12/11/2015: Bethel Middle School, Waynesville, NC. Jared Rennie gave a presentation on climatology and coding at NCICS and NCEI.
- 12/15/2015: In collaboration with NCEI, Jenny Dissen developed a poster presentation that portrays how NCEI’s data reaches the general public for the Dec. 2015 American Geophysical Union conference, presented by NCEI’s Information Services Division Chief, Tim Owen.

- 2/26/2016: Asheville Museum of Science (AMOS) Pub Science Friday, Asheville, NC. Jake Crouch (NCEI) gave a presentation on the 2015 State of the Climate.
- 3/8/2016: Bell Elementary School STEAM Festival, Asheville, NC. Theresa Stone hosted a CICS-NC booth focused on careers in climate science, the Cyclone Center, and climate literacy.
- 3/12/2016: Asheville Museum of Science Super Science Saturday, Asheville, NC. Theresa Stone and Laura Stevens provided Extreme Weather events and Climate Change information and hands-on activities including “Make your own rain gauge,” “Be a climate scientist with the Cyclone Center,” and "Extreme Weather arts and crafts.”
- 3/19/2016: UNC-Charlotte WeatherFest, Charlotte, NC. Theresa Stone hosted a booth focused on extreme weather and Cyclone Center demonstrations.

Figure 1 (L): Jared Rennie with students at Bethel Middle School in Waynesville, NC, Dec. 2015.
Figure 2 (R): Laura Stevens and Theresa Stone at the Mountain Science Expo, April 2015.

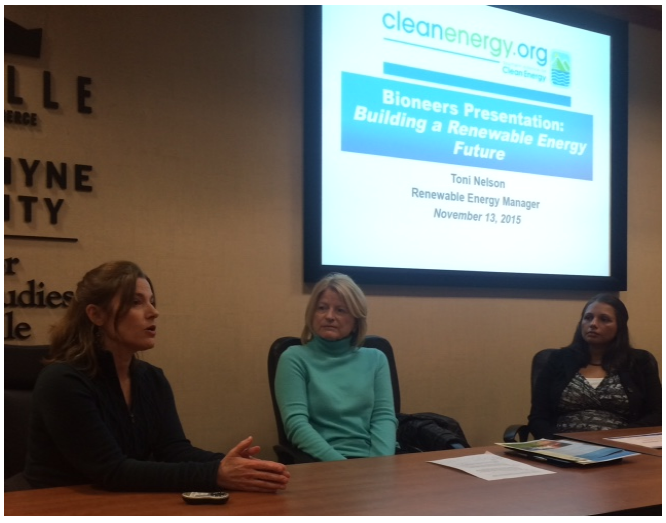


Figure 2 (L): Engagement panel discussion at the Asheville Bioneers Conference, Nov. 2015.
Figure 4: Asheville Science Museum Super Science Saturday weather arts and crafts, March 2016.

Engaging with Business and Industry Sectors

Jenny Dissen partnered with Phil Hanser of the Brattle Group to present at the National Association of Regulatory Utility Commissioners (NARUC) Summer Meeting in July 2015 to understand requirements for environmental information, particularly related to their upcoming survey state plans for climate change resiliency and the potential impacts to the energy industry.

CICS-NC has created an innovative program called the Executive Forum on Business and Climate (EFBC), where academic researchers, business leaders, and federal science experts examine use of environmental information for business decisions. Working with a team across U.S. EPA, NIH, Research Triangle Foundation (RTF), and NOAA Regional Climate Services, Dissen and CICS-NC are currently co-hosting a webinar series on impacts of a changing climate and opportunities in adaptation and resilience with the RTF that will culminate in the next Executive Forum on Business and Climate (EFBC) focused on resiliency and adaptation for RTF's member companies, including BASF, Biogen, Cree, IBM, NetApp, RTI, and others.

Otis Brown and Jenny Dissen currently serve on the Executive Advisory Council (EAC) for the Utility Analytics Institute, a membership-based group for energy industry professionals that discusses strategic analytics issues and promote leading practices of innovation to transform the energy business. Otis Brown, Ken Kunkel, and Jenny Dissen presented at the Fall 2015 EAC meeting at Southern Company Headquarters on climate risks and impacts, and attended the Utility Analytics Summit (New Orleans, October 2015) to further build collaborations with industry partners on uses and applications of environmental data.

Dissen continues to build engagement capacity in the energy sector by serving on the NOAA Energy Team and being involved in the World Meteorological Society Global Framework for Climate Services' new interest in expanding into the energy sector.

Engagement with private sector companies continues with Acclimatise, where both organizations collaborate to pursue research opportunities in climate adaptation practices. Dissen worked with Acclimatise to submit an application to the Global Facility for Disaster Reduction and Recovery (GFDRR) Challenge Fund to promote innovative technologically viable solutions to global issues such as landslides in Northern India.

Building Engagement and Information Services Activities at NCEI

Dissen supports, leads, and advises various strategic and operational customer and stakeholder engagement activities with the NCEI Center for Weather and Climate Information Services Division and the NCEI Data Information Services, Communications, and Outreach Team (DISCO) team. Dissen supports the Division Chief in working across organizational boundaries to formulate an integrated NCEI framework for improved customer service and user engagement, specifically to:

- Deliver Information: Expand and enrich use of NCEI's environmental information
- Incorporate Requirements: Understand user needs for NCEI's environmental information and translate them into requirements
- Partner with Providers: Strengthen networks for developing and delivering NCEI's products and services

Dissen helped in developing a sector prioritization activity that examines and utilizes the U.S. Census Bureau of Economic Analysis sectors for the U.S. In mapping various NCEI activities against the Census Bureau sectors, information services can be catalogued with economic information from the bureau and

merged with environmental information about the sector. The team developed a sector prioritization activity for the following NCEI calendar years where work efforts would map the sector prioritizations.

- **Prioritized Sectors for FY 2016:**

PRIORTIZED SECTORS	ACTIVITY	REGION	TIMING
Energy	• Energy Resilience Workshop Workshop • Utility Analytics Summit* • NOAA Energy Team • Industry sector engagement continues (Jenny Dissen)	• National / South • National	• January 2016 • April 2016 • FY 2016 - 2017
Agriculture / Forestry / Fishing / Hunting	• USDA, High Plains Regional Climate Center (HPRCC) and NOAA Regional Climate Services Meetings (Doug Kluck) • Ongoing APGA collaboration (Tami Houston)	• Western • Eastern • National	• March 2016 • March 2016 • Ongoing
Transportation / Infrastructure	• NC Department of Transportation Summer Workshop (Committee on Waste Management and Resource Efficiency) • ***Developing engagement options for FY17***	• National	• July 2016 • Focus for 2017
Government / Interagency	• NWS Climate Services Meeting • Ongoing Tribal Engagement • Department of Energy Partnership for Resilience • ***New opportunity with US EDA (in discussion)***	• National	• May 2016 • FY 2017 • Ongoing • Ongoing
Healthcare	• Partnership established with NIH / NIEHS • Working with NCA Climate and Health Team • Regional Meeting on Climate and Dengue Forecasting • ***Developing engagement options for FY17***	• State/National • National • International	• Ongoing • Ongoing • January 2016
Insurance **Finance**	• NOAA's Strategic reinsurance industry engagement project (Adam Smith) • ***New - developing engagement options for FY 2017***	• National • ***TBD***	• Ongoing • ***FY 2017***

Figure 5: NCEI engagement activities for FY 2016 by sectors

Dissen works on an interdisciplinary NCEI team to develop a strategy, roadmap, and an implementation approach to capturing customer engagement information, a multi-phase technical solution approach that will catalog customer information, requests, and feedback from customers.

Otis Brown, Jessica Matthews, and Dissen were core team members in the planning and hosting of the 2015 Climate Data Record Program's 2015 Annual PI meeting, in Asheville, NC. The meeting focused on sharing the latest information from NOAA's CDR Program, best practices, and new processes, and included a featured discussion on collaboration with other U.S. Government and international agency program leads.
(For more information, please visit https://www.ncdc.noaa.gov/cdr).

Dissen was also involved in designing and hosting of the NCEI executive forum discussion "Moving from Environmental Data to Resilience" on January 14, 2016, in New Orleans, Louisiana.
Key outcomes from the forum included:

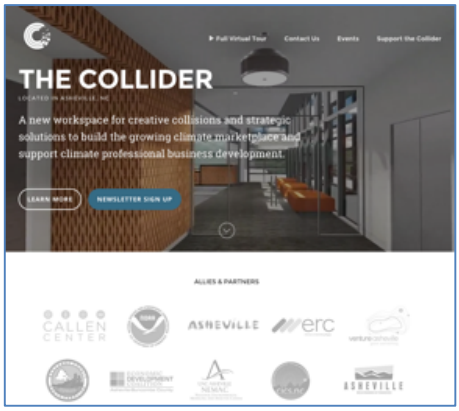
- A desire on the part of industry to continue engagement with NOAA on existing data opportunities and future data needs as industry plans evolve
- The need for accurate, reliable, and timely information and case studies of environmental information use from a known, reliable source such as NCEI
- The need to promote environmental information within the energy industry, including the translation and interpretation of climate data and events, and simplified access to graphics.

(For more information, please visit https://www.cicsnc.org/events/energy-sector-resilience).

Figure 6: Executive forum industry panel discussion. (L – R) Moderator: John Firth (Acclimatise), Panel Members: Cheryl Maleteich (ComEd), Aaron Strickland (Georgia Power/Southern Company), Kent Mathis (JEA), and Phil Hanser (The Brattle Group).

Supporting Innovation and Economic Development

Dissen collaborates with the Economic Development Coalition for Asheville-Buncombe County Coalition (Asheville EDC) in promoting activities in climate entrepreneurship and services, helping to grow STEM skills and capabilities, particularly in climate science. CICS-NC supported the sponsorship of the 2016 AMS Asheville information booth, which showcased climate activities and companies advancing climate services in Western North Carolina.



CICS-NC also supports Asheville Buncombe Sustainable Community Initiatives (ABSCI), a NC501(c)3 with a mission to support and catalyze climate services activities. ABSCI successfully launched The Collider, a consortium of public–private partners focused on climate adaptation and resiliency of communities and businesses in Asheville, North Carolina. The Collider project includes a collaborative work and event space in downtown Asheville. Collider partnerships encourage the development and application of adaptation tools, exploit research data and information developed by the public sector, facilitate the growth of private sector companies, and highlight areas of needed research and development in the growing field of climate services and technology.

PLANNED WORK

- Continue to increase K-12 outreach engagement and events, including participation in the NC Mountain Science Expo and the Buncombe County “Celebrate STEM Expo” events in April 2016.
- Host future RTF webinar discussions, and the Executive Forum on Business and Climate to engage with companies located in RTP
- Design and support the NCEI annual engagement discussion during the 2017 AMS conference as well as the 2016 AMS Summer Community Meeting

- Support the implementation activities of NCEI's engagement strategy
- Support activities of the new Partnership for Resilience

PUBLICATIONS

- Carl J. Schreck III, Stephen Bennett, Jason M. Cordeira, Jake Crouch, Jenny Dissen, Andrea L. Lang, David Margolin, Adam O'Shay, Jared Rennie, Thomas Ian Schneider, and Michael J. Ventrice, 2015: Natural Gas Prices and the Extreme Winters of 2011/12 and 2013/14: Causes, Indicators, and Interactions. Bull. Amer. Meteor. Soc., 96, 1879–1894. doi: http://dx.doi.org/10.1175/BAMS-D-13-00237.1

PRESENTATIONS

- Brewer, Michael. "NCEI User Engagement Strategy." Climate Data Record Annual PI Meeting, August 2015 (input and co-author as part of the NCEI Engagement Team)
- American Association of State Climatologists, 2015 Annual Meeting (input and co-author as part of NCEI Engagement Team)
- 2015 NARUC Summer Meeting (presentation in collaboration with Phil Hanser)
- Brown, O., Kunkel, K., Dissen, J. "Opportunities in Climate Analytics for Utilities." Utility Analytics Executive Advisory Council, August 2015
- Brown, O., Kunkel, K., Dissen, J. "Storm Data for Utilities." Utility Analytics Storm Analytics Working Group Presentation, September 2015
- (Panel Discussion Presentation) Dissen, J. "Panel Discussion: Climate Change and Clean Energy." Asheville Bioneers Conference, Lenoir-Rhyne University Center for Graduate Studies of Asheville, November 2015

OTHER

- Jenny Dissen and Otis Brown supported various activities and in-kind support in the development of the new Asheville Museum of Science.
- As a co-chair of the AMS Committee on Effective Communication of Weather and Climate Information, Dissen led a panel discussion during the January 2016 Annual AMS Conference titled "Communicating the State of Understanding of Climate and Climate Change."
- Dissen supports internal CICS-NC interdisciplinary activities including the National Climate Assessment evaluation proposal, an Eastern Carolina University consortium project proposal in documenting rip tides, and the evaluation of the NCEI website proposals.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	4
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Communications

Task Leader	Tom Maycock
Task Code	NC-CLOEC-02-NCICS-TM
NOAA Sponsor	Tim Owen
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 0%
Main CICS Research Topic	Climate Literacy, Outreach, Engagement, and Communications
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

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

BACKGROUND

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

ACCOMPLISHMENTS

- Wrote and distributed the third edition of CICS-NC's newsletter, *Trends*. The template for the newsletter was redesigned to incorporate strong NC State University branding.
- Developed a new brochure describing the Institute and its activities.
- Wrote and posted 13 press releases/website stories on new scientific papers and other activities. Coordinated with NCEI staff to provide content for additional web stories related to research work involving collaboration between CICS-NC and NCEI scientists.
- Contributed to a paper on scientific data stewardship which has been accepted for publication.
- Expanded CICS-NC Twitter and Facebook audiences.
- Provided feedback on CICS-NC staff presentations.
- Initiated project to redesign the CICS-NC website with NC State branding and improved navigation. Completion expected in May-June 2016.
- Provided scientific copyediting services in support of the *Explaining Extreme Events of 2014* report, produced by NCEI and published in the *Bulletin of the American Meteorological Society* in late 2015.

PLANNED WORK

- Complete CICS-NC website redesign and branding project
- Produce two issues of *Trends* newsletter
- Continue to highlight and promote work done by CICS-NC and the Institute as a whole
- Build reach of Facebook and Twitter accounts
- Provide scientific editorial and communications support to NCEI.

PUBLICATIONS

- Peng, G., Nancy A. Ritchey, Kenneth S. Casey, Edward J. Kearns, Jeffrey L. Privette, Drew Saunders, Philip Jones, T. Maycock, and Steve Ansari, 2016: Scientific Stewardship in the Open

Data and Big Data Era - Roles and Responsibilities of Stewards and Other Major Product Stakeholders. Accepted by *D.-Lib Magazine.*

PRODUCTS

- One issue of CICS-NC Trends newsletter
- New CICS-NC brochure
- Eight press releases and five web stories
- Copyediting of several chapters of *Explaining Extreme Events* report

PERFORMANCE METRICS

	FY16
# of new or improved products developed (please identify below the table)	16
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Products count includes web stories, press releases, newsletter, brochure, and contribution to *Explaining Extreme Events* report.

Surface Observing Networks

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

The National Centers for Environmental Information (NCEI) along with NOAA partner institutions lead two new 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 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 has built a task group of research scientists supporting various climate observing network initiatives and providing relevant scientific expertise.

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

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

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

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

Evaluation of U.S. Climate Reference Network (USCRN) Soil Moisture and Temperature Observations

Task Leader	Jesse Bell
Task Code	NC-SON-01-NCICS-JB
NOAA Sponsor	Howard Diamond
NOAA Office	NCEI/USCRN
Contribution to CICS Themes (%)	Theme 1: 25%; Theme 2: 50%; Theme 3: 25%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

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

BACKGROUND

The U.S. 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 accurately estimating drought, soil observations were added to the list of USCRN instrumentation. In the summer of 2011, the USCRN team completed the installation of all soil observational probes in the contiguous United States. Each station, along with traditional measurements of surface air temperature, precipitation, infrared ground surface temperature, wind speed, and solar radiation, now also transmits relative humidity, soil temperature, and soil moisture measurements every hour. The data is maintained and stored at NCEI, while installation and maintenance is performed by NOAA's Atmospheric Turbulence and Diffusion Division (ATDD). In order to improve the ability of the network, multiple projects were started to analyze soil moisture variability and change. 1). An analysis of the 2012 drought using soil moisture observations from 2011 – 2013. 2). Spatial representativeness of USCRN soil observations using a dense temporary network.

ACCOMPLISHMENTS

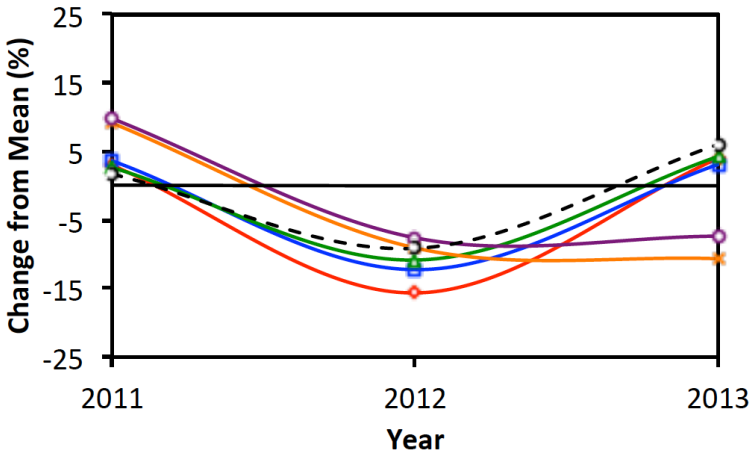


Figure 1: National soil moisture signal for each soil depth of the USCRN soil observations during the summers of 2011, 2012, and 2013. The top three levels (5cm, 10cm, 20cm) experienced full recovery from the 2012 drought, but the bottom two levels (50cm, 100cm) never completely recovered.

USCRN soil observations were fully installed in 2011, which does not allow for much time to perform long-term analysis. However, dramatic changes in soil moisture conditions occurred over the first three years after installation. In 2011, many of the stations in the Midwestern region of the United States experience flooding and saturated soil conditions. The following year there was a severe drought that covered much of the United States. These yearly changes allow for a national analysis of soil moisture. Soil moisture was analyzed on a monthly basis for each station in the CONUS for 2011–2013. Analysis was then performed to determine seasonal and regional changes in soil moisture for the period of record. USCRN soil observations showed a decreasing national soil moisture signal. The results of individual climate regions varied based on local conditions. These results will be useful for developing a drought-monitoring index for USCRN.

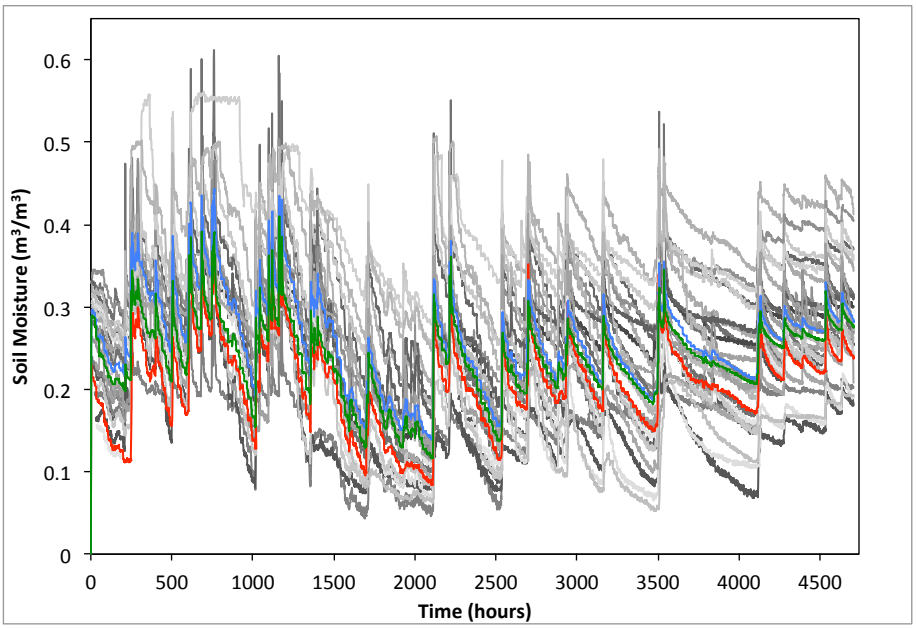


Figure 2: Mean soil moisture variability of the temporary network at Millbrook, NY. Red line is the USCRN value, blue line is the 9km average, and green line is the 3km average. The various shades of grey represent the individual probe values for the temporary network.

To assist with drought analysis and improve satellite calibration activities, two temporary networks were installed around the USCRN stations at Crossville, TN, and Millbrook, NY. Each temporary network was installed around the USCRN station in 3km grids to represent the minimum spatial extent of the NASA SMAP satellite. The Millbrook site was also expanded to a 9km grid to represent the larger satellite product of SMAP. Each network consists of 15 to 25 stations that were randomly installed in various habitats to represent the nature soil variability around the stations. Both networks were installed for the growing season of 2013 and remained in the ground for the fall of 2013. This amount of time allowed for the sensors to catch the entire wetting and drying cycle of the soil for that season. Analysis was then performed to determine the spatial variability and change between the temporary network and the permanent USCRN station. Soil samples were also collected at each USCRN station to determine the gravimetric soil moisture and bulk density of the soil near the temporary station. This research provides a tool for determining the spatial representativeness of a permanent station to the surrounding area for improved calibration and research activities for SMAP.

PLANNED WORK

- Continue to evaluate drought indices for metric for USCRN
- Continue to improve USCRN soil observation quality control
- Finish manuscript for the Millbrook and Crossville
- Evaluate ways to continue expand the analysis of the spatial study

PUBLICATIONS

- Bell, J. E., Leeper, R. D., Palecki, M. A., Coopersmith, E., Wilson, T., Bilotta, R., & Embler, S. (2015). Evaluation of the 2012 Drought with a Newly Established National Soil Monitoring Network. Vadose Zone Journal.
- Coopersmith, E.J., Cosh, M.H., Bell, J.E., & Crow, W. (2015). Multi-profile analysis of soil moisture within the climate reference network. Vadose Zone Journal

DELIVERABLES

- Instrumentation development for scaling and calibration

PRESENTATIONS

- Bell, J.E. Monitoring Drought with a National Soil Monitoring Network. AMS Annual Meeting, New Orleans. January 2016.
- Bell, J.E. Evaluation of the California Drought with USCRN Soil Observations. Irvine, CA. AGU Chapman Conference on California Drought. April 2015

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration for operations use	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Expansion and Development of U.S. Climate Reference Network (USCRN) Soil Moisture Observations

Task Leader	Jesse Bell
Task Code	NC-SON-02-NCICS-JB
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 25%; Theme 3: 25%
Main CICS Research Topic	Land and Hydrology
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlights: This research involves modeling of the USCRN soil observations for developing a historical soil moisture record for improved drought monitoring.

BACKGROUND

The United States Climate Reference Network (USCRN) recently added soil instrumentation provides an opportunity to evaluate national signals for changes in soil climate. The main purpose for adding the soil instrumentation was to improve drought-monitoring capabilities in the United States as well as provide soil moisture and temperature observations to assist with validation of climate models and remotely sensed measurements. As drought severity may increase in the future, there is an increased need for the near real-time drought monitoring capabilities that USCRN observations can provide. Because the addition of soil observations to the network was only recently completed (August 2011), there has been limited opportunity to use these measurements for an evaluation of long-term changes in drought conditions or soil climate. However, modeling can be used to extend the record for any station that has historical precipitation record. By modeling the changes in historical soil moisture, the artificial record can be used to develop drought indices.

ACCOMPLISHMENTS

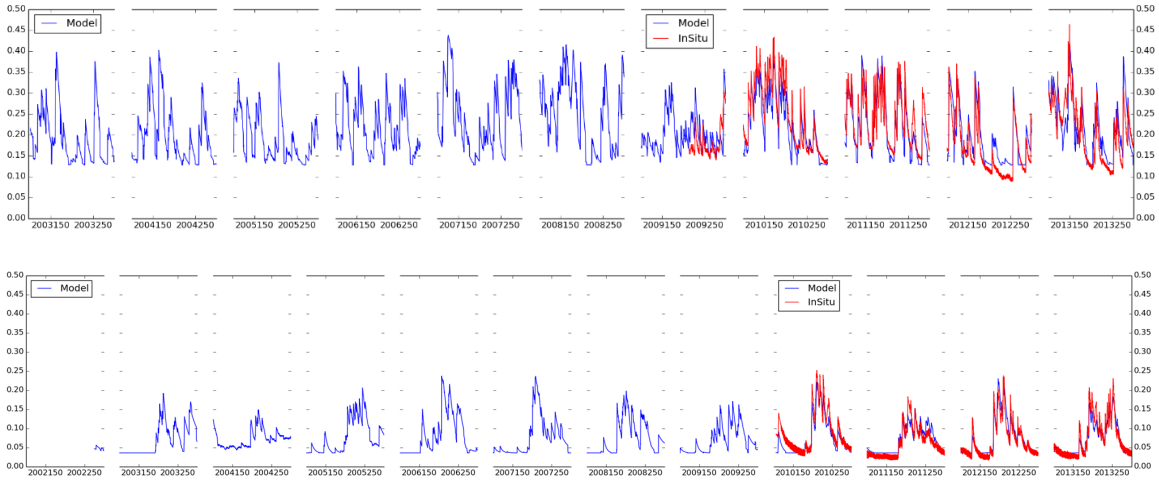


Figure 1 (top): USCRN #1003, Nebraska. In Situ (2009-2013), Historical Extension (2003-2009)
Figure 1 (bottom): USCRN #1010, Arizona. In Situ (2010-2013), Historical Extension (2002-2009)

Soil moisture estimates are valuable for hydrologic modeling, drought prediction and management, climate change analysis, and agricultural decision support. However, in situ measurements of soil moisture have only become available within the past few decades with additional sensors being installed each year. Comparing newer in situ resources with older resources, previously required a period of

cross-calibration, often requiring several years of data collection. One new technique to improve this issue is to develop a methodology to extend the in situ record backwards in time using a soil moisture model and ancillary available data sets. This study will extend the soil moisture record of the U.S. Climate Reference Network (USCRN) by calibrating a precipitation-driven model during the most recent few years when soil moisture data are available and applying that model backwards temporally in years where precipitation data are available and soil moisture data are not. This approach is validated by applying the technique to the Soil Climate Analysis Network (SCAN) where the same model is calibrated in recent years and validated during preceding years at locations with a sufficiently long soil moisture record. Results suggest that if two or three years of concurrent precipitation and soil moisture time series data are available, the calibrated model's parameters can be applied historically to produce RMSE values less than 0.033 m^3/m^3. With this approach, in locations characterized by in situ sensors with short or intermittent data records, a model can now be used to fill the relevant gaps and improve the historical record as well.

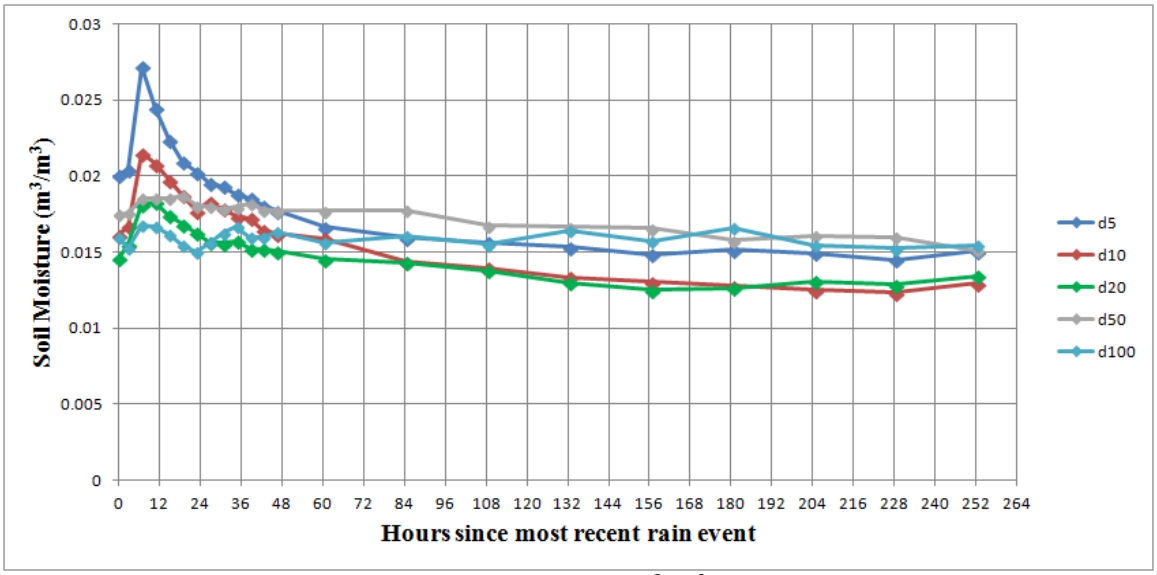


Figure 2: Random errors calculated by triple-collocation (m^3/m^3) as a function of hours after precipitation events at 5cm 10cm, 20cm, 50cm, and 100cm depths

Soil moisture estimates are crucial for hydrologic modeling and agricultural decision-support efforts. These measurements are also pivotal for long-term inquiries regarding the impacts of climate change and the resulting droughts over large spatial and temporal scales. However, it has only been the past decade during which ground-based soil moisture sensory resources have become sufficient to tackle these important challenges. Despite this progress, random and systematic errors remain in ground-based soil moisture observations. Such errors must be quantified (and/or adequately minimized) before such observations can be used with full confidence. In response, this paper calibrates and analyzes USCRN profile estimates at each of three sensors collocated at each USCRN location. With each USCRN location consisting of three independent, hydroprobe measurements, triple collocation analysis of these sensory triads reveals the random error associated with this particular sensing technology in each individual location. This allows a quantification of the accuracy of these individual profiles, the random errors associated with these measurements in different geographic locations, and offers the potential for more adept quality control procedures in near real-time. Averaged over USCRN gauge locations nationally, this random error is determined to be approximately 0.01 m^3/m^3.

PLANNED WORK

- Evaluate the modeled historical soil moisture record for drought monitoring purposes.
- Continue developing soil moisture analysis for SMAP

PUBLICATIONS

- Coopersmith, E. J., Bell, J. E., & Cosh, M. H. (2015). Extending the soil moisture data record of the US Climate Reference Network (USCRN) and Soil Climate Analysis Network (SCAN). *Advances in Water Resources*, *79*, 80-90.
- Coopersmith, E.J., Cosh, M.H., Bindlish, R., Bell, J.E. (2015). Comparing AMSR-E soil moisture estimates to the extended record of the U.S. Climate Reference Network (USCRN). *Advances in Water Resources*, Advances in Water Resources, 85, 79-85.
- Coopersmith, E. J., Cosh, M. H., Bell, J. E., & Crow, W. T. (2016). Multi-Profile Analysis of Soil Moisture within the US Climate Reference Network.*Vadose Zone Journal*, *15*(1).

DELIVERABLES

- Extended soil moisture record for improved drought monitoring.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	3
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Climate Monitoring and Research Support for NOAA's Air Resources Laboratory (ARL) Atmospheric Turbulence and Diffusion Division (ATDD)

Task Leader	Mark E. Hall
Task Code	NC-SON-03-ORAU
NOAA Sponsor	Jay Lawrimore
NOAA Office	NCEI/USCRN/ATDD
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%.
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Additional USCRN stations were installed in Alaska, continuing expansion of the Alaska Climate Reference Network (ACRN).

BACKGROUND

Atmospheric Turbulence and Diffusion Division (ATDD) is one of three field divisions of the NOAA's Air Resources Laboratory (ARL). Federal and Oak Ridge Associated Universities (ORAU) contractor personnel work closely with NOAA to perform lower atmosphere research in the areas of air quality, contaminant dispersion, and climate. ATDD is also responsible for the installation and maintenance of the infrastructure and instruments used to gather data for research.

ATDD's objectives are to:

- Develop better methods for predicting transport and dispersion of air pollutants.
- Improve modeling of air-surface exchange of water, energy, and carbon so that their effect on the earth's climate may be better understood.
- Make high-quality measurements in support of these efforts toward increased understanding.
- Install and maintain a long-term, reliable system of uniform instruments providing trustworthy data used in monitoring climate across the United States.

ATDD's staff has historically consisted of NOAA Federal civil service and contractor personnel from ORAU. The ORAU contractors are dedicated 100% to supporting ATDD's mission, working toward goals set by the ATDD Director, and are co-located with the Federal personnel.

One of the primary foci for the ATDD/ORAU partnership has been sustaining NOAA's climate observing systems and developing research efforts that will enhance our understanding of a changing environment in the different ecosystems within the United States.

ACCOMPLISHMENTS

Two installations were done in Alaska bringing the total to 18 broadcasting sites. The site names are AK Denali 27 N located in the Denali National Park near the Wonder Lake Campground and AK Selawik 28 E in the Selawik National Wildlife Refuge.

Both stations are low power, dual system sites (redundancies include 2 transmitters, 2 data loggers, 6 temperature sensors – 3 each in 2 aspirated shields, 2 wetness sensors and 2 infrared surface temperature sensors. The sites are solar powered, supplemented by a methanol fuel cell during the winter months.

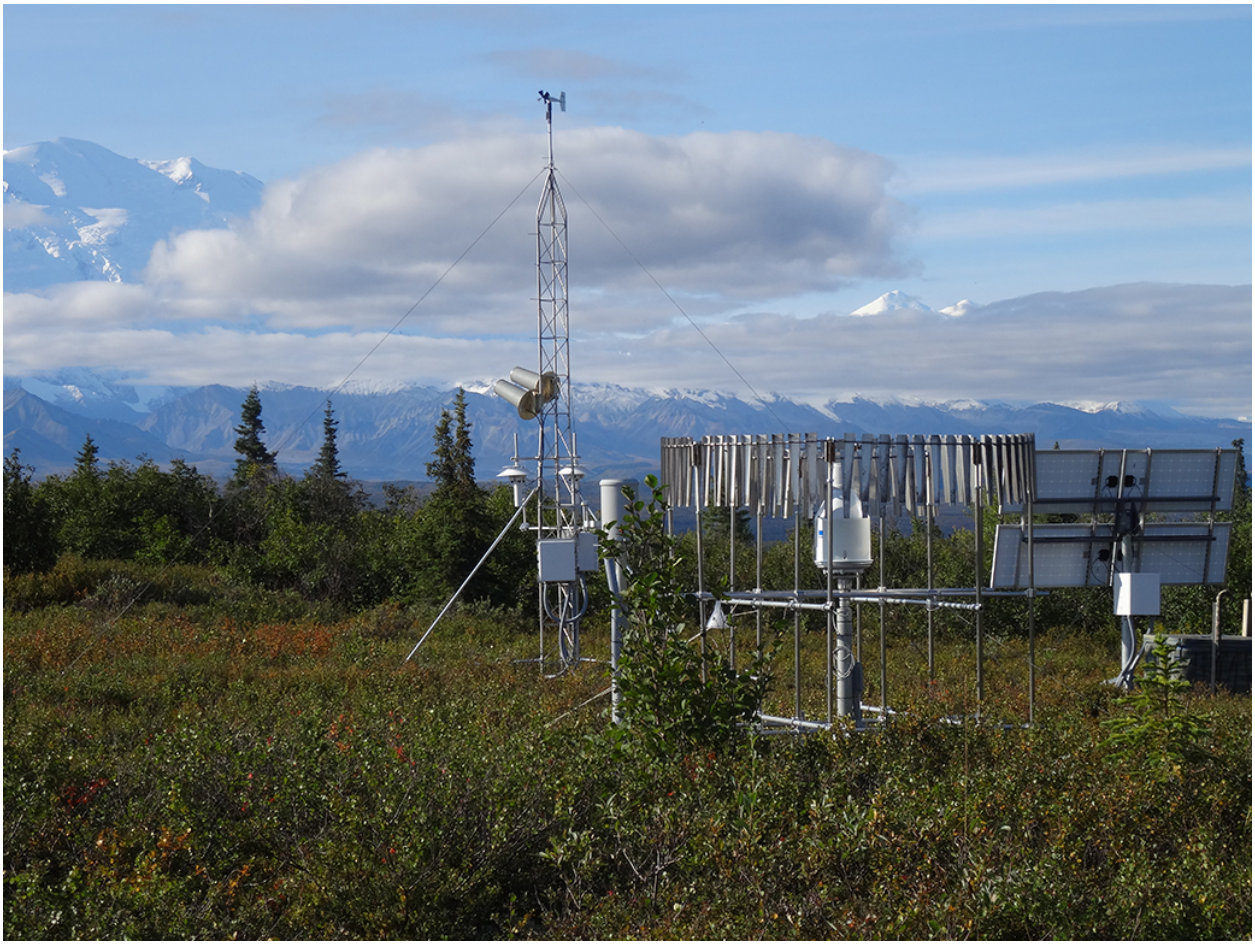


Figure 1: Alaska CRN Site in Denali National Park.

Completed 16 annual maintenance visits to the previously installed sites and surveyed 5 additional sites for future installations.

The ATDD DJI S-1000 octocopter, a small Unmanned Aerial System platform, has been flown 5.5 hours since its first flight October 13, 2015. It is being used in support of the VORTEX SE research program (http://www.arl.noaa.gov/sUAS_CIstudy.php). Instruments on-board measure the spatial variability of both the thermal infrared and visible wavelengths reflected from the Earth's surface.

Figure 2: DJI S-1000 is 41" diagonally and weighs 9.25 lbs.

PLANNED WORK

When completed, the Alaska USCRN network will have a total of 29 sites. Pending the completion of the site license agreement, 1 additional site will be installed in 2016. This site is projected to be near the town of Yakutat in the Tungass National Forest. Site maintenance will be performed on the 18 existing sites in Alaska.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Development and verification of U.S. Climate Reference Network (USCRN) Quality Assurance Method

Task Leader	Ronald Leeper
Task Code	NC-SON-04-NCICS-RL
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 5%; Theme 2: 40%; Theme 3: 55%
Main CICS Research Topic	Surface Observing Network
Contribution to NOAA Goals (%)	Goal 1: 20%; Goal 2: 80%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Given the acceptance of the new revised precipitation algorithm by the USCRN configuration management and NCEI science council, it was deployed operationally this year. In addition, Leeper worked closely with the National Ecological Observatory Network to help them adopt a variant of this precipitation algorithm for their quality control needs.

BACKGROUND

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

ACCOMPLISHMENTS

The revised precipitation algorithm was deployed in October 2015 following approval from USCRN configuration management and NCEI's science council. With the deployment of the new algorithm, a calculation log capturing intermediate steps of the algorithm is now available. The log was used to identify suspicious precipitation events (*Figure 1*) and apply manual exceptions to remove suboptimal gauge data for several events at 12 stations. These efforts will continue into 2016 to resolve issues before using the help of a Hollings Scholar to continue analyzing network precipitation extremes. Leeper also worked closely with Derek Smith of NEON's fundamental instrument unit (FIU) to develop a working version of USCRN's OAP for their system, which is currently under review.

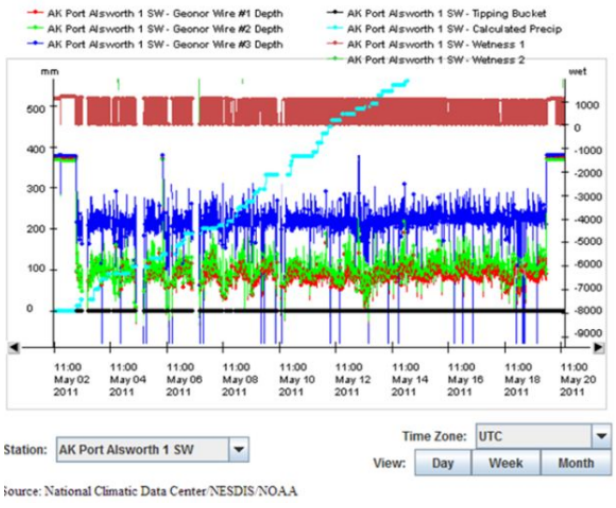


Figure 2: An example of sub-optimal gauge data at Port Alsworth, AK showing observations from May 2nd to May 20th 2011 for Geonor gauge depths from wire 1 (red-bottom), wire 2 (light green), and wire 3 (dark blue), wetness sensor channel 1 resistance (light red-top), accumulated tipping bucket precipitation (black) and OAP 1.0 accumulated precipitation (light blue).

PLANNED WORK

- Continue to identify and exception out suspicious gauge data
- Analyze USCRN precipitation extremes with Hollings Scholar
- Develop routines to evaluate the quality of the collocated disdrometer used at USCRN stations to detect wetness

DELIVERABLES

- Analysis and documentation of network precipitation extremes
- Improved quality of USCRN precipitation data through manual QC

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

The deployment of the revised precipitation algorithm with NOAA's guidance has greatly improved the network's precipitation product and is the final step to reaching the transition from research to operations.

Development of an Extra-Tropical Cyclone Track dataset

Task Leader	Ronald Leeper
Task Code	NC-SON-05-NCICS-RL
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 40%; Theme 2: 0%; Theme 3: 60%
Main CICS Research Topic	Climate Research, Data Assimilation, and Modeling
Contribution to NOAA Goals (%)	Goal 1: 80%; Goal 2: 20%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Extra-tropical cyclone (ETC) tracks were generated from a 56-member ensemble of the 20th century reanalysis. Ensemble mean and member ETC tracks were placed within a database for public dissemination. In addition, ETC track densities since 1950 were analyzed by MJO phase, which revealed tracks favoring heavier Northeast snowfall were more likely in MJO phases 7-8.

BACKGROUND

This project draws upon earlier work of Scott Applequist, who created extra-tropical cyclone tracks for each member of the 20th Century Reanalysis ensemble separately by linking the location of low-pressure centers in time. The purpose of this study was to create spatially average ensemble mean tracks from the 20th Century Reanalysis and provide this dataset to the public through a web-based application. The goal was to foster research using the ETC dataset since ETCs are responsible for much of the weather conditions outside of the tropics.

ACCOMPLISHMENTS

Extra-tropical cyclone tracks were both associated in time and space and spatially averaged from 1878 to 2011. Only tracks during the winter season November to March were associated, as this is when ETCs are generally stronger and well modeled. Spatially averaged ensemble mean and members tracks were placed within a database and a web-based geographic information system (GIS) application created for public access to this dataset. Users can explore the track information from the website and download the track dataset in multiple formats (*Figure 1*). In addition, ETCs since 1950 were analyzed to create track density anomalies by phases of the Madden Julian Oscillation (MJO). This collaborative effort revealed that MJO phases 7 and 8 tended to result in higher track anomalies similar to Nor'Easter type tracks, which can bring heavy snowstorms to the Northeast. Phases 4-5 tended to result in lower anomalies for Nor'Easter type tracks.

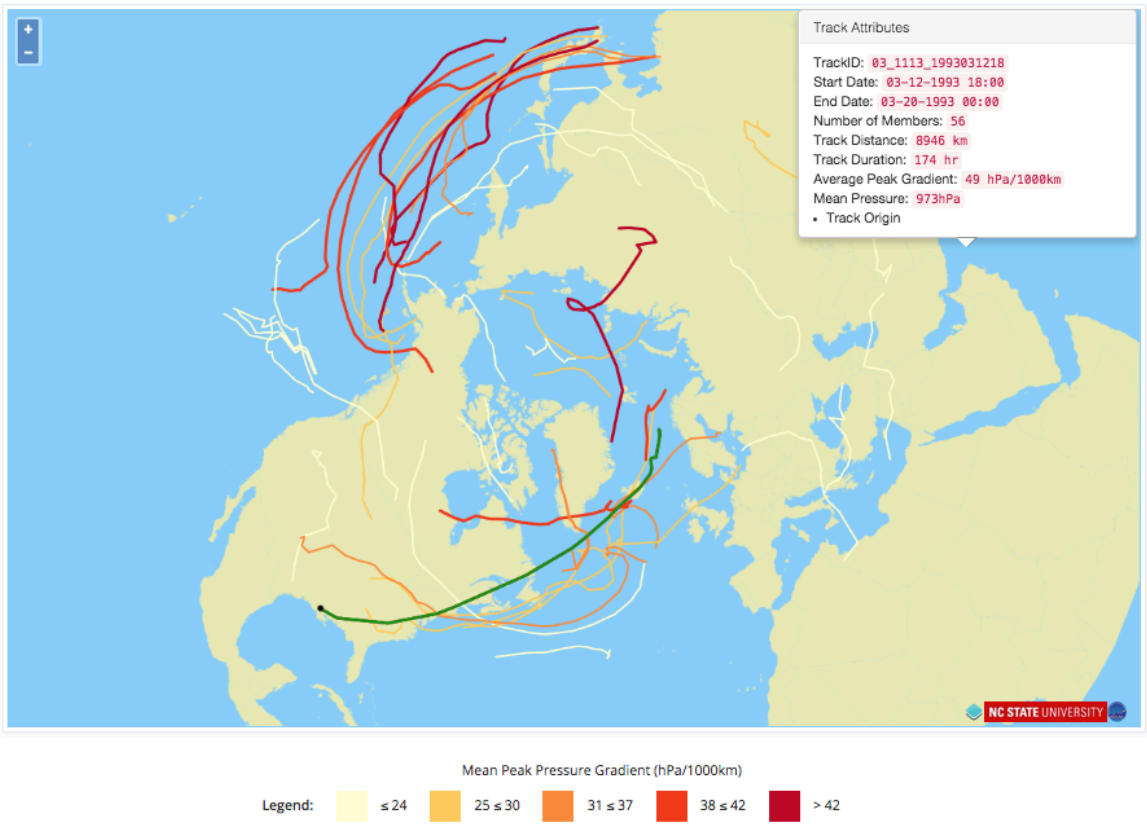


Figure 1: Snapshot of the web-based application showing ETC tracks for March 1993 with the 93' storm of the century selected (green) and track attributes displayed at the top right

PLANNED WORK

- Explore climatological shifts in ETC tracks
- Associate observed precipitation fields (station and radar) with ETC tracks
- Define fronts along the ETC tracks as part of the SERDP project

PUBLICATIONS

- Klotzbach, J. P., Oliver, J. C. E., Leeper, R. D., Schreck III, C. J. (2016) The Relationship between the Madden–Julian Oscillation (MJO) and Southeastern New England Snowfall. *Monthly Weather Review*, doi: 10.1175/MWR-D-15-0434.1

DELIVERABLES

- An Extra-Tropical Cyclone track database
- A web-based application that allows users to interact and access track data (etcsrv.cicsnc.org)

PRESENTATIONS

- Leeper, R. D. An Exploratory Analysis of the 20th Century Reanalysis Extra-Tropical Cyclone Track Density, Wednesday 13th Poster Session at the 96th American Meteorological Society Annual Meeting in New Orleans, LA January 2016

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Project is funded by a grant from NOAA's Climate Program Office (NA09OAR4310104) without NOAA guidance.

Analysis of hydrological extremes from the U.S. Climate Reference Network (USCRN)

Task Leader	Ronald Leeper
Task Code	NC-SON-06-NCICS-RL
NOAA Sponsor	Howard Diamond
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 80%; Theme 3: 20%
Main CICS Research Topic	Surface Observing Network
Contribution to NOAA Goals (%)	Goal 1: 80%; Goal 2: 20%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Analyzed changes to USCRN precipitation patterns over the 2012 drought and compared USCRN soil conditions to a commonly used reanalysis model; the North American Regional Reanalysis. These two studies highlighted the severity of the 2012 drought and the model's capacity to simulate the evolution of hydrological extremes. In addition, the development of a soil product for the USCRN that can monitor both sides of hydrological extremes (droughts and floods) is currently underway.

BACKGROUND

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

ACCOMPLISHMENTS

An investigation into the evolution of the 2012 drought using USCRN surface and sub-surface hydrological data was completed and the manuscript published in the journal *Vadose Zone*.

Student intern projects morphed into a modeling comparison study and an outline for a soil product by identifying ways to standardize volumetric soil moisture measurements using station anomalies, which evaluate soil conditions with respect to each station's unique mean. This allows soil conditions to be monitored across regions with differing soil type, textures, and climates, and has been found to detect hydrological extremes on both ends (*Figure 1*). While the soil product is still under development, the concept was used to compare modeled soil conditions from the North American Regional Reanalysis (NARR) and USCRN. While volumetric measurements varied greatly, anomalous soil conditions were much more similar, and indicated that NARR was capable to capturing the evolution of the 2012 drought (*Figure 2*). These results were shared with colleagues at Texas A&M University (TAMU) who are developing similar metrics with the goal of collaborating on a project that identifies best practices to merge data from multiple soil monitoring networks.

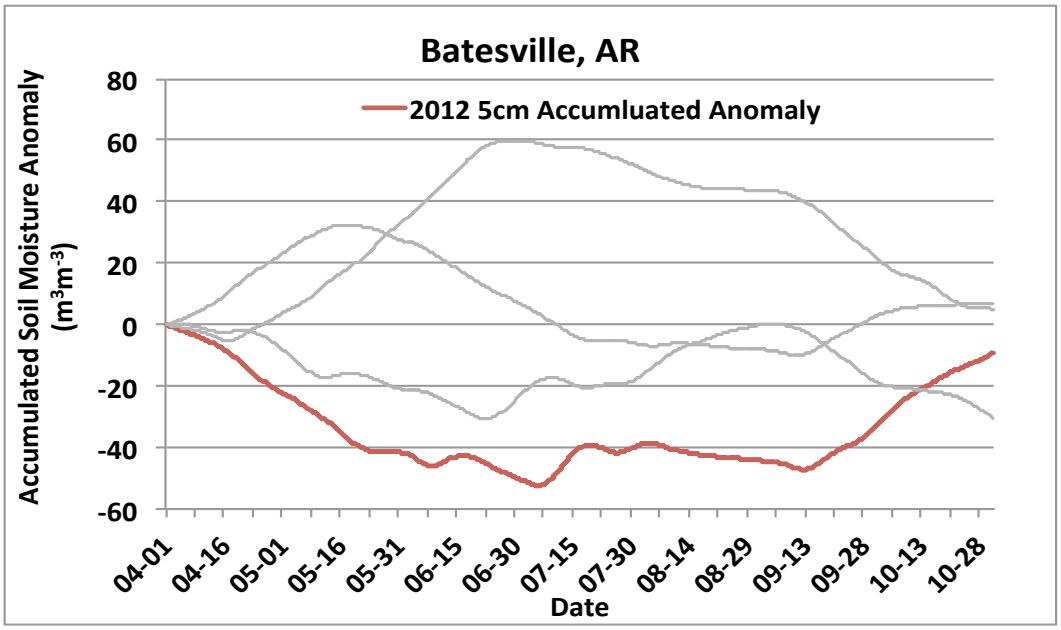


Figure 1: Cumulative 5 cm volumetric soil moisture anomaly at the USCRN Batesville, AK station from 2012 (red) to 2015. Cumulative deficits can be a possible metric to evaluate the timing of drought intensification (April to June at this station) and recovery (after September). The gray lines represent the other years (2013-2015) with 2015 having the higher cumulative values, which coincided with flooding near this station (not shown).

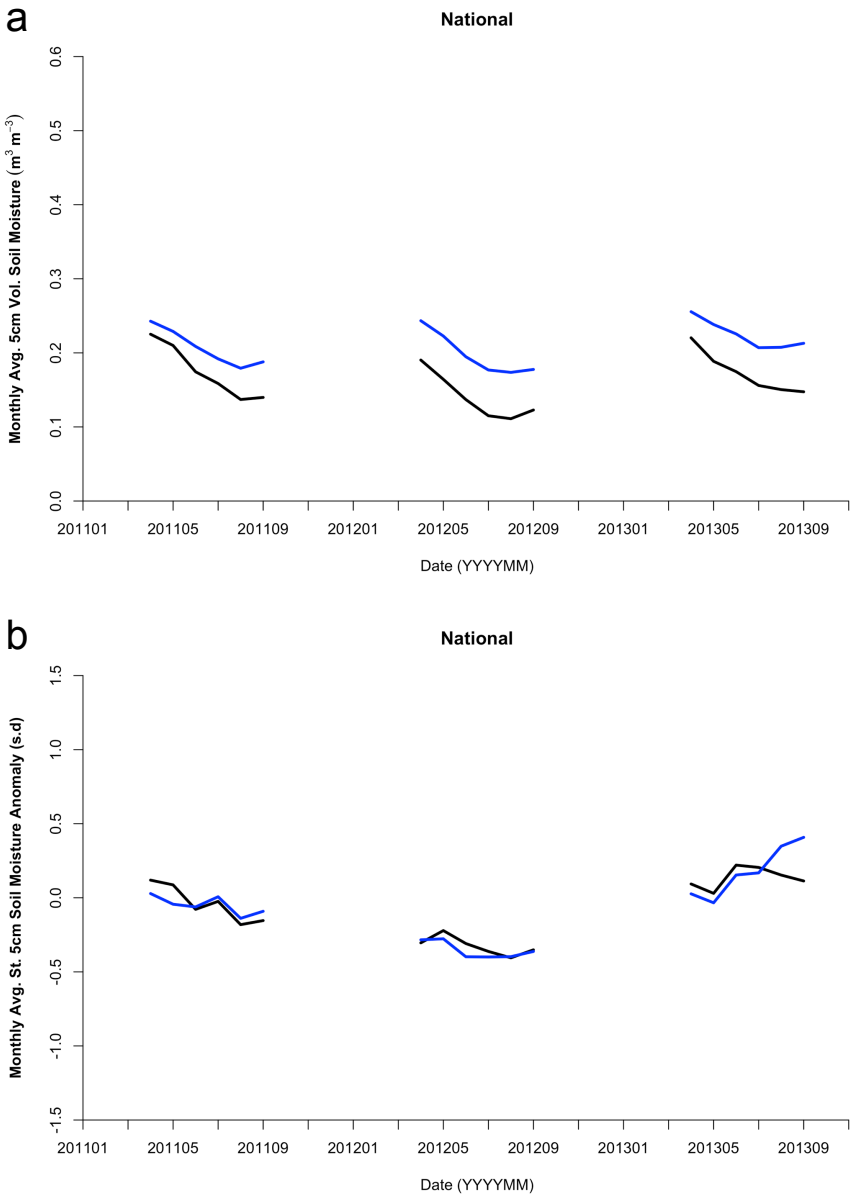


Figure 2: Nationally averaged growing season (a) volumetric (b) standardized anomalous soil moisture at USCRN stations (black line) and the nearest NARR grids to USCRN sites (blue line) from 2011 to 2013. The figure reveals that the 2012 drought signal, while discernable from volumetric observations, was more clearly evident using standardized anomalies particularly for NARR.

PLANNED WORK

- Complete adjustments to USCRN soil monitoring product and analysis
- Submit USCRN and NARR comparison study to the Journal of Hydrometeorology

DELIVERABLES

- A National USCRN soil moisture product highlighting wet and dry conditions across the U.S.
- Outline approaches to merge multiple soil monitoring networks into a single dataset.

PRESENTATIONS

- Leeper R. D., Bell, J. E., Palecki, M. An investigation of soil moisture extremes over the 2012 drought, 30th Conference of Hydrology at the 96th American Meteorological Society Annual Meeting in New Orleans, LA January 2016.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Maintenance and Streamlining of the Global Historical Climatology Network – Monthly (GHCN-M) Dataset

Task Leader	Jared Rennie
Task Code	NC-SON-07-NCICS-JR
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Using an open and transparent databank of land surface stations, the next iteration of NOAA's global temperature product has been developed and released as a public beta. This new version includes more stations, along with enhancements to the data quality and homogenization algorithms.

BACKGROUND

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

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

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

ACCOMPLISHMENTS

Since version 1.0.0 of the Databank was released, there has been much feedback from the public. In addition, analysis was run at NCEI to determine where improvements could be made. These changes, along with updates to current sources required a small numeric increment to the versioning system, and version 1.1.0 was released on October 15th, 2015. A brief description of the updates follows. First, most of the databank comes from the Global Historical Climatology Network – Daily (GHCN-D) database. In June 2015, GHCN-D underwent a large update, which included a new average temperature element (TAVG), along with the addition of 1,400 stations that are a part of the World Meteorological Organization's (WMO) Regional Basic Climatology Network (RBCN). Because these stations are important for real-time updates, it was necessary to include this new version of GHCN-D in v1.1.0. The

algorithm used to build station series into long, complete time series underwent no code changes. However, a couple of thresholds were modified in order to maximize the amount of data. This includes a stricter threshold of matching stations through its metadata information, along with lowering the amount of gap required to add new data. These small differences helped to optimize the amount of the stations in the latest product (*Figure 1*).

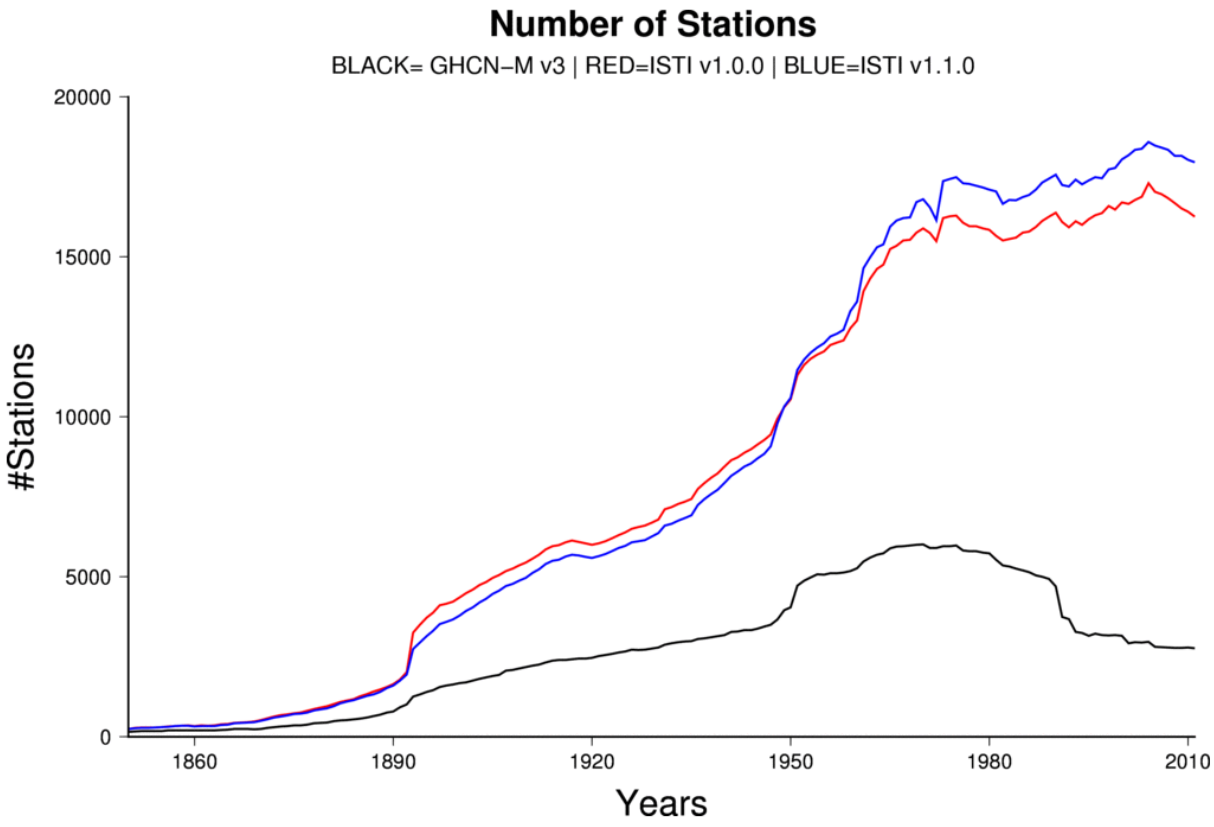


Figure 1: Station count of v1.1.0 by year from 1850-2014, compared to version 1.0.0, along with the operational product, GHCN-M version 3.3.0.

Version 1.1.0 of the databank serves as the starting point for version 4.0.0 of GHCN-Monthly. Because of this, the GHCN-M team has worked on setting up a new end-to-end process on an internal server. A three-tiered system has been set up, including a development, test, and production box. Processing is done nightly, and it is performed in multiple steps. The first step incorporates the latest Databank data that has near-real-time updates, including GHCN-Daily, as well as stations sent as climatic summary data, known as CLIMAT data. This data is compiled into ISTI format and then appended to version 1.1.0 of the databank. Afterwards, they are converted into a format that is similar to the GHCN-M format, run through a suite of quality control algorithms, and then finally through the Pairwise Homogeneity Algorithm (PHA) to remove non-climatic influences such as station moves and instrument changes. While no new code was introduced, the current code needed to be updated to account for an increase in the number of stations, as well as handling new data formats. As new data comes in each month, analysis is performed to make sure there is complete data coverage, without any additional loss. An example can be found in *Figure 2*. This highlights areas where new data is introduced, and also shows where data loss may have occurred. There are times where data loss is justified, because of updated

metadata (such as station latitude and longitude) that places stations in different gridboxes, along with additional analysis where newer data might have failed quality assurance checks.

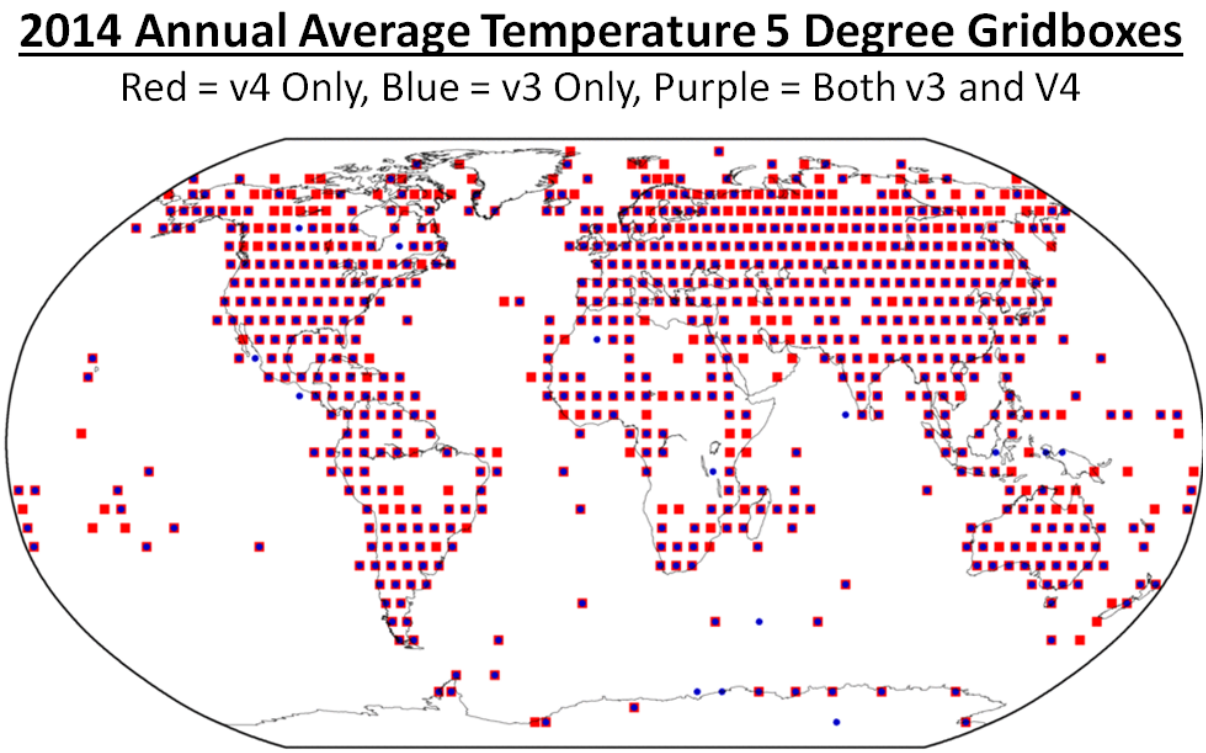


Figure 2: Analysis of 5-degree gridbox locations for the operational version of GHCN-M (v3.3.0) and the research version (v4.b.1) for the entire 2014 year.

In October of 2015, GHCN-M version 4 was released as a public beta (known as v4.b.1). Since then, members of the public, along with other organizations who use this data, including NASA and the United Kingdom's MetOffice, have given feedback. Changes, made from user comments, have been incorporated in the daily update system as needed. Work is underway to finalize the operational structure, provide documentation on the product, and produce a journal article that will be published along with the official data release.

PLANNED WORK

- Continue to engage with public on feedback regarding both the ISTI Databank version 1.1.0 and GHCN-M version 4.b.1. Provide updates to processing as needed.
- Continue to evaluate gridbox differences between version 3 and 4 of GHCN-M, including checking for consistency with NOAA's Global Temperature Product, which includes both global land and ocean data.
- Finalize processing on servers and draft documentation, along with journal article.
- Release GHCN-M version 4 as an operational product.

DELIVERABLES

- Updated to ISTI Databank (v1.1.0) after addressing feedback from community.
- Established end-to-end process for GHCN-M version 4 on new three-tiered server.

- Compared research version with operational for consistency, make changes as needed.
- Released public beta of GHCN-M version 4 and engaged with user community on feedback.

OTHER RELEVANT INFORMATION

- The International Surface Temperature Initiative: www.surfacetemperatures.org
- Technical report for ISTI Databank version 1.1.0: ftp://ftp.ncdc.noaa.gov/pub/data/globaldatabank/monthly/stage3/ISTI_Databnk_Technical_Report_v1.1.0.pdf
- FTP site of GHCN-M version 4 beta: ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/v4/beta/

PERFORMANCE METRICS

	FY16
# of new or improved products developed	2
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	0
# of non-peered reviewed papers	1
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

This year, the project team worked on improving the ISTI Databank Product, and provided updates on a monthly timescale. The latest version (1.1.0) was released and a technical document was provided. In addition, the group developed a beta version of GHCN-M version 4 for public use. Both will lead to the eventual operational release of GHCN-M version 4.

Development of a Homogenized Sub-Monthly Temperature Monitoring Tool

Task Leader	Jared Rennie and Ken Kunkel
Task Code	NC-SON-08-NCICS
NOAA Sponsor	Jay Lawrimore
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Steps have been made to create a sub-monthly tool for monitoring impacts of temperature extremes in the United States. Using products already distributed at NCEI, station data is aggregated on the State, NCA region, and contiguous U.S. levels to analyze current temperatures against its period of record. A dataset has been produced internally, with plans to undergo research to operation status.

BACKGROUND

Land surface air temperature products have been essential for monitoring the evolution of the climate system. Before a temperature dataset is included in such reports, it is important that non-climatic influences be removed or changed so the dataset is considered homogenous. These inhomogeneities include changes in station location, instrumentation, and observing practices. Very few datasets are free of these influences and therefore require homogenization schemes. While many homogenized products exist on the monthly time scale, few daily products exist, due to the complication of removing break points that are truly inhomogeneous rather than effects due to natural variability (for example, sharp temperature changes due to synoptic conditions such as cold fronts). Since there is a demand for sub-monthly monitoring tools, there is a need to address these issues.

The Global Historical Climatology Network – Daily (GHCN-D) dataset provides a strong foundation 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 NCEI, including the climate divisional dataset (nClimDiv), the North American monthly-homogenized product (Northam), and the 1981-2010 Normals. Since these downstream products already provide homogenization and base period schemes, it makes sense to combine these datasets to provide a sub-monthly monitoring tool for the United States.

ACCOMPLISHMENTS

A system has been set up on CICS-NC servers to grab the latest version of the following datasets: GHCN-D, Northam, the 1981-2010 Normals, and nClimDiv. Using these datasets, monthly adjustments are applied to daily data, and then anomalies are created using a base climatology defined by the 1981-2010 Normals. Station data is then aggregated through to the state level and then regions defined by the National Climate Assessment (NCA). Plots are then made for each day to analyze the state of the U.S. temperature values and anomalies. Once daily averages for each defined state and NCA region are made, probability distribution functions are then generated to provide ranks on different time scales. These are important to understand recent extremes in a changing climate.
An example of ranks can be seen in *Figure 1*.

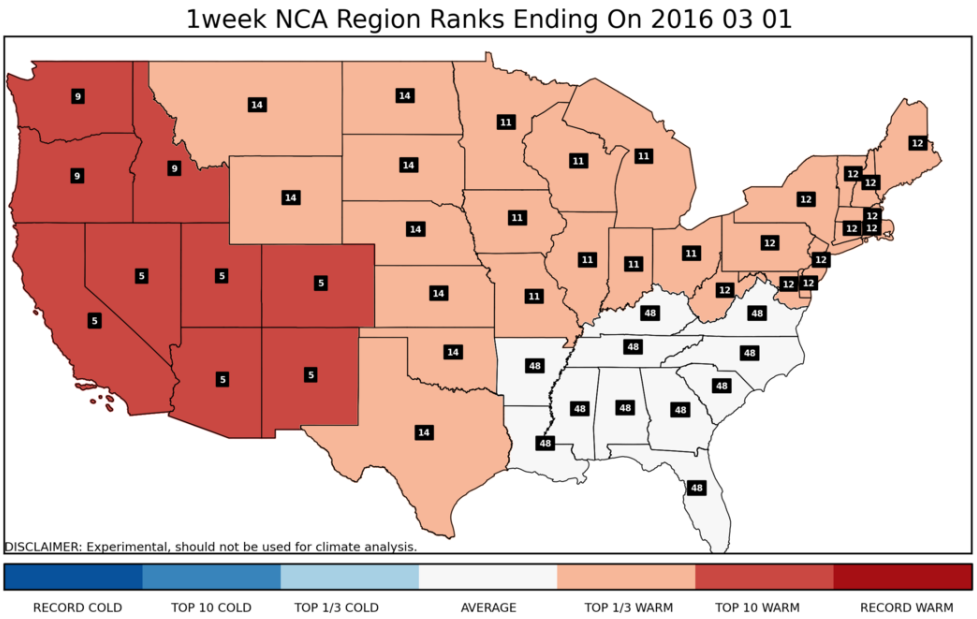


Figure 1: NCA Averaged Ranks of surface temperate, ending on March 1st, 2016.

This process has been finalized, and runs each night. Results are archived, and also published on a public website for collaborative feedback (http://monitor.cicsnc.org/sub/). Archived analysis is also available—the dataset goes as far back as 1895. This data has been used in numerous projects, including an analysis of heat waves done by the Society of Actuaries, along with a comparison of these values to teleconnections, including the Madden Julian Oscillation (MJO) and El Nino Southern Oscillation (ENSO). A draft of a journal article is currently underway, which will highlight the overall process. Work is also underway at Clemson University to build a daily homogenization algorithm. Once published, their process will be incorporated here to provide a more robust analysis.

PLANNED WORK

- Continue to engage with users on the product.
- Include divisions in Alaska and Hawaii.
- Address uncertainty parameters.
- Publish journal article on processing and results.
- Incorporate new daily homogenization algorithm developed by Clemson University.

DELIVERABLES

- A new, state of the art monitoring tool for sub-monthly data for the lower 48 states.
- Nightly processing system to update and archive ranks and statistics.
- Public facing website to display maps and ranks.

PRESENTATIONS

- Rennie, J.J. and K. Kunkel (2016) Steps Towards an Experimental Homogenized Sub-Monthly Temperature Monitoring Tool, 22nd Conference on Applied Climatology, AMS Annual Meeting, New Orleans, LA, 14 Jan 2016
- Schreck, C. J., J. Rennie, L. Watkins, K. Dobeck, and D. Podwitz (2016), Scale-Dependent Relationships Between U.S. Temperatures and Teleconnections, 4th MJO Symposium, AMS Annual Meeting, New Orleans, LA, 13 Jan 2016
- Rennie, J.J. and K. Kunkel (2015) Steps Towards an Experimental Homogenized Sub-Monthly Temperature Monitoring Tool, POSTER American Geophysical Union Fall Meeting, San Francisco, CA, 17 Dec 2015

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	3
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

This product has been set up in an operational fashion, and has been released publicly on CICS website. Rennie has given numerous talks on the product, including a poster at the AGU Fall meeting, and presentations at the AMS Annual Meeting.

Building a Climatology of Extreme Snowfall Events in the United States

Task Leader	Jared Rennie
Task Code	NC-SON-09-JR
NOAA Sponsor	Jay Lawrimore, Derek Arndt
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 50%; Theme 2: 50%; Theme 3: 0%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: A project is underway with both NOAA and FEMA to validate snowfall extremes for every county in the United States. This will help mitigate future snowfall events, and also build better spatial quality algorithms in our weather station data products.

BACKGROUND

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

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

ACCOMPLISHMENTS

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

There are two validation methods. The first is by looking up the original paper record where available (*Figure 1*). If a paper record is hard to read, or unavailable, a spatial eye-ball test is performed using neighboring stations (*Figure 2*). At the time of writing, 13 states, as well as the District of Columbia, have been confirmed using data up to the latest winter season (2015-2016). Soon, the states seeing the most snowfall on average will have been completed (around 25) and then the remaining states will be validated. Using what has been learned, updates to quality assurance algorithms will be worked on to

make the snowfall data more robust.

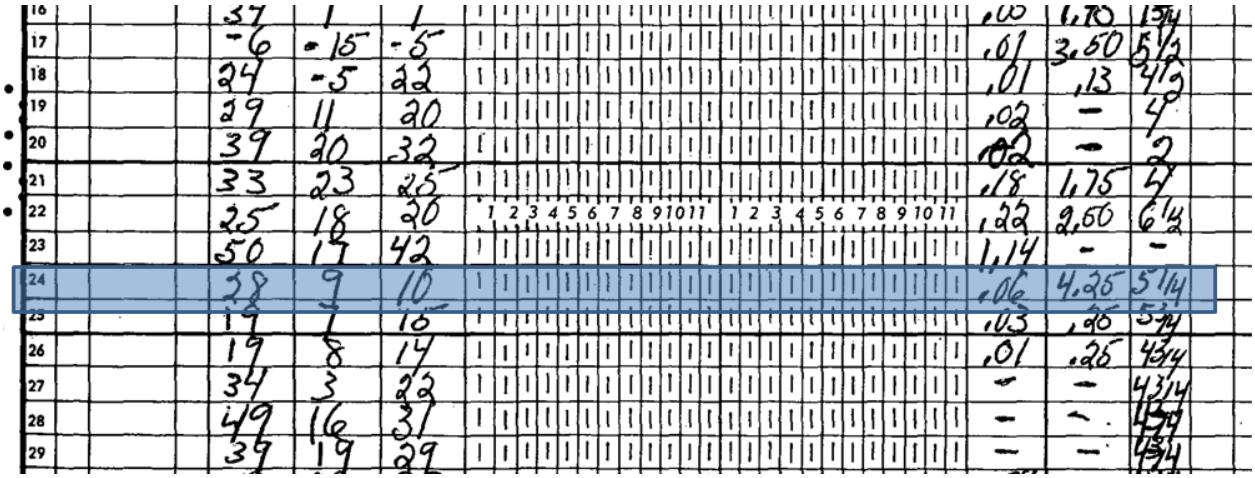


Figure 1: An example of a paper record for Johnstown, PA in January 1982. GHCN-Daily marks the snowfall event of January 24th as 42.5 inches. However, the paper record shows a recording of 4.25 inches. This case is flagged as bad, and the next 1-day record is considered.

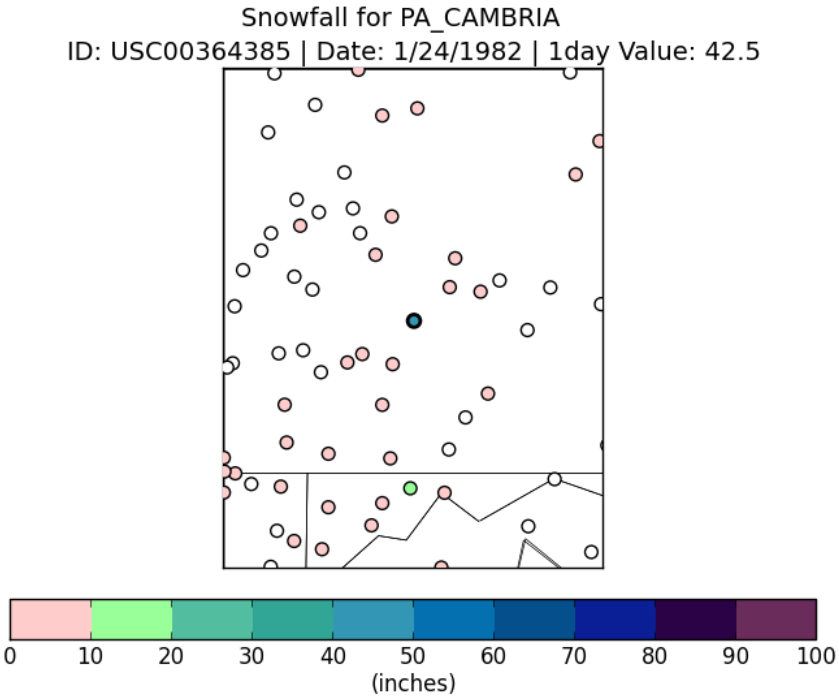


Figure 2: Eyeball Test of the January 24th, 1982 snowfall event for Johnstown, PA (Cambria County). All neighbors recorded snowfall less than 10", which further invalidate this report.

PLANNED WORK

- Finish all 50 states and deliver FEMA product of ranks.
- Update quality assurance procedures using known bad data to make snowfall data more robust in GHCN-Daily.
- Draft journal article of project and submit to Bulletin of American Meteorological Society.

DELIVERABLES

- An update to 1-day, 2-day, and 3-day snowfall climatologies for every county in the United States.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	2

Two student interns assisted with the project, including developing spatial plots, and looking up archived paper records. Once completed, a new dataset will be made available to FEMA, and numerous presentations and papers will come from this project.

Workforce Development

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

Senior CICS-NC scientists hold research faculty positions in the Marine, Earth, and Atmospheric Sciences Department (MEAS) in the College of Sciences (COS) at NCSU and provide mentorship to junior scientists and students both in CICS-NC and MEAS. Several junior scientists have also secured adjunct appointments in pertinent NCSU departments as well as other universities to gain experience and exposure with their academic peers and mentor graduate students. CICS-NC scientists are also engaged in various outreach activities to promote awareness and pique interest in science and climate studies at the K-12 level.

CICS-NC initiated its program in workforce development through the hiring of an initial cadre of post-doctoral research scholars working on applied research topics in Climate Data Records and Surface Observing Networks. Senior scientists from NOAA and CICS-NC provide mentoring for these post-docs. The expectation is a 2-3 year commitment, dependent on circumstances and individual interests.

Meanwhile, CICS-NC has been successful in recruiting and involving local high school students and UNC Asheville undergraduates 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.

- Jesse Bell holds an adjunct faculty appointment with Emory University's Rollins School of Public Health where he mentored Masters in Public Health students investigating the relationship of climate to health issues including: Holly Vinn (mental health and drought), Gwen Parker (impact of various climate variables on Valley fever occurrences in AZ and CA), Shengnan Han (heat indices evaluation), Leslie Waller (climate variables on Vibrio occurrences along the Gulf Coast), Erin Firestone (using climate data to develop a wildfire vulnerability index for OR), and Jennifer Strieber (Valley Fever vulnerability index for AZ and CA).
- Carl Schreck holds adjunct faculty appointments with NCSU and with NC A&T University and serves as PhD co-advisor for Hilawe Semunegus (NCEI). Schreck also advised a NASA DEVELOP student intern team, Derek Podowitz (TAMU) and Kelly Dobeck (UNCA), on their project focused on the relationship of long-wave radiation data to U.S. temperatures for energy industry users.
- William Clark is an Atmospheric Sciences major with a concentration in Weather Forecasting at the University of North Carolina-Asheville. During the reporting period, William Clark worked on two projects examining economic impacts to climate change: 1) an inundation impact model using a Geographic Information System (GIS) in New Hanover County, NC, reflecting the amount of potential losses in dollars and the buildings that are exposed to an increase in sea level rise

ranging from 1 to 4 feet; and 2) economic research and analysis, specifically looking at U.S. Census sectors and their economic value added to the U.S. economy to support NCEI's redesign of their engagement with various sectors. William completed his internship at CICS-NC in November 2015.

- Sean Feirstein is a current Asheville High School student and completed a 2015 summer internship with CICS-NC working with Jared Rennie on the NCEI/FEMA Snowfall project assisting with the data verification process to confirm or deny snowfall values. Verification included reviewing the original paper record archives and the spatial plots created by fellow intern, Jason Yu.
- Kelly Gassert completed a second bachelor's degree in Atmospheric Sciences at the University of North Carolina-Asheville in May 2015. She developed a project in support of the next National Climate Assessment, analyzed radar data, gained knowledge in Python, and continued a more detailed study of climate science. Kelly completed her internship at CICS-NC in May 2015.
- Tiffany Maupin completed a bachelor's degree in Weather Forecasting and a minor in Mathematics at the University of North Carolina-Asheville in May 2015. Tiffany worked closely with the Technical Support Unit and the National Climate Assessment learning the process of climate modeling with computer applications. Tiffany completed her internship at CICS-NC in July 2015.
- Dr. Elsa Nickl completed her Ph.D. in 2012 at the University of Delaware and joined CICS-NC as a Post-Doctoral Research Scholar in March 2014. She is collaborating in the analysis of the impact of Polar Regions missing information on the global temperature average as part of the Global Surface temperature Portfolio team and is also collaborating in the application of spatial interpolation methods for precipitation estimation.
- Isaac Pohl-Zaretsky is a current Asheville High School student and completed a 2015 fall semester internship in software engineering support, including the reprocessing of climate model projections using the LOCA (localized constructed analogs) downscaling technique.
- Dr. Steve Stegall completed his Ph.D. from North Carolina A & T State University in atmospheric science and joined the CICS-NC team in May 2014 as a post-doctoral Research Scholar. He is collaborating in assessment on the utility of HIRS 2-m air temperature on NCEI's global temperature product as well as providing further analysis of CMIP5 temperature and precipitation trends.
- Bobby Taylor completed his bachelor's degree in Atmospheric Sciences with a concentration in Climatology and minor in Mathematics at the University of North Carolina-Asheville in May 2015. Bobby contributed to the TSU's support of the USGCRP's National Climate Indicators System through his understanding of climate science and geographic information systems. Bobby also participated in several outreach and engagement efforts related to the National Climate Assessment and gained a greater understanding of the intersection between climate science and policy. Bobby completed his internship at CICS-NC in May 2015.
- Jason Yu is a current AC Reynolds High School student and completed a 2015 summer internship with CICS-NC working with Jared Rennie on the NCEI/FEMA Snowfall project gathering and plotting data for specific counties and neighboring climate observing stations to provide a quick visual scan of the data in the verification process. He used Python to set a system and successfully created a map for all 10,000 cases.

Evaluation of a new spatial interpolator to estimate land surface precipitation over the contiguous U.S. region

Task Leader	Elsa Nickl
Task Code	NC-WFD-01-NCICS-EN
NOAA Sponsor	Russ Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0% Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Estimations of land surface precipitation climatologies at 2.5-minute resolution using a new spatial interpolator are evaluated and compared with estimations from Cressman's traditional interpolator, NCEI /NOAA and PRISM.

BACKGROUND

During 2014-2015, Nickl's new spatial interpolation method was applied to estimate monthly and seasonal land surface precipitation climatologies over the contiguous U.S. region at 2.5-minutes resolution. This new method is the integration of estimated precipitation using a traditional interpolation method and the estimated bias when topography is not taken into account. In order to estimate these bias fields, errors at stations are correlated with four topographic variables (elevation, latitudinal and longitudinal slope orientation, and exposure) at different orographic scales (resolution of topography at which the relationship with precipitation is optimal).

Correlations between precipitation errors and topographic variables showed moderate to high values in most of the stations within the mountains regions. In general, elevation, west-oriented slopes and protruding areas are more related to under-estimations of precipitation, and there is not a clear relationship between south/north slope orientation and precipitation errors.

The principal goal of this task is to assess the performance of the new spatial interpolator using spatial cross-validation. Estimations of monthly and seasonal land surface precipitation climatologies are compared with estimations from Cressman's traditional interpolator, the National Centers for Environmental Information (NCEI/NOAA), and the Parameter-elevation Regressions on Independent Slope Model (PRISM).

ACCOMPLISHMENTS

Estimations of precipitation climatologies using the new spatial interpolator were completed for all months and seasons at 2.5-minute resolution.

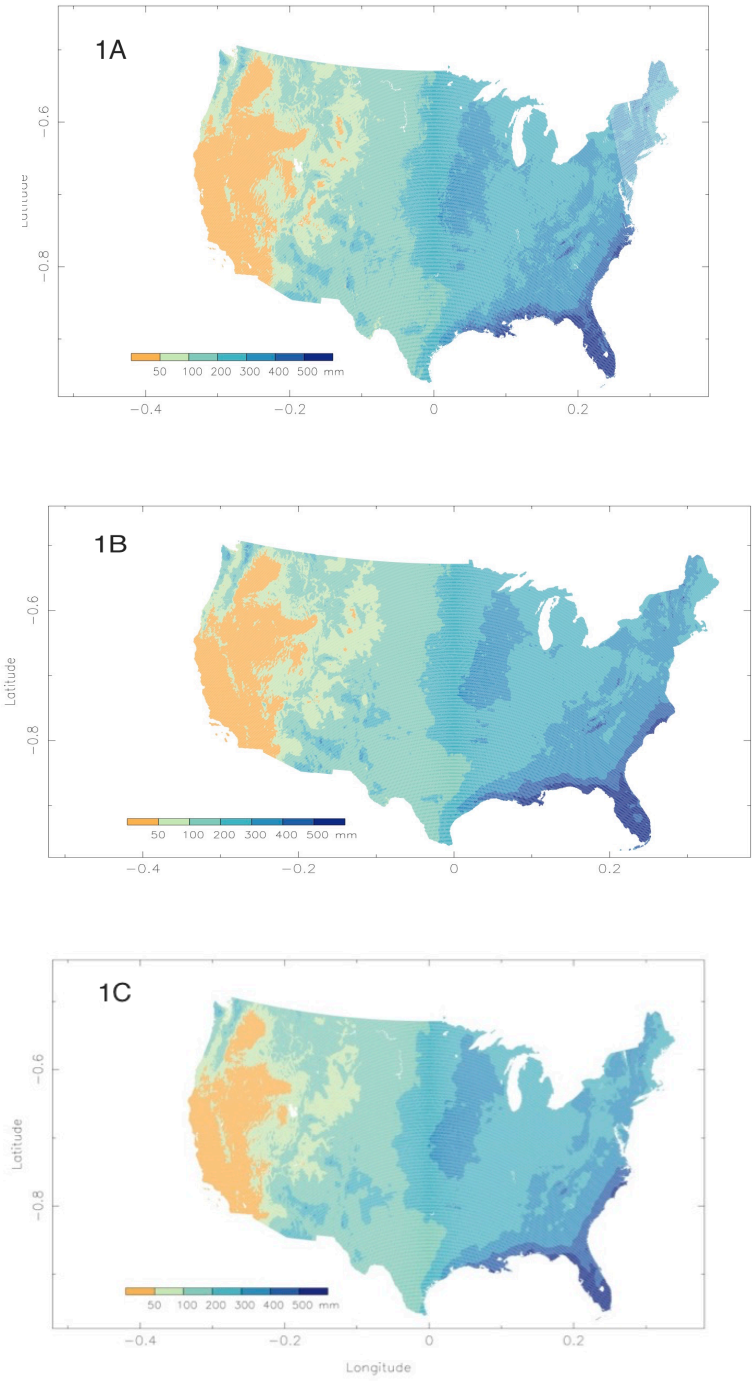


Figure 1: Estimated precipitation for JAS climatology (1981-2010) using A) new spatial interpolator, B) PRISM and C) NCEI/NOAA.

From *Figure 1* (in this case JAS climatology) we can observe that spatial patterns are similar with PRISM and NOAA/NCEI maps. The same similarity is found in all months and seasons. When estimating the grid differences, higher differences are found in the Western mountain regions (*e.g.* Rockies) and for winter season (JFM). These differences may be a result of sensitivity of parameters when applying the MLR

(Multi Linear Regression) in areas with high topographic variability (large differences of observed values or low density of stations).

Spatial cross-validation is applied to evaluate the performance of the new interpolator and Cresman traditional. It is important to mention that a different method is used by NCEI/NOAA to estimate errors. *Figure 2* shows that errors show lower values for the new spatial interpolator compared to traditional interpolation. Errors from NCEI/NOAA show lower values especially for JFM. The West mountainous region exhibits larger errors for JFM. The East mountainous region shows similar errors for JFM and JAS and both the estimations from the new spatial interpolator and NCEI/NOAA show similar errors.

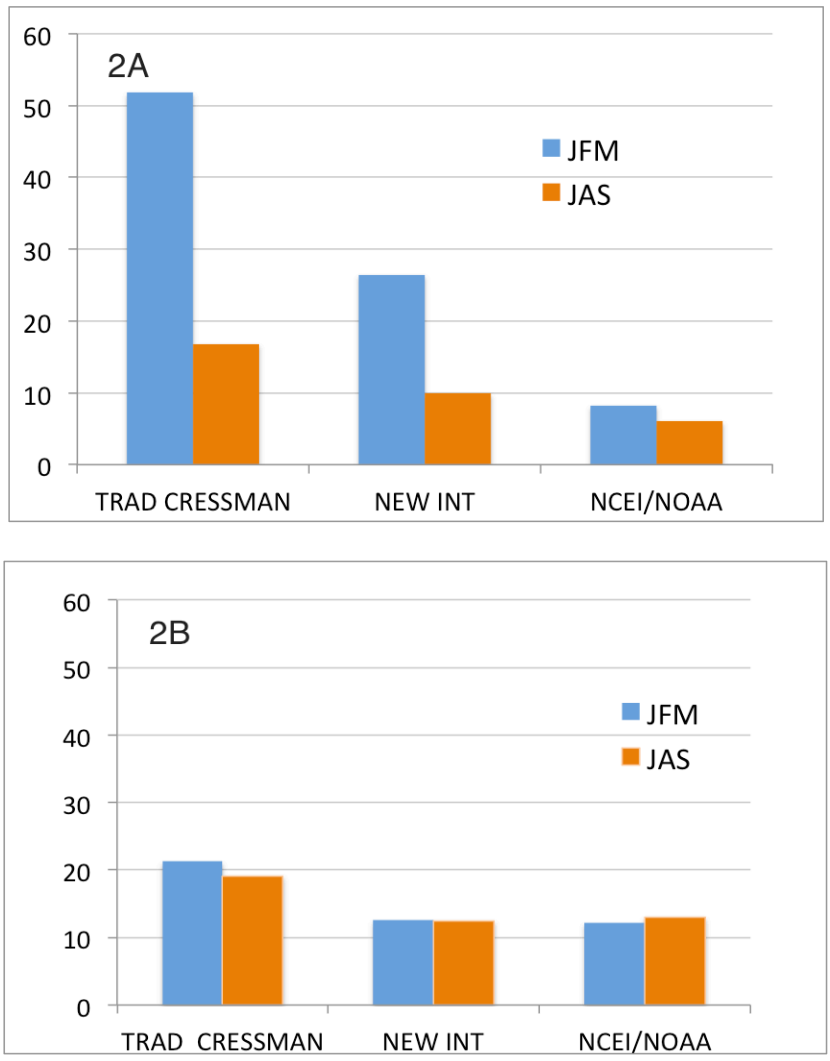


Figure 2: Errors at stations with elevations greater than 500m for A) West mountainous region and B) East mountainous region for the different interpolators and seasons.

The new spatial interpolator represents a promising contribution to precipitation interpolation and estimation, since it can be applied to any region of the world and does not require a number of area-specific parameters.

PLANNED WORK

- Article in preparation
- To elaborate a proposal to evaluate the performance of my interpolator method in other mountainous regions of the world and to study the possibility to improve estimated of land-surface water budget based on enhanced fields of precipitation and temperature.

PUBLICATIONS

In preparation:

- Nickl, E., C. Willmott, and R. Vose, 2016. Estimation of land surface precipitation for contiguous U.S. using a new spatial interpolator method.

DELIVERABLES

- Estimates of land surface precipitation climatologies at 2.5-minute resolution using a new spatial interpolator for each month and season (JFM, AMJ, JAS, OND)
- Cross validation errors at stations for each month and season

PRESENTATIONS

- Nickl, E., C. Willmott, and R. Vose (2016). Estimation of land surface precipitation for contiguous U.S. using a new spatial interpolator method. Annual meeting of the American Meteorological Society (AMS), New Orleans, LA, January.
- Nickl, E., C. Willmott, and R. Vose, (2016). Estimation of land surface precipitation for contiguous U.S. using a new spatial interpolator method. Annual Meeting of Association of American Geographers (AAG), San Francisco, CA, March.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	2
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

The new spatial interpolator method was used to estimate new precipitation fields taking into account topographic variables and cross-validation was applied to estimate errors.

Estimation of topographic variables at different resolutions

Task Leader	Elsa Nickl
Task Code	NC-WFD-02-NCICS-EN
NOAA Sponsor	Russ Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme1: 0%; Theme2: 50%; Theme3: 50%
Main CICS Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Using DEM information from GTOPO30 to estimate topographic variables (elevation, latitudinal and longitudinal components of slope and exposure to orography) at different resolutions for contiguous U.S. and global scale.

BACKGROUND

One important aspect of Nickl's new spatial interpolator is to take into account four important topographic features: elevation, latitudinal and longitudinal components of slope, and exposure to orography). These topographic features are evaluated at different spatial scales in order to identify optimal relationships with precipitation errors that arise when topographic influences are not taking into account in the interpolation. An adjustable-scale spatial ellipse is used to represent topographic features within a spatial scale.

When performing correlations between precipitation errors and topographic variables for contiguous U.S., moderate to high values in most of the stations within the mountains regions were found. These results brought the attention of some researchers. Owen Kelley from NASA-Goddard is considering the possibility of using these relationships between precipitation errors and topographic features in his study of arid-region precipitation over both flat and mountainous regions. In 2014, Olivier Prat (CICS-NC) used the topographic variables at contiguous U.S. stations to analyze their relationships with estimation errors from satellite and radar.

ACCOMPLISHMENTS

Four topographic variables (elevation, latitudinal and longitudinal components of slope, and exposure to orography) were produced for contiguous U.S. at 1km resolution and for global scale at 0.25^{o} resolution.

Olivier Prat (CICS-NC) used this information in two research projects. One is related to the analysis of relationships between topographic features and NEXRADAR reanalysis over contiguous U.S. region. The other research is on the evaluation of different Quantitative Precipitation Estimates (QPEs) from different satellite products. The product inter-comparisons are performed at various temporal (annual, seasonal, daily or sub-daily when possible) and spatial scales (global, overland and over ocean, tropics or higher latitudes, high elevation).

PLANNED WORK

Evaluate possibility of writing and article with Olivier Prat (CICS-NC) about relationship of bias between radar and surface observations and topographic variables at global scale.

DELIVERABLES

- Estimated topographic variables (elevation, latitudinal and longitudinal components of slope, and exposure to orography) for contiguous U.S. at 1km resolution.
- Estimated topographic variables (elevation, latitudinal and longitudinal components of slope, and exposure to orography) for global scale at 0.25^{o} resolution.

PRESENTATIONS

- Prat, O., Nelson, B., Stevens, S., Nickl, E., Seo, D-J, Kim, B., Zhang, J. and Qi, Y. (2015). Merging radar quantitative precipitation estimates (QPEs) from the high-resolution NEXRADAR reanalysis over CONUS with rain-gauge observations. American Geophysical Union (AGU) Fall Meeting, Poster Presentation (H24E-04), San Francisco, CA, December.
- Prat, O., Nelson, B., Nickl, E., Adler, R., Ferraro, R., Sorooshian, S. and Xie, P. (2016) Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs) from the Reference Environmental Data Records (REDRs), EGU General Assembly, Vienna, Austria, April.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	2
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Information of topographic variables at different resolutions and scales were estimated and are available for researchers.

Global Surface Temperature Portfolio: Evaluation of NOAA Temp/MLOST Land Surface Temperature using ERA Interim

Task Leader	Elsa Nickl
Task Code	NC-WFD-03-NCICS-EN
NOAA Sponsor	Russ Vose
NOAA Office	NESDIS/NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: The purpose of this task is to use ERA Interim as a benchmark for NOAA Temp/MLOST land surface temperature evaluation.

BACKGROUND

According to the Project Plan for the Improvement of NOAA Temp/MLOST Surface Temperature dataset, one of the principal tasks is the assessment and benchmark of various product generation methods. In 2014, Zhang (NCEI) and Nickl investigated the impacts of data gaps in the estimation of surface temperature trends, concluding that it was important to address those gaps in order to enhance the estimation of surface temperature trends. In 2015 Nickl compared the spatial and temporal variability of global surface temperature trends for different datasets (*e.g.* University of York, GISTEMP and NOAATemp/MLOST), identifying regions, and periods of discrepancies.

After some meetings with the Surface Temperature group, it was decided to focus on the evaluation of NOAATemp/MLOST using ERA Interim dataset as a benchmark. The first step in this evaluation was the estimation of EOTs from ERA Interim. Then, the evaluation used these new EOTs in the NOAATemp/MLOST codes for land surface temperature estimation and compared both land surface temperatures (using original EOTs and from ERA) to evaluate the possibility to use ERA as a benchmark.

In May 2015, Nickl, with assistance from Boyin Huang, performed changes in the code (originally designed to estimate SST EOT) to estimate land surface temperature EOTs using ERA monthly anomalies (period 1979-2014). The EOTs from ERA showed some strange repetitive patterns after the Mode 15 were presented in a group meeting. The group decided to use these EOTs in the NOAATemp/MLOST codes to verify if these EOTs were correctly estimated. Results of the application of NOAA Temp/MLOST showed errors. In August 2015, with Boyin Huang's assistance, the EOT code was corrected to estimate accurate EOTs from ERA Interim.

Unfortunately, since September/October 2015, Nickl was not permitted access to NCEI Linux servers due to her status as a foreign national. While the Information System Security Office processed an Alt_Token Card for Nickl, she used the CICS server to run NOAA temp/MLOST codes. However, this process was slow due to NCEI links in the codes and a different configuration in servers, so Nickl decided to wait for the availability of an Alt-Token card, which was granted in January 2016; access to NCEI Linux servers began in February 2016.

ACCOMPLISHMENTS

Correct EOTs from ERA Interim monthly anomalies could be estimated with Boyin Huang assistance. *Figure 1* shows the first 2 modes of these EOTs.

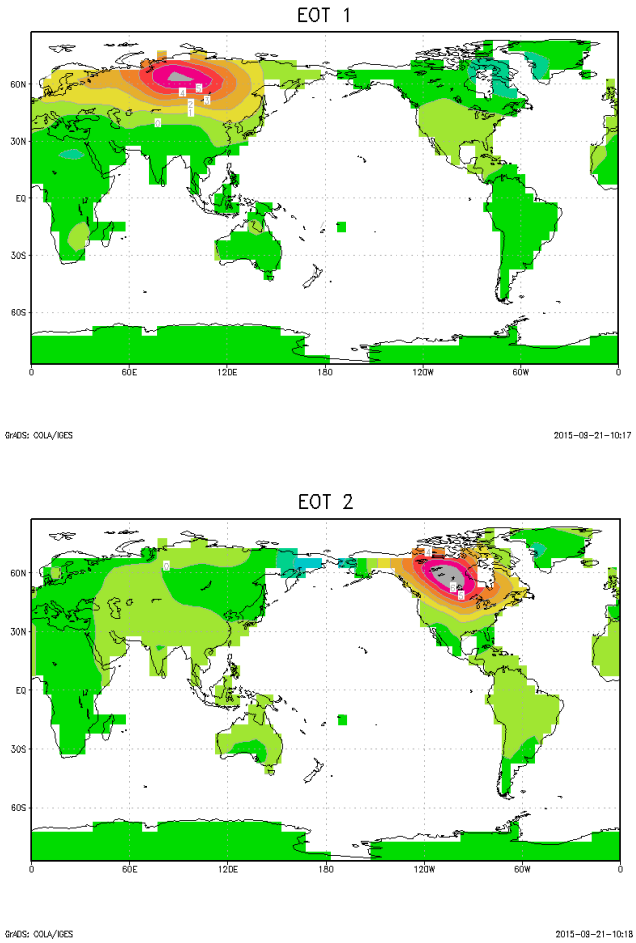


Figure 1: Mode 1 and 2 from from ERA Interim

PLANNED WORK

- Estimate land surface temperature using NOAATemp/MLOST codes and EOTs from ERA Interim
- Evaluate NOAATemp/MLOST land surface temperature using ERA Interim as a dataset benchmark

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Due to time taken in EOT code changes and corrections and problems in access NCEI servers the process was slow. Access to NCEI server trough an Alt-Token card will allow me to continue task.

Global Surface Temperature Portfolio: Land Surface Temperature Analysis and Assessment of HIRS Surface Temperature Collocated with USCRN Observed Surface Temperature and Global Land Surface Temperature Datasets

Task Leader	Steve Stegall
Task Code	NC-WFD-04-NCICS-SS
NOAA Sponsor	
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Bias and RMSE are calculated for HIRS surface temperatures vs. the USCRN observation network from 2006-2013 for the N17 and M02 satellites. This effort applies a calibration scheme that shows the results that the bias and RMSE are improved and lower when compared to USCRN, especially for the western U.S.

BACKGROUND

The goal of this task is to provide a detailed assessment of HIRS surface temperature with high-quality observed surface temperatures. One of the best-quality surface temperature observed data sets is the USCRN station network. Bias and RMSE of HIRS surface temperature is collocated to the observed USCRN stations from 2006 to 2013.

In order to evaluate and improve the quality of HIRS surface temperatures, bias and RMSE metrics are calculated using the USCRN network. HIRS surface temperatures are collocated hourly and within 25km of each USCRN station for each day from 2006 to 2013. The two main satellites evaluated for this time period are the N17 (2006-2008) and the M02 (2007-2013). Detailed comparisons can be done using these metrics, and bias schemes can be derived and applied to the HIRS data and improvements made to the quality of the HIRS surface temperature.

The above provides excellent analysis and assessment for the United States. However, it is very important to expand this assessment to the global land surface temperatures and for a longer time period. The goal will be to collocate the HIRS surface temperatures to four reanalysis data sets (ERA-40, ERA-Interim, MERRA, and NCEP/NCAR) that are downscaled to 0.5° lat/lon and interpolated to hourly output from 1980-2009 (Wang and Zhang, 2013). This will provide bias and RMSE on a long-term global scale for all HIRS satellites from 1980-2009.

ACCOMPLISHMENTS

HIRS surface temperatures were collocated to the USCRN observation network from 2006 to 2013. Annual bias and RMSE are calculated for each station that the temperatures are collocated. Results show that there is higher bias and RMSE in the western U.S. vs. the eastern U.S. This is most likely due to the heterogeneous topography and land surface types in the western U.S. vs. the more homogenous land surface types and topography in the Eastern U.S. To correct this higher bias, a calibration scheme was developed.

Calibration Scheme:

Remotely sensed and retrieved surface measurements require in situ calibration to reduce retrieval biases. High quality USCRN observations are a good candidate to build a calibration database. Our

examinations showed that the biases of SAT retrievals are linearly correlated with the USCRN observed SAT's for a large range of SAT's. In selecting a calibration database, scatter plots of M02 retrieval biases with respect to USCRN observations for each year were analyzed with linear regression. There are small variations of regression coefficients from year to year. We choose the year that has the medium regression slope (year 2011) to represent the mean condition of the datasets (*Figure 1*).

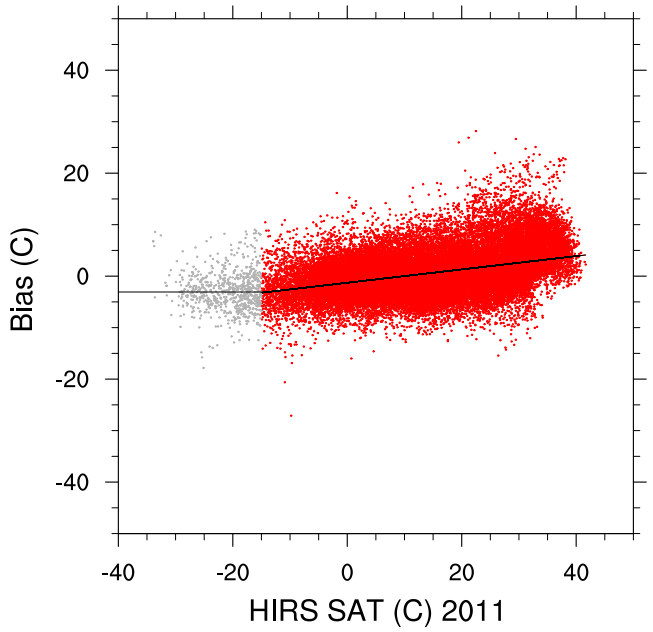


*Figure 1: Scatterplot of the 2011 M02 bias (HIRS SAT minus USCRN SAT) vs. the HIRS SAT for 2011. The black line is the best fit and the equation is: 0.1252202*x - 1.200186 in which x is the HIRS SAT. This equation is for HIRS temperatures at or above -15°C. For HIRS temperatures below -15°C, a bias correction is done which is represented by the black line at -3.078488. The units of bias and temperature are °C.*

The linear regression equation used is 0.122202*x – 1.200186, where x is the HIRS co-located SAT. The 2011 regression coefficient is derived as a calibration to HIRS retrievals, both to other years of M02 and to inter-satellite calibrated HIRS data of other satellites. In analyzing the scatter plots, we observe that for SAT < -15°C, there is not much variation in the mean bias. Therefore, a constant bias calibration value of -3.078488 that corresponds to the SAT of -15°C at the linear regression equation is applied.

Figure 2 shows the annual bias vs. longitude of HIRS surface temperature after the bias correction is applied. Clearly the bias is reduced, especially in the western U.S. where before the bias correction there were much larger bias between HIRS and USCRN. Annual RMSE of HIRS surface temperature and USCRN show similar results as *Figure 2* with the bias correction applied.

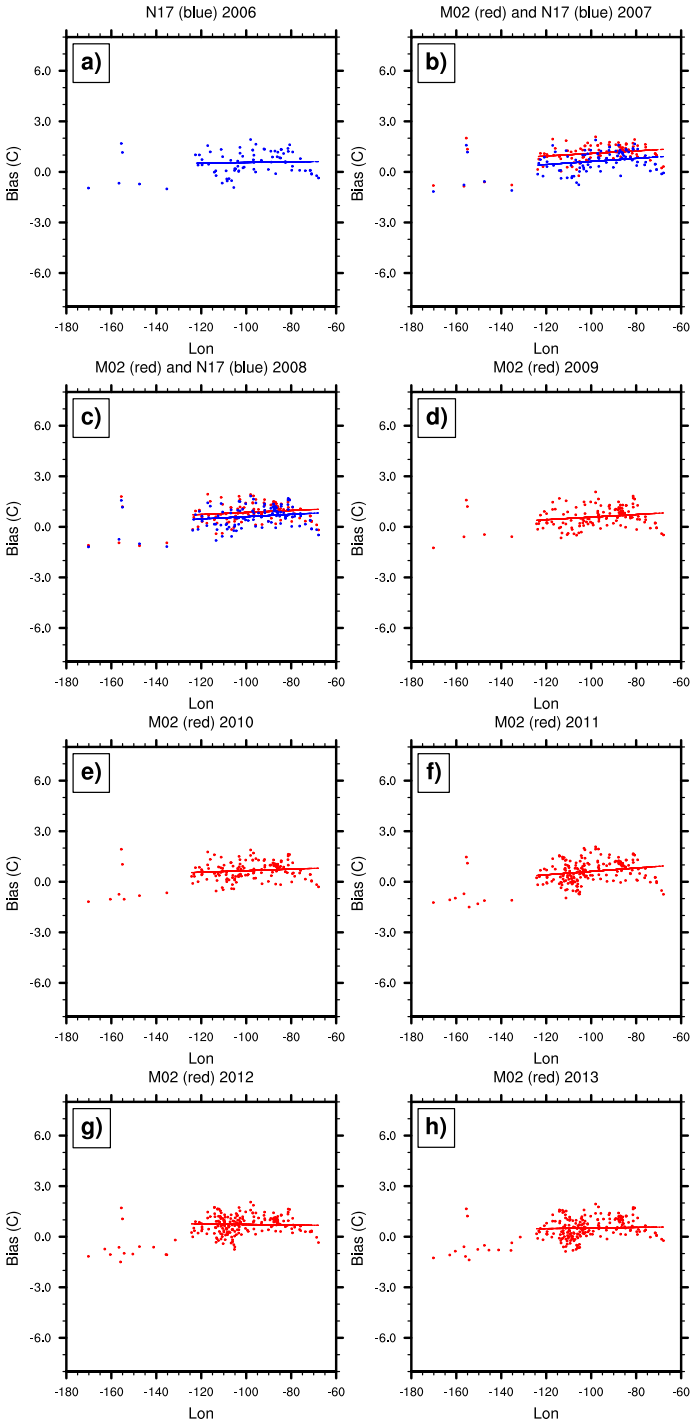


Figure 2: Scatter plots of annual bias (°C) of HIRS SAT co-located to each USCRN station along longitude from 2006 to 2013. Lines represent the least squares fit to the data. N17 data are in blue and M02 data are in red.

The annual Bias and RMSE from 2006-2013 for both N17 and M02 satellites after the bias correction show very good agreement both between the USCRN data and the two satellites themselves. Bias for both satellites is ~0.5°C and the RMSE for both is about 1.5°C (not shown). When the bias, RMSE, and collocated temperatures (both day and night) are averaged for all stations for each year for both N17 and M02 satellites the results show good performance for each. Both satellites show bias for both the daytime and nighttime with -0.0°C and 1.5°C respectively (not shown). The RMSE for day and night are 1.0°C and 2.0°C for both satellites. The higher bias for the daytime is expected since daytime temperatures can fluctuate substantially throughout the year. Nighttime temperatures for each satellite compare well with USCRN nighttime temperatures. The daytime temperatures also compare well but there is a bigger difference mainly due to the larger fluctuation of daytime temperatures throughout the year.

For the global analysis, the 2009 HIRS surface temperatures were collocated to the ERA-Interim, MERRA, and NRA land surface temperature datasets. ERA-40 is not included since this dataset is only for the time period ending in 2001. To expand the collocation time period, the HIRS surface temperatures were collocated to the ERA-Interim land surface temperature data from 1980-2009. The collocation is parallelized for efficiency.

PUBLICATIONS

- Steve T. Stegall, Lei Shi, "An Assessment of HIRS Surface Air Temperature with USCRN Data", *submitted Remote Sensing* (2016).

PLANNED WORK

- Write and publish research in a peer-reviewed journal.

PERFORMANCE METRICS

	FY16
# of new or improved products developed following NOAA guidance	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Other CICS PI Projects

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

Research dealing with the impacts of climate on health

Task Leader	Jesse E. Bell
Task Code	NC-OTH-01-NCICS-JB
Other Sponsor	CDC (IPA)
Contribution to CICS Themes (%)	Theme 1: 80%; Theme 2: 10%; Theme 3: 10%
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals:	Goal 1: 45%; Goal 2: 45%; Goal 3: 0%; Goal 4: 10%; Goal 5: 0%

Highlights: This report illustrates the collaboration and interaction with the Centers for Disease Control and Prevention on issues related to climate and health. The goal of this interaction is to increase the understanding of climate on human health and assist with projects that can further this knowledge.

BACKGROUND

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

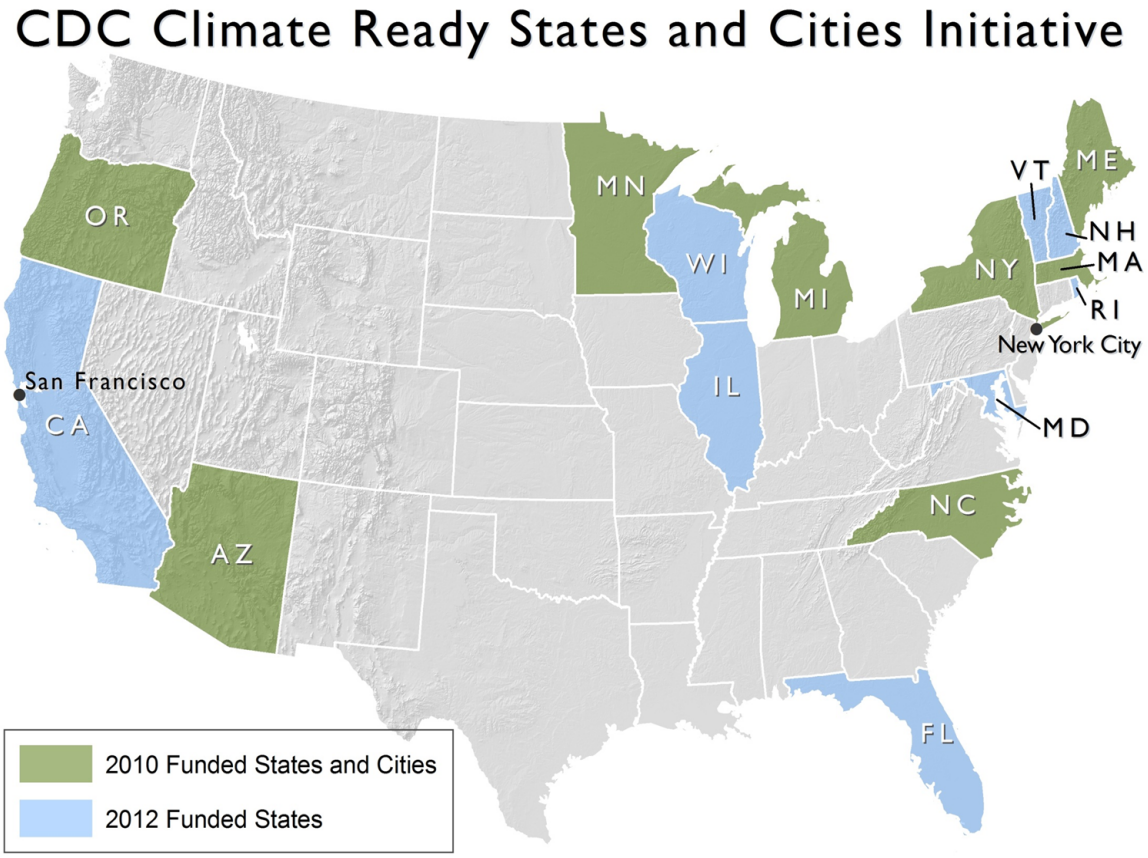


Figure 1: List of states and cities being funded by CDC's Climate-Ready States and Cities Initiative.

ACCOMPLISHMENTS

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

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

Dr. Bell is also an Adjunct Faculty member at Emory University, where he serves as an advisor to Emory Master of Public Health. In May of 2015, he had four students that finished their theses on issues related to climate and health. He has two other students graduating in May of 2016.

Dr. Bell worked on Dengue Forecasting project with several departments in the U.S. Federal government (Department of Health and Human Services, Department of Defense, Department of Commerce, and the Department of Homeland Security), with the support of the Pandemic Prediction and Forecasting Science and Technology Interagency Working Group under the National Science and Technology Council, to design an infectious disease forecasting project with the aim of galvanizing efforts to predict epidemics of dengue. As part of CICS-NC's mission to connect users and decision-makers with climate and weather data and research, Dr. Bell worked with colleagues Jessica Mathews, Jared Rennie, and Carl Schreck to develop and provide the environmental data used in this project.

PLANNED WORK

- Finish current student theses projects and submit for publication.
- Lead and complete the USGCRP – Climate and Health Assessment chapter on Extremes and Human Health.
- Continue to serve as a mentor for MPH students at Emory University.
- Continue to develop CICS connections to health community.

PUBLICATIONS

- **Bell, J. E.**, S. C. Herring, L. Jantarasami, C. Adrianopoli, K. Benedict, K. Conlon, V. Escobar, J. Hess, J. Luvall, C. P. Garcia-Pando, D. Quattrochi, **J. Runkle**, and **C. J. Schreck, III**, 2016: Ch. 4: Impacts of Extreme Events on Human Health. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, U.S. Global Change Research Program, 99–128.
- Vins, H., Bell, J.E., Saha, S., & Hess, J. J. (2015). The Mental Health Outcomes of Drought: A Systematic Review and Causal Process Diagram. International Journal of Environmental Research and Public Health, 12(10), 13251-13275.

DELIVERABLES

- NCA Heat and Precipitation Projection Data on the CDC Environmental Tracking Portal
- Environmental data for the White House OSTP Dengue Forecasting project (http://dengueforecasting.noaa.gov/)

PRESENTATIONS

- Bell, J.E. Drought and Health. Midwest Drought Early Warning System Kickoff meeting last week in St. Louis, MO. February 2016
- Bell, J.E. Climate data for health studies. CDC Annual Grantee Meeting. May 2015.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	2
# of non-peered reviewed papers	0
# of invited presentations	2
# of graduate students supported by a CICS task	0
# of graduate students formally advised	6
# of undergraduate students mentored during the year	0

The Partnership for Resilience

Task Leader	Dr. Paula Ann Hennon
Task Code	NC-OTH-02-NCICS-PH
Other Sponsor	NCSU
Contribution to CICS Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Climate Literacy, Education, Outreach, and Engagement
Contribution to NOAA goals (%)	Goal 1: 40%; Goal 2: 0%; Goal 3: 0%; Goal 4: 40%; Goal 5: 20%

Highlight: A public-private partnership organization in the form of a consortia was instituted to foster collaborative activities to stimulate economic opportunities and cultivate relationships and critical connections to foster a dynamic environmental change solution-provider industry for environmental analytics and adaptation strategies.
Link to a research web page: http://www.partnershipforresilience.org

BACKGROUND
The Partnership for Resilience (PfR) is a consortium-in-planning administered by NCSU and affiliated with the North Carolina Institute for Climate Studies to serve the public, business, non-profit, and academic communities by supporting fundamental research, workforce development, an active program of information transfer, and economic development activity. The consortia's mission is to empower society to use environmental information in decision-making processes to address increasingly complex social, environmental, and economic situations.

The concept of a "Partnership for Resilience" was formulated within NCICS with NOAA support in response to Presidential Executive Order 13653's call for "public-private partnerships to ensure federal actions are responsive to the needs of communities and businesses as the nation prepares for climate impacts." An initial workshop in Asheville explored how such a consortium could be most beneficial for partners in federal, private, nonprofit, and academia, and to society. Sufficient unmet needs and initial collaborative opportunities have been identified to encourage the continuing development and implementation of the PfR Consortium.

Recognizing that governmental agencies must engage the emerging solution provider community—business and industry, non-profit, and academic organizations—to meet the growing demand for environmental information and analytics, the PfR will provide a more efficient and accessible mechanism for climate information, resources, and solutions development. In practice, it can be confusing to determine how to get the necessary information and expertise to flow across these organizational boundaries. Through deliberate cross-collaboration, PfR will stimulate economic opportunities and cultivate relationships and critical connections to foster a dynamic environmental change solution-provider industry for environmental analytics and adaptation strategies.

ACCOMPLISHMENTS
As founding Director of the Partnership for Resilience (PfR), Dr. Hennon assembled an Advisory Board and convened preliminary Advisory Board meetings, drafted and submitted the consortium charter and bylaws to NCSU General Counsel and Administration, and developed a functional business model and 5-year operating and financial plans.

Figure 1: Partnership for Resilience functional model illustrating the role of the consortia in facilitating critical connections to foster a dynamic environmental change solution-provider industry for environmental analytics and adaptation strategies.

Dr. Hennon, Jenny Dissen, and other NCICS associates developed a "concept plan" detailing the proposed activities of the PfR including capital, facilities, and staffing needs. The NCSU Office of Research, Innovation, and Economic Development facilitated the development of foundational intellectual property sharing agreements and a mechanism for open-source software development within the consortia. The membership and dues structure was developed and reviewed by the advisory board and potential members. Currently a "Letter of Intent to Join" is being circulated to proposed members.

Preliminary collaborations intended to be foundational Working Groups are underway with private sector partners and other research organizations. The PfR expects most of its activities will be related to supporting and facilitating projects undertaken by these topical Working Groups formed to address needs of the Partners. These Working Groups will be convened to produce usable data and science, produce or add value to an open-source product, or make more than an incremental contribution to the resilience, environmental analytics, and adaptation bodies of knowledge. A representative of a Partner organization will chair each Working Group. Notional governance documents to organize and facilitate activities within these working groups have been drafted and are in review.

Once the supporting documents and infrastructure are in place, the PfR will be well-positioned to leverage the shared robust public collection of large and complex environmental data sets, data resources ,and environmental models and to develop collective expertise amongst the Partners to use the data to inform decision-making.

PLANNED WORK

- Build-out the NCICS/NCSU-branded website including a member's-only area for forums and downloads.
- Engage a broad community of scientific experts and stakeholders from across academia, industry, government, and not-for-profit associations for consortia membership activities.
- Convene and host this year's Advisory Board meetings.
- Draft the inaugural PfR State-of-the-Science Briefing, example Strategic Outlooks, and develop a template for white paper reports.
- Develop guidelines to govern access to NCICS research and computational facilities and environmental analytics expertise by Partners.
- Finalize the technology transfer and intellectual property agreement templates.
- Institute a "Resilience Fellow Exchange Program" among academic, corporate, and government partners that gives Partners the opportunity to work with leading scientists, regulators, and business leaders in a new way.
- Plan and host the inaugural Partnership for Resilience "solution showcase," working-group workshops, and an expert panel to drive innovative "Resilience Thinking" approaches.
- Begin to shape, create, and distribute learning and continuing education materials.

PRODUCTS

An industrial consortia administered by the North Carolina State University and affiliated with the North Carolina Institute for Climate Studies in Asheville, North Carolina, to serve the public, business, non-profit, and academic communities by supporting fundamental research, workforce development, an active program of information transfer and economic development activity.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	1
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	1

This is a new consortia developed to help NCICS and NOAA NCEI cultivate relationships and critical connections to foster a dynamic environmental change solution-provider industry for environmental analytics and adaptation strategies.

Water Sustainability and Climate Change: A Cross-Regional Perspective

Task Leader	Kenneth Kunkel
Task Code	NC-OTH-03-NCICS-KK
Other Sponsor	NSF
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	Climate Research, Data Assimilation and Modeling
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%

Highlight: Model simulations from the CMIP5 hindcast/predictive experiment were found to reproduce observed temperature trends for six regions of the U.S. for the period 1981-2010 and 2006-2035. Trends in the number of extreme monthly temperatures are simulated well for most regions, but not for the northwest. The very large-scale features of historical trends in extreme daily precipitation are simulated moderately well.

BACKGROUND

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

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

maintaining freshwater biodiversity. In doing so, the project will also investigate the degree to which regions have pursued 'hard path' (*i.e.*, supply augmentation) vs. 'soft path' (*i.e.*, demand reduction) strategies by explicitly modeling potential societal interventions for water sustainability.

ACCOMPLISHMENTS

The major objectives for this period were to (1) complete an analysis of trends in monthly extremes; and (2) perform an initial analysis of trends in daily precipitation extremes. Monthly temperature and daily precipitation data for thirteen models from the CMIP5 30-yr hindcast/predictive experiments for 1980-2010 and 2006-2035 were used. The total number of ensemble members for these thirteen models was 77 (64 for the predictive simulations since only ten of the thirteen are used).

Several types of analyses were performed on these model simulations:

1. An extreme temperature index was constructed by calculating standardized monthly anomalies of temperature and precipitation for the observations and models for individual grid points. This index is then divided into two parts: a positive index for values that are >+1.5σ (σ is the standard deviation of the standardized monthly anomalies) and a negative index for values that are <-1.5σ. The index is then aggregated into six regions of the U.S., *i.e.* the Southeast, Southwest, Northeast, Northwest, the Great Plains, and the Midwest (these regions are defined in the Third National Climate Assessment; Melillo et al. 2014). For each region, the total numbers of grid point values above and below 1.5σ (POS and NEG indices respectively) are summed up for each of the 30 years for observations and the models.
2. For the extreme daily precipitation, the trends and regressions are calculated based on the 99.5^{th} extremes. The extreme index is the number of days exceeding the 99.5 percentile of all daily values. This uses the hindcast data from 1981-2010 and the predictive from 2006-2035 from CMIP5.

There is good agreement between models and observations for all the regions for the annual cold index. The annual warm index shows good agreement for all the regions except the NW, where the trends are opposite *i.e.* the observed trend decreases over the study period whereas the CMIP5 multi-model mean shows an increasing trend. Seasonal disaggregation of the temperature index into winter, spring, summer, and fall indicate that most regions agree with the sign of the observed seasonal trends, except for the NW, which shows greatest disagreement with the sign of the observed trends. The major conclusion is that there is potential skill in use of GCMs to provide projections of hot and cold extremes on the 30-yr timescale. However, it is important to note that natural variability is comparable to the forced signal on this timescale and thus introduces uncertainty. Work is still in progress in calculating and diagnosing the 2006-2035 extreme temperature index.

Precipitation trends were calculated as regressions at each grid point for the 1981-2010 models and observations and the 2006-2035 models. Both the 1981-2010 observations and model mean show the central and eastern U.S. increasing in extreme precipitation, while the western U.S. generally decreases. The exception between the two is the Pacific Northwest, where the model mean shows increasing extreme precipitation whereas the observations show a decreasing trend.

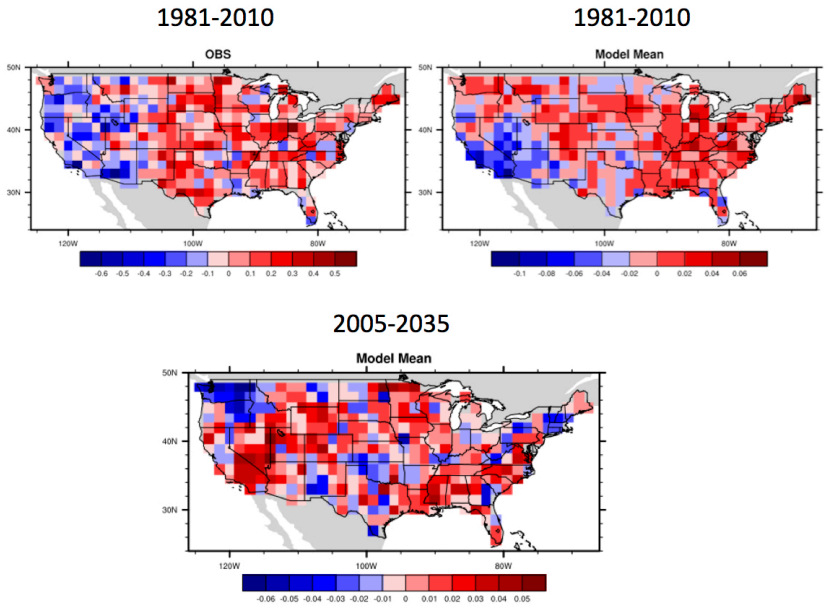


Figure 1: The regression of the 99.5th percentile precipitation calculated at each grid point for the 1981-2010 model mean and the observations and the 2006-2035 model mean. The units of the regression is %/decade.

PLANNED WORK

- Continue to analyze daily data from CMIP5 hindcast simulations for extremes
- Resubmit a peer-reviewed paper on the 1891-2035 extreme temperature index "Monthly Extreme Temperature Trends In CMIP5 Hindcast/Predictive Simulations, 1981-2010 and 2006-2035".

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

A paper is being revised for resubmission to a peer-reviewed journal after review

Incorporation of climate change into Intensity-Duration-Frequency Design Values

Task Leader	Kenneth Kunkel
Task Code	NC-OTH-04-NCICS-KK
Other Sponsor	DOD/SERDP
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Environmental Decision Support Science
Contribution to NOAA Goals (%)	Goal 1: 50%; Goal 2: 50%; Goal 3: 0%

Highlight: A comprehensive analysis of historical trends in extreme precipitation found larger increasing trends for the shortest durations and longest return periods. A candidate metric for identifying North American Monsoon heavy rainfall events has been identified.

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 will be evaluated to determine the potential impact for a wide range of frequencies and durations used by civil engineers. Then a means for adjusting and delivering the IDF values and uncertainty estimates, similar to the National Oceanic and Atmospheric Administration Atlas 14, will be provided.

ACCOMPLISHMENTS

A set of 3122 precipitation stations with a minimum of missing data was identified for analysis. Extreme precipitation events were identified for selected combinations of average recurrence interval (ARI) and duration. ARI values are 1, 2, 5, 10, and 20 years and duration values are 1, 2, 3, 5, 10, 20, and 30 days. All combinations of these values were analyzed. First, events were identified at individual stations using station-specific thresholds. Then, annual time series of grid box (1 degree latitude x 1 degree longitude) average number of events were computed as the simple average of all stations in that grid box. Finally, regional time series were constructed as the simple average of all grid boxes in the region. Trends were computed using median of pairwise trends and statistical significance evaluate with the Kendall tau test. Most regional trends are upward (*Fig. 1*) and they are mostly statistically significant in the Midwest, Northeast, and Southeast. Trend magnitude tends to be higher for larger values of ARI.

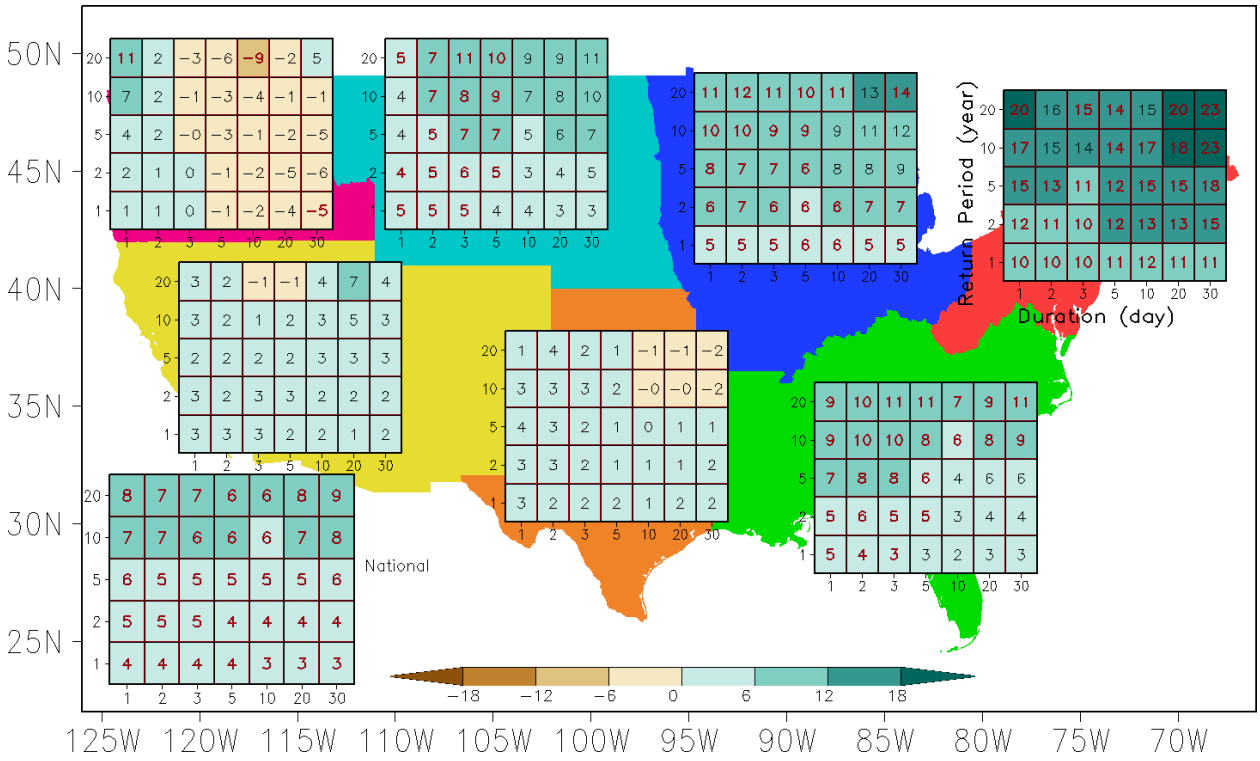


Figure 1: Observed trend in the number of extreme precipitation events for 1949-2013 for selected combinations of average recurrence interval (ARI) and duration. ARI values (vertical axis of table array) are 1, 2, 5, 10, and 20 years and duration values (horizontal axis of table array) are 1, 2, 3, 5, 10, 20, and 30 days. The number in each cell is the trend in %/decade. Teal colors indicate positive trends and brown colors indicate negative trends. The red color indicates that the trend is statistically significant at the 95% level of confidence. Trends are averages over the regions shown in the colored background map. National average trends are given in the box in the lower left corner.

Exploratory research examined various approaches to identify meteorological situations with heavy rainfall in the southwest part of the U.S. affected by the North American Monsoon. Daily events with rainfall exceeding the 20-yr ARI threshold were identified at each station in Arizona and New Mexico for 1979-2013. There were 133 days with at least 1 event. Several potential diagnostic metrics reflecting large-scale features that might be accurately simulated by climate models were tested. One of them, moisture flux convergence, appears to be well correlated with the occurrence of these very heavy events. These are preliminary results and research is ongoing.

Other exploratory research examined approaches to automatically detect warm and cold fronts in reanalysis and climate model data sets. A verification data set was identified: NOAAPort high resolution coded surface bulletins. JSON format files were generated from these bulletins. These will be used to test various automated algorithms. Candidates include neural network approaches and identification of areas of rapid change in equivalent potential temperature.

An analysis of radar rainfall estimates found that spatial correlation of heavy amounts was less for stations in the southeast U.S. An analysis of events associated with tropical cyclones found that in some areas tropical cyclones were responsible for about half of daily 4-inch rain events.

PLANNED WORK

- Complete analysis of historical trends for various regional definitions and submit journal article on results
- Complete algorithm for automated identification of fronts
- Complete analysis of historical North American Monsoon events and metrics for identification in climate model simulations
- Complete historical analysis of events associated with tropical cyclones

PUBLICATIONS

Peer-Reviewed

- Easterling, D.R., K.E. Kunkel, and M.F. Wehner, 2016: Detection and attribution of climate extremes in the observed record. *Weather and Climate Extremes*, doi:10.1016/j.wace.2016.01.001.

PRESENTATIONS

- Kunkel, K.E., 2016: Precipitation Extremes and Anthropogenically-forced Warming: Considerations for Future Changes in Design Values, Annual Meeting of the American Meteorological Society, New Orleans, LA, (13 January).
- Kunkel, K.E., 2015: Precipitation Extremes: Considerations for Anthropogenically-Forced Future Changes, Invited talk, Fall Meeting of the American Geophysical Union, San Francisco, CA, (18 December).
- Kunkel, K.E., 2015: Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values, Invited talk, Interagency Forum on Climate Change Impacts and Adaptation, Washington, DC, (8 December 8).
- Kunkel, K.E., 2015: A New Look at Precipitation Extremes in the central U.S., Invited talk, Workshop-Implications of a Changing Arctic on Water Resources and Agriculture in the Central U.S., Lincoln, NE, (10 November).
- Kunkel, K.E., 2015: Precipitation and Temperature Extremes in the U.S.: Trends and Causes, Invited talk, 40th Climate Diagnostics and Prediction Workshop, Denver CO, (26 October).

OTHER

- Kenneth Kunkel, Member, Task Committee on "Use of Atmospheric Numerical Models for Estimating Probable Maximum Precipitation", Surface Water Hydrology Technical Committee; Risk, Uncertainty & Probabilistic Approaches Technical Committee; Hydro Climate Technical Committee; Watershed Council; Environmental & Water Resources Institute (EWRI), ASCE, 2015-2017.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques transitioned to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	4
# of graduate students supported by a CICS task	0
# of graduate students formally advised	1
# of undergraduate students mentored during the year	0

One paper was published with results extracted from this project. Several invited talks were given on the project plans and results.

Role of Kelvin Waves in Tropical Cyclogenesis

Task Leader	Carl Schreck
Task Code	NC-OTH-05-NCICS-CS
Other Sponsor	NASA
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Kelvin waves encourage tropical cyclogenesis by closing the midlevel circulation in the predecessor easterly waves.

BACKGROUND

Kelvin waves are among the most prominent sources of synoptic scale rainfall variability in the tropics, but large uncertainties surround their role in tropical cyclogenesis. It is hypothesized that Kelvin waves may promote tropical cyclogenesis in four primary ways: 1) enhancing deep moist convection; 2) generating low-level cyclonic potential vorticity through diabatic heating; 3) decreasing the vertical wind shear through their vertical circulations; and 4) providing equatorial westerly anomalies that enhance the recirculation of moisture. This project uses Kelvin-filtered NASA TRMM multi-satellite rainfall estimates to identify which Kelvin wave phases produce the most tropical cyclones. For each basin and each phase, storm-relative composites are then used to test each of the hypothesized mechanisms.

ACCOMPLISHMENTS

During Year 1 of this project, we examined the frequency of tropical cyclogenesis relative to the local phase of Kelvin waves using TRMM multi-satellite precipitation analyses. In Year 2, we used MERRA data to make composites of common tropical cyclogenesis parameters for the Kelvin phases that were found to be most favorable for tropical cyclogenesis. This work was published in Year 3, the final year of the project. We also explored the interaction between eastward propagating Kelvin waves and westward moving easterly waves in a semi-Lagrangian framework.

Recent studies have shown the value of a semi-Lagrangian framework for examining tropical cyclogenesis within easterly waves. This framework is achieved by simply subtracting the easterly wave phase speed from the zonal winds. A key advantage is that it highlights the recirculation of air around the easterly wave, which appears to be an open wave with no westerlies in the earth-relative framework.

We confirmed our hypothesis that the equatorial westerlies from Kelvin waves can play a role in enhancing this closed circulation. In fact, this relationship explains the results from previous years of the project that showed tropical cyclones typically form 0–3 days *after* the passage of a Kelvin wave's convection.

Figure 1 shows vertical composites of Lagrangian zonal wind for eastern Pacific storms that formed 3.00–3.75 days after a Kelvin wave's peak convection. The equatorial westerlies in Kelvin waves (red contours) are tilted westward with height. Before intersecting the Kelvin wave (*Fig. 1a*), the easterly wave (vertical dashed line) has only shallow westerlies (red shading). These deepen somewhat as they are reinforced by the Kelvin wave's low-level westerlies (*Fig. 1b*). As the Kelvin wave passes, these

westerlies deepen due to the Kelvin wave's tilt. Tropical cyclogenesis happens when these westerlies extend up to 400 hPa (*Fig. 1c*), which would support a deep cyclonic circulation.

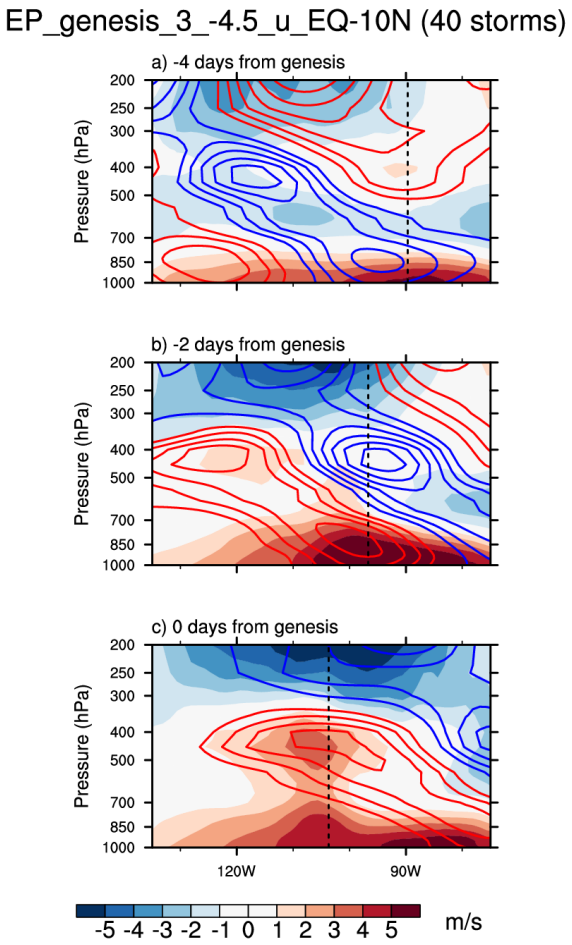


Figure 1: Vertical cross-section composites for eastern Pacific tropical cyclones forming 3.00–3.75 days after Kelvin wave passage. Semi-Lagrangian zonal winds are shaded and Kelvin-filtered zonal winds are contoured.

PLANNED WORK

- Publish the semi-Lagrangian results and present them at the 32nd AMS Tropical Conference in April 2016.

PUBLICATIONS

- Schreck, C. J., 2015: Kelvin Waves and Tropical Cyclogenesis: A Global Survey. *Mon. Wea. Rev.*, 143, 3996–4011, doi:10.1175/MWR-D-15-0111.1.

PRESENTATIONS

- Schreck, C. J., 2016: Kelvin Waves and Tropical Cyclogenesis in a Lagrangian Framework. *Fourth Symposium on the Madden–Julian Oscillation*, 10-14 January 2016, New Orleans, LA.
- Schreck, C. J., 2016: Kelvin Waves and Tropical Cyclogenesis in a Lagrangian Framework. *NASA Precipitation Measurement Mission Science Team Meeting*, 13–15 July 2015, Baltimore, MD.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

German Wind Power Model Development Support

Task Leader	Carl Schreck
Task Code	NC-OTH-06-NCICS-CS
Other Sponsor	EarthRisk/Riskpulse
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 50%; Theme 3: 50%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 100%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Wind power generation over Germany can be statistically forecast out to 30 days using teleconnections, including tropical diagnostics of outgoing longwave radiation.

BACKGROUND

Wind power constitutes a significant portion of the power generation portfolio in Germany. As such, it can significantly impact energy-related commodities markets in the region. Financial sector companies are seeking long-range (2-4 weeks) forecasts of wind power to improve their trading efficiency. In particular, they are seeking to leverage tropical forcing like ENSO and the Madden–Julian Oscillation (MJO) to improve those forecasts.

ACCOMPLISHMENTS

CICS-NC provided research support to Riskpulse, Inc. for their development of WindRisk, a statistical model to forecast German wind power. The predictors in this model are the leading EOFs for a variety of atmospheric variables, including NCEI's daily outgoing longwave radiation (OLR) CDR. These EOFs were calculated using both raw daily data and time-averaged data to leverage intraseasonal-to-interannual climate variability. OLR proved to be a valuable predictor in week 2 and beyond. A sample forecast is shown in *Figure 1* below.

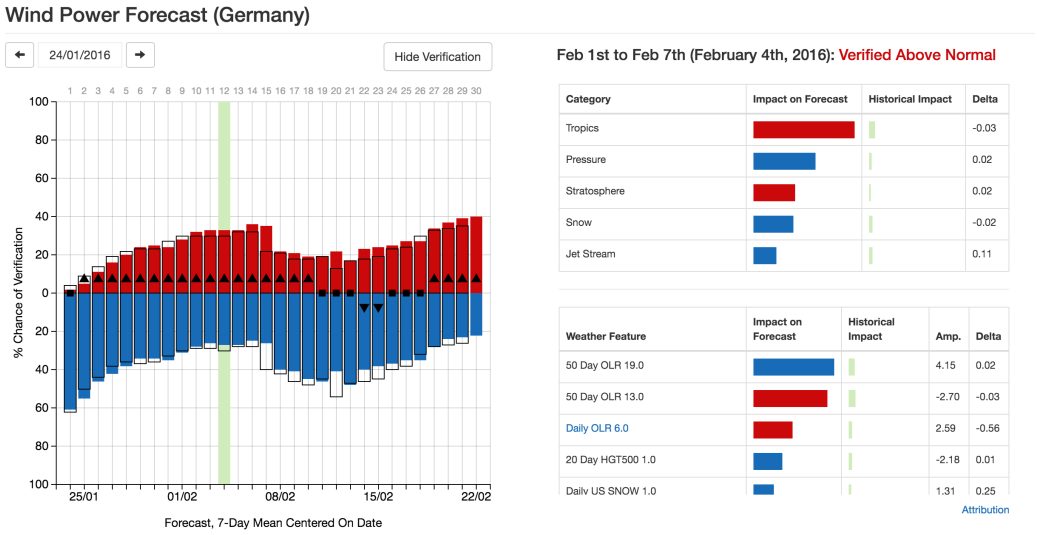


Figure 1: Left- Probability of low (blue) and high (red) wind power for overlapping 7-day windows. Arrows indicate actual verification. Right- Relative contributions of individual predictors (bottom-right) and groups of predictors (top-right). Red bars indicate predictors that increase the wind power, blue bars suppress it.

The model performance was skillful compared to climatology out to 30 days in a 30-year hindcast. Unfortunately, the skill in the last five years only extended to 15 days. This has been a period of particularly high wind, which may have changed the forecast difficulty. The statistical model also failed to out-perform the ECMWF dynamical model over this period. Even so, a combination of the ECMWF and WindRisk was found to be significantly more skillful than either model alone. Thus the model still provides unique value to its users.

PLANNED WORK

- This project is complete; no further work is planned at this time.

DELIVERABLES

- This research has been implemented into Riskpulse's new WindRisk model, which is now operational

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	1
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Relationship between occurrence of precipitation and incidence of traffic fatalities using high-resolution NEXRAD reanalysis

Task Leader	Scott Stevens
Task Code	NC-OTH-07-NCICS-SS
Other Sponsor	CDC
Contribution to CICS Themes (%)	Theme 1: 70%; Theme 2: 30%; Theme 3: 0%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 10%; Goal 2: 60%; Goal 3: 0%; Goal 4: 30%; Goal 5: 0%

Highlight: This project is using the recently completed NMQ/Q2 NEXRAD reanalysis to study the impact of precipitation on the frequency of fatal auto accidents across the United States. The new product has the ability to determine the intensity of precipitation (if any) within five minutes and one kilometer of a crash.

BACKGROUND

The recently completed high-resolution NEXRAD reanalysis (NMQ/Q2) provides the ability to study precipitation at a very fine scale in both space and time. Using data from the Fatality Analysis Reporting System (FARS), we are able to cross-reference the time and location of every fatal accident in the United States with radar-based precipitation estimates over a six-year period, which includes nearly 200,000 fatal accidents. This allows us to determine if the incidence of precipitation has a measureable impact on the frequency of fatal crashes under a variety of conditions such as time of day, region, and season.

ACCOMPLISHMENTS

We have been able to show that in all regions, the occurrence of precipitation is associated with a measureable and significant increase in the frequency of fatal auto crashes. The strength of this relationship varies strongly by time of year, time of day, and region. *Figure 1* shows, as an example, the frequency of rainfall (blue) compared to the frequency of crashes that occur during rain (red) at each hour of the day for the Southeast region of the United States.

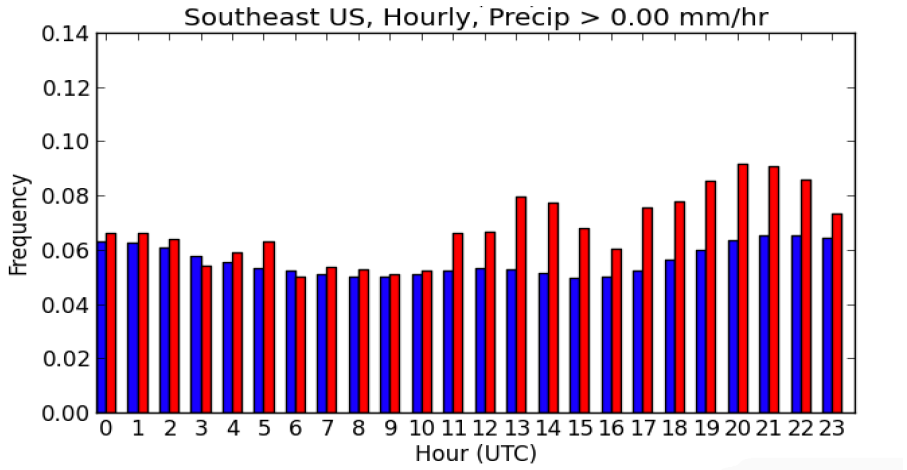


Figure 1: Comparison of frequency of precipitation (blue) to percentage of fatal accidents that occur during rain (red) by hour for the Southeast region of the United States.

PLANNED WORK

- Refine graphs and prepare for publication
- Submit manuscript to a journal yet to be determined

DELIVERABLES

- Manuscript to be submitted for publication soon

PRESENTATIONS

- 2016-02-16: Presented findings to Climate and Health group at the Centers for Disease Control and Prevention in Atlanta, GA.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Trends and Projections of Northern Hemisphere Blocking Highs

Task Leader	Brooke Stewart and Kenneth Kunkel
Task Code	NC-OTH-08-NCICS-BS
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	Climate Research and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Analysis of 20th Century Reanalysis data provides a 141-year climatology of blocking high events—a period longer than any previous analysis.

BACKGROUND

For certain types of extreme weather, most notably heat waves and droughts, a phenomenon known as the "blocking high" is often responsible. These are upper level high pressure systems that are essentially stagnant and "block" the movement of ETCs into the region where the high pressure system is located. Future changes in extreme weather in mid- to high-latitudes will likely involve changes in the frequency, intensity, and tracks of ETCs and blocking highs.

A new analysis of surface pressure data has extended the availability of pressure field data from the mid-20th century as used in previous studies, back to the late 19th century. This project used this new 20th Century Reanalysis (20CR) dataset to extend the analysis of blocking high occurrence, including long-term trends.

ACCOMPLISHMENTS

- Ran all 56 ensemble members from 20CR dataset through the blocking high algorithm
- Adapted algorithm to be able to run NCEP NCAR Reanalysis data through the same algorithm
- A blocking event is defined as a positive geo-potential height anomaly at the mid-tropospheric level (500-hPa) persisting for at least five days and spatially covering at least five blocked longitudes on a 2º x 2º grid using the Twentieth Century Reanalysis (version 2c) dataset. Initial analyses find approximately 21 blocking events per year over a 141-year period. This result is lower than that found by previous studies, but can be explained by differences in the algorithm used here versus those used by other studies. The duration of most events is between 5 and 9 days, with an average value of 7.68 days. Durations show an exponentially decreasing and long-tailed distribution. Annual and seasonal longitudinal frequency distributions are consistent with those found by previous studies.

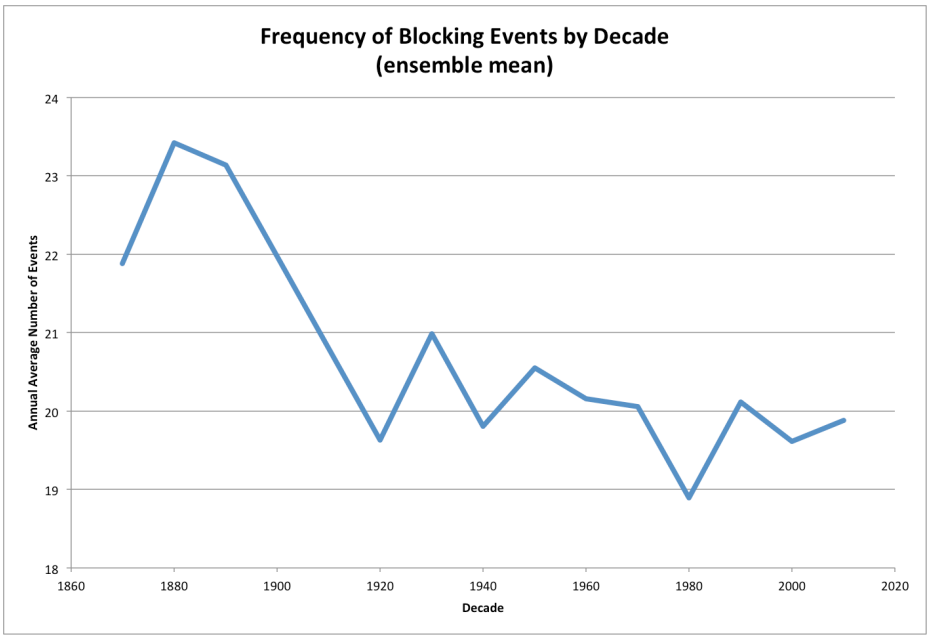


Figure 1: Frequency of blocking events by decade, ensemble mean for the first 25 ensemble members of the 20CR dataset.

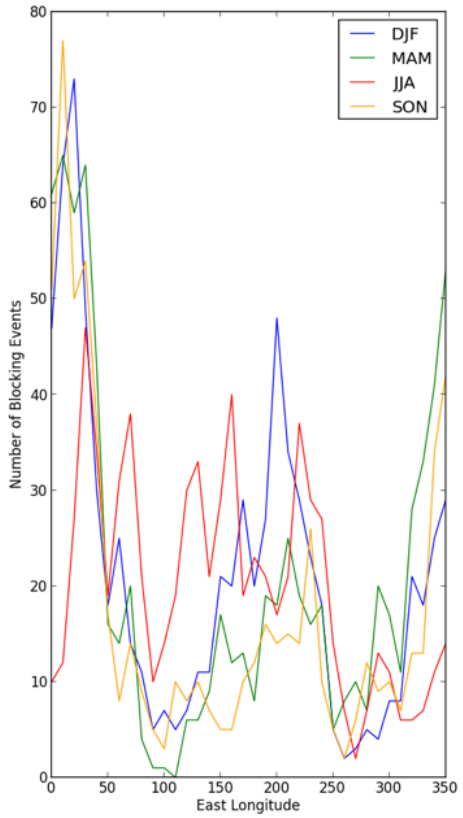


Figure 2: Seasonal longitudinal frequency of blocking high events for one ensemble member from the 20CR data set.

PLANNED WORK

- Run NCEP NCAR Reanalysis Data through blocking high algorithm
- Compare results between 20CR data and NCEP NCAR reanalysis data
- Complete manuscript on historical trends in blocking highs
- Run CMIP5 data through blocking high algorithm
- Develop blocking high algorithm based on potential vorticity and potential temperature and compare results to geo-potential height-based algorithm in order to draw conclusions about the sensitivity of the occurrence of events to the detection method used

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	0
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Trends and Projections of Northern Hemisphere Extratropical Cyclones

Task Leader	Liqiang Sun and Kenneth Kunkel
Task Code	NC-OTH-08-NCICS-LS
NOAA Sponsor	David Easterling
NOAA Office	OAR/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	Climate Research and Modeling
Contribution to NOAA goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%

Highlight: Analysis of CMIP5 future projections indicates a decrease in weak ETCs and an increase in strong ETCs. Also a northward shift in the mean track is projected.

BACKGROUND

ETCs are large-scale, non-tropical low-pressure storm systems that typically develop along a frontal boundary between air masses of contrasting temperature. The ETC is the principal atmospheric phenomenon through which sensible and latent heat fluxes are exchanged between the subtropical and polar regions. These large-scale cyclonic storms are the major feature of mid-latitude weather during the colder times of the year and often have severe weather associated with them. These storms can produce large snowfall amounts, which, together with high winds, result in blizzard conditions, large waves leading to coastal erosion, and severe convective events with lightning and tornadoes. In fact, these storms (or their absence in the case of drought) are responsible for many of the extreme weather types experienced at mid- and high-latitudes. ETCs are ubiquitous throughout the year, but tend to be stronger and located more equator-ward in the cold season. Future changes in extreme weather in mid to high latitudes will likely involve changes in the frequency, intensity, and tracks of ETCs.

A number of recent studies focused on the Northern Hemisphere have documented a significant poleward shift of the storm track in both the Pacific and Atlantic Ocean basins, a decrease in ETC frequency in mid-latitudes, and a corresponding increase in ETC activity at higher latitudes for the latter half of the 20th century. Future climate warming may lead to a decrease in polar low activity. A new analysis of surface pressure data has extended the availability of pressure field data from the mid-20th century as used in previous studies, back to the late 19th Century. We have used this new 20th Century Reanalysis (20CR) data set to extend the analysis of ETC occurrence in the Northern Hemisphere to the period 1871-2007.

ACCOMPLISHMENTS

- Identification and tracking of extra-tropical cyclones (ETC) in the CMIP5 simulations were carried out, in support of the ETC/Blocking project. A paper is in preparation, to summarize the climate change of ETC frequency, intensity and duration during 1950-2100.
- A 6-hourly dataset of geopotential height on pressure levels was created using CMIP5 temperature, surface pressure and topography data. This dataset covers the time period from 1950 to 2100, and is used for identification and tracking of blocking anticyclones.
- Contributed to the metadata collection for the CMIP5 report, Health Assessment, and State Summaries.
- Provided CMIP5 annual, monthly, and daily data and technical support to Ryan Smith at the 14th Weather Squadron.

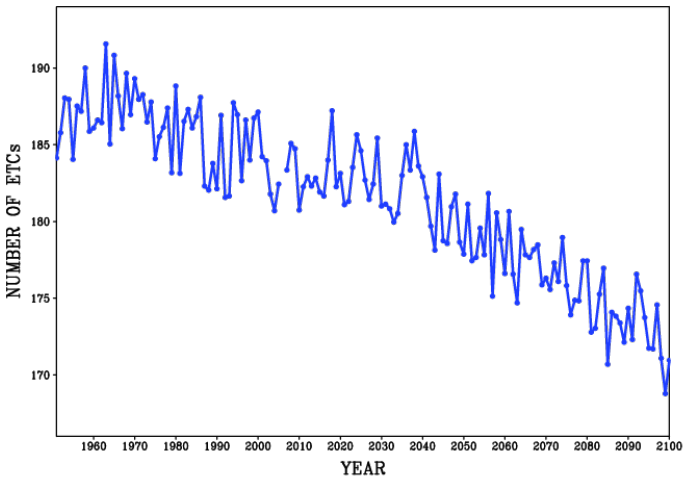


Figure 1: Annual time series of the cold season (November – March) ETC occurrences in the Northern Hemisphere. The numbers of ETCs are multi-model means from 23 CMIP5 global climate simulations for the historical period (1950-2005), and under the RCP8.5 scenarios (2006-2100).

PLANNED WORK

- Publish scientific journal paper on future projections
- Incorporate results into research on frontal climatologies
- Select models based on historical performance for use in other projects

PRESENTATIONS

- Sun, L.: Seasonal climate prediction in a changing climate: Northeast Brazil, invited talk via Skype, Climate Prediction Committee Meeting, Brazil, January 18, 2016.
- Banzon, V., G. Liu, K. Fornry, E.A. Becker, L. Sun, K. Arzayus: Use of a Blended Satellite and In situ Sea Surface Temperature Climate Data Record for Evaluating Long-term Impacts on Coral and Marine Mammal Communities, 2016 Ocean Sciences Meeting, New Orleans, LA, Feb. 21-26, 2016.

OTHER

- Committee member: *14th International Regional Spectral Model Workshop*, Rio de Janeiro, Brazil, October 2016.
- Visitor host: Dr. Tian-Kuay Lim, deputy director of National Environmental Agency, Singapore, October 28-30, 2015.

PERFORMANCE METRICS

	FY16
# of new or improved products developed	0
# of products or techniques submitted to NOAA for consideration in operations use	0
# of peer reviewed papers	0
# of non-peered reviewed papers	0
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

Appendix 1: Performance Metrics for CICS-NC

TOTAL CICS-NC PERFORMANCE METRICS

	FY16
# of new or improved products developed	89
# of products or techniques submitted to NOAA for consideration in operations use	18
# of peer reviewed papers	41
# of non-peered reviewed papers	7
# of invited presentations	52
# of graduate students supported by a CICS task	3
# of graduate students formally advised	11
# of undergraduate students mentored during the year	9

Appendix 2: CICS-NC Publications 2015–2016

Bell, J. E., S. C. Herring, L. Jantarasami, C. Adrianopoli, K. Benedict, K. Conlon, V. Escobar, J. Hess, J. Luvall, C. P. Garcia-Pando, D. Quattrochi, **J. Runkle**, and **C. J. Schreck, III**, 2016: Ch. 4: Impacts of Extreme Events on Human Health. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*, U.S. Global Change Research Program, 99–128. http://dx.doi.org/10.7930/J0BZ63ZV

Bell, J. E., **R. D. Leeper**, M. A. Palecki, E. Coopersmith, T. Wilson, R. Bilotta, and S. Embler, 2015: Evaluation of the 2012 Drought with a Newly Established National Soil Monitoring Network. *Vadose Zone Journal*, **14**. http://dx.doi.org/10.2136/vzj2015.02.0023

Claverie, M., **J. L. Matthews**, E. F. Vermote, and C. O. Justice, 2016: A 30+ year AVHRR LAI and FAPAR Climate Data Record: Algorithm description and validation. *Remote Sensing*, **8,** 263. http://dx.doi.org/10.3390/rs8030263

Coopersmith, E. J., **J. E. Bell**, and M. H. Cosh, 2015: Extending the soil moisture data record of the U.S. Climate Reference Network (USCRN) and Soil Climate Analysis Network (SCAN). *Advances in Water Resources*, **79,** 80-90. http://dx.doi.org/10.1016/j.advwatres.2015.02.006

Coopersmith, E. J., M. H. Cosh, **J. E. Bell**, and W. T. Crow, 2016: Multi-profile analysis of soil moisture within the US Climate Reference Network. *Vadose Zone Journal*, **15**. http://dx.doi.org/10.2136/vzj2015.01.0016

Coopersmith, E. J., M. H. Cosh, R. Bindlish, and **J. Bell**, 2015: Comparing AMSR-E soil moisture estimates to the extended record of the U.S. Climate Reference Network (USCRN). *Advances in Water Resources*, **85,** 79-85. http://dx.doi.org/10.1016/j.advwatres.2015.09.003

Easterling, D. R., **K. E. Kunkel**, M. F. Wehner, and **L. Sun**, 2016: Detection and attribution of climate extremes in the observed record. *Weather and Climate Extremes*, **11,** 17-27. http://dx.doi.org/http://dx.doi.org/10.1016/j.wace.2016.01.001

Frei, A., **K. E. Kunkel**, and A. Matonse, 2015: The seasonal nature of extreme hydrological events in the Northeastern United States. *Journal of Hydrometeorology*, **16,** 2065–2085. http://dx.doi.org/10.1175/JHM-D-14-0237.1

Hennon, C. C., K. R. Knapp, **C. J. Schreck, III**, **S. E. Stevens**, J. P. Kossin, P. W. Thorne, **P. A. Hennon**, M. C. Kruk, **J. Rennie**, J.-M. Gadéa, M. Striegl, and I. Carley, 2015: Cyclone Center: Can citizen scientists improve tropical cyclone intensity records? *Bulletin of the American Meteorological Society*, **96,** 591-607. http://dx.doi.org/10.1175/BAMS-D-13-00152.1

Inamdar, A., and P. Guillevic, 2015: Net surface shortwave radiation from GOES imagery—product evaluation using ground-based measurements from SURFRAD. *Remote Sensing*, **7,** 10788. http://dx.doi.org/10.3390/rs70810788

Inamdar, A., and K. R. Knapp, 2015: Inter-comparison of independent calibration techniques applied to the visible channel of the ISCCP B1 data. *Journal of Atmospheric and Oceanic Sciences*, **32,** 1225-1240. http://dx.doi.org/10.1175/JTECH-D-14-00040.1

Jacobs, J., S. K. Moore, **K. E. Kunkel**, and **L. Sun**, 2015: A framework for examining climate-driven changes to the seasonality and geographical range of coastal pathogens and harmful algae. *Climate Risk Management*, **8,** 16-27. http://dx.doi.org/10.1016/j.crm.2015.03.002

Kibler, S. R., P. A. Tester, **K. E. Kunkel**, S. K. Moore, and R. W. Litaker, 2015: Effects of ocean warming on growth and distribution of dinoflagellates associated with ciguatera fish poisoning in the Caribbean. *Ecological Modelling*, **316,** 194-210. http://dx.doi.org/10.1016/j.ecolmodel.2015.08.020

Klotzbach, P. J., E. C. J. Oliver, **R. D. Leeper**, and **C. J. Schreck, III**, 2016: The relationship between the Madden–Julian Oscillation (MJO) and southeastern New England snowfall. *Monthly Weather Review*, **144,** 1355-1362. http://dx.doi.org/doi:10.1175/MWR-D-15-0434.1

Kossin, J. P., T. R. Knutson, K. A. Emanuel, T. R. Karl, **K. E. Kunkel**, and J. J. O'Brien, 2015: Reply to 'Comment on "Monitoring and Understanding Trends in Extreme Storms - State of Knowledge"'. *Bulletin of the American Meteorological Society*, **96,** 1177–1179. http://dx.doi.org/10.1175/BAMS-D-14-00261.1

Kunkel, K. E., and **R. M. Frankson**, 2016: Global land surface extremes of precipitation. *Journal of Extreme Events*, **2,** 1550004. http://dx.doi.org/10.1142/S2345737615500049

Kunkel, K. E., R. Moss, and A. Parris, 2015: Innovations in science and scenarios for assessment. *Climatic Change*, **135,** 55-68. http://dx.doi.org/10.1007/s10584-015-1494-z

Miao, C, H. Ashouri, **K. Hsu**, S. Sorooshian, and Q. Duan, Evaluation of the PERSIANN-CDR Daily Rainfall Estimates in Capturing the Behavior of Extreme Precipitation Events over China, *Journal of Hydrometeorology*, 16(3), 1387-1396, 2015. doi: http://dx.doi.org/10.1175/JHM-D-14-0174.1.

Nasrollahi, N., A. AghaKouchak, L. Cheng, L. Damberg, T.J., Phillips, C. Miao, **K. Hsu**, and S. Sorooshian, How Well do CMIP5 climate simulations replicate historical trends and patterns of meteorological droughts, *Water Resources Research*, . http://dx.doi.org/10.1002/2014WR16318, 2847-2864, 2015.

Nelson, B. R., **O. P. Prat**, D. J. Seo, and E. Habib, 2015: Assessment and implications of NCEP Stage IV quantitative precipitation estimates for product intercomparisons. *Weather and Forecasting*, **31,** 371-394. http://dx.doi.org/10.1175/WAF-D-14-00112.1

Nguyen, P., A. Thorstensen, S. Sorooshian, **K. Hsu**, and A. AghaKouchak, Flood Forecasting and Inundation Mapping Using HiResFlood-UCI and Near-Real-Time Satellite Precipitation Data: The 2008 Iowa Flood, *Journal of Hydrometeorology*, 16, 1171-1183. . http://dx.doi.org/10.1175/JHM-D-14-0212.1

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

Peng, G., L. Shi, **S. T. Stegall**, **J. L. Matthews**, and C. W. Fairall, 2016: An evaluation of HIRS near-surface air temperature product in the Arctic with SHEBA data. *Journal of Atmospheric and Oceanic Technology*, **33,** 453-460. http://dx.doi.org/10.1175/JTECH-D-15-0217.1

Prat, O. P., and B. R. Nelson, 2015: Evaluation of precipitation estimates over CONUS derived from satellite, radar, and rain gauge data sets at daily to annual scales (2002–2012). *Hydrology and Earth System Sciences*, **19,** 2037-2056. http://dx.doi.org/10.5194/hess-19-2037-2015

Schreck, C. J., III, 2015: Kelvin waves and tropical cyclogenesis: A global survey. *Monthly Weather Review*, **143**. http://dx.doi.org/10.1175/MWR-D-15-0111.1

Schreck, C. J., III, S. Bennett, J. M. Cordeira, J. Crouch, **J. Dissen**, A. L. Lang, D. Margolin, A. O'Shay, **J. Rennie**, and M. J. Ventrice, 2015: Natural gas prices and the extreme winters of 2011/12 and 2013/14: Causes, indicators, and interactions. *Bulletin of the American Meteorological Society*, **96,** S93-S96. http://dx.doi.org/10.1175/BAMS-D-13-00237.1

Shi, L., **J. L. Matthews**, S.-p. Ho, Q. Yang, and J. J. Bates, 2016: Algorithm development of temperature and humidity profile retrievals for long-term HIRS observations. *Remote Sensing*, **8,** 280. http://dx.doi.org/10.3390/rs8040280

Sun, L., **K. E. Kunkel**, **L. E. Stevens**, **A. Buddenberg**, J. G. Dobson, and D. R. Easterling, 2015: Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment. NOAA Technical Report, NESDIS 144, 111 pp. http://dx.doi.org/10.7289/V5RB72KG

Thorstensen, A., P. Nguyen, **K. Hsu**, and S. Sorooshian, Using Densely Distributed Soil Moisture Observations for Calibration of a Hydrologic Model, *Journal of Hydrometeorology*, 17, 571-590. http://dx.doi.org/10.1175/JHM-D-15-0071.1

Vins, H., **J. Bell**, S. Saha, and J. J. Hess, 2015: The Mental Health Outcomes of Drought: A Systematic Review and Causal Process Diagram. *International Journal of Environmental Research and Public Health*, **12**. http://dx.doi.org/10.3390/ijerph121013251

Waple, A. M., **S. M. Champion**, **K. E. Kunkel**, and C. Tilmes, 2016: Innovations in information management and access for assessments. *Climatic Change*, **135,** 69-83. http://dx.doi.org/10.1007/s10584-015-1588-7

Appendix 3: CICS-NC Presentations 2015–2016

- **Bell, J.E.** Evaluation of the California Drought with USCRN Soil Observations. Irvine, CA. AGU Chapman Conference on California Drought. April 2015
- **Bell, J.E.** Climate data for health studies. CDC Annual Grantee Meeting. May 2015.
- **Bell, J.E.** Monitoring Drought with a National Soil Monitoring Network. AMS Annual Meeting, New Orleans. January 2016.
- **Bell, J.E.** Drought and Health. Midwest Drought Early Warning System Kickoff meeting last week in St. Louis, MO. February 2016
- **Brown, O., Kunkel, K., Dissen, J.** "Opportunities in Climate Analytics for Utilities." Utility Analytics Executive Advisory Council, August 2015
- **Brown, O., Kunkel, K., Dissen, J.** "Storm Data for Utilities." Utility Analytics Storm Analytics Working Group Presentation, September 2015
- **Champion, S.** and **Kunkel, K.E**., 2015: Data Management and the National Climate Assessment: A Data Quality Solution, Invited talk, Fall Meeting of the American Geophysical Union, San Francisco, CA, (14 December).
- Brewer, Michael. "NCEI User Engagement Strategy." Climate Data Record Annual PI Meeting, August 2015 (**Jenny Dissen**, input and co-author as part of the NCEI Engagement Team)
- **Dissen, J.** (Panel Discussion Presentation) "Panel Discussion: Climate Change and Clean Energy." Asheville Bioneers Conference, Lenoir-Rhyne University Center for Graduate Studies of Asheville, November 2015
- American Association of State Climatologists, 2015 Annual Meeting (**Jenny Dissen**, input and co-author as part of NCEI Engagement Team)
- 2015 NARUC Summer Meeting (**Jenny Dissen**, presentation in collaboration with Phil Hanser)
- Nguyen, P., A. Thorstensen, H. Liu, S. Sellars, H. Ashouri, D. Braithwaite, **K. Hsu**, X. Gao, and S. Sorooshian. CHRS CONNECT – A global extreme precipitation event database using object-oriented approach. Poster session at the Fifth annual workshop on Understanding Climate Change from Data; 2015 Aug 4-5; University of Minnesota, Minneapolis, Minnesota, USA.
- **Kunkel, K.E.**, 2015: NOAA State Summaries for the National Climate Assessment, Annual meeting of the American Association of State Climatologists, invited talk, Cape May, NJ, (25 June).
- **Kunkel, K.E.**, 2015: Opportunities in Climate Analytics for Utilities, Summer Meeting of the Utility Analytics Institute Executive Advisory Council, Atlanta, GA, (11 August).
- **Kunkel, K.E.**, 2015: Downscaling of Global Climate Models, U.S.-India Joint Working Group on Combating Climate Change, Washington, DC, (21 September 21).
- **Kunkel, K.E.**, 2015: Extreme Climate Trends and Projections for the Southeast U.S., invited keynote, Annual Meeting of the Southeast Climate Consortium, Athens, GA, (20 October).
- **Kunkel, K.E.**, 2015: Attribution of Heat and Cold Events, Invited talk, National Academy of Sciences Extreme Weather Events and Climate Change Attribution Workshop, Washington, DC, (22 October).
- **Kunkel, K.E.**, 2015: Precipitation and Temperature Extremes in the U.S.: Trends and Causes, Invited talk, 40th Climate Diagnostics and Prediction Workshop, Denver CO, (26 October).
- **Kunkel, K.E.**, 2015: Climate Resilience for the Southeast U.S., Invited talk, "Climate Resilient Design in the Southeast", Asheville chapter of The American Institute of Architects and The Collider, Asheville, NC, (6 November).

- **Kunkel, K.E.**, 2015: A New Look at Precipitation Extremes in the central U.S., Invited talk, Workshop-Implications of a Changing Arctic on Water Resources and Agriculture in the Central U.S., Lincoln, NE, (10 November).
- **Kunkel, K.E.**, 2015: Incorporation of the Effects of Future Anthropogenically-Forced Climate Change in Intensity-Duration-Frequency Design Values, Invited talk, Interagency Forum on Climate Change Impacts and Adaptation, Washington, DC, (8 December 8).
- **Kunkel, K.E.**, 2015: Precipitation Extremes: Considerations for Anthropogenically-Forced Future Changes, Invited talk, Fall Meeting of the American Geophysical Union, San Francisco, CA, (18 December).
- **Kunkel, K.E.**, 2016: Communicating Uncertainty in Weather and Climate-From PoPs to Beyond CO2, invited talk, Town Hall Panel, Annual Meeting of the American Meteorological Society, New Orleans, LA, (12 January).
- **Kunkel, K.E.**, 2016: The Development of Climate Scenarios for the National Climate Assessment, Annual Meeting of the American Meteorological Society, New Orleans, LA, (13 January).
- **Kunkel, K.E.**, 2016: Precipitation Extremes and Anthropogenically-forced Warming: Considerations for Future Changes in Design Values, Annual Meeting of the American Meteorological Society, New Orleans, LA, (13 January).
- **Kunkel, K.E.**, 2016: Climate Resilience for the Southeast U.S., Research Triangle Park Foundation webinar, (22 February).
- **Leeper, R**. D. An Exploratory Analysis of the 20th Century Reanalysis Extra-Tropical Cyclone Track Density, Wednesday 13th Poster Session at the 96th American Meteorological Society Annual Meeting in New Orleans, LA January 2016
- **Leeper R. D.**, Bell, J. E., Palecki, M. An investigation of soil moisture extremes over the 2012 drought, 30th Conference of Hydrology at the 96th American Meteorological Society Annual Meeting in New Orleans, LA January 2016.
- Privette, J. L., **G. Peng**, and K. Casey, 2015: Stewardship Frameworks in the National Centers for Environmental Information. NCEI/CICS-NC Branch Seminar Series. June 30, 2015, Asheville, NC, USA.
- **Peng, G.**, 2015: A new paradigm for ensuring and improving data quality and usability – Roles and responsibilities of key players and stakeholders. 2015 ESIP Summer Meeting, Jul 14 – 17, 2015, Pacific Cove, CA, USA.
- **Peng, G.**, 2015: Towards a consistent measure of stewardship practices applied to individual digital Earth Science datasets. 2015 ESIP Summer Meeting, Jul 14 – 17, 2015, Pacific Cove, CA, USA.
- **Peng, G.,** 2015: Stewardship maturity assessment of GHCN-Monthly v3 and lessons learned. NCEI stakeholders and management briefing. September 28, 2015. Asheville, NC, USA.
- Ramapriyan, H., D. Moroni, and **G. Peng**, 2015: Improving information quality for Earth Science data and products – overview. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Downs, R., **G. Peng**, Y. Wei, H. Ramapriyan, and D. Moroni, 2015: Enabling the usability of Earth Science data products and services by evaluating, describing, and improving data quality throughout the data lifecycle (invited). 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Ritchey, N. and **G. Peng**, 2015: Assessing stewardship maturity: use case study results and lessons learned. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.

- Hou, C.-Y., M. Mayermik, **G. Peng**, R. Duerr, and A. Rosati, 2015: Assessing formation quality: Use case studies for the data stewardship maturity matrix. Poster. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Austin, M. and **G. Peng**, 2015: A Prototype for content-rich decision-making support in NOAA using data as an asset. Poster. 2015 AGU Fall meeting, 14 – 18 December 2015, San Francisco, CA, USA.
- Ritchey, N., A. Milan, P. Jones, D. Collins, Y. Li, J. Mize, and **G. Peng**, 2016: NOAA OneStop: Metadata Plans and Progress. 4 – 5 January 2016, NOAA's Environmental Data Management Workshop, Washington, D.C., USA.
- Kim, B., D.-J. Seo, B.R. Nelson, and **O.P. Prat** 2015. Improving Multisensor Precipitation Estimation via Conditional Bias-Penalized Optimal Estimation. *2015 EWRI World Environmental & Water Resources Congress*, May 17-21 2015, Austin, TX, USA. (O)
- **Prat, O.P.**, B.R. Nelson, **S.E. Stevens**, **E. Nickl**, and **L. Vasquez**, 2015. Toward the development of an evaluation framework of climate data records for precipitation. *2015 NOAA Climate Data Record (CDR) Program Annual Meeting*, August 3-7 2015, Asheville, NC, USA.
- Nelson, B.R., D. Kim, **O.P. Prat**, **S.E. Stevens**, J. Zhang, and K. Howard, 2015. NOAA's NEXRAD Reprocessing Effort - Bias assessment and adjustment of a long-term high-resolution quantitative precipitation estimates. *37th AMS conference on radar meteorology*, September 13-18 2015, Norman, OK, USA.
- **Prat, O.P.**, B.R. Nelson, **S.E. Stevens**, **E. Nickl**, D.-J. Seo, B. Kim, J. Zhang, and Y. Qi, 2015. Merging radar Quantitative Precipitation Estimates (QPEs) from the high-resolution NEXRAD reanalysis over CONUS with rain-gauge observations. *2015 AGU fall meeting*, December 14-18 2015, San Francisco, CA, USA.
- Nelson, B.R., **O.P. Prat**, and **L. Vasquez**, 2015. Precipitation Climate Data Records. *2015 AGU fall meeting*, December 14-18 2015, San Francisco, CA, USA.
- **Prat, O.P**., B.R. Nelson, **E. Nickl**, R. Adler, R. Ferraro, S. Sorooshian, and P. Xie, 2016. Global Evaluation of Satellite Based Quantitative Precipitation Estimates (QPEs) from the Reference Environmental Data Records (REDRs). *2016 EGU General Assembly*, April 17-22 2016, Vienna, Austria.
- Lattanzio, A., **J. Matthews**, M. Takahasi, K. Knapp, J. Schulz, R. Roebeling, R. Stoeckli. 2014. 30 years of land surface albedo from GEO satellites. *QA4ECV Review Meeting*, 5-6 February 2015, Mainz, Germany.
- Shi, L., **J.L. Matthews**, **S. Stegall**, **G. Peng**. 2015. Deriving long-term global dataset of temperature and humidity profiles from HIRS. The 20th International TOVS Study Conference, 28 October-3 November 2015, Lake Geneva, Wisconsin, USA.
- NCEI Branch Seminar on the Climate and Health Assessment and related TSU activities. July 28, 2015. National Centers for Environmental Information, Asheville, North Carolina. (**Tom Maycock** and **Jennifer Runkle**)
- **Tom Maycock:** "Climate Change and the 2014 National Climate Assessment." September 12, 2015, Omaha, NE. Presentation to a book club.
- **Tom Maycock:** "Asheville, Climate, and Climate Change." November 16, 2015. Ardenwoods Senior Living Center, Arden, North Carolina.
- **Nickl, E.**, C. Willmott, and R. Vose (2016). Estimation of land surface precipitation for contiguous U.S. using a new spatial interpolator method. Annual meeting of the American Meteorological Society (AMS), New Orleans, LA, January.

- **Nickl, E.**, C. Willmott, and R. Vose, (2016). Estimation of land surface precipitation for contiguous U.S. using a new spatial interpolator method. Annual Meeting of Association of American Geographers (AAG), San Francisco, CA, March.
- **Rennie, J.J.** and **K. Kunkel** (2015) Steps Towards an Experimental Homogenized Sub-Monthly Temperature Monitoring Tool, POSTER American Geophysical Union Fall Meeting, San Francisco, CA, 17 Dec 2015
- **Rennie, J.J.** and **K. Kunkel** (2016) Steps Towards an Experimental Homogenized Sub-Monthly Temperature Monitoring Tool, 22nd Conference on Applied Climatology, AMS Annual Meeting, New Orleans, LA, 14 Jan 2016
- **Schreck, C. J.**, 2016: Kelvin Waves and Tropical Cyclogenesis in a Lagrangian Framework. *NASA Precipitation Measurement Mission Science Team Meeting*, 13–15 July 2015, Baltimore, MD.
- Thorne, P., C. C. Hennon, K. R. Knapp, **C. J. Schreck**, **S. E. Stevens**, J. P. Kossin, **J. Rennie**, **P. A. Hennon**, and M. C. Kruk, 2015: Cyclone Center: Insights on historical tropical cyclones from citizen volunteers. *2015 AGU Fall Meeting*, December 14 -18, December 2015, San Francisco, CA.
- **Schreck, C. J.**, 2016: Kelvin Waves and Tropical Cyclogenesis in a Lagrangian Framework. *Fourth Symposium on the Madden–Julian Oscillation*, 10-14 January 2016, New Orleans, LA.
- **Schreck, C. J**., **J. Rennie**, L. Watkins, K. Dobeck, and D. Podowitz, 2016: Scale-Dependent Relationships Between U.S. Temperatures and Teleconnections. *Fourth Symposium on the Madden–Julian Oscillation*, 10-14 January 2016, New Orleans, LA.
- **Sorooshian, S.,** P. Nguyen, H. Liu, and H. Ashouri. Building an Atmospheric Rivers Catalog using Big Data Approach – CHRS CONNECT and PERSIANN CDR. Oral presentation at "Improving Sub-Seasonal & Seasonal Precipitation Forecast for Drought Preparedness" at DWR-WSWC Workshop; 2015 May 28; San Diego, California, USA.
- **Sorooshian, S.** (Invited) PERSIANN-CDR daily precipitation for hydrologic application, AGU Fall Meeting, 14-18 December, 2015. San Francisco, 2015.
- Zhang, J, Y. Qi, **S.E. Stevens**, B. Kaney, C. Langston, K.L. Ortega, B.R. Nelson, K. Howard, and **O.P. Prat**, 2015. Multiple Year Reanalysis of Remotely Sensed Storms-Precipitation (MYRORSS-P). *37th AMS conference on radar meteorology*, September 13-18 2015, Norman, OK, USA.
- **Stevens, Scott**, 2016-02-16: Presented findings to Climate and Health group at the Centers for Disease Control and Prevention in Atlanta, GA.
- **Sun, L.,** Seasonal climate prediction in a changing climate: Northeast Brazil, invited talk via Skype, Climate Prediction Committee Meeting, Brazil, January 18, 2016.
- Banzon, V., G. Liu, K. Fornry, E.A. Becker, **L. Sun**, K. Arzayus: Use of a Blended Satellite and In situ Sea Surface Temperature Climate Data Record for Evaluating Long-term Impacts on Coral and Marine Mammal Communities, 2016 Ocean Sciences Meeting, New Orleans, LA, Feb. 21-26, 2016.