CICS-NC
Annual Report
2014–2015

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CICS-NC Overview

The Cooperative Institute for Climate and Satellites-North Carolina (CICS-NC) is an Inter-Institutional Research Center (IRC) of the University of North Carolina (UNC) System, referred to as the North Carolina Institute for Climate Studies (NCICS). CICS-NC/NCICS is administered 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 the collaborative research into the use of satellite and surface observations in climate research and applications that is closely coordinated with NCEI. CICS-NC is also engaged in collaborative research with other NOAA line offices and units including the National Weather Service (NWS), the Climate Program Office (CPO) and the Atmospheric Research Laboratory's Atmospheric Turbulence and Diffusion Division (ATDD).

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 satellite observations in climate research and applications. NCSU provides CICS-NC with access to a strong graduate program in Earth sciences, and many of the CICS partners offer complementary programs. Other 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 proposal, thus, a number of additional partners were added to the CICS Consortium. Additions include: Oak Ridge Associated Universities (ORAU), the Institute for Global Environmental Sciences (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 support for community engagement and outreach is provided by the North Carolina Arboretum, an affiliate member of the UNC System, and by the Centers for Environmental and Climatic Interaction (CECI), an Asheville, NC-based organization of academic, non-profit, community, and private organizations with a common 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 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), the US Global Change Research Program (USGCRP), 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 funding comes from NESDIS/NCEI; however, current CICS activities are also supported by OAR's Climate Program Office (CPO), ARL's Atmospheric Turbulence and Diffusion Division (ATDD), and the OAR's Earth System Research Laboratory (ESRL). Other research sponsors during this reporting period include: the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), *Ouranos* and *EarthRisk*.

Administration [NCEI/NCSU]
Information Technology Systems Improvement, Management, and Maintenance: CICS-NC staff members require technological infrastructure and resources at a variety of levels. Modern approaches keep CICS-NC at the competitive edge of technology while maintaining core technologies as a stable base for CICS-NC staff operations. The 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 computational and communication needs of the institute.

Access and Services Development [CPO]
Programming and Applications Development for Climate.gov: UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with the development and launch of the U.S Climate Resilience Toolkit, the Climate Explorer application, and the Data Snapshot application for the Climate.gov website. The White House launched the Climate Resilience Toolkit in November 2014 as a key piece of the President's Climate Action Plan citing the website as providing "centralized, authoritative, easy-to-use information, tools, and best practices to help communities prepare for and boost their resilience to the impacts of climate change." These products also support the overall advancement and progression of the NOAA's Climate Services Portal (NCSP) program.

Assessment Activities — Assessment Technical Support Unit (TSU) [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. To date, the TSU has delivered two major drafts of the report – one for the Subcommittee on Global Change Research and, on April 7, 2015, a draft for public comment and review by the National Research Council. The final report is due to be released in mid-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.

National Climate Assessment Science Support: A report comparing CMIP3 and CMIP5 model simulations entitled "NOAA Technical Report NESDIS 144: Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment" was completed and submitted for NESDIS approval. The report advances the understanding of the differences between the older and newer models and provides additional context for projections presented in NCA3.

In response to growing demand for localized information on climate change, the TSU is also developing a series of 50 state-level reports. These reports will summarize the physical climate of each state, highlighting important climatic features of each state and presenting information on observed and projected climate changes. Drafts of all 50 reports will be complete by June 30, 2015, and several have already been submitted to NOAA Regional Climate Centers to obtain their input.

Development of Geospatial Visualizations, Online resources, and Decision Support Tools for the National Climate Assessment: The TSU continued development and operation of their unique Product Suite and production processes in order to collect, curate, and display the metadata for four assessments [*The Third National Climate Assessment (NCA3), Impacts of Climate Change on Human Health in the United States, A Scientific Assessment, Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment, and the NOAA State Climate Summaries*]. 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.

Climate Data Records and Scientific Data Stewardship [NCEI]

Climate Data Record (CDR) Integrated Product Team (IPT) Support: Several CICS-NC scientists serve as Products and Operations Branch representatives on multiple CDR IPTs.

Expansion of CDR User Base (e.g., Obs4MIPs): Several CICS-NC scientists are working to make observational products more accessible for climate model intercomparisons.

Big Data technologies for NOAA Metadata: A proof-of-concept tool was created that demonstrates search capabilities across multiple, disparate datasets.

Reanalyzing Tropical Cyclones Imagery with Citizen Scientists: CycloneCenter.org has collected more than 400,000 tropical cyclone classifications from citizen scientists with consensus estimates from these "non-experts" generally doing as well as, and in some cases better than, an automated computer algorithm applied to the same data. A *Bulletin of the American Meteorological Society* project paper reflects how citizen scientists can help address uncertainties in the historical record of these storms.

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 longwave from geostationary imagers.

Transitioning of International Satellite Cloud Climatology Project (ISCCP) processing to NCEI NC: The mission of the project is to transfer the ability to process ISCCP Cloud products from the ISCCP team (at CCNY and NASA-GISS) to NOAA/NCEI, resulting in a higher resolution ISCCP product, extended period of record, and an expanded user base owing to the availability and ease of access of data.

Revisiting Calibration of the Visible Channel of the ISCCP B1 data for the Geostationary Surface Albedo (GSA) project: 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 GSA project and also extended for years beyond 2009.

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 United States to produce a joint climate data record.

Uncertainty Quantification in Climate Data Records: Uncertainty quantification in climate research is a multidisciplinary area of increasing importance.

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

Evaluation and Characterization of Satellite Products: Satellite climate data records (CDRs) that are in various stages of development for the Arctic areas are being evaluated and characterized. The NCEI High-resolution Infrared Radiation Sounder (HIRS) product and NOAA Extended AVHRR Polar Pathfinder (APP-x) product are evaluated for the Arctic using the integrated SHEBA dataset and the NOAA PATMOS-x CDR dataset. The impacts of factors such as cloud contamination and day and night measurements are examined and used as the basis for an improved HIRS surface and near-surface air temperature dataset for the high latitudes.

Scientific data stewardship for digital environmental datasets: Refined and baselined a unified framework in the form of a scientific data stewardship maturity matrix (SMM) for assessing the vigor of stewardship practice applied to individual digital environmental data product.

Bias–assessment and bias-adjustment of the National Mosaic and Multi-Sensor QPE (NMQ) over CONUS (2002-2011): 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).

Toward the development of Climate Data Records for precipitation: Characterization of CONUS rainfall using a suite of satellite, radar, and rain gauge QPE products: A suite of quantitative precipitation estimates (QPEs) derived from satellite, radar, surface observations, and models is used to derive long-term precipitation characteristics at fine spatial and temporal resolution over CONUS for the period 2002-2012. This work is part of a broader effort to evaluate long-term multi-sensor QPEs in the perspective of developing Climate Data Records (CDRs) for precipitation.

Mapping the World's Tropical Cyclone Rainfall Contribution Over Land Using Satellite Data: Precipitation Budget and Extreme Rainfall: This work examines the over-land rainfall contribution originating from tropical cyclones for basins around the world for the period 1998-2009. Using the global database IBTrACS and satellite precipitation data from the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) product 3B42, the precipitation budget and extreme rainfall were determined for different TC basins around the world.

Dual-Pol signature of microphysical processes in warm rain: This work combines an explicit bin microphysical model with an electromagnetic scattering model. The goal is to assess the signature of microphysical processes (settling, coalescence, drop breakup, evaporation) on radar dual-polarization variables: the reflectivity factor at horizontal polarization (Z_H), the differential reflectivity (Z_{DR}), and the specific differential phase (K_{DP}).

Identifying Tropical Variability with CDRs: Tropical variability identified through Climate Data Records can be leveraged for numerous end users, including water management and the energy sector.

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 0.25^0 lat-long scale covering from 60^oS to 60^oN and 0° to 360° longitude from 1983 to December 2014. PERSIANN-CDR application to hydro-climatological studies is demonstrated.

Reanalysis of archived NEXRAD data using NMQ/Q2 algorithms to create a high-resolution precipitation dataset for the continental United States: Eleven years of a high-resolution gridded precipitation product for the entire continental U.S. has been generated at CICS-NC. This joint project with the NOAA National Severe Storms Laboratory (NSSL)/Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) in Norman, OK, produced a suite of gridded precipitation products at a far finer temporal frequency (five-minute) and spatial scale (0.01° / 1 km) than was previously available.

Ingest Archive System Agile Development Team: Implemented agile development methodologies for the rejuvenation of the Ingest Archive System.

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.

CICS-NC staff participated in K-12 educational outreach events in conjunction with the celebration of the state-wide 2015 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*.

Engagement and collaboration with the private sector and industry occurs both through interactions with individual organizations and through the existing Executive Forum on Business and Climate (EFBC) series. The latest EFBC was held in March 2015 co-hosted with UNC Chapel Hill's School of Law and focused on the insurance industry.

CICS-NC engagement with private sector companies during the past year included Facebook on a development case study related to their experience of using NCEI climate data for the siting and operations of their data farm. This also led to collaborations with the NC State Climate Office, Isothermal Community College (ICC), and NCEI to install and deploy a new weather station on Isothermal's campus in Spindale, NC. The project was made possible through matching grants from Facebook's Community Action Grant program and the National Oceanic and Atmospheric Administration, as well as contributions from CICS-NC.

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 twelve press releases/website stories, the distribution of a reformatted institute newsletter, *Trends*, the establishment of a Twitter account and building Twitter and Facebook audiences.

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

Expansion and Development of U.S. Climate Reference Network (USCRN) Soil Moisture Observations: This research involves modeling of the USCRN soil observations for developing a historical soil moisture record for improved drought monitoring.

Climate Monitoring and Research Services Support to the Atmospheric Turbulence and Diffusion Division (ATDD) of NOAA's Air Resources Laboratory (ARL): Additional USCRN stations were installed in Alaska continuing expansion of the Alaska Climate Reference

Network (ACRN) and bringing the total number of active ACRN stations to 16 broadcasting sites.

Development and verification of US Climate Reference Network (USCRN) Quality Assurance Methods: Manuscripts documenting the new automated quality assurance (QA) algorithm for precipitation and comparisons with the existing approach have been published in the Journals of Atmospheric and Oceanic Technology and Atmospheric Measurement Techniques. Reports were drafted that describe implementation plans of the algorithm necessary for operational deployment as well as manual QA efforts to further improve the quality of station data.

Collocated US Climate Reference Network (USCRN) and Cooperative Observer Network (COOP) Comparisons: The USCRN and COOP networks were compared and a paper accepted for publication in the Journal of Atmospheric and Oceanic Technology.

Analysis of hydrological extremes from the U.S. Climate Reference Network (USCRN): Hydrological studies linking surface precipitation and sub-surface soil moisture measurements were initiated and involved local high school and undergraduate interns. A cumulative distribution function was applied to station soil moisture observations so soil conditions across the U.S. can be monitored on the same scale. This approach was applied to the California drought.

Maintenance and Streamlining of the Global Historical Climatology Network – Monthly (GHCN-M) Dataset: A new land surface temperature Databank has been operational since June 2014, with openness and transparency as one of its highlights. This product lays the groundwork for the next iteration of NOAA's global temperature product that will include more stations along with updates to its quality assurance and bias correction algorithms.

Development of an Experimental Homogenized Sub-Monthly Temperature Monitoring Tool: A sub-monthly tool for monitoring impacts of temperature extremes in the United States is under development. Using current in house 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 and will undergo research to operation readiness review.

Workforce Development [NCEI]

Global Surface Temperature Portfolio: Data gap impacts on global surface temperature anomalies trends using GFDL CM3-CMIP5 model: Data gaps from US NOAA Temp/MLOST and UK HadCRUT4 were applied to NOAA GFDL CM3-CMIP5 model to analyze the impacts on temperature trends for different periods and for future scenarios. A decrease on surface temperature trends was observed when data gaps are taken into account.

Global Surface Temperature Portfolio: Evaluation of global surface temperature methods: The strengths and limitations of the best-known existing global surface temperature datasets (NOAA Temp/MLOST, UK HadCRUT4, NASA GISTEMP, University of York, and Berkeley BEST) are under evaluation.

Estimation of land surface precipitation for contiguous U.S. using a new spatial interpolation method: A new spatial interpolation method that takes topography into account is applied to estimate monthly land surface temperatures for United States and compared with NOAA/NCEI and PRISM estimated precipitation fields.

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: Bias and RMSE are calculated for HIRS surface temperatures vs. the USCRN observation network and global reanalysis datasets (ERA-40, ERA-Interim, MERRA, and NCEP/NCRA). Results show that the bias and RMSE are low when compared to USCRN, especially for nighttime temperatures.

Other CICS PI Projects

Trends in Extra-tropical Cyclone and Blocking High Occurrence: Analysis of uncertainties in extra-tropical cyclone (ETC) occurrence have identified periods when the analyzed temporal variations can be considered reliable, including 1891-present for mid-latitude land areas and the North Atlantic, 1921-present for the North Pacific, and 1931-present for high latitude land areas. Analysis of blocking high frequency points to a similar early period high bias. **[NOAA/CPO]**

Research Dealing with the Impacts of Climate on Health: This CICS-NC PI is on a half-time Intergovernmental Personnel Act (IPA) assignment as a Guest Researcher in the Centers for Disease Control and Prevention's National Center for Environmental Health (CDC NCEH) Climate and Health Program. The goal of this interaction is to increase the understanding of the effects of climate change on human health and assist with projects that can further this knowledge. As a conduit between NOAA's NCEI and CDC's NCEH, he assists CDC researchers in accessing climate data and better understanding data applications. During the past year, he has helped develop projects dealing with precipitation extremes and traffic accidents, soil moisture conditions and Valley Fever, and assisting CDC grantees with climate expertise. He has also helped CDC gain access to National Climate Assessment climate change projections and National Integrated Drought Information System (NIDIS) drought data for the National Environmental Health Tracking Network. **[NCEI/CDC]**

Water Sustainability and Climate Change: a Cross-Regional Perspective: Model simulations from the CMIP5 hindcast experiment were found to generally reproduce observed regional trends in the number of monthly temperature extremes for the period 1981-2010. **[NSF]**

Role of Kelvin Waves in Tropical Cyclogenesis: Kelvin waves are shown to significantly affect the formation of tropical cyclones in all basins through interactions with the Madden–Julian Oscillation and easterly waves. **[NASA]**

Scientific Guidance for Revision of Probable Maximum Precipitation Estimates in Canada: In support of a Natural Resources Canada project to improve and operationalize a methodology to estimate Probable Maximum Precipitation (PMP) under changing climate (CC) conditions for use in Canada's hydroelectrical industry safety assessment of critical dam

infrastructure, the CICS-NC PI provided advice and analysis of regional climate model simulations. **[Ouranos]**

Wind Energy Forecast Model Development Phase 2 Support: CICS-NC PI is providing key improvements to an EarthRisk prototype statistical model for forecasting wind power production through the addition of time-extended indices. **[EarthRisk]**

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 the second of the dual-location campuses for CICS and is collocated with NCEI in the Veach-Baley Federal Complex in Asheville, NC. As an Inter-Institutional Research Center (IRC) of the UNC System, referred to as the North Carolina Institute for Climate Studies (NCICS), 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 a Task I contract. The NOAA Task I contract provides partial support for the director, a business manager, a university program specialist, and IT operations and systems support. There is travel support for administration and research facilitation purposes 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. Travel support is budgeted to promote face-to-face interactions with the diverse climate science and applications community.

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	
NOAA Office	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%

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. The headnode is a powerful server where users can prototype ideas and perform light work tasks including coding and testing. The headnode can then queue heavy workloads onto the cluster where a number of different queues are available to suit different 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.

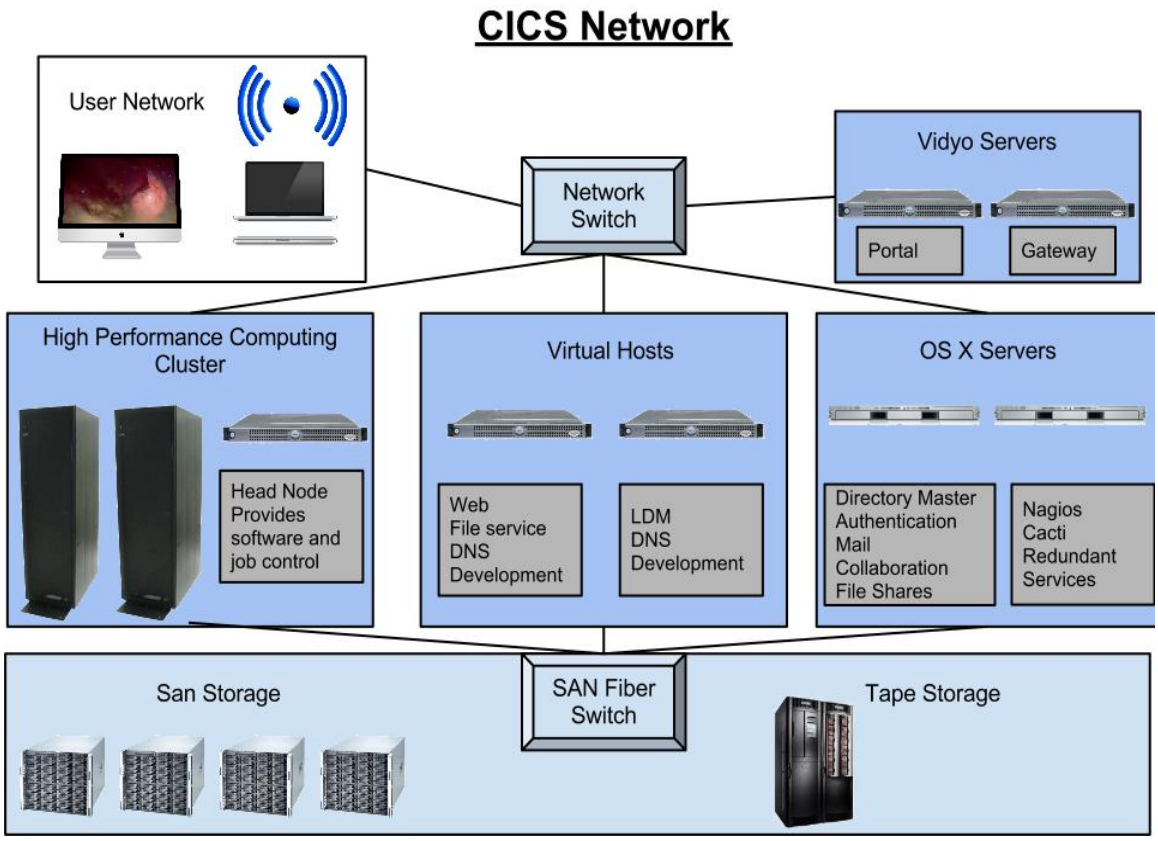


Figure 1: Network, and system diagram.

CICS-NC provides a distributed file system for concurrent system-wide access to high-speed storage. The Quantum Storenext 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. The head node provides access to a large variety of software as well as command and control tools to push tasks into the cluster. Users may execute tasks using multiple approaches, including, but not limited to, batch mode processing and OpenMPI.

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 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 off site 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 Linux KVM 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. The KVM environment supports load balancing, live migration, and service redundancy by placing the virtual systems storage on a shared LVM SAN. 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 incluing *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

Upgrades were made to distributed-file system controllers. Stornext metadata controllers were upgraded to latest software. This upgrade doubled metadata performance. The tape library drives were upgraded, doubling the capacity of the library to 1.6PB. This allows users to stage more data for processing using the Hierarchical Storage Managment system as it was designed. Later, we upgraded each controller to 96GB of RAM and moved the metadata and journals to directly attached SAS storage. This greatly improved metadata performance and prepared the controllers for the upgrade to Stornext 5.

Upgrades were made to our Promise SAN controllers. A new SAN controller was installed with 72 4TB drives, increasing storage capacity. We also evenly distributed the storage trays between the two newer SAN controllers, doubling the potential throughput of each file system. Two additional SAN controllers received from Miami University were installed and upgraded. The drives were replaced with enterprise class 4TB drives bringing the total storage to 1.2 PB and spreading the load over 6 SAN controllers.

Building-wide WIFI access was updated with availability of eduroam services allowing federated WIFI access to hundreds of existing university systems.

The *Vidyo* system was improved by adding an additional VidyoRouter. This increases the capacity of our infrastructure and allows for VidyoProxy services. VidyoProxy allows Vidyo access from behind restrictive client side firewalls.

We maintain three data subscriptions from NCDC Comprehensive Large Array-data Stewardship System (CLASS) that provide VIIRS and AVHRR data to our collaborators in Miami. We maintain a fourth service to download daily MODIS data for both Terra and Aqua from NASA for our Miami collaborators. These read-only datasets are available to all scientists using the CICS-NC servers.

In preparation of moving equipment from Miami University to CICS-NC we renegotiated our lease with the ERC. This included planning and replacing our server power infrastructure and reducing our rack space requirements. During negotiations we also evaluated four other colocation facilities. Using the information obtained by this process we were able to negotiate agreeable terms to keep our colocation facilities in the current building.

Two new Dell servers were designed, ordered, and installed. These servers greatly enhanced our virtual server environment by increasing both the number of virtual servers we can support and the performance and memory capacity of the virtual server platform.

We intergrated a significate amount of hardware and software transferred from Miami University. This included 3 servers, a blade center, 600TB of SAN with 4 controllers. We setup Openlava to accommodate LSF compatible scheduling and upgraded the Miami SAN with new drives. We reconfigured the networking and fiber channel equipment to accomodate the new hardware. We also converted the GPFS volumes to Stornext, which included reorganizing over 200 TB worth of existing data.

PLANNED WORK

- Expected upgrades (e.g. blade center migration, VM improvements, OS updates)
- Continuous tasks (maintenance)
- Planning for expected end of life equipment
- Assist with NCEI processing, storage, research requierments

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	8
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

Access and Services Development

Access and services development activities support improvements to access mechanisms for NCEI's data and product holdings. NOAA's National Centers for Environmental Information (NCEI) have 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 product 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. 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 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.gov

Task Leader	Jim Fox
Task Code	NC-ACD-01- UNCA
NOAA Sponsor	David Herring
NOAA Office	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 the development and launch of the U.S Climate Resilience Toolkit, the Climate Explorer application, and the Data Snapshot application. These products support the overall advancement and progression of the NOAA's Climate Services Portal (NCSP) program.

BACKGROUND

There is an increasing 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. Towards this end, the NCSP has had a need for expertise and resources to support programming work for applications development and data visualization in support of the following tasks:

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

The following tasks were completed by UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) during this reported project period:

ACCOMPLISHMENTS

Drupal Content Management System for Climate.gov

This task involves the development of custom software modules to support integration of science news articles, visualization applications, and customized user interface components into the Climate.gov Drupal content management system. The following tasks were completed during this project period:

- Drupal Module for Data Snapshots

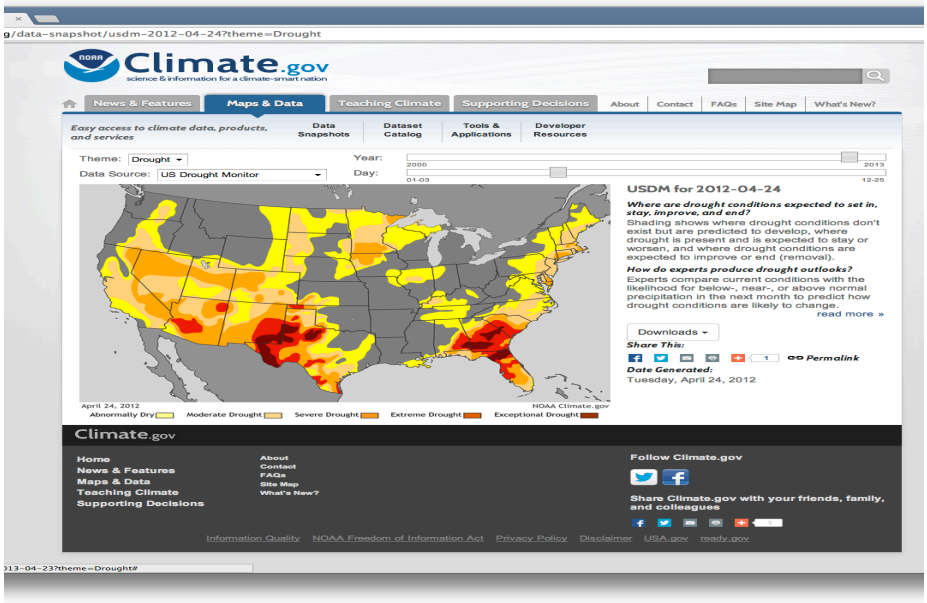


Figure 1. Screenshot of Data Snapshots

U.S Climate Resilience Toolkit

The U.S. Climate Resilience Toolkit (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. This website offers:

- Steps to Resilience: A five-step process you can follow to initiate, plan, and implement projects to become more resilient to climate-related hazards.
- Taking Action stories: Real-world case studies describing climate-related risks and opportunities that communities and businesses face, steps they're taking to plan and respond, and tools and techniques they're using to improve resilience.
- A catalog of freely available Tools for accessing and analyzing climate data, generating visualizations, exploring climate projections, estimating hazards, and engaging stakeholders in resilience-building efforts.
- Climate Explorer: A visualization tool that offers maps of climate stressors and impacts as well as interactive graphs showing daily observations and long-term averages from thousands of weather stations.
- Topic narratives that explain how climate variability and change can impact particular regions of the country and sectors of society.
- Pointers to free federally developed training courses that can build skills for using climate tools and data.
- Maps highlighting the locations of centers where federal and state agencies can provide regional climate information.

- The ability to Search the entire federal government's climate science domain and filter results according to your interests.

During this project period, the following tasks were completed:

- Completion of site design: In the initial phases of the project NEMAC designed and iterated over numerous prototype designs. After outside consultant Brian Ziffer created mockups of the final site design NEMAC designers implemented them and created the mobile responsive layouts.
- Development of custom Drupal modules: In the process of building the CRT several modules were built or modified by NEMAC in order to improve the functionality of Drupal. Such changes included the re-ordering of search fields by topic, implementing consultant David Stroud's slider for the front page of the site, and implementing responsive design in consultant firm WebLyzard's search module.
- Full website launch in November, 2014: The CRT was released by the White House on November 27, 2014, in conjunction with a meeting between Vice President Biden and Senior White House officials with members of the President's State, Local and Tribal Leaders Task Force on Climate Preparedness and Resilience. At launch, the CRT had fully developed content for the Coastal Flood Risk and Food Resilience topics, including over 20 Taking Action case studies, and topic-narrative-only content for the Ecosystem Vulnerability and Human Health topics.
- Coordination of content generation and editorial tasks for the following themes before and after launch, etc.: Pre- and post-launch content development for the CRT was and continues to be handled jointly with NOAA staff, and includes science writing, editing, and content entry into the site's content management system for all aspects of the website. This includes interaction with, and coordination of content across, multiple federal agencies (NOAA, USDA, USGS, DOI, USFS, NIEHS, BIA, etc.) to create and publish topic and subtopic narratives, Taking Action case studies, tools, and other content. Since launch, the Ecosystem Vulnerability and Human Health topics have been more fully developed to include tools and Taking Action stories, and a new fully developed Water Resources topic was launched. Topic development is underway for Tribal Nations, Energy, and Transportation. As of May 21, 2015, the CRT includes 155 published tools and 64 published Taking action case studies.

Global Climate Dashboard

The Global Climate Dashboard is a web application that provides the user an interactive view of several global climate data sets such as temperature, carbon dioxide, arctic sea ice extent, etc., which are essential to understanding climate change trends. This task involves the maintenance and further development of the Global Climate Dashboard Drupal module and supporting interactive graphs. This includes development and installation of a Drupal module for incorporating interactive data graphs into Climate.gov pages, and streamlining the process of keeping dashboard data sets up to date.

In order to allow work on the Data Snapshots project in the Maps and Data Section (see *Maps and Data Leadership*), work on the Global Climate Dashboard was suspended for the period of this report.

Climate Explorer and online Map Viewers

The Climate Explorer is a web application whose purpose is to facilitate the viewing of historical weather data in the context of long-term climate. The Climate Explorer provides a more in-depth and graphical display of historical weather in the context of the long-term climate conditions of the location and is housed in the U.S. Climate Resilience Toolkit.

- A prototype of the Climate Explorer application was developed and deployed to NEMAC's development server. This prototype allows the user to browse and view daily temperature, precipitation, and snowfall data from roughly 10,000 stations in the GHCND data set.
- Additional development resulted in the tool's interactive visualizations for exploring maps and data related to the U.S. Climate Resilience Toolkit's Taking Action case studies. The map layers in the tool represent geographic information available through climate.data.gov. Each layer's source and metadata can be accessed through its information icon. The Climate Explorer graphs display 1981-2010 U.S. Climate Normals for temperature and precipitation, overlain with daily observations from the Global Historical Climatology Network-Daily (GHCN-D) database.
- This work and development were in preparation for the full application launch in November 2014.

Climate Interactive tools

This task involves the development of a Climate Interactive tools for the Climate.gov site, which will allow users quick access to location-based climate summaries as part of the site's regular search feature. These features will arrange for a graphical climate summary for a given location to appear at the top of the search results when a user performs a search for that location. One example of these tools is called the Climate Widget.

In order to allow work on the Data Snapshots project in the Maps and Data Section, work on the Climate Widget was suspended for the period of this report.

Maps and Data Section Leadership

NEMAC provided strategic planning and leadership for the developmental evolution the Maps and Data section of Climate.gov. Emphasis was given to integrating key, select building blocks (such as those tasks summarized above) into a more seamless and interoperable interface for finding and using data from multiple source providers across and beyond NOAA. The Data Snapshots project, housed in the Maps and Data section of Climate.gov, is an application that provides a common interface for viewing map-based "snapshots" of several key data sets from the period 2000 to present. The following tasks were completed during this project period:

- Creating a feed of the new images to be imported into Climate.gov.
- Implementing the sections design prototyped by consultant David Stroud.
- Developing functionality to rapidly display maps and other associated metadata from different dates using sliders.

- Developing functionality to rapidly switch between different data sets.
- Creating the templates for more complete metadata about each data set to be stored and displayed.

PLANNED WORK

Work will continue on the Climate Explorer, Climate Resilience Toolkit and other interactive tools under Year 2 of the CICS cooperative agreement project.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	3
# of products or techniques transitioned from research to ops following NOAA guidance	3
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	3

PERFORMANCE METRICS EXPLANATION

During this reporting period, a new website was planned, designed and launched called the U.S Climate Resilience Toolkit, the Climate Explorer application, and the Data Snapshots application was launched in the Maps and Data Section (3).

LINKS TO RESEARCH PAGES

- U.S Climate Resilience Toolkit: www.toolkit.climate.gov
- Climate Explorer: http://toolkit.climate.gov/climate-explorer
- Data Snapshots: 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 an emerging activity to support overall "Assessment Services." NOAA is also participating 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). 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 National Centers for Environmental Information (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.

Support of NOAA- and NCEI-led climate assessment 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 leader and his staff, will continue to provide necessary expertise in the following areas:

- Scientific expertise and science oversight: A Lead Senior Scientist providing scientific expertise and 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. This will support a more rigorous, appropriate, and organized downscaling activity across the agency and for the National Assessment.
  The Lead Scientist also provides scientific oversight regarding the model-to-observational inter-comparisons; works with scientific and technical leadership of the NOAA Climate Model Portal to provide guidance on data access and management; provides oversight and guidance on appropriateness of data, reports,

and published literature used in the assessment development; and works with a data coordinator to guide framework for ensuring transparency and traceability of data and products incorporated into the assessments.

- Program management expertise providing program management for NOAA's and the NOAA Technical Support Unit's (TSU's) extensive portfolio of national and regional activities associated with the National Climate Assessment, including timely delivery of information, graphics, and related content for the national assessment as well as transitioning the assessment activities into a sustaining process and providing assistance to the Director of the Assessments TSU in executing annual plans and budgets and discussing NOAA's National Climate Assessment contribution in interagency settings.
- Climate attribution expertise, providing expertise in the integration of surface, model, and satellite fields; contributing to research efforts in domestic and international initiatives; assisting in the development of attribution assessments for important climatic events and anomalous climatic trends of interest; developing attribution analyses; incorporating attribution assessments into periodic broader-scale regional and national assessments to support improved decision-making associated with knowing whether climate trends and events are anthropogenic, natural, or combined in origin; and providing multivariate statistical expertise, model, and observational analysis and experience in working with reanalysis products and data.
- Technical/science expertise to provide support for the lead scientist (on coordination, programming, ad hoc graphics, and data support) with technical and scientific support for the external partners.
- Media coordination and production expertise providing scientific writing/editorial expertise and overall media coordination working with writing and technical implementation teams; leading the overall assessment content development; and production expertise providing scientific graphics and visualizations expertise to develop high quality, dynamic, and user-defined visualization tools to support access and utility of assessment data and products; and editorial/copy editing expertise for the spectrum of assessment activities and media. Assessment products will be evolving from printed media to more dynamic, web-based products that will allow users flexibility to render images dynamically and access underlying data.
- Software engineering expertise to provide advanced web engineering and scalable device presentation of various scientific assessment data and information; ad hoc data manipulation as well as systematic changes to data processes to enable rapid and high quality/well-documented data access and plots/graph development and to work with the NCEI Climate Monitoring Branch with existing data sets, including global temperature, extremes indices, drought, and other types of data.
- Data expertise in information provenance and tracking to support scientific information categorized as "Highly Influential Scientific Assessments (HISAs)."

The Third National Climate Assessment (NCA3) was released on May 6, 2014, representing a landmark achievement for the TSU and CICS-NC. CICS-NC staff contributed to virtually all aspects of the report by providing scientific, editorial, graphics, project management,

metadata, software engineering, and web design expertise. All of these efforts culminated in the very successful release of the report, which has been praised for its readability and accessibility. The NCA3 website (nca2014.globalchange.gov), which involved significant CICS-NC contributions, was also widely praised.

Since the release of NCA3, CICS-NC staff members have been working hard to develop and refine the sustained assessment process, with efforts centered on the forthcoming USGCRP report on the impacts of climate change on human health.

National Climate Assessment Scientific Support Activities

Task Leader	Kenneth Kunkel
Task Code	NC-ASSESS-01-NCICS-KK
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: A report on the CMIP5 model simulations was completed and submitted for NESDIS approval. Scientific support contributions to the climate and human health public review draft report, including contributing authorship of Chapter 1 and the appendix, were completed.

BACKGROUND

NOAA is participating in the high-level, visible, and legally mandated National Climate Assessment (NCA) process, which will be responsive to greater emphasis on user-driven science needs under the auspices of the US Global Change Research Program (USGCRP). National climate assessments are intended to advance the understanding of climate science in the larger social, ecological, and policy systems to provide integrated analyses of impacts and vulnerability. NOAA's National 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), a support scientist (Laura Stevens), 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

Metadata for all of the climate science figures in the Third National Climate Assessment (NCA3) produced by the TSU were compiled and input by the science team to the web system. These metadata were made publicly available.

A draft technical report comparing climate projections from the CMIP3 and CMIP5 projects was completed. This is a follow-up to NOAA Technical Report NESDIS TR142, which was produced to support the development of NCA3. The draft report was submitted to the NOAA anonymous review process. A set of three reviews was received. Revisions to the report and formal responses to the review comments were completed. The completed report was submitted for formal NESDIS approval. 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.

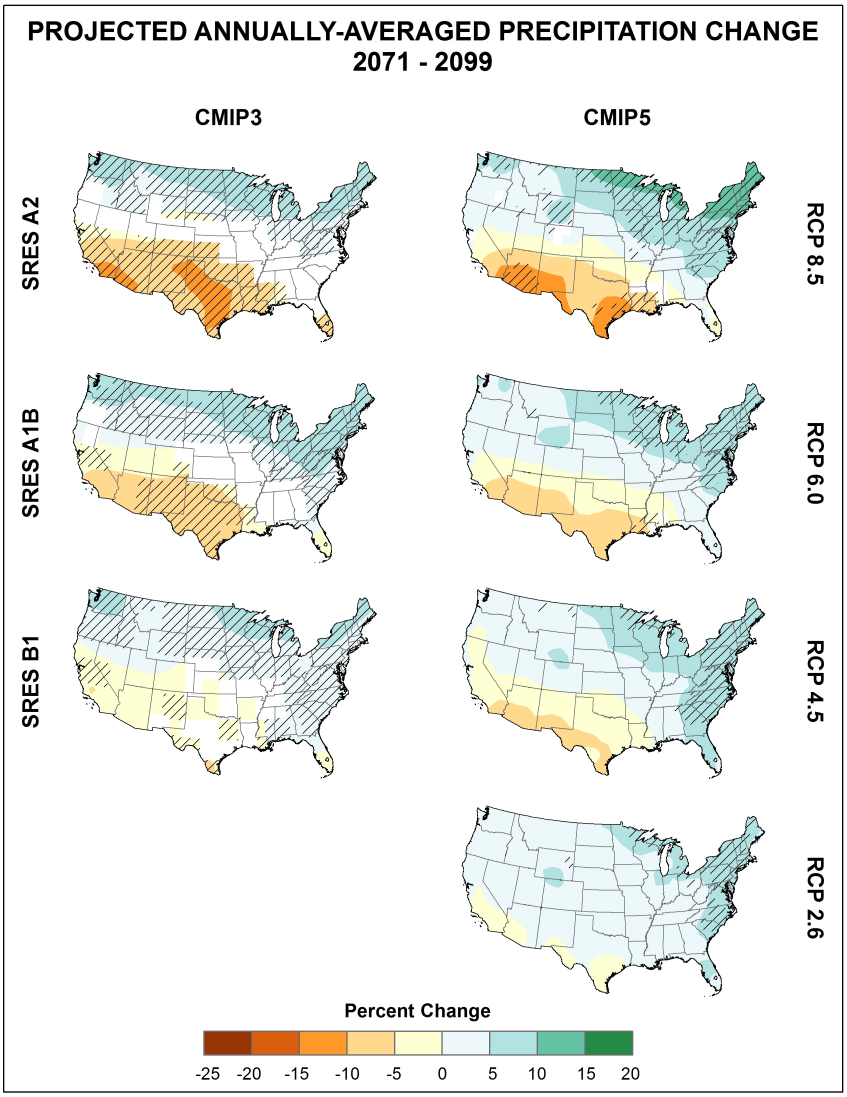


Figure 1. CMIP3 (left column) vs. CMIP5 (right column) comparison of climate model simulations of projected annual precipitation for the U.S. for 2070-2099 relative to 1971-2000. The different panels each column represent different emissions scenarios from high on top to low on bottom. In general, there is little difference between CMIP3 and CMIP5.

Scientific support was provided for the draft climate change and human health report. Climate scenarios 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 state summaries was initiated. These states summaries are intended to be 2-6 pages in length and summarize historical climate trends and CMIP5 projections of temperature and precipitation. A total of 40 state summaries have been drafted and 8 sent to the Regional Climate Centers for their input.

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

PLANNED WORK

- Release the report comparing CMIP3 and CMIP5 climate simulations for the NCA regions, along with data sets and metadata
- Complete scientific support for the climate and health report
- Complete state summaries
- Complete papers on the effect of the changeover to MMTS on extreme temperature trends, global extreme precipitation trends, seasonal trends in U.S. extreme precipitation, and retrospective analyses of scenarios work on the NCA3.

PUBLICATIONS

- Kossin, J., T. Knutson, K. Emanuel, T.R. Karl, K. Kunkel, and J. O'Brien, 2015: Reply to 'Comment on "Monitoring and understanding trends in extreme storms-state of knowledge. *Bull. Amer. Meteor. Soc*., accepted.
- 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*, accepted.
- Kunkel, K.E., R.S. Vose, L.E. Stevens, and R.W. Knight, 2015: Is the monthly temperature climate of the United States becoming more extreme? *Geophys. Res. Lett*., **42**, doi:10.1002/ 2014GL062035.
- Lawrimore, J., T.R. Karl, M. Squires, D.A. Robinson, and K.E. Kunkel, 2014: Trends and variability in severe snowstorms east of the Rocky Mountains. *J. Hydromet*., **15**, 1762-1777, doi: http://dx.doi.org/10.1175/JHM-D-13-068.1

DELIVERABLES

- Publication of papers on climate extremes
- Completion of metadata for NCA3 figures
- Completion of CMIP5 report
- Completion of two chapters of public review draft of climate change and health report as contributing author

PRESENTATIONS

- Kunkel, K.E., 2015: Extreme Climate Conditions Past and Future: Implications for Food Security and Water Resources, 13th Annual Climate Prediction Applications Science Workshop, Las Cruces, NM, (25 March).
- Brown, O. and Kunkel, K.E., 2015: State of the Climate Science in Identification of Risks; Presentation and Use of Data from National Climate Center and Affiliates, invited talk, Executive Forum on Business and Climate Workshop: Private Property, Information Disclosure, and the Roles of Insurance and Government, Chapel, NC, (20 March).
- Kunkel, K.E., 2015: Projected Effects of Climate Change on Extreme Weather, invited talk, Kickoff Meeting, Effects of Climate Change on Dam-Related Health and Safety Interagency Assessment Team, Washington, DC, (25 February).
- Kunkel, K.E., 2015: Future Projections of Extreme Climate Conditions from the National Climate Assessment: Implications for Food Security, invited paper, Annual Meeting of the American Association for the Advancement of Science, San Jose, CA, (15 February).
- Kunkel, K.E., 2015: Historical Perspective on Recent Hot and Cold Extremes, poster paper, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (7 January).
- Kunkel, K.E., 2015: Looking back on NCA3 and forward to NCA4, Town Hall Meeting: Developing Climate Scenarios for the 4th National Climate Assessment and the Sustained Assessment Process, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (6 January).
- Kunkel, K.E., 2015: Science and Communication Issues Associated with Precipitation in the NCA, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (5 January 5).
- Kunkel, K.E., 2015: Data Management and the National Climate Assessment: Best Practices, Lessons Learned, and Future Applications, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (5 January).
- Kunkel, K.E., 2015: Overview of the National Climate Assessment, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (5 January).
- Kunkel, K.E., 2014: Regional Climate Model Simulation of Extreme Precipitation in North America", invited talk, Fall Meeting of the American Geophysical Union, San Francisco, CA, (19 December 19).
- Kunkel, K.E., 2014: Science Issues Associated with Precipitation and Storm Extremes, Fall Meeting of the American Geophysical Union, San Francisco, CA, (19 December).
- Kunkel, K.E., 2014: Climate change and risk? - How variable are climate projections and implications for disturbance risk, invited talk, Southern Forests Economic Issues Forum. Raleigh, NC, (4 November).
- Kunkel, K.E., 2014: NOAA Climate Data in the National Climate Assessment, invited paper, Workshop on Sources, Uses and Access to Regional Climate Forecasts and Projections, U.S. Department of Agriculture, Washington, DC, (14 May).
- Kunkel, K.E., 2014: Climate Change: Regional Climate Scenarios, invited paper, Climate Change Adaptation Planning Workshop, National Exercise Program, The White House, Washington, DC, (7 May).

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	4
# of non-peered reviewed papers	0
# of invited presentations	7
# of graduate students supported by a CICS task	N/A
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

The project group completed a report comparing CMIP5 climate model simulations with CMIP3 simulations. We also completed scientific support contributions to the climate and human health public review draft report, including contributing authorship of Chapter 1 and the appendix. Four scientific journal papers were published or accepted. Numerous invited talks were given.

Assessments Program Support	
Task Leader	Paula Ann Hennon
Task Code	NC-ASSESS-02-NCICS-PH
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	National Climate Assessment
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: %; Goal 3: %; Goal 4: %; Goal 5: %

Highlight: Program support, project management, and supervision for National Climate Assessment activities and the Technical Support Unit. Founding Director for the Partnership for Resilience.

BACKGROUND

Since the rollout of the 3rd National Climate Assessment, Paula Hennon has provided program support, project management, and supervision for NOAA's Technical Support Unit (TSU), primarily in support of the development of the U.S. Global Change Research Project Climate and Health Assessment, the Sustained Assessment activities, and the web services and technical report production infrastructure. The TSU is an eleven-person unit providing critical web, publishing, scientific data and coordination, and technical support to inter-agency Climate Assessment activities.

Since September 2014, Hennon has also acted as the founding director of the Partnership for Resilience. The Partnership for Resilience is a new activity to establish and facilitate a dialog between academic, public, and private participants in the climate change adaptation community. Founded in response to 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," the Partnership for Resilience is envisioned to be a marketplace for sharing research, technology, concepts, ideas, and approaches for improving national resilience to the impacts of environmental change.

Effective adaptation to change requires public, business, academic, and non-profit organizations to communicate and collaborate to make decisions for the long term. In practice, it can be confusing to determine how to get the necessary information and expertise. The Partnership for Resilience will empower organizations to make decisions by increasing effective communication and collaboration among members and stimulating adaptation and mitigation activities across all sectors. Recognizing that federal agencies must engage the solution provider community—business and industry, non-profit, and academic organizations—to meet the growing demand for environmental information, the Partnership for Resilience provides a mechanism to more effectively meet the capacity for adaptation and mitigation information to foster resilience across sectors.

The value propositions for the private sector, governmental agencies, academic research communities, and non-governmental partner organizations are shown in the following figure.

ACCOMPLISHMENTS

As the Climate Assessment Technical Support's Program Manager, Hennon has coordinated day-to-day activities and provided assistance to the Director of the Technical Support Unit (TSU) for Sustained Climate Assessment activities.

Assistance to, and support of, the TSU Director, Dr. David Easterling, included:

- Direct support and coordination efforts in the development, implementation, and execution of current year operating plans and budget implementation timetables.
- Coordination and monitoring of relevant contracts and grants and other execution options and needs to support the unit.
- Coordination of TSU team to support efficient execution of operating plan and effective communication across the entire team.
- Implemention of project management charters to define and refine interactions with stakeholders.
- Presentation of NOAA's National Climate Assessment contribution in inter-agency settings and conferences.
- Coordination with NOAA Program Managers to work toward synergizistic activities.

As Founding Director of the Partnership for Resilience, she has lead the development of a prospectus and implementation plan for the Partnership, managed its development, and engaged internal and external partners from the academic, governmental, and private sectors.

These foundational activities have included:

- Development and socialization of a Partnership for Resilience concept plan.
- Development of an implementation plan, including a viable fiscal model.
- Development of branding (electronic, social, and print media.)
- Ongoing development of appropriate intellectual property policies for use by the members of the Partnership for Resilience.
- Development of Partnership marketing and rollout strategies.
- Engagement of private, public, and academic sector partners.
- Formation of the Partnership for Resilience Advisory Board.

PLANNED WORK

- Continue to manage and coordinate the dynamic TSU team, enhance team activities, and push for innovative solutions during the re-design of the necessary technical and process interfaces with the clients and stakeholders served.
- Instantiation of the Partnership for Resilience Implementation Plan.
- Formalize membership development procedures and develop Partnership for Resilience Working Groups through engagement and recruitment of private, public, and academic sector partners.
- Continue to develop the National Partnership for Resilience Advisory Board.

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. Gadéa, M. Striegl, and I. Carley, 2014: Cyclone Center: Can citizen scientists improve tropical cyclone intensity records? *Bulletin of the American Meteorological Society*, **In press**, doi:10.1175/BAMS-D-13-00152.1. Available online at: **http://dx.doi.org/10.1175/BAMS-D-13-00152.1**

DELIVERABLES

The following products were delivered:

- Project charters for: 1) GlobalChange.gov, 2) Public Contribution System, 3) Review and Comment System, 4) Climate & Health Assessment website and editorial activities.
- Project planning and requirements documents for the USGCRP Climate & Health Assessment website.
- Concept and implementation plan for the Partnership for Resilience.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	6
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	4

PERFORMANCE METRICS EXPLANATION

Products: Successfully adopted project charters, requirements plan for the USGCRP Climate Change & Human Health website, and Partnership for Resilience Concept and implementation plan.

National Climate Assessment Technical Support Unit Software Engineer

Task Leader	Andrew Buddenberg
Task Code	NC-ASSESS-03-NCICS-AB
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 25%; Goal 3: 25%; Goal 4: 25%; Goal 5: 0%

Highlight: CICS technical support staff have 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

With the release of the Third National Climate Assessment, the focus has shifted to a number of smaller reports that build on that foundation. In support of the forthcoming USGCRP Climate and Health Assessment, a new downscaled sea surface temperature dataset based on CMIP5 model and buoy data was created to project incidence of waterborne diseases (Figure 1).

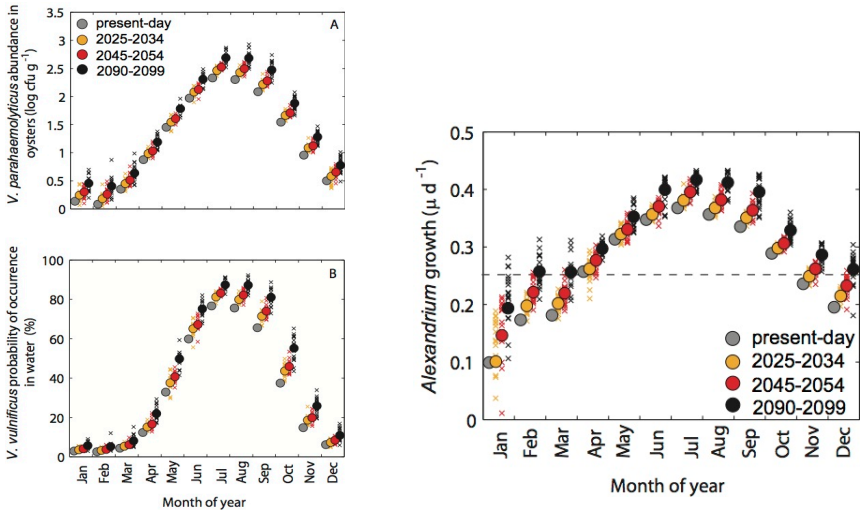


*Figure 1. Published in Jacobs, J., S. K. Moore, **K. E. Kunkel**, and **L. Sun**, 2015: A framework for examining climate-driven changes to the seasonality and geographical range of coastal pathogens and harmful algae. Climate Risk Management, **In press**, doi:10.1016/j.crm.2015.03.002, and used in the USGCRP Climate and Health Assessment review draft.*

In collaboration with Liqiang Sun and in support of NOAA Technical Report NESDIS 144 ("Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States") a comparison of various precipitation uncertainty schemes was created (Figure 2).

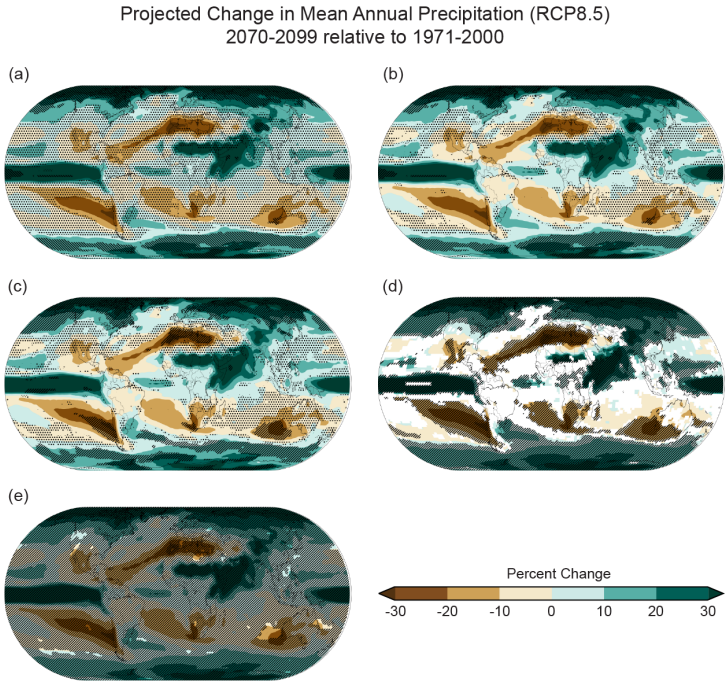


Figure 2. An analysis and comparison of historical drought data for drought-afflicted states in support of the upcoming state-based climate fact sheets project was also performed (Figure 3).

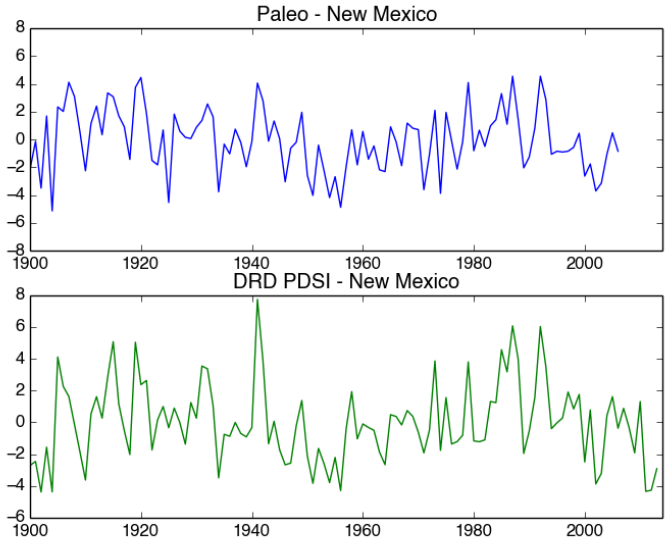


Figure 3.

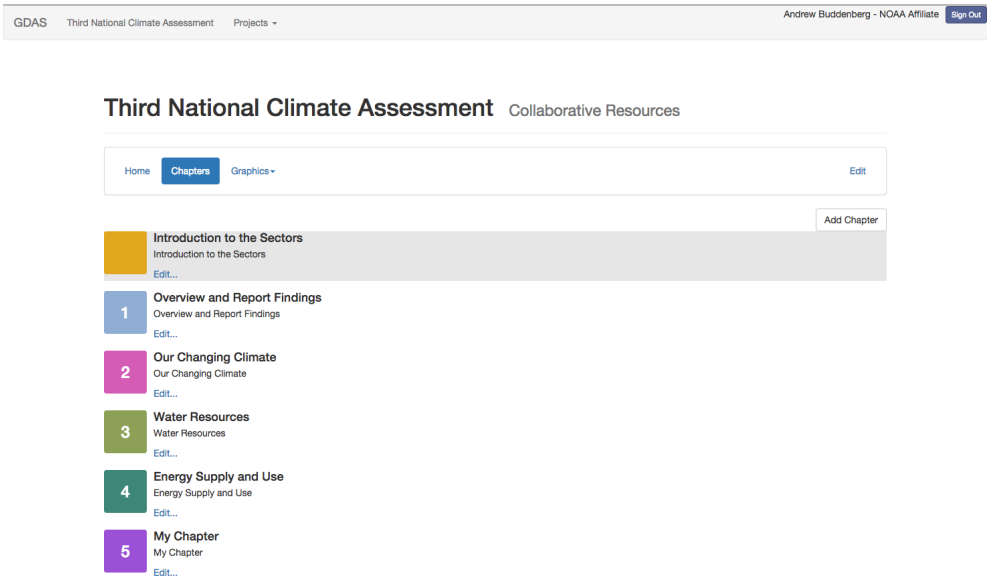
In collaboration with and in support of US Global Change Research Program's (USGCRP) greater emphasis on user-driven science needs, the Global Change Information System (GCIS) has been developed and released for public use.

From USGCRP: *The Global Change Information System (GCIS) is intended to eventually become the United States Government's unified web based source of authoritative, accessible, usable, and timely information about climate and global change for use by scientists, decision makers, and the public.*

To support these efforts, a Structured Data Server (SDS) was developed to provide a common repository to collect, discover, and disseminate metadata about the data used in analyses. The TSU Software Engineer created the initial relational database schema for this system as well as proof-of-concept RESTful web services; USGCRP staff iterated upon that design to its current version (1.27 as of this writing) in consultation with the TSU.

Several software products have been created or improved to facilitate the continuing automated transfer of TSU metadata to the SDS:

- Client software to access the SDS RESTful API, pull survey results, and perform the actual translation and transfer (gcis_client.py, webform_client.py, and sync.py, respectively) as well as an automated test suite (test_suite.py) to ensure the integrity of the software. This software was made available to the general public.
- Scripts to reverse-engineer Thomson-Reuters' Endnote file format to facilitate automatic assignment of identifiers to citations within the NCA and their transmission to the SDS.
- An improved, public-facing metadata collection system comprising an interactive survey utilizing real-time updates to facilitate collaboration between NCA authors and TSU metadata staff.



To further the TSU's objectives to adhere to best practices of data management and software engineering, version control of both scientific datasets and analysis software continues to be employed. A document management system with native versioning capability was also trialed and installed to support future assessments. These tools proved their worth both internally and when disseminating work products with external collaborators.

The software engineer continues to demonstrate these best practices and provide training in advanced techniques of scientific computing to diverse groups of people:

- Federal scientists (4) at NCEI as well as contractors and other staff.
- Cooperative Institute scientists (8) and other staff.
- Graduate and undergraduate interns (5).

PLANNED WORK

- Continue development of metadata collection system and supporting technologies.
- Continue transitioning legacy research code to operations.
- Continue assisting lead scientist and associates with scientific programming tasks.
- Continue to mentor undergraduate interns.

DELIVERABLES

- GCIS SDS populated with all available metadata supporting the Climate and Health Assessment.
- An improved, public-facing metadata collection system for public release, including documentation.
- Various figures and analyses produced by the TSU with comprehensive supporting metadata.

PRESENTATIONS

- Paula A Hennon, Andrew Buddenberg, et al 2015: Technial Support for Climate Assessment Data Services, Joint Assembly (AGU), Montreal, Canada (4 May 2015).

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	9
# of products or techniques transitioned from research to ops following NOAA guidance	2
# of new or improved products developed without NOAA guidance	1
# of products or techniques transitioned from research to ops without NOAA guidance	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	5

PERFORMANCE METRICS EXPLANATION

This year, we created three data analysis packages, approximately a dozen figures for various publications, and one new metadata collection application. We improved one Drupal module, one client software package for GCIS SDS, and enhanced the poor performance of one critical web application. TSU transitioned several datasets from the NCA from research to operations as well as a document management system. An invited presentation was given to Joint AGU Assembly (1) and five undergraduate interns (5) were mentored.

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

Task Leader	Sarah Champion
Task Code	NC-ASSESS-04-NCICS-SC
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: The TSU continued development and operation of their unique Product Suite and production processes in order to collect, curate, and display the metadata for four assessments (*The Third National Climate Assessment (NCA3), Impacts of Climate Change on Human Health in the United States: A Scientific Assessment, Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment, and the NOAA State Climate Summaries*). 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. The NCA3 is 80% complete; the Health Assessment is 60% complete; the CMIP Assessment is 100% complete; the State Summaries are in development.

BACKGROUND

This report summarizes the work of the Technical Support Unit (TSU) Data Team. This team uses an internal Product Suite to ensure compliance with all federal requirements as defined by the Information Quality Act, while also contributing to the Sustained Assessment process. The TSU Product Suite collects, curates, and displays all associated metadata for the Sustained Assessment, ensuring traceability (transparency), and reproducibility of all data. The Product Suite includes a collection point, repository of inputs, reported statuses of all production milestones and overall requirements, and delivers the final products via a metadata viewer and web module. The viewer and web module are populated by an internal connection to a structured data server. This structured data server is maintained by continued integration to the U.S. Global Change Research Program (USGCRP) Global Change Information System (GCIS).

ACCOMPLISHMENTS

The TSU developed a robust Product Suite and evolved metadata collection process, which have been now been extended to four total assessment products, as noted above in the *Highlight* section. Additionally, the level of support to an Assessment has transitioned from internal and behind-the-scenes, to the actual authors and contributors of a report. The metadata collection for the *Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* has been provided nearly exclusively by the EPA report coordinators and associated authors; the TSU has merely guided them through the process in using the TSU Product Suite applications to produce the Assessment and meet federal guidelines. This particular effort is a major accomplishment in that it demonstrates success

with automating the collection process outside of the TSU, further aiding in the necessary cultural shift in scientific documentation. The *Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment* is a NESDIS Technical Report, and the content has been developed internal to the TSU. However, the Report analysts fully documented all of their metadata in accordance with the TSU Product Suite, allowing complete metadata documentation to be curated prior to the Report being released for formal review. Combined, the successes of both of these assessments shows significant advances in metadata documentation processes, and specific accomplishments for the TSU. This is further evident in formal requests to learn our particular approach to metadata from entities such as the Partnership for Resilience and the Oak Ridge National Laboratory, and a request to contribute a paper to a special issue of *Climatic Change* on our metadata experiences.

The additional Assessment documentation also is a measure of success of the collaborative effort with the USGCRP in development of their GCIS. While the NCA3 was the USGCRP proof of GCIS concept, the TSU has transitioned from role of GCIS Co-Developer to GCIS Contributor, instead only delivering metadata content to the GCIS as agreed upon in collaborative agreements.

Lastly, the TSU Data Team development of a Product Suite specifically accomplished the deliverable defined in the previous end-of-year report, which outlined the development of an end-to-end data process.

PLANNED WORK

- Continue metadata documentation efforts for the NCA3, USGCRP Climate and Health Assessment, NESDIS CMIP Technical Report, and NOAA State Climate Summaries
- Continue development of the TSU Product Suite, as needed
- Continue collaborative efforts with GCRP in populating the GCIS with Report metadata, data, and contributors

DELIVERABLES

- Fully documented metadata for Third National Climate Assessment, the EPA Health Assessment, the NESDIS CMIP comparison report, and the NOAA State Climate Summaries

PRESENTATIONS

- Champion, S., and Kunkel, K. 2015: Data Management and the National Climate Assessment: Best Practices, Lessons Learned, and Future Applications. *95TH Annual Meeting the American Meteorological Society*, Phoenix, AZ

PERFRORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	2
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

This year, TSU improved a process to collect metadata in accordance with Federal Requirements (1), and two additional supporting components to support a sustainable and seamless process (online collaborative suite and internal accompanying processes) (2). The progress of these components and process were invited as a presentation at the 2015 Annual Meeting of the AMS in Phoenix, AZ.

National Climate Assessment Editorial and Project Management Services	
Task Leader	Jessicca Griffin
Task Code	NC-ASSESS-05-NCICS-JG
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	National Climate Assessment
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5:0%

Highlight: Provided graphics design support for the USGCRP Climate and Health Assessment, the NOAA 50 State Climate Summary project, and other NCEI communications projects.

BACKGROUND

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the ongoing 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, NCDC'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.

ACCOMPLISHMENTS

Graphic design support services were provided for the development of the USGCRP Climate and Health Assessment. Tasks included basic image editing and more extensive editing to improve readability and ensure accuracy, as well as work to create entirely new infographics based on author input. Production services included preparing graphics for various pre-release drafts and developing draft layouts for report PDFs. The final report is expected to be released in the second quarter of 2016.

Graphics support was also provided for various NCEI communication products, including the 2014 State of the Climate Report published in the *Bulletin of the American Meteorology Society*.

PLANNED WORK

- Continued development of graphics and layout for the Health Assessment Report expected in Spring 2016
- Continue providing graphical support as a Visual Communications team member in the Communications and Outreach Branch of NCEI.

DELIVERABLES

The following products were delivered:

- *Bulletin of the American Meteorology Society*'s State of the Climate 2013 report
- Graphics for SGCR and public/NRC drafts of the USGCRP Climate and Health Assessment Report

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	3
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

BAMS State of the Climate report and graphics for two review drafts of the USGCRP Climate and Health Assessment.

Web Development for Assessments	
Task Leader	Angel Li
Task Code	NC-ASSESS-06-NCICS-AL
NOAA Sponsor	David Easterling
NOAA Office	NESDIS/OSD/SGSP/SEID
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	National Climate Assessment
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: %; Goal 3: %; Goal 4: %; Goal 5: %

Highlight: Built and launched the USGCRP Public Contribution website. The website for the forthcoming USGCRP Climate and Health Assessment is currently being developed.

BACKGROUND

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the ongoing 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, NCDC'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.

ACCOMPLISHMENTS

- Wrote a Metadata Survey used for three major projects: the USGCRP Climate and Health Assessment, a NOAA NESDIDS Technical Report comparing CMIP5 and CMIP3 model simulations, and the development of 50 state climate summary documents
- Participated in the maintenance of the USGCRP website (www.globalchange.gov)
- Prototyped a web site for the 50 state climate summary project
- Re-styled various web pages for CICS-NC scientists found in monitor.cicsnc.org

PLANNED WORK

- Planned code releases developed and deployed to GlobalChange.gov
- Theming of the Climate & Health Assessment website along with Javascript coding
- Continued maintenance of the CICS-NC web site

DELIVERABLES

The following products were delivered:

- Theming of USGCRP Public Contribution website.
- Continued maintenance and upkeep of CICS–NC web site.
- Metadata survey

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	6
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

Three metadata survey sites, theming for the USGCRP public contribution site, new tools on the monitor.cicsnc.org website, and and updates (multiple releases) to the globalchange.gov website.

National Climate Assessment Editorial and Project Management Services	
Task Leader	Tom Maycock
Task Code	NC-ASSESS-07-NCICS-TM
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	National Climate Assessment
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5:0%

Highlight: Provided project management and editorial and technical support for USGCRP Climate and Health Assessment currently under development, as well as continuing editorial and production support related to the Third National Climate Assessment, which was released on May 6, 2014.

BACKGROUND

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the ongoing 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, NCDC'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.

ACCOMPLISHMENTS

Post-Release NCA Support: Support for the NCA continued beyond the release of the report, including contributing to the development of a process for managing errata. Minor issues identified post-release were corrected in both the PDF and web versions, and and described in an errata document added to the website.

Climate and Health Assessment:

Project Management

- Worked with TSU staff and project leads from EPA and USGCRP to develop and refine processes and timelines for the development of the USGCRP Climate and Health Assessment.
- Coordinated activities of the TSU's editorial, graphics, metadata, software engineering, and metadata teams. Tasks included significant science editing and copyediting, graphics development and production, metadata collection, software development of collaboration tools, and initial design work on PDF layouts and the report website.
- The TSU successfully delivered a draft for review by the Subcommittee on Global Change Research and another draft for review by the public and the National Research Council.

Editorial Support
The editorial team provided developmental and copyediting support for several drafts of the assessment and led multiple webinars with authors to discuss comments and revisions. The team also contributed to the development of several figures for the report. Other tasks included:

- Preparing and delivering PDFs of two review drafts
- Assisting in the collection and management of citations

PLANNED WORK

- Continuing TSU project management and editorial support of the USGCRP Climate and Health Assessment. Delivery of the final report is expected in the second quarter of 2016.
- Work with USGCRP staff to continue planning for the fourth National Climate Assessment, based on lessons learned from NCA3 and from the ongoing Climate and Health Assessment process.

DELIVERABLES

The following products were delivered:

- Errata update for the third National Climate Assessment (revised PDFs and website)
- SGCR and Public/NRC review drafts of the USGCRP Climate and Health Assessment

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	3
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

Update to the National Climate Assessment and two review drafts of the USGCRP Climate and Health Assessment.

Web Development for Assessments	
Task Leader	April Sides
Task Code	NC-ASSESS-08-NCICS-AS
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%
Main CICS Research Topic	National Climate Assessment
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: %; Goal 3: %; Goal 4: %; Goal 5: %

Highlight: Built and launched the USGCRP Public Contribution website. The website for the forthcoming USGCRP Climate and Health Assessment is currently being developed.

BACKGROUND

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the ongoing 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, NCDC'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.

ACCOMPLISHMENTS

- Added performance enhancements to the USGCRP Review and Comment System website and added a Git workflow for updating the site.
- Deployed three code releases with new or modified features to GlobalChange.gov.
- Deployed code updates and Errata content changes to the Third National Climate Assessment website.
- Set up a Git workflow for updating legacy Resources sites and added a Photo Management feature to the Resources websites.
- Developed initial design for the USGCRP Climate and Health Assessment website

PLANNED WORK

- Planned code releases developed and deployed to GlobalChange.gov.
- Visual design of the USGCRP Climate & Health Assessment website.

DELIVERABLES

The following products were delivered:

- Project charters for the GlobalChange.gov, Public Contribution, Review and Comment System, and the Climate & Health Assessment websites.
- USGCRP Public Contribution website.
- Requirements document for the USGCRP Climate & Health Assessment website.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	5
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

Products: GlobalChange.gov, USGCRP Review and Comment System, Third National Climate Assessment, USGCRP Public Contribution, and Resources websites.

National Climate Assessment Science Support: Analysis of Observational and Modeled Climate Data

Task Leader	Laura Stevens
Task Code	NC-ASSESS-09-NCICS-LSt
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Analysis of observational and model data has been performed, and several figures produced for the upcoming NOAA Technical Report NESDIS 144. In addition, 50 NOAA state climate summary documents are in preparation, and continuing support is being provided following the release of the Third National Climate Assessment report.

BACKGROUND

Primary science and technical support has been provided to NOAA and the NOAA Technical Support Unit (TSU) of the National Climate Assessment (NCA) process. This included the processing and analysis of observational and modeled climate data and the production of graphics for the upcoming NOAA Technical Report NESDIS 144, the coordination of 50 NOAA state climate summary documents, the review of several chapters of the upcoming USGCRP Climate and Health Assessment, research on Assessment-relevant topics, and continued support following the release of the Third National Climate Assessment report.

ACCOMPLISHMENTS

Analyses of multiple observational and model data sets were carried out for the upcoming NOAA Technical Report NESDIS 144, "Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment." This report, which includes three additional CICS-NC co-authors, primarily uses data directly from the Coupled Model Intercomparison Project phase 3 (CMIP3) and phase 5 (CMIP5) in order to assess the similarities and differences in future temperature and precipitation projections across the United States between the two sets of model simulations. For examination of future extreme conditions, indices from the Climate Extremes Indices (CLIMDEX) project were analyzed. Analyses of historical temperature and precipitation used data from the U.S. Climate Divisional Dataset (nClimDiv).

These analyses led to the production of several figures for the report, an example of which is given in Figure 1. Comprehensive metadata were also compiled for all report figures and tables, and all data files were packaged to be made available online. These analyses and figures were compiled into a NOAA Technical Report format, totaling 111 pages and containing 68 figures and 10 tables, and put through a peer-review process.

In addition to providing input for NOAA Technical Report NESDIS 144, the coordination of 50 NOAA state climate summary documents is currently in progress. These documents are

being produced in the lead up to the Fourth National Climate Assessment, due to the request for historical and projected temperature, precipitation, and other climate data at the individual state level.

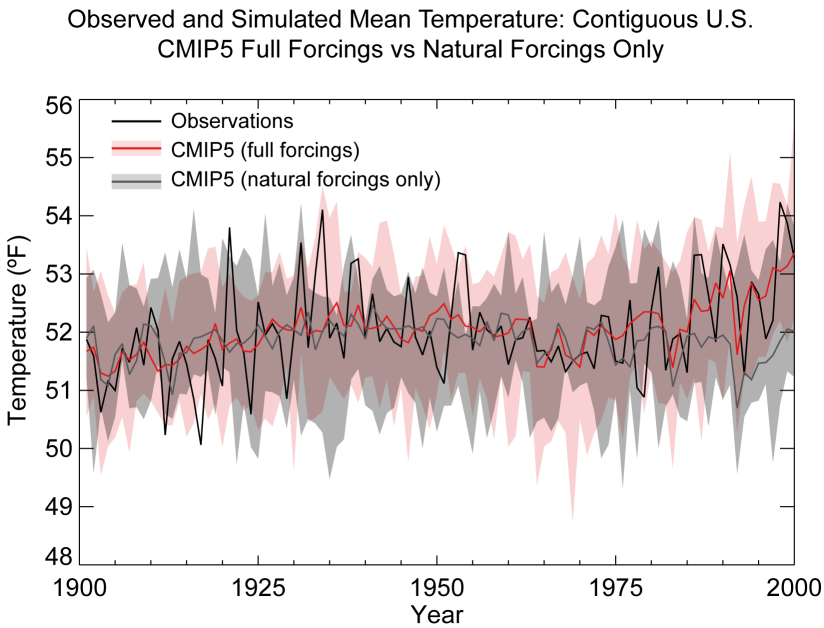


Figure 1. Observed and simulated annual mean temperature (°F) for the contiguous U.S. for 1901–2000. Observational data are from NCEI's Climate Divisional Dataset (nClimDiv, black); simulations are CMIP5 multi-model means using full forcings (red) and natural forcings only (gray). Shaded areas represent the 5th–95th percentile range of the model simulations. Source: NOAA Technical Report NESDIS 144 (in press).

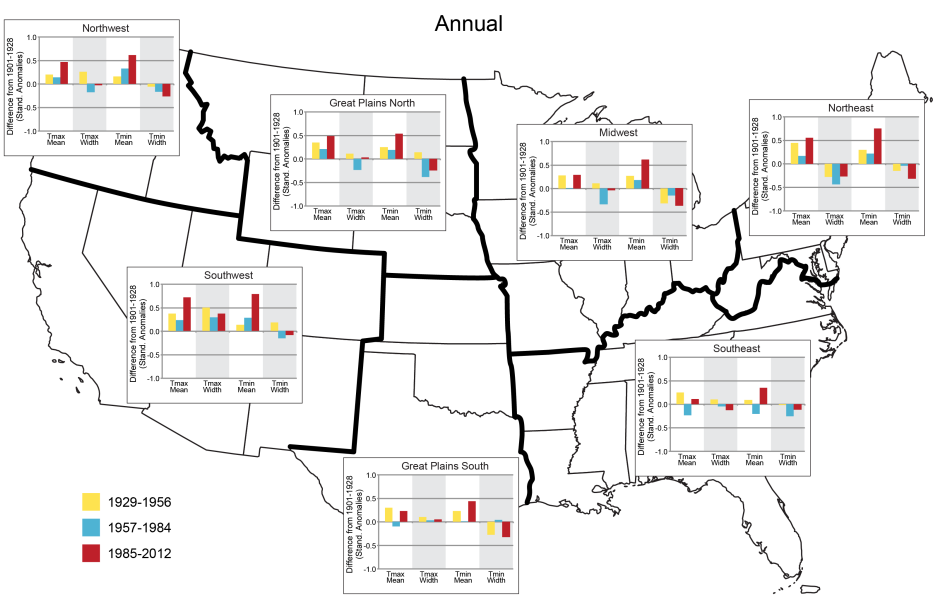


Figure 2. Regional time series of monthly temperature PDF characteristics (expressed as the difference from the 1901–1928 period values in standardized temperature anomaly units) for mean maximum temperature (leftmost set of 3 bars in each graph), the width of the

Tmax PDF (the second from left set of 3 bars in each graph), mean minimum temperature (the second from right set of 3 bars in each graph), and the width of the Tmin PDF (the rightmost set of 3 bars in each graph) for the periods of 1929–1956 (yellow), 1957–1984 (teal), and 1985–2012 (red). PDFs were generated from monthly temperature anomalies using all 12 months of the year. Source: Kunkel et al. (2015).

Other tasks involved the review of several chapters for the upcoming USGCRP Climate and Health Assessment and additional research on Assessment-relevant topics, one example being the publication of a paper assessing temporal changes in the probability distribution of U.S. monthly temperatures titled "Is the monthly temperature climate of the United States becoming more extreme?" This paper, which included two additional CICS-NC co-authors, was published in January 2015 in Geophysical Research Letters. An example figure can be seen as Figure 2.

Continued support was also provided following the release of the Third National Climate Assessment report (NCA3) by compiling metadata for numerous TSU-created figures, as well as by fielding data inquiries and providing information and data files when requested. This involved responding to requests from government agencies, universities, and others for detailed information on NCA figures and data sources, and for new content based on NCA work.

PLANNED WORK

- Publication of NOAA Technical Report NESDIS 144 with associated metadata and data files to be made available online;
- Completion of 50 NOAA state climate summary documents;
- Continued review of chapters for the upcoming USGCRP Climate and Health Assessment as requested;
- Assistance in the production of a website displaying 20th century extratropical cyclone tracks;
- Additional research on Assessment-relevant topics, e.g., analysis of temperature and humidity metrics for the contiguous U.S. using NCEI's Integrated Surface Hourly Dataset.

PUBLICATIONS

- Kunkel, K. E., R. S. Vose, L. E. Stevens, and R. W. Knight, 2015: Is the monthly temperature climate of the United States becoming more extreme? Geophysical Research Letters, 42, 2014GL062035, doi:10.1002/2014GL062035. Available online at: http://dx.doi.org/10.1002/2014GL062035

DELIVERABLES

- Provided analyses and figures for NOAA Technical Report NESDIS 144, accompanied by the compilation of metadata and data files for all 68 figures and 10 tables;
- Coordination of 50 NOAA state climate summary documents currently in preparation;

- Review of several chapters for the upcoming USGCRP Climate and Health Assessment;
- Research on Assessment-relevant topics, including a publication assessing temporal changes in the probability distribution of U.S. monthly temperatures;
- Continued support following the release of NCA3, including the fielding of data inquiries and compilation of metadata for numerous figures.

PRESENTATIONS

- Stevens, L.E., 2015: Climate Change Impacts in the United States, Asheville-Buncombe Technical Community College (presentation for AB Tech Environmental Biology Students), Asheville, NC (10 March)
- Rennie, J., A. Buddenberg, K. Gassert, R. Leeper, L.E. Stevens, and S.E. Stevens, 2015: Computation, Analysis and Visualization of In-Situ and Remote Sensing Data using Python, 95th AMS Annual Meeting, Phoenix, AZ (5 January)
- Stevens, L.E., K.E. Kunkel, R.S. Vose, and R.W. Knight, 2014: Has the Temperature Climate of the United States Become More Extreme?, 2014 AGU Fall Meeting, San Francisco, CA (16 December)
- Taylor, R., and L.E. Stevens, 2014: Teaching Climate Using the Third National Assessment, AGU-NESTA Geophysical Information For Teachers (GIFT) Workshop 2014, San Francisco, CA (15 December)
- Stevens, L.E., 2014: Climate Change Impacts in the United States, NOAA's National Climatic Data Center (presentation for AB Tech Environmental Biology Students), Asheville, NC (3 November).

OTHER

- Co-led a workshop activity for K-12 educational uses of the NCA at the 2014 AGU-NESTA Geophysical Information For Teachers (GIFT) Workshop;
- Nominee for the 2015 North Carolina State University Office of Research and Innovation Awards for Excellence, in recognition of organizing and participating in several community service and outreach events in the local area.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	0
# of invited presentations	5
# of graduate students supported by a CICS task	0
# of graduate students formally advised	0
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

Three invited talks were given relating to the Third National Climate Assessment. One peer-reviewed paper was published and one invited talk was given based on Assessment-relevant research.

National Climate Assessment Scientific Support Activities

Task Leader	Liqiang Sun
Task Code	NC-ASSESS-10-NCICS-LSu
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Scientific analysis of CMIP5 and CMIP3 data has been performed to support the development of the Third National Climate Assessment (NCA).

BACKGROUND

The NOAA Assessments Technical Support Unit (TSU) is developing state-of-art scientific products that support the development of the NCA Reports. The primary effort for this task is the preparation of robust and reliable climate information at regional scales for the United States, using observations, CMIP3 and CMIP5 model simulations, and dynamically and statistically downscaled data. Research on understanding of climate change and uncertainty is also conducted to improve the continuing assessment process.

ACCOMPLISHMENTS

A NOAA technical report was developed that compares CMIP3 and CMIP5 simulations. In this report, we compared annual and seasonal surface temperature and precipitation, warm (cold) spell duration, consecutive dry (wet) days, maximum one (five) day precipitation, precipitation above 99th percentile, minimum T_{max} and T_{min}, and maximum T_{max}, growing season length, number of nights above 20°C, and number of nights below 0°C for seven emissions scenarios.

Seasonal and annual surface temperature and precipitation, T_{max} and T_{min}, maximum one-day precipitation, growing season length from CMIP5 simulations were interpolated onto 5 km x 5 km grids over the United States, and maps were generated for each of the 50 states. This is in support of the development of 50 State Climate Summaries.

Analysis of sea surface temperature, surface temperature, T_{max} and T_{min}, and precipitation from CMIP5 simulations was carried out. This is in support of the development of USGCRP Climate and Health Assessment report.

Identification and tracking of extratropical cyclones and blocking episodes in the CMIP5 simulations are in process. We examine if the CMIP5 models can reproduce the observed spatial and temporal variations of ETCs and blocking episodes in the observational record, and analyze changes in CMIP5 simulations for the future.

The Global/Regional Integrated Model System (GRIMs) is configured over the Southern

Plains to examine the climate change impact on convective precipitation. One-month simulation with horizontal resolution of 4 km was done to determine optimal physics and parameterization choices.

Analysis of CMIP5 simulations for various needs of the assessment and collaborations, e.g., analysis of temperature changes over the 50 U.S. states and 8 NCA regions under global temperature changes of 1 ^{o}F to 10°F; providing CMIP5 data and guidance to Ryan Smith at the 14th Weather Squadron.

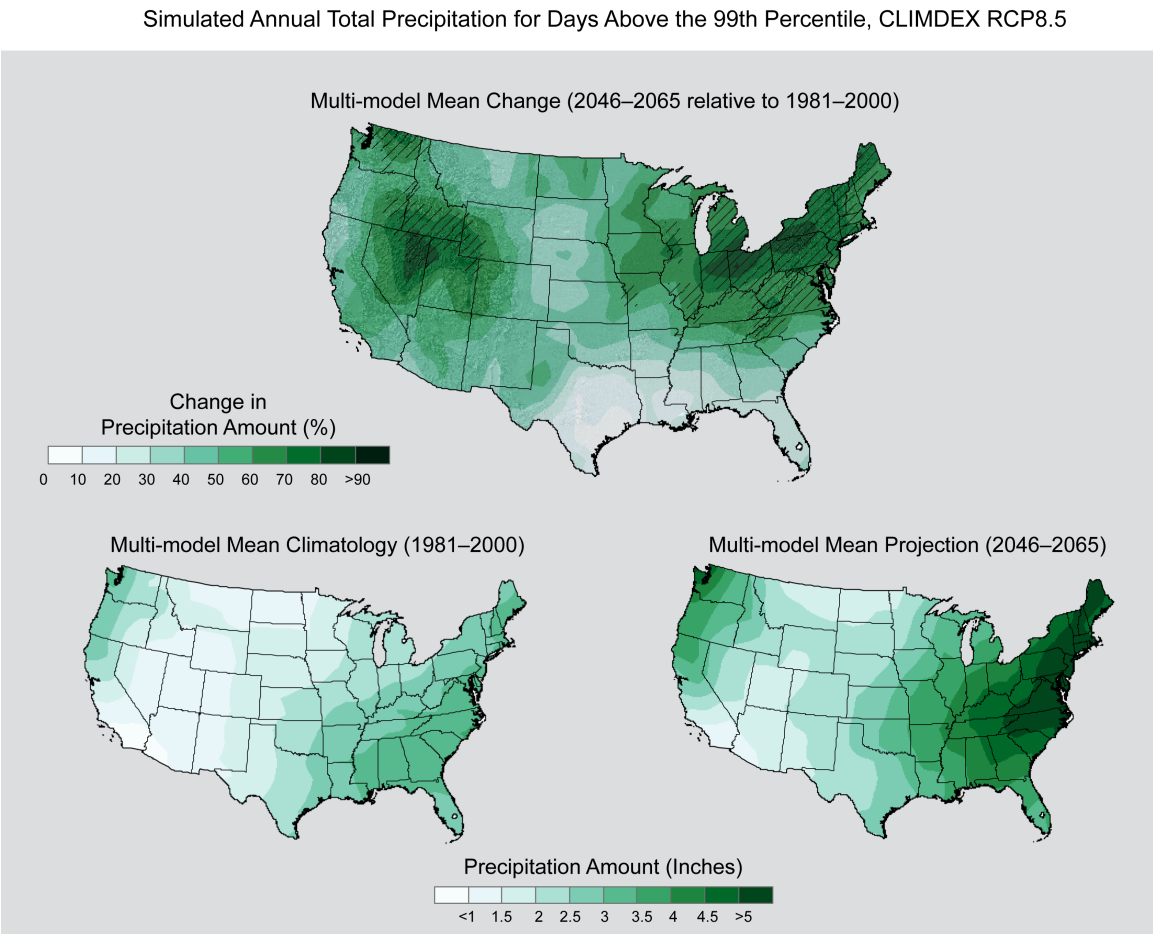


Figure 1. Simulated multi-model mean change in annual total precipitation for days above the 99th percentile (R99pTOT) for the contiguous United States, for 2046-2065 with respect to the reference period of 1981-2000, using the CLIMDEX RCP8.5 scenario (top). Color only (category 1) indicates that less than 50% of the models show a statistically significant change. Color with hatching (category 3) indicates that more than 50% of the models show a statistically significant change, and more than 67% agree on the sign of the change. Multi-model mean climatology indicating the R99pTOT for 1981-2000 (bottom left). Multi-model mean projection indicating the R99pTOT for 2046-2065 (bottom right).

PLANNED WORK

- Trend analysis at the state level in the United States for annual and seasonal means of temperature and precipitation, and other climate extreme indices
- Analysis of potential future changes in tropical cyclones (SERDP project)
- Continue research on mesoscale convection systems in changing climate
- Data analysis to meet the specific needs of the assessment.

PUBLICATIONS

- Sun, L., K.E. Kunkel, L.E. Stevens, A. Buddenberg, J.G. Dobson, and D.R. Easterling: 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,* in review
- 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*, In press, doi:10.1016/j.crm.2015.03.002.
- Dehaan, L., M. Kanamitsu, F. D. Sales, and L. Sun, 2014: Seasonal prediction downscaling over North America using regional models: Added values. *Theor. Appl. Climatol.*, **118**, DOI 10.1007/s00704-014-1278-9.

DELIVERABLES

- Report on trend analysis
- Report on tropical cyclone research
- Report on regional modeling of weather characteristics in a changing climate
- Graphics for NCA report

PRESENTATIONS (invited)

- Sun, L., K. E. Kunkel, and L. Stevens, 2014: "Deliver and improve climate science for National Climate Assessment in the United States", SOUSEI symposium "Challenges toward Regional Climate Change Risk Prediction", Yokohama, Japan (26 November 2014)
- Sun, L., 2014: Climate Downscaling Forecasts over Northeast Brazil: An Update. *13th International Regional Spectral Model Workshop*, Yokohama, Japan (26 November 2014)
- Sun, L., K. E. Kunkel, and L. Stevens, 2014: "Regional climate extremes in the United States: Observed changes and future outlook", Seminar at Sun Yat-sen University, China (24 November 2014)
- Sun, L., 2014: "Dynamical downscaling for the National Climate Assessment", Seminar at Tsinghua University, China (20 November 2014)

OTHER

- Committee member: *13th International Regional Spectral Model Workshop*, Yokohama, Japan.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	3
# 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

PERFORMANCE METRICS EXPLANATION

The primary effort is the preparation of robust and reliable climate information for NCA, using observations, CMIP3 and CMIP5 model simulations, and downscaled 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.

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 algortihm 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 NCDC 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, Carl Schreck
Task Code	NC-CDR/SDS-01-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: %; Theme 3: %.
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 scientist 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, execution, and reporting of member's office/organization tasks required to transition the CDR to an IOC state.

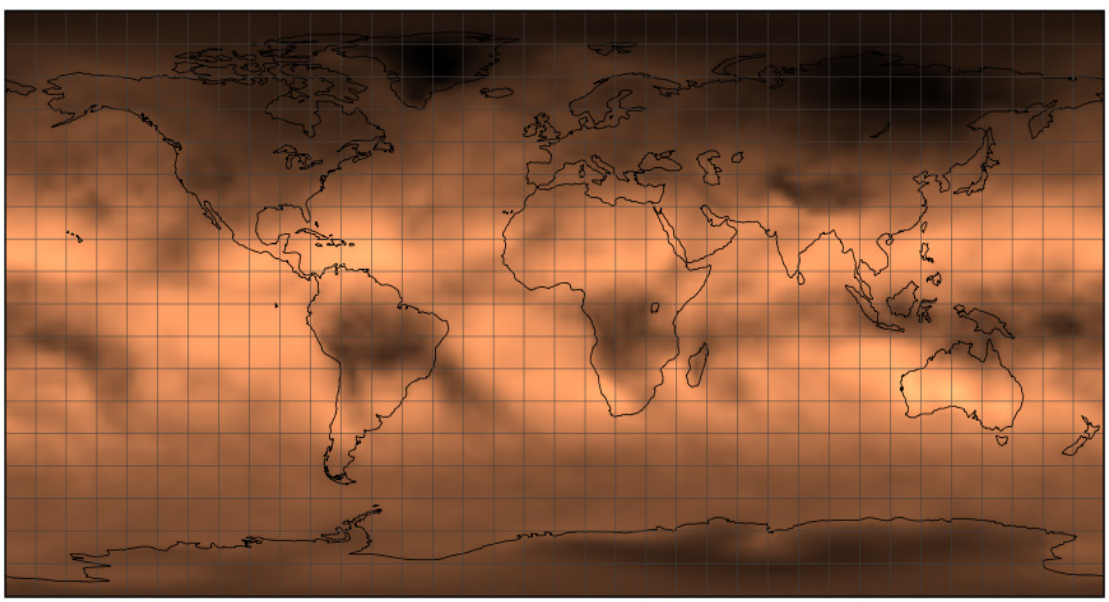


Figure 1. A sample image for the Outgoing Longwave Radiation-Monthly CDR.

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)
- Cryosphere Bundle – Snow cover fraction (Peng)
- Precipitation – PERSIANN-CDR (Prat)
- Precipitation – CMORPH (Prat)
- Outgoing Longwave Radiation – Monthly (Schreck)
- Outgoing Longwave Radiation – Daily (Schreck)

Products Branch representative IPT responsibilities include:

- leading and scheduling IPT meetings needed for resolving technical issues on the products with PI,
- conducting initial assessment of CDR readiness for transition from scientific perspective,
- reviewing PI-submitted draft products against IOC requirements,
- providing feedback to PI on draft products,
- verifying PI-submitted final products conform to IOC requirements ,
- participating in management and technical meetings as required,
- working with PI, IPT, and O&M Project Manager to complete each CR and route for signatures
- attending Change Control Board meetings, when needed,
- reviewing PI-submitted documents delivered as part of the WA (C-ATBD, Maturity Matrix, Data Flow Diagram, Implementation Plan) and providing feedback, and
- reviewing PI-submitted documents delivered as part of the WA (QA procedure, QA results, VDD, annual reports) for information only.

Operations Branch representative IPT responsibilities include:

- leading and scheduling IPT meetings needed for resolving technical issues related to operations,
- assisting with initial assessment of CDR readiness for transition from an operational perspective,
- entering the source code into the NCEI version control system,
- requesting an initial security review,
- verifying source code and Readme packages for compliance with IOC standards,
- informal source code reviewing with feedback for CDRP,
- porting code for implementation on NCEI systems as requested by CDRP, PI, and/or other IPT members.
- assisting with ingest and archival of the CDR source code, documentation, and data packages,
- participating in management and technical meetings as required, and
- working with PI, IPT, and O&M Project Manager to complete each CR.

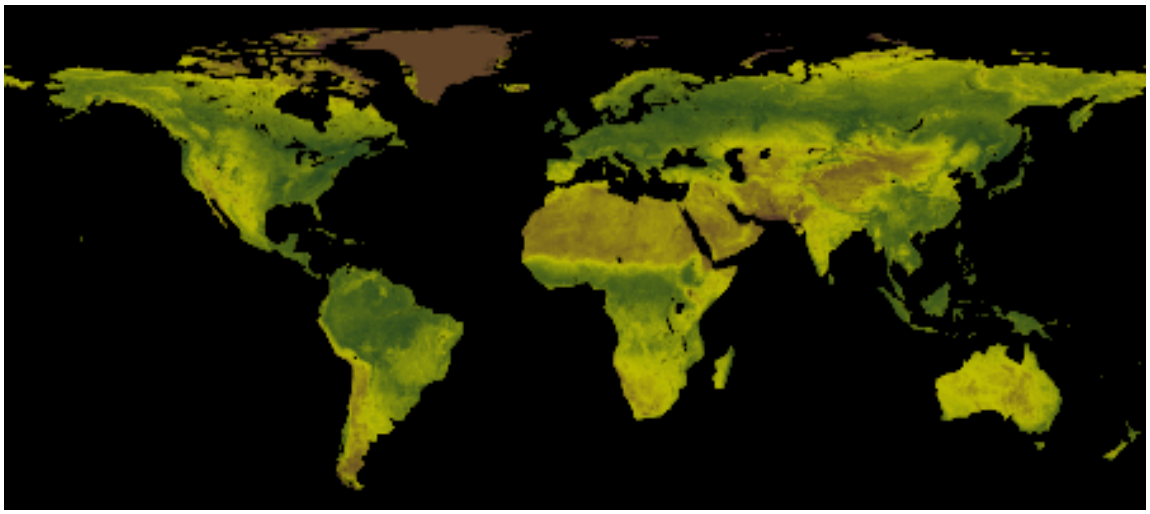


Figure 2: An example image of Normalized Difference Vegetation Index (NDVI) for the Land Surface Bundle CDR.

PLANNED WORK

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

PUBLICATIONS

- Ashouri, H, K. Hsu, S. Sorooshian, D. Braithwaite, K.R. Knapp, L.D. Cecil, B.R. Nelson, and O.P. Prat, 2015. PERSIANN-CDR: Daily precipitation climate data record from multi-satellite observations for hydrological and climate studies. Bulletin of the American Meteorological Society. 96, 69-80.

PRESENTATIONS

- Matthews, J.L. 2015. Land surface albedo from a constellation of geostationary satellites compared and fused with polar-orbiting data. *Annual meeting of the American Meteorological Society*, 4-8 January 2015, Phoenix, AZ, USA.
- Peng, G., 2015: NOAA/WHOI Climate Data Record of Ocean Surface Bundle, v1.0 (Sea Surface Temperature, Ocean Near-Surface Properties, and Heat Fluxes) (DSI – 371201). NCDC User & Engagement Services Branch Briefing. January 8, 2015. Asheville, NC, USA.
- Schreck, C.J., H.-T. Lee, and K. Knapp, 2015: A new daily OLR dataset for identifying the MJO and tropical waves. Third Symposium on Prediction of the Madden-Julian Oscillation, 4-8 January 2015, Phoenix, AZ, USA.
- Schreck, C.J., H.-T. Lee, and K. Knapp, 2014: A new daily OLR dataset for identifying the MJO and tropical waves. *39th Climate Diagnostics and Prediction Workshop*, 20-23 October 2014, St. Louis, MO, USA.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	4
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without 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

PERFORMANCE METRICS EXPLANATION

The Land Surface Bundle CDR LAI/FAPAR variables and Ocean Surface Bundle CDRs (three datasets: Ocean Surface Heat Fluxes, Sea Surface Temperatures, and Ocean Near-Surface Atmospheric Properties) have been transitioned to IOC status. Olivier Prat coauthored one journal article describing the PERSIANN-CDR algorithm published in Jan 2015. Jessica Matthews gave 1 presentation on the albedo CDR, Ge Peng gave 1 presentation on ocean surface bundle CDR, Carl Schreck gave 2 presentations on the daily OLR CDR.

Expansion of CDR User Base (e.g., Obs4MIPs)

Task Leader	Jim Biard, Jessica Matthews, Ge Peng, Carl Schreck
Task Code	NC-CDR/SDS-02-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: %; Theme 3: %.
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 provide NOAA Climate Data Records (CDRs) from observational platforms (e.g., satellite and in situ datasets) that can be used for climate model evaluation (Coupled Model Intercomparison Project or CMIP5 for the 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 temporal/spatial resolution, documentation, and data access support.

CMIP5 model output allows the international climate modeling community to project simulated climate when adjusted to changes in climate forcings (e.g., an increase in carbon dioxide for the next several decades). By participating in the Observations for Model Intercomparison Projects (Obs4MIPs) to provide observational datasets for comparison with CMIP5 model output, NOAA CDRs will be able to provide observational data that has a "time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change." Currently, the CDR Program already serves several essential climate variables (e.g., outgoing longwave radiation, sea ice area fraction, and sea surface temperature) that are highly sought-after as candidates for the Obs4MIPs project. Unlike most observational datasets, NOAA's CDRs address the challenges of using data from multiple instruments and provide systematic, comprehensive, and sustainable long-term climate records that would greatly benefit the international community for addressing critical climate questions.

ACCOMPLISHMENTS

The pilot study portion of this project, which involved process application to three operational CDRs, has been completed as of June 30, 2015. Key accomplishments of the team include:

- Development of a software tool capable of creating Obs4MIPs-compliant versions of CDRs from operational CDRs
- Verified output from this tool with original CDRs
- Validated that all metadata compliances are met in the Obs4MIPs version of CDRs
- Produced complete period of record in Obs4MIPs-compliant resolutions and formats for three selected operational CDRs (see Table 1)

- Composed the required Technical Note documentation to accompany each Obs4MIPs CDR

Input CDR (temporal resolution, spatial resolution)	**Obs4MIPs-compliant CDR (temporal resolution, spatial resolution)**
Outgoing Longwave Radiation (daily, 1°)	Outgoing Longwave Radiation (daily, 1°)
Outgoing Longwave Radiation (daily, 1°)	Outgoing Longwave Radiation (monthly, 1°)
Sea Ice Concentration (daily, 25 km)	Sea Ice Concentration (daily, 25 km)
Sea Ice Concentration (monthly, 25 km)	Sea Ice Concentration (monthly, 25 km)
Sea Surface Temperature – Optimum Interpolation (daily, ¼ °)	Sea Surface Temperature – Optimum Interpolation (daily, ¼ °)
Sea Surface Temperature – Optimum Interpolation (daily, ¼ °)	Sea Surface Temperature – Optimum Interpolation (monthly, ¼ °)

Table 1. Summary of input NOAA CDRs and Obs4MIPs-compliant CDRs from pilot study portion of this project, including input and output resolutions.

PLANNED WORK

- Apply the developed software tool to additional operational CDRs

DELIVERABLES

- A software tool with the capacity to translate existing operational CDRs to the Obs4MIPs-compliant format
- Technical Notes to accompany delivered Obs4MIPs CDRs
- Complete period of record for 3 operational NOAA CDRs (Outgoing Longwave Radiation – Daily, Sea Ice Concentration, Sea Surface Temperature – Optimum Interpolation) in Obs4MIPs-compliant format, each at two temporal resolutions (daily and monthly)

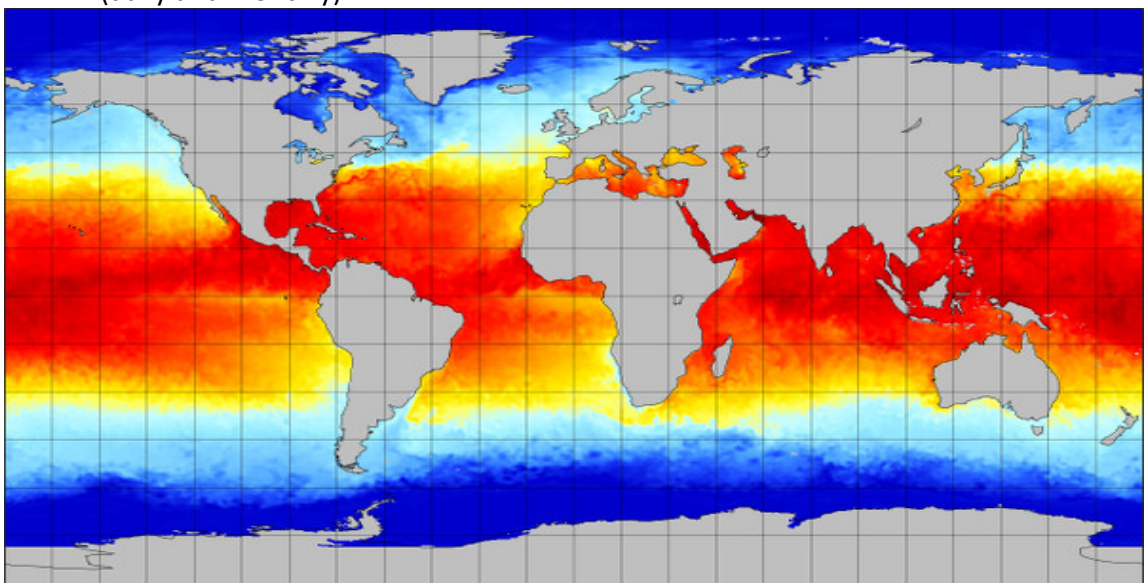


Figure 1. A sample image of the Optimal Interpolation Sea Surface Temperature CDR prepared for Obs4MIPs.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	6
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

Six Obs4MIPs-compliant CDRs were produced (Both daily and monthly products at native spatial resolutions for each of: Outgoing Longwave Radiation, Sea Ice Concentration, and Sea Surface Temperature – Optimum Interpolation). The software tool capable of translating operational CDRs to Obs4MIPs-compliant CDRs was transitioned from a research concept to an operational tool.

Big Data Technologies for NOAA Metadata

Task Leader	Linda Copley, Jim Biard
Task Code	NC-CDR/SDS-03-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	
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: Created a proof-of-concept tool that demonstrates search capabilities across multiple, disparate datasets.

BACKGROUND

"Big Data" technologies are currently being implemented in private, scientific, and government organizations that allow researchers and analysts to gain new insights into the ever-increasing volume of data being collected. These new technologies provide the ability to maintain linkages among vast but varied sets of data. An opportunity exists to exploit these new technologies to link disparate NOAA datasets together using a single search and discovery mechanism across multiple platforms.

The nature of graph database technology, as used in geospatial computing, social networking and recommendation engines, can provide rapid access to datasets based on various relationships inherent in the data, such as temporal, spatial, and qualitative measures, as well as based on information about the data, such as societal impacts, citations, and quantitative measures. Graph databases are particularly well suited to implementing fast search algorithms concerned with pinpointing data with close relationships (e.g., spatially) or with similar characteristics (e.g., qualitatively). The unstructured nature of graph databases provides the ability to accommodate, and easily relate, differing metadata from multiple sources using different vocabularies. NoSQL and graph databases have been engineered to scale horizontally, and thus are suited to support the unprecedented growth of satellite and in situ metadata being generated.

ACCOMPLISHMENTS

The initial proof-of-concept implemented a NoSQL graph database to collect descriptive information for the data in different unrelated systems and demonstrate the capabilities of linking associated datasets into a new search and discovery interface. This application provided for data discovery across Suomi-NPP VIIRS SDR (Suomi National Polar-Orbiting Partnership Visual Infrared Imaging Radiometer Suite Sensor Data Records) satellite data and the Storm Events in situ dataset. Starting with one year of data for the Storm Events, and an overlapping six months of data for the VIIRS SDR data, the descriptive dataset information was loaded into a graph database to construct a searchable inventory based on spatial, temporal, and qualitative measures. The VIIRS SDR satellite data is geo-located using latitude and longitude based polygons, and contains approximately 85 seconds of data per

granule. On the other hand, the Storm Events are reported by various observational sources, and only occasionally report latitude and longitude. Each event may be located at a single point, along a line (such as a tornado track), or within a named place (e.g., city, county or state). The geographic locations of the Storm Events are tagged with ANSI/FIPS codes to identify the location. Storm Events may be at discrete point in time, or may span several days or months (as is the case with a drought or a flood).

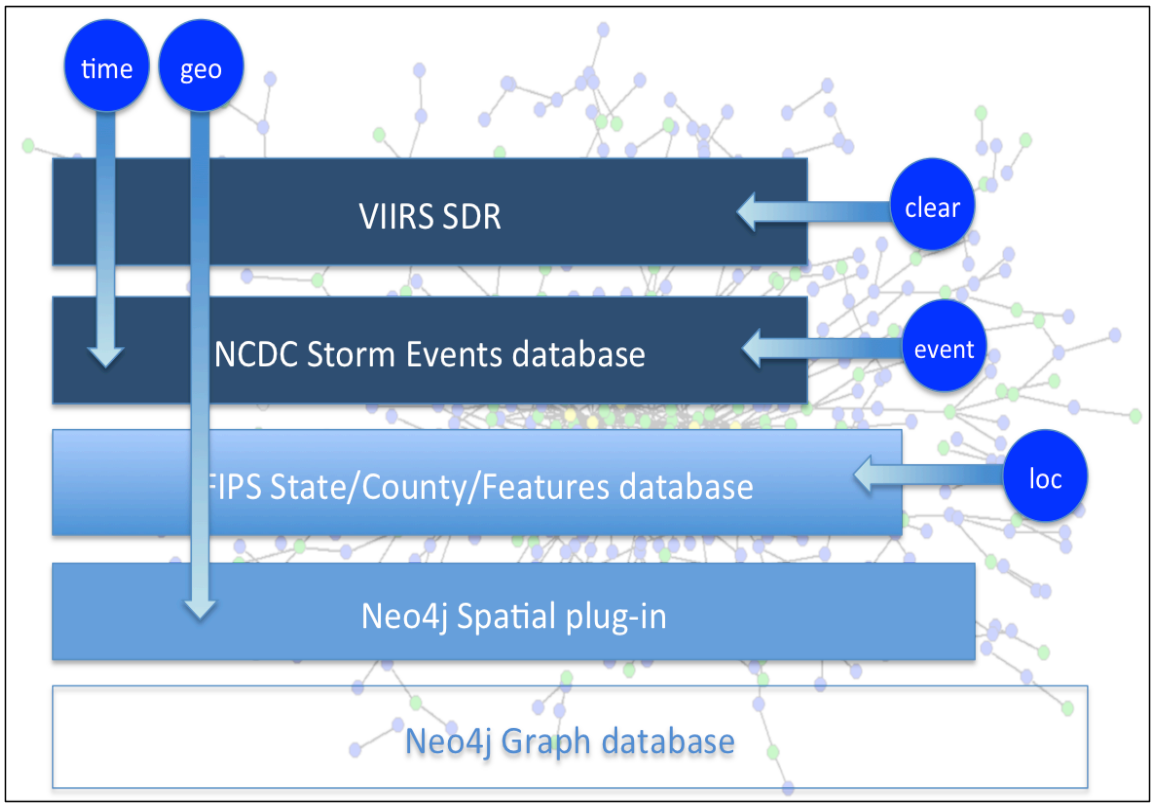


Figure 1: Graph Database Stack

The Neo4j graph database was built to include the Neo4j spatial extension, which provides GIS-like searching capabilities over the graph database. The Neo4j spatial extension then allows for the discovery of VIIRS SDR data based on latitude and longitude, using operations such as 'within distance' and 'within bounding box'. Pertinent sections of the ANSI/FIPS geographic codes were loaded into the database to allow for mapping of geographic codes to latitude and longitude. Since the Storm Events can be located using the FIPS geographic codes, all events can then be resolved to latitude and longitude with the graph database. Similarly, both the VIIRS SDR and Storm Events data were mapped to a data tree in the graph database to allow for temporal searches. The strong relationship properties of the graph database were exploited to provide for rapid and unique queries over these two datasets.

In addition to the granule-level graph database and search, a graph database has been built that contains information extracted from the collection-level metadata that has been compiled for numerous datasets held by the National Centers for Environmental Information (NCEI) and by the Comprehensive Large Array-data Stewardship System (CLASS). The collection-level metadata for a dataset describes the dataset in a variety of ways, possibly including but not limited to:

- Title
- Abstract
- Date range covered
- Geospatial extent
- Edition
- Producer
- Distributor
- Point of Contact
- Processing history
- Other datasets used as inputs
- Date archived
- Type of data
- Format of files in the collection
- Science domain for the data
- Instrument(s) used to acquire the data

One of the ways the collections are described is by use of keywords taken from a number of controlled vocabularies. Many of the keyword vocabularies that have been used are those maintained by the NASA Global Change Master Directory (GCMD). The GCMD keywords are organized as multilevel taxonomies.

NCEI and CLASS store the collection-level metadata for their datasets in files that use the ISO 19115-2 Geographic Metadata Standard XML format. An application was written that parses an ISO XML metadata file and extracts a core set of identification entries, most of the "Responsible Party" entries, and all of the "Keywords" entries from it. The application then adds this data to a graph database and builds relationships between the information found for this particular collection and the information already present in the graph.

This application was used to build a graph database containing a total of 346 collection-level metadata records. The different collections are related to one another via common responsible parties, keywords in taxonomy trees, start and end times in a time tree, and geospatial extents in a range tree.

Figure 2 shows the results of a query for all collections that were identified with the keyword 'AEROSOLS', or of a keyword that had 'AEROSOLS' as an ancestor or descendant in its taxonomy tree. The results show that the keyword is found in two different keyword vocabularies, and that three out of the seven collections found were described by a descendant keyword, 'AEROSOL OPTICAL DEPTH/THICKNESS'. A wide variety of other queries are possible, and they can be quite complex.

Figure 2. Result of a graph query for collections associated with the keyword 'AEROSOLS'

This graph database can be used as part of a collection-level search and discovery tool that provides powerful filtering capabilities based on keywords, time ranges, and geospatial extents, and that can display lists of collections that contain similar or related types of data. This graph database can also be used to build quality assurance applications that can help curators identify errors and inconsistencies in their collection-level metadata.

PLANNED WORK

- Create a collection search and discovery tool.
- Link the collection-level and granule-level graphs.
- Integrate the collection level and granule-level search and discovery tools.
- Add additional granule-level metadata for NCEI datasets into the graph and make them accessible through the tools.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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 Cyclones Imagery with Citizen Scientists

Task Leader	Chris Hennon, Carl Schreck, and Scott Stevens
Task Code	NC-CDR/SDS-04-NCICS
NOAA Sponsor	Ed Kearns
NOAA Office	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 400,000 tropical cyclone classifications from citizen scientists. A manuscript published by 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 are enlisting 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

In its first three years, Cyclone Center has collected more than 8,000 citizen scientists who have produced over 400,000 classifications. This year, the website underwent its second overhaul to improve its aesthetics and attract even more volunteers. 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 have been presented at several major conferences. Most notably, the WMO's Eighth International Workshop on Tropical Cyclones (IWTC-VIII) dedicated an entire session to discussing the project.

One of the key motivations for this project is the discrepancies found amongst the best track datasets from various agencies around the globe. To demonstrate this problem, a paper was published in *Monthly Weather Review* examining the differences between data from the U.S. Joint Typhoon Warning Center (JTWC) and the WMO agencies in each basin. It showed that some of these regional differences are substantial enough to affect global metrics of tropical cyclone activity. This paper appeared in the December 2014 issue and has already become one of the ten most-read papers of the past twelve months for this journal.

The initial results indicate that the classifications from our users are at least comparable to automated techniques like the Advanced Dvorak Technique (ADT). Figure 1 shows the

distribution of wind speeds from Cyclone Center, ADT, and best track for storms in the North Atlantic that had low-level aircraft reconnaissance. The distribution of the Cyclone Center winds appears more physically realistic than that of ADT, which over-estimates the number of storms near 55 kt. This is a known bias of ADT, which struggles when high cirrus clouds obscure a nascent eye. Our human classifiers do not seem to have this issue and show a smoother transition for storms with eyes.

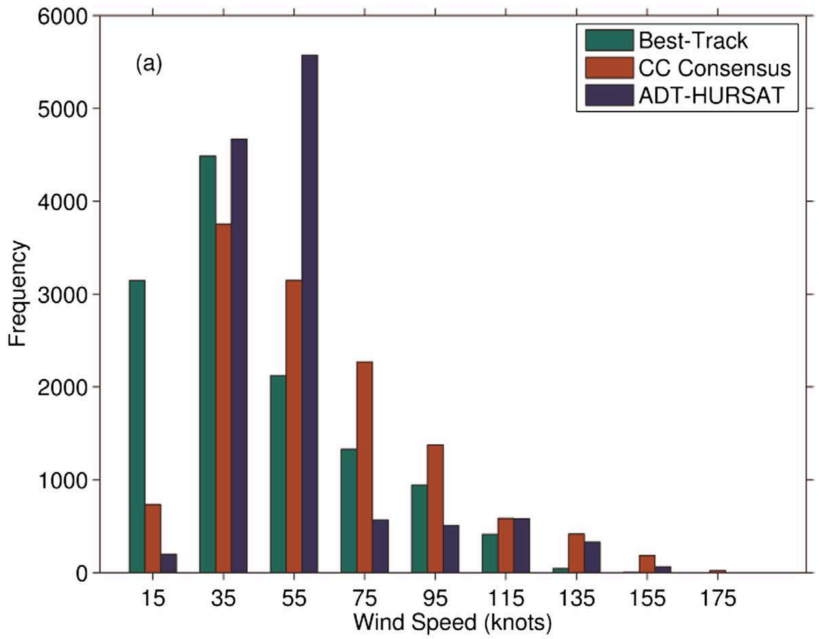


Figure 1. Comparison of intensity estimate distributions between Cyclone Center (CC consensus), ADT-HURSAT, and global best track data.

PLANNED WORK

- Continue promoting this project through a variety of media outlets, particularly during the 2015 Atlantic Hurricane Season
- Develop method for applying the full Dvorak analysis to the data collected, including the "Data T-Number"

PUBLICATIONS

- Schreck, C. J., K. R. Knapp, and J. P. Kossin, 2014: The Impact of Best Track Discrepancies on Global Tropical Cyclone Climatologies using IBTrACS. *Mon. Wea. Rev.*, **142**, 3881–3899, doi:10.1175/MWR-D-14-00021.1.

PRESENTATIONS

Invited

- Hennon, C. C., K. R. Knapp, C. J. Schreck, S. E. Stevens, J. P. Kossin, P. W. Thorne, P. A. Hennon, M. C. Kruk, and J. Rennie, 2014: Cyclone Center: Using citizen science to reconcile global tropical cyclone intensity. *Eighth International Workshop on Tropical Cyclones (IWTC-VIII),* 2-10 December 2014, Jeju, Republic of Korea.

Other

- Hennon, C. C., K. R. Knapp, C. J. Schreck, J. P. Kossin, and S. E. Stevens, 2015: Cyclone Center: A crowd sourcing application of the HURSAT-B1 data record. *20th Conference on Satellite Meteorology and Oceanography*, 4-8 January 2015, Phoenix, AZ.
- Hennon, C. C., K. R. Knapp, C. J. Schreck, S. E. Stevens, J. P. Kossin, P. W. Thorne, P. A. Hennon, M. C. Kruk, and J. Rennie, 2014: Toward a homogeneous global tropical cyclone intensity record. *31st Conf. on Hurricanes and Tropical Meteorology*, 31 March-4 April 2014, San Diego, CA.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

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-05-NCICS-AI
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Data Fusion and Algorithm Development
Contribution to NOAA Goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%; Goal 4: 0%; 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 shortwave and longwave from geostationary imagers.

BACKGROUND

The ability to better monitor each of the shortwave and longwave 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. The NASA-operated Clouds and Earth's Radiant Energy System (CERES) instrument on board the EOS platform is the only instrument that has been making measurements of broadband TOA and surface radiative components, but the spatial and temporal resolution is inadequate for the aforementioned applications. However, with a wide array of sensors (like Moderate Resolution Imaging Spectroradiometer or 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

- A technique has been developed to derive net surface radiation in the shortwave domain from GOES-10 and GOES-12 visible imagery. 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 NOAA's surface radiation network (SURFRAD) has been extended to include all 8 SURFRAD stations for the years 2003 and 2007. An advantage of this product is a significantly extended spatial and temporal coverage compared to that offered by the CERES instrument;
- Collaboration with John Augustine (NOAA ESRL, Boulder) is continuing on the analysis of the four-mile Canyon fire event of Sep 2010. Contributed on the use of MODIS IR channels to retrieve the OLR;
- Recently the technique has been extended by employing the GOES-11 sensor to estimate the broadband SW and LW fluxes at TOA at 15 minute intervals during the fire event, which will help in assessing the radiative forcing efficiency due to smoke aerosols (see fig.1).

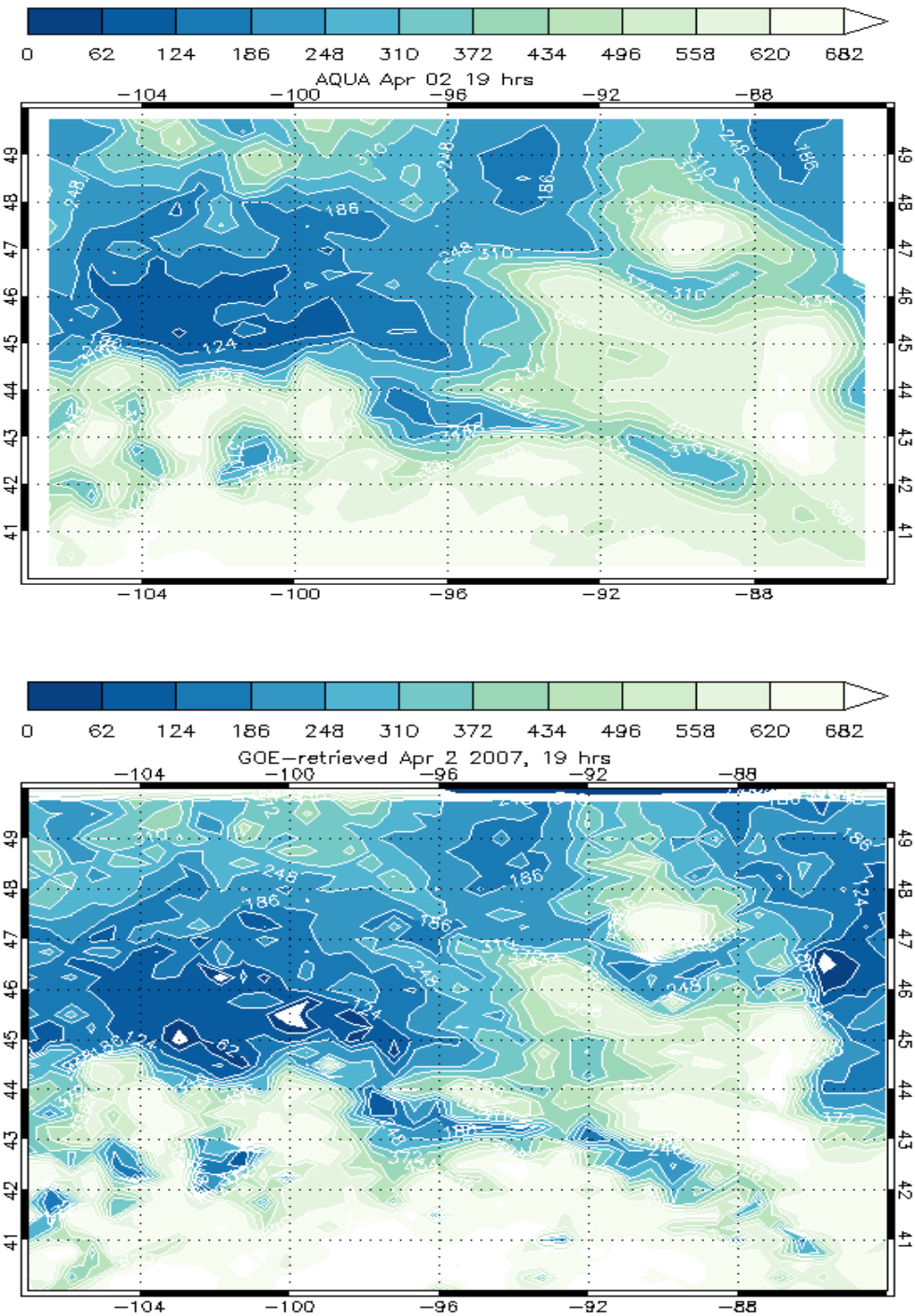


Fig. 1. Top: Regional distribution of surface net SW radiation for the domain bounded by (-107 E to -84 E; 40 N to 50 N) for April 2, 2007, 1900 hours UTC, derived from CERES; Bottom: Same as top except retrieved from GOES-12.

PLANNED WORK

- Extension of the 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.

PUBLICATIONS

- Inamdar, A. K., and P. Guillevic, 2015: Net Surface Shortwave Radiation from GOES Imagery – Product evaluation using ground-based measurements from SURFRAD. Submitted to the Special Issue on Surface Solar Radiation, *Remote Sensing* (MDPI).

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

Transitioning of International Satellite Cloud Climatology Project (ISCCP) processing to NCEI

Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-06-NCICS-AI
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: 70%; Theme 3: 30%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: The mission of the project is to transfer the ability to process ISCCP Cloud products from the ISCCP team (at CCNY and NASA-GISS) to NOAA/NCEI, resulting in a higher resolution ISCCP product, 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 longest-lived and most widely used satellite climate datasets in existence. It has been extensively cited in the peer-reviewed literature. An example of its widespread application is the ISCCP simulator, an algorithm developed to mimic ISCCP observations from Global Climate Models (GCMs) in order to evaluate model simulation of current environment. This simulator is in widespread use today. Furthermore, ISCCP data (and its derivative datasets) have been used to study and understand a wide array of weather and climate phenomena, including: clouds, Earth's radiation budget, aerosols, surface radiation budgets, renewable energy, hurricanes, tropical cyclone genesis, climate modeling, stratospheric moisture, weather states, cloud forcing and cloud feedbacks, and the relationship of clouds with numerous other phenomena.

However, the ISCCP Product has not been updated since 2009. Its current resolution is somewhat antiquated at 2.5 degrees latitude. NCEI routinely and regularly received requests for updated ISCCP data from customers. Therefore, the opportunity exists for NOAA and NCEI to acquire the knowledge and capability to maintain this important climate data record.

ACCOMPLISHMENTS

The ISCCP processing code, build 3, along with ancillary data (atmospheric profiles, aerosols, ozone, snow and ice) and HBT tables (radiance calibration tables) have been delivered in March 2014. The code has been adapted to successfully compile and run on the CICS cluster computing environment. A total of 5 patches have been delivered for the "build 4" software package so far to correct the several run-time errors. The core inputs needed in the processing of ISCCP cloud products are the 3-hourly, 10 km resolution geostationary meteorological satellite (B1U) imagery and the Global Area Coverage (GAC) AVHRR data. A primary requirement before the launch of full production are the Quality Control (QC) of these inputs, along with creation of the missing HBT tables for the B1U and GAC imagery. Our team has undertaken an extensive QC operation of all data for the base period (1983–2009). Several scripts have been developed to identify fatal errors such as bad scan lines, navigation and calibration errors, missing images,

corrupted images, etc. The bad images are quarantined and not used in the production. The QC processing will be completed soon for the base period of 1983–2009. A large number of gaps in the B1U data have been filled in the Meteosat series through the EUMETSAT website for the base period. Further, the pre-GVAR (prior to GOES-8) series has been reprocessed to a more uniform B1U format adding an additional 500+ B1U files, through the NOAA CLASS archive.

PLANNED WORK:

- Quality check of all ISCCP B1U and GAC images for the base period (1983–2009) manually to continue before they are employed in ISCCP cloud processing;
- Fill in data gaps in the B1U stream;
- Implement the next and final build 5 software package and complete H-series production of ISCCP cloud properties for the base period;
- Extend QC and production beyond base period, that is prior to 1983 and beyond 2009;
- Comparison of the H-series cloud products with the former D-series and scientific analysis of the H-series cloud products;
- We are targeting IOC transition of the ISCCP cloud products CDR for 2016;
- A series of papers including a BAMS article are planned.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

Revisiting Calibration of the Visible Channel of the ISCCP B1 data for the Geostationary Surface Albedo (GSA) project	
Task Leader	Anand Inamdar
Task Code	NC-CDR/SDS-07-NCICS-AI
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: 70%; Theme 3: 30%
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 30%; Goal 2: 70%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

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

BACKGROUND

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

ACCOMPLISHMENTS

Calibration for the GOES-8, GOES-10, and GOES-12 satellites has been completed (see attached figures) with the new approach and compare favorably with the ISCCP and previous calibration (as reported in the cited journal paper). The reprocess of the pre-GVAR (prior to GOES-8) has been already completed and the reprocess for the GVAR series is presently underway. The reprocessed data will have single SPC source and result in a more uniform format.

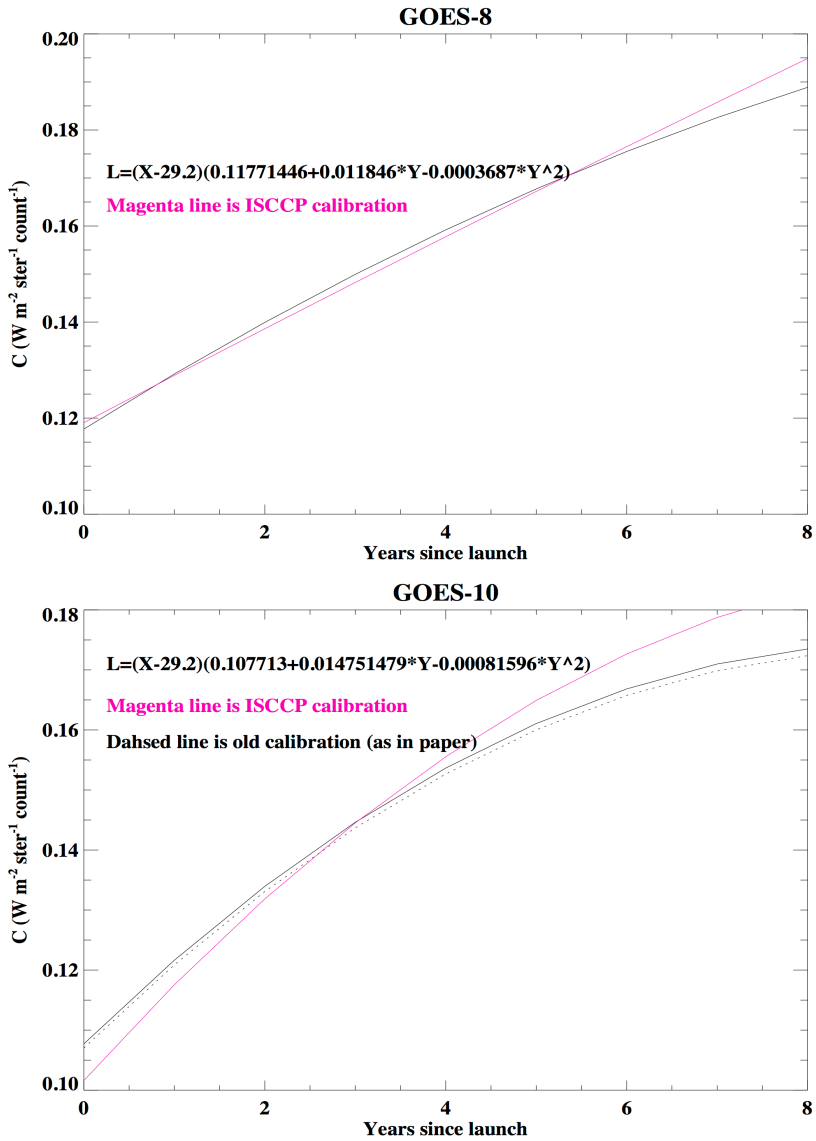


Figure 1. New calibration for GOES-8 and GOES-10 for fixed space constant of 29.2 counts.

PLANNED WORK

- Completing the reprocess of GVAR series;
- Calibration with the new approach for the entire GOES stream;
- Extend calibration for years 2009-2015 for the GSA processing.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

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

Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-08-NCICS-JM
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: %; Theme 3: %.
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 United States 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 and JMA. 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 the GSA algorithm was run with GOES data only for viability studies with 10 days of data. To effectively and efficiently generate products with this algorithm over large time periods, much effort must be extended to understand the application to GOES data specifically. The effort may be divided into two general categories: Operations and Science. Examples of Operations tasks include: porting code developed in the EUMETSAT computing environment to be functional in the NCEI computing environment, code development to work with GOES data format imagery, code development for ancillary NWP input data, etc. Examples of Science tasks include: calibration of GOES data, evaluation of the effect of different spatial and temporal resolutions of GOES as compared to the resolutions of EUMETSAT and JMA satellites, validation of the algorithm as applied to GOES data with external data sets, development of uncertainty bounds for the product, etc.

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 intercalibration method, exploration of different temporal resolutions and formats of output, and validation of Level 2 products. We are now in year 2 (2015) of this 5-year plan.

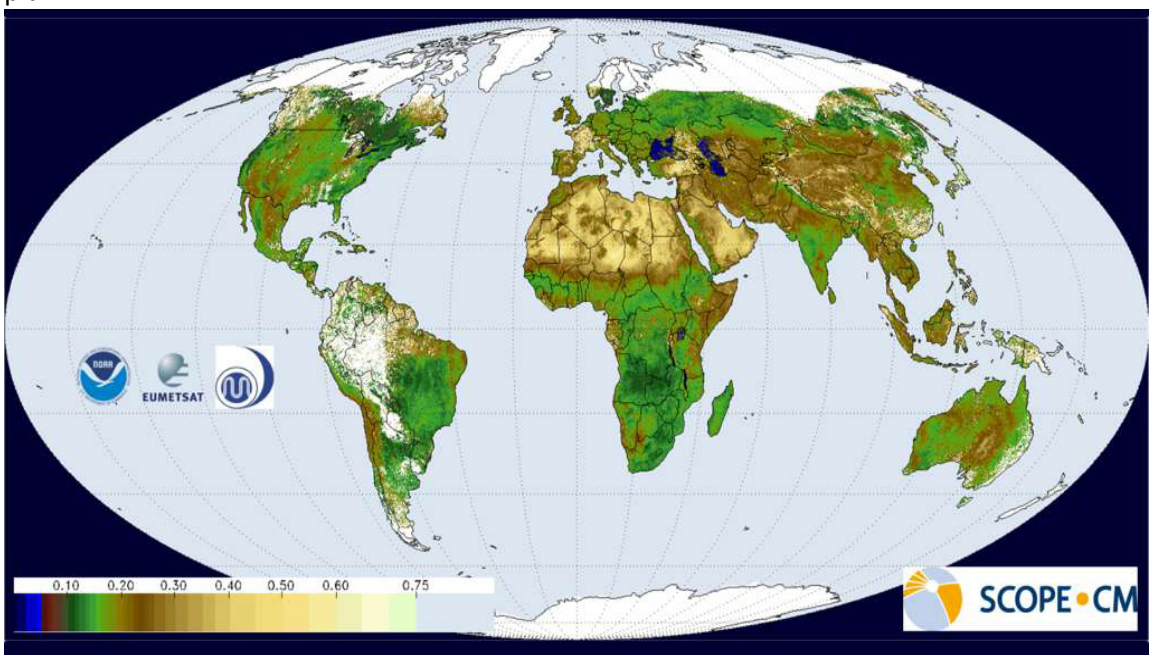


Figure 1. Broadband black sky albedo spatial composite product for the period 1-10 May 2001.

To facilitate the SCOPE-CM collaboration with EUMETSAT, JMA, and Meteo-Swiss, Matthews was invited as a visiting scientist to EUMETSAT in October of 2014. Key accomplishments during this visit:

- Delivery of code to produce a daily product
- Incorporation and testing of new unified NWP code
- Definition of a common validation framework
- Decision on unified approach for cloud detection and removal

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.

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

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: Status of the SCOPE-CM LAGS Project. *The Climate Symposium 2014*, 13-17 October 2014, Darmstadt, Germany.
- Matthews, J.L. 2015. Land surface albedo from a constellation of geostationary satellites compared and fused with polar-orbiting data. *Annual meeting of the American Meterological Society*, 4-8 January 2015, Phoenix, AZ, USA.
- Matthews, J.L. 2014 Land surface albedo climate data record from a constellation of geostationary satellites. *EUMETSAT visiting scientist seminar*, 4 October 2014, Darmstadt, Germany.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

Uncertainty Quantification for Climate Data Records

Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-09-NCICS-JM
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: %; Theme 3: %.
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: Uncertainty quantification in climate research is a multidisciplinary area of increasing importance

BACKGROUND

Observations are key to uncertainty quantification in climate research because they form the very basis for any evidence of climate change and provide a corroborating source of information about the way in which physical processes are modeled and understood. However, observations themselves possess uncertainties originating from many sources including measurement error and errors imposed by the algorithms generating derived products (see *Figure 1*). Over time global observing systems have undergone transformations on pace with technological advances and these changes require adequate quantification of resultant imposed biases to determine the impact upon long term trends. The uncertainties in climate observations pose a set of methodological and practical challenges for both the analysis of long-term trends and the comparison between data and model simulations.

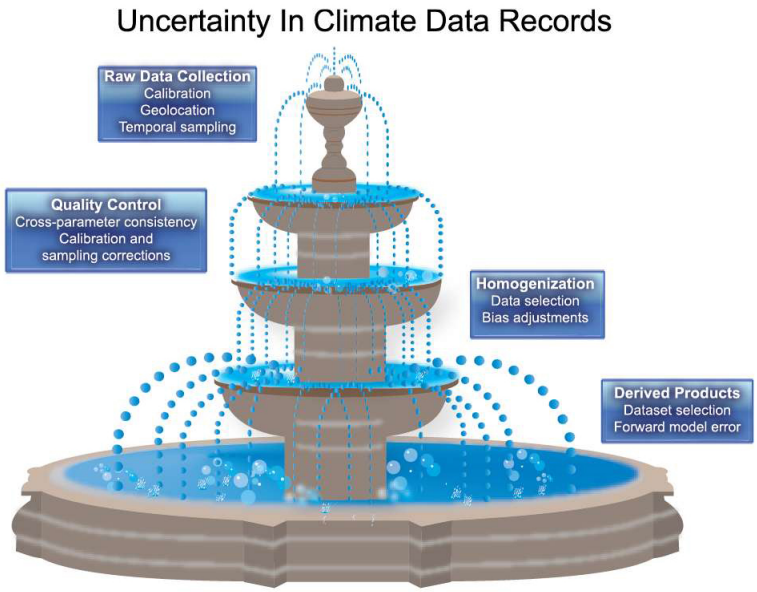


Figure 1. Uncertainties in climate data records; it is necessary to understand all the uncertainties in the observing system and data manipulation processes. Additional uncertainties are introduced at each level leading to an uncertainty cascade.

ACCOMPLISHMENTS

Collaboration with NCEI Physical Scientist Adam Smith was initiated in July of 2014. Smith is responsible for calculating loss estimates for U.S. Billion Dollar Weather and Climate Disaster events. A pilot study was completed for three cases (September 2008 Hurricane Ike, April 25-28, 2011, tornado outbreak, 2012 U.S. drought) researching the sensitivity of contributing factors and an overall uncertainty quantification methodology to apply to these loss estimates. This research resulted in a peer-reviewed paper. Current work is ongoing to develop a generic tool that may apply the methodology to all future and historical U.S. Billion Dollar Weather and Climate Disaster events.

In February 2014, collaboration with Sandia National Laboratories was begun to apply uncertainty quantification technology based on random fields to an NCEI Climate Data Record. In particular, the OISST CDR product was selected for this pilot study. This CDR does not yet have a full end-to-end quantification of the product uncertainties. Our goal is to demonstrate uncertainty quantification in the product, thus improving the overall confidence and applicability of the dataset. To date, a Sandia postdoc has performed analysis and a whitepaper presenting the results is undergoing revisions. Pending successful implementation of UQ methodologies to the OISST CDR, we hope to encourage the CDR Program to more formally assess uncertainties on other operational and developmental datasets.

Multiple validation exercises to assess the uncertainties in Climate Data Records are ongoing. Working with Brian Reich and Elizabeth Mannshardt of the North Carolina State University Statistics Department, the Geostationary Surface Albedo product is being compared to both MODIS and in situ data with careful consideration to spectral, spatial, and temporal compositing differences between the data sets. Comparisons of the nnHIRS temperature and humidity profiles to radiosonde and surface observations is currently underway. Consideration of the uncertainties as provided with select radiosonde observations is included. Additionally, bootstrap methods of the underlying neural network calibration are being investigated which could provide an uncertainty estimate for every nnHIRS profile data point.

PLANNED WORK

- Continue to bridge between NCEI and the largely academic mathematical and statistical communities.
- Evolve the Uncertainty Quantification for Climate Observations workshop, like the one co-organized by CICS-NC and held at NCDC in 2012, into a regular event to facilitate continued cooperation and communication within the science.
- Continue research on methodologies to apply UQ to Climate Data Records.
- Utilize North Carolina State University Mathematics Department Adjunct faculty appointment to engage students in this field.

PUBLICATIONS

- Smith, A.B., and J.L. Matthews, 2015. Quantifying uncertainty and variable sensitivity within the US billion-dollar weather and climate disaster cost estimates. *Natural Hazards*, doi:10.1007/s11069-015-1678-x.

PRESENTATIONS

- Matthews, J.L., 2014. Research applications at the National Climatic Data Center*, North Carolina State University Mathematics Department First Year seminar*, Raleigh, NC (14 Nov.).

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

HIRS Temperature and Humidity Profiles

Task Leader	Jessica Matthews
Task Code	NC-CDR/SDS-10-NCICS-JM
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: %; Theme 2: %; 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: The HIRS project group is developing a global temperature and humidity profile dataset for the time period of 1978-present. Applying neural networks to High-resolution Infrared Radiation Sounder (HIRS) data produces the data.

BACKGROUND

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

For the temperature profiles HIRS Channels 2–12 were used, while for the humidity profiles HIRS Channels 4–8 and 10–12 were used as inputs. These selections were based on the known relations of the channel information to the different physical variables. The HIRS data coupled with CO_2 data were used as inputs to a neural network. The neural networks were calibrated according to surface pressure bins. There were three different neural nets, one each for: surface pressures less than 700 mb, greater than 850 mb, and those in between 700 and 850 mb. Radiative Transfer for Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) (RTTOV) data was 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 1978–2014 time period. When processing the data, USGS topography information on a 1-degree grid was used to define topography (and thus surface pressure) to select which of the three neural nets to apply. Additionally, monthly CO^2 inputs (assumed to be global) were obtained from the Scripps CO_2 program.

ACCOMPLISHMENTS

The previous version of the temperature and specific humidity data sets were processed through 2013. 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 hour 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 Ionsphere and Climate (COSMIC) 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 COSMIC 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 COSMIC measurements for one year of data through excluding HIRS data associated with cloud probability and fraction above the thresholds. Then, one year of these clear-sky HIRS data were used to formulate bias correction equations via comparisons with COSMIC observations.

These cloud-clearing and bias-correction procedures were then applied to the time series of 1978–2014, 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
2 = Likely cloudy
3 = No matching PATMOS-x data

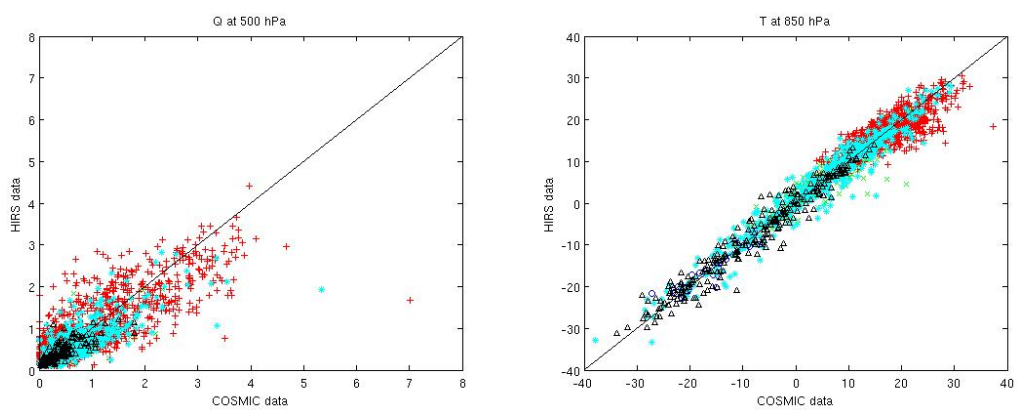


*Figure 1. Comparisons of HIRS specific humidity profile data at 500 hPa to analogous COSMIC data from 2009 (left panel). Comparisons of HIRS temperature profile data at 850 hPa to analogous COSMIC data from 2009 (right panel). Symbols represent different latitude ranges: -90° to -60°, blue circle; -60° to -30°, green x; -30° to 30°, red +; 30° to 60°, cyan *; and 60° to 90°, black triangle.*

PLANNED WORK

- Continue validation work to assess the performance of the algorithms
- Investigate alternative bias correction methodology using a hybridized approach of COSMIC2013 and RS92 as proposed by Ben Ho

- Explore implementing bootstrap methodology to provide associated uncertainty estimates
- Submit two manuscripts, one on the retrieval methodology and one on validation and initial analysis

DELIVERABLES

- Quality-flagged, temperature and specific humidity profile data through 2014

PRESENTATIONS

- Shi, L., J.L. Matthews, Q. Yang, S.-P. Ho. 2015. HIRS-Derived temperature and humidity profiles and comparisons with GPS R0 derived profiles, *Annual meeting of the American Meteorological Society*, 4-8 January 2015, Phoenix, AZ, USA.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

This year we developed new, quality-flagged, temperature and humidity profile data sets through 2014 (2).

Evaluation and Characterization of Satellite Products

Task Leader	Ge Peng
Task Code	NC-CDR/SDS-11-NCICS-GP
NOAA Sponsor	Ed Kearns
NOAA Office	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 has been focused on evaluation and characterization of satellite climate data records (CDRs) that are in various stages of development for the Arctic areas. The NCEI High-resolution Infrared Radiation Sounder (HIRS) product and NOAA Extended AVHRR Polar Pathfinder (APP-x) product are evaluated for the Arctic using the integrated SHEBA dataset and the NOAA PATMOS-x CDR dataset. The impacts of factors such as cloud contamination and day and night measurements are examined and used as the basis for an improved HIRS surface and near-surface air temperature dataset for the high latitudes.

BACKGROUND

The primary object of this task is to evaluate, validate, and characterize satellite-based products that have been, or are in the process of being, transitioned to operation from research or is being developed at NOAA's National Centers for Environmental Information (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.

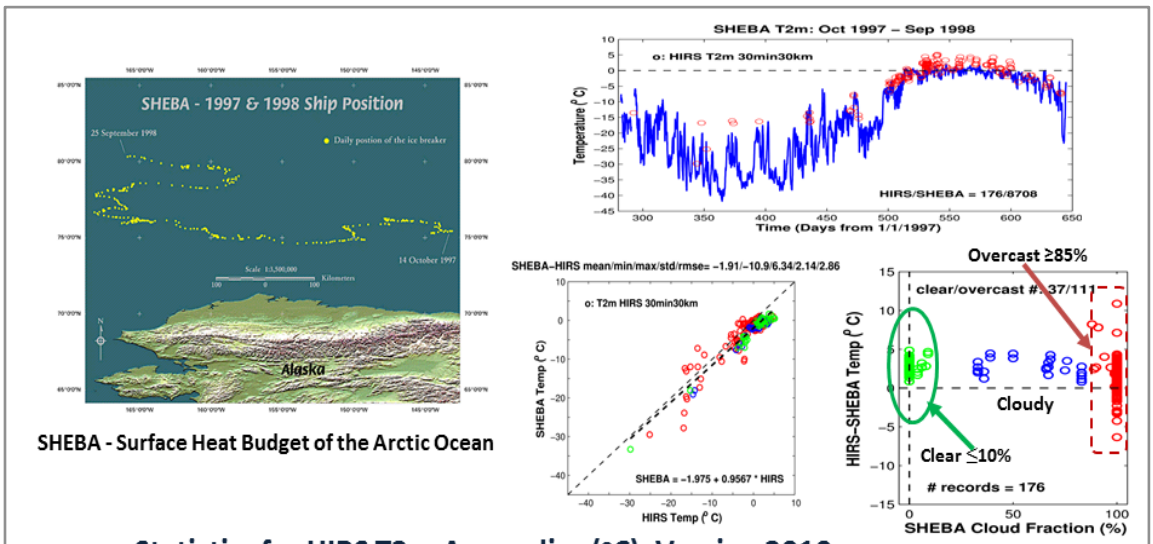
ACCOMPLISHMENTS

A passive microwave sea ice concentration CDR has been transitioned by NOAA's Satellite CDR Program, with Initial Operation Capability (IOC) since 2011, and has been updated annually. Sea ice concentration values are derived from gridded brightness temperatures from the Defense Meteorological Satellite Program (DMSP) F8, F11, and F13 Special Sensor Microwave Imager (SSM/I) passive microwave radiometers and the DMSP F17 Special Sensor Microwave Imager/Sounder (SSMIS) passive microwave radiometer. An evaluation of the product has been carried out in collaboration with PI (principal investigator). Co-authored a peer-reviewed paper published by the *Polar Research Journal* (Meier et al. 2014).

The preliminary analysis on regional trend and temporal variability of sea ice has also been carried out and will be used for the development of regional sea ice climate indicators if the task is funded.

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. The along-swath air temperature

retrievals at surface (Tsurf) and 2 meter (T2m) are evaluated in the Arctic region. Cloud contamination is identified using high-quality observations from the integrated Surface Heat Budget of the Arctic Ocean (SHEBA) dataset (*Fig. 1*). Based on this finding, the cloud mask technique for the HIRS temperature product is improved and a new version of the product is derived. Our analysis has shown noticeable improvement (Table 1). A short paper describing the analysis results is currently in preparation.



Statistics for HIRS T2m Anomalies (°C): Version 2010

	Records	Mean	Min	Max	Std	RMSE
Clear	37	2.79	0.85	4.84	0.95	2.95
Cloudy	28	2.68	0.81	4.45	1.05	2.87
Clear/ Cloudy	65	2.757	0.81	4.84	0.99	2.92
Overcast	111	1.43	-6.34	10.88	2.47	2.84
All	176	1.91	-6.34	10.88	2.14	2.86

Figure 1: A summary of results from the comparison of HIRS T2m version 2010 with SHEBA data. The panel in the upper left displays the ship position for the SHEBA period (Oct 1997 – Sep 1998) (Image source: http://nsidc.org/data/docs/noaa/g02180_sheba/shiptrack.html). The top right figure shows the time series of SHEBA hourly air temperature at 2-meter (T2m, solid) and collocated HIRS T2m (circles). The middle two figures are scatter diagrams of HIRS and SHEBAT T2m (left) and their temperature differences as a function of SHEBA cloud fraction (right). The color code denotes clear, cloudy, and overcast conditions when the SHEBA cloud fractions are less than 10%, between 10% and 85%, and more than 85%. The table at the bottom summarizes statistics from the comparison with co-location temporal and spatial radius of 30 minutes and 30 km, respectively.

Version	Type	Records	Mean	Min	Max	STD	RMSE
2010	Clear/ Cloudy	484	-2.96	-14.1	0.89	1.64	3.38
	All	1450	-2.0	-14.1	6.34	2.18	2.96
2014	Clear/ Cloudy	380	-0.98	-7.59	0.96	0.95	1.36
	All	674	-0.36	-7.59	8.4	1.85	1.88

Table 1. Statistics for the difference between SHEBA and HIRS T2m of the previous version (2010) and the new version (2014). The temporal and spatial radii for co-location are 60 minutes and 60 km, respectively. The RMSE (Root-Mean-Square Error) for the types of clear and cloudy (i.e. SHEBA cloud fraction < 85%) is 3.38^{o}C for the previous version and is reduced to 1.36^{o}C for the new version. Noticeable reduction is seen for the mean errors and standard deviation (STD).

A gridded cryosphere product derived from the Advanced Very High Resolution Radiometer (AVHRR) and Extended AVHRR Polar Pathfinder (APP-X) also onboard the NOAA's POES series is currently under NOAA's research-to-operation transition. A preliminary comparison between collocated APP-x and SHEBA temperatures has shown a distinct dependency of temperature differences between the two on ice age. As APP-x product is been revised, we are waiting for the revised product to finish our comparison.

PLANNED WORK

- Continue to work on the short paper on HIRS evaluation and submit it to a peer-reviewed journal
- Finish the analysis with the updated version of the APP-x surface temperatures and examine the impact of ice age to the APP-x retrievals. Dependency of bias on day and night, cloud properties will be examined.
- Present the results of the Arctic surface flux products analyses at a national or international conference if travel is permitted.
- Continue to work on the Arctic surface flux products evaluation paper and submit it to a peer-reviewed journal if findings are scientifically significant
- Continue to work on the regional sea ice characteristics if time permits, laying ground for a regional sea ice climate indicator project.
- A NASA proposal was submitted (Co-I) for developing new sea ice climate indicators. If funded, 22% of my time will be working on that project.

PUBLICATIONS

- Meier, W. N., G. Peng, D. J. Scott, and M. Savoie, 2014: Verification of a new sea ice concentration climate data record. *Polar Research*. doi: http://dx.doi.org/10.3402/polar.v33.21004.
- Peng, G. and L. Shi, 2015: Towards a Long-term, consistent HIRS near-surface air temperature product in the Arctic region. *To be submitted to J. atmos. and Oceanic Tech.*

OTHER

- Served as an internal reviewer for the NCDC manuscript central for 2 papers.
- Continued to serve as a Scientific Steward for SurFA datasets, monitored daily for potential data quality and data access issues of SurFA wind products utilizing a near-real-time product quality monitoring portal, identified several data ingest and data quality issues for surface buoy sites and NCDC Blended sea wind product, and notified our collaborators in the Tropical Atmosphere Ocean (TAO) and Ocean Climate Station (OSC) groups at NOAA's Pacific Marine Environmental Laboratory, the Ocean Reference Station (ORS) group at the Woods Hole Oceanographic Institution (WHOI) and satellite sea wind data producer at NCDC. This daily monitoring activity and direct communication with data managers/providers have helped data providers resolve the issues in a timely fashion, resulted more accurate data quality classification and less data interruption to users.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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 datasets

Task Leader	Ge Peng
Task Code	NC-CDR/SDS-12-NCICS-GP
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: %.
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: Refined and baselined a unified framework in the form of a scientific data stewardship maturity matrix (SMM) for assessing the vigor of stewardship practice applied to individual digital environmental data product.

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 knowledge of the current stage and of 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

Developed and baselined a unified framework of assessing stewardship practices applied to NOAA climate environmental data products in the form of stewardship maturity matrix with a five-level graduated maturity scale for each component, representing Ad Hoc, Minimal, Intermediate, Advanced, and Optimal stage (*Fig. 1* – pdf version of SMM). Published the results in a peer-reviewed journal (Peng et al. 2015).

PLANNED WORK

- Carry out use case study with selected or all IOC CDRs – potentially baseline stewardship maturity rating for all IOC CDRs, which will help the CDR program with a more informed and efficient stewardship management and improvement process, pending task allocation and prioritization.
- 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 EUMETSAT CORE-CLIMAX project.

- Continue to promote improving data quality and usability to the scientific and data management community and encourage a consistent way to measure data stewardship maturity in the Earth Science data community.

Document ID: NCDC-CICS-SMM_0001
Version: Rev. 1. 12/09/2014

Dataset Name

Maturity Level as of mm/dd/yyyy

Stewardship Maturity Matrix for Digital Environmental Data Products

Maturity Scale	Preservability	Accessibility	Usability	Production Sustainability	Data Quality Assurance	Data Quality Control/Monitoring	Data Quality Assessment	Transparency /Traceability	Data Integrity
Level 1 – Ad Hoc **Not Managed**	Any storage location Data only	Not publicly available Person-to-person	Extensive product-specific knowledge required No documentation online	Ad Hoc or Not applicable No obligation or deliverable requirement	Data quality assurance (DQA) procedure unknown or none	None or Sampling unknown or spotty Analysis unknown or random in time	Algorithm/method/model theoretical basis assessed (method and results online)	Limited product information available Person-to-person	Unknown or no data ingest integrity check
Level 2 - Minimal **Managed Limited**	Non-designated repository Redundancy Limited archiving metadata	Publicly available Direct file download (e.g., via anonymous FTP server) Collection/dataset level searchable	Non-standard data format Limited documentation (e.g., user's guide) online	Short-term Individual PI's commitment (grant obligations)	Ad Hoc and random DQA procedure not defined and documented	Sampling and analysis are regular in time and space Limited product-specific metrics defined & implemented	Level 1 + Research product assessed (method and results online)	Product information available in literature	Data ingest integrity verifiable (e.g., checksum technology)
Level 3 - Intermediate **Managed Defined, Partially Implemented**	Designated archive Redundancy Community-standard archiving metadata Conforming to limited archiving process standards	Level 2 + Non-standard data service Limited data server performance Granule/file level searchable Limited search metrics	Community Standard-based interoperable format & metadata Documentation (e.g., source code, product algorithm document, processing or/and data flow diagram) online	Medium-term Institutional commitment (contractual deliverables with specs and schedule defined)	DQA procedure defined and documented and partially implemented	Level 2 + Sampling and analysis are frequent and systematic but not automatic Community metrics defined and partially implemented Procedure documented and available online	Level 2 + Operational product assessed (method and results online)	Algorithm/method/model Theoretical Basis Document (ATBD) & source code online Dataset configuration managed (CM) Unique Object Identifier (OID) assigned (dataset, documentation, source code) Data citation tracked (e.g., utilizing Digital Object Identifier (DOI) system)	Level 2 + Data archive integrity verifiable
Level 4 - Advanced **Managed Well-Defined, Fully Implemented**	Level 3 + Conforming to community archiving standards	Level 3 + Community-standard data services Enhanced data server performance Conforming to community search metrics Dissemination report metrics defined and implemented internally	Level 3 + Basic capability (e.g., subsetting, aggregating) & data characterization (overall/global, e.g., climatology, error estimates) available online	Long-term Institutional commitment Product improvement process in place	DQA procedure well documented, fully implemented and available online with master reference data Limited data quality assurance metadata	Level 3 + Anomaly detection procedure well-documented and fully implemented using community metrics, automatic, tracked and reported Limited quality monitoring metadata	Level 3 + Quality metadata assessed (method and results online) Limited quality assessment metadata	Level 3 + Operational Algorithm Description (OAD) online, OID assigned, and under CM	Level 3 + Data access integrity verifiable Conforming to community data integrity technology standard
Level 5 - Optimal **Level 4 + Measured, Controlled, Audit**	Level 4 + Archiving process performance controlled, measured, and audited Future archiving standard changes planned	Level 4 + Dissemination reports available online Future technology and standard changes planned	Level 4 + Enhanced online capability (e.g., visualization, multiple data formats) Community metrics of data characterization (regional/cell) online External ranking	Level 4 + National or international commitment Changes for technology planned	Level 4 + DQA procedure monitored and reported Conforming to community quality metadata & standards External review	Level 4 + Cross-validation of temporal & spatial characteristics Physical consistency check Conforming to community quality metadata & standards Dynamic providers/users feedback in place	Level 4 + Assessment performed on a recurring basis Conforming to community quality metadata & standards External ranking	Level 4 + System information online Complete data provenance available online	Level 4 + Data authenticity verifiable (e.g., data signature technology) Performance of data integrity check monitored and reported

Dataset Information: URL Goes Here
Dataset POC: Name & E-mail Here

SMM POC: Ge.Peng@noaa.gov

Figure 1. The pdf version of the NCEI/CICS-NC Scientific Data Stewardship Maturity Matrix

PUBLICATIONS

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

PRESENTATIONS

- Peng, G., 2014: Introduction to scientific data stewardship maturity matrix. NCDC/CICS-NC Branch Seminar. November 13, 2014, Asheville, NC, USA.
- Jones, P. R., N. A. Ritchey, G. Peng, V. A. Toner, H. Brown, and K. Roberts, 2014: ISO, FGDC, DIF and Dublin Core – making sense of metadata standards for Earth Science data. AGU Fall meeting, 15 – 19 December 2014, San Francisco, CA, USA.
- Peng, G., 2015: Towards a consistent measure of stewardship practices. NCEI Archive Branch Briefing. May 6, 2015, Asheville, NC, USA.

OTHER

- Participate when time permit monthly telecons of NOAA metadata and data management working groups and ESIP data stewardship and preservation/documentation clusters

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

Bias–assessment and bias-adjustment of the National Mosaic and Multi-Sensor QPE (NMQ) over CONUS (2002-2011)

Task Leader	Olivier Prat
Task Code	NC-CDR/SDS-13-NCICS-OP
NOAA Sponsor	Ed Kearns
NOAA Office	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) is completed for the period covering from 2002 to 2011. This important milestone constitutes a unique opportunity to study precipitation processes at a 1-km spatial resolution for a 5-min temporal resolution. However, in order to be suitable for hydrological, meteorological, and climatological applications, the radar-only product needs to be bias-adjusted and merged with in situ rain gauge information. Several in situ datasets are available to assess the biases of the radar-only product and to adjust for those biases to provide a multi-sensor QPE. The rain gauge networks that are used, such as the Global Historical Climatology Network-Daily (GHCN-D), the Hydrometeorological Automated Data System (HADS), the Automated Surface Observing Systems (ASOS), and the Climate Reference Network (CRN), have different spatial density and temporal resolution. The challenges related to incorporating non-homogeneous networks over a vast area and for a long-term record are enormous. Among the challenges we are facing are the difficulties incorporating differing resolutions and quality surface measurements to adjust gridded estimates of precipitation. Another challenge is the type of adjustment technique.

The purpose of the present work is as follows:

- Bias assessment of the radar-only NMQ (1-d, 1-hr, 5-min).
- Bias adjustment of the radar-only NMQ by merging with in situ rain gauge information.
- Investigate the optimal techniques for bias-adjustment.

ACCOMPLISHMENTS

The bias assessment of the radar-only product was performed using surface datasets at the daily (GHCN-D) and hourly (HADS) scales. Figure 1 displays the spatial repartitions of the biases and the influence of the topography at the daily (top row) and hourly (bottom row) scales. At the daily scale, the radar-only NMQ displays an underestimation over the Western United States, in particular along the SW (Windward) direction (Fig. 1d: top row). Over the Eastern U.S. (Fig. 1c: top row), the NMQ biases are less important and closer to the unity. At the hourly scale (Fig. 1: bottom row), the radar-only NMQ displays an underestimation (overestimation) over the Western U.S. (Eastern U.S.).

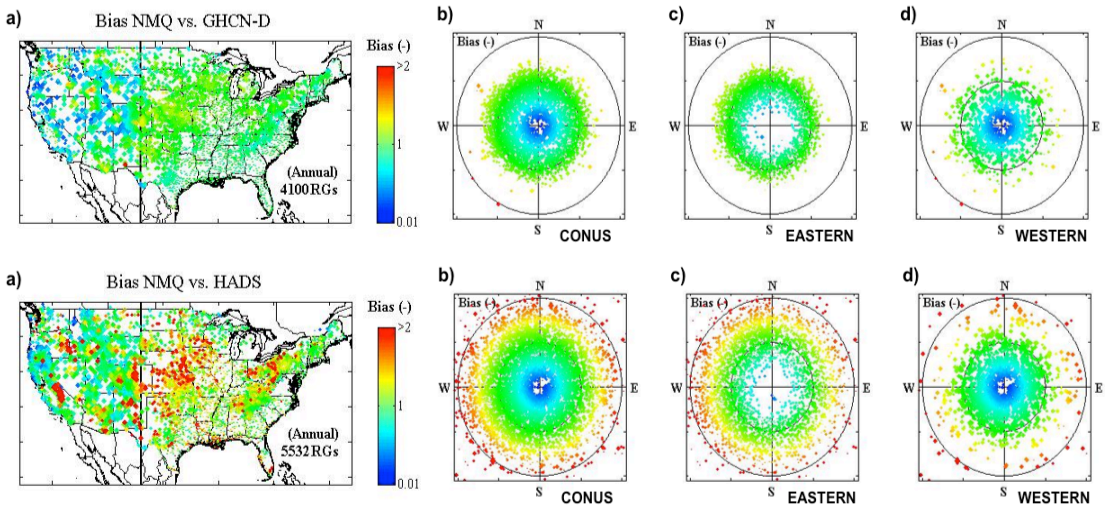


Figure 1. Daily (top row) and hourly (bottom row) bias between NMQ/Q2 and surface observations GHCN-D (daily) and HADS (hourly) for the period 2002-2011. The circles (b, c, d) represent the biases plotted as a function of the topography. The angular position represents the orientation of the slope at the station location while the position along the radius represents the value of the bias (inner circle R=1 represents no-bias). Results are presented for CONUS (b), East of 104°W (c), and West of 104°W (d).

The bias-adjustment using an Inverse Distance Weighting (IDW) approach was performed at the daily scale for the entire period of record (2002-2011). A comparison between the radar-only (*Fig. 2.* left) and the bias-adjusted QPE (*Fig. 2.* right) shows that the bias adjustment procedure using in situ GHCN-D considerably improved the precipitation patterns over the Western United States.

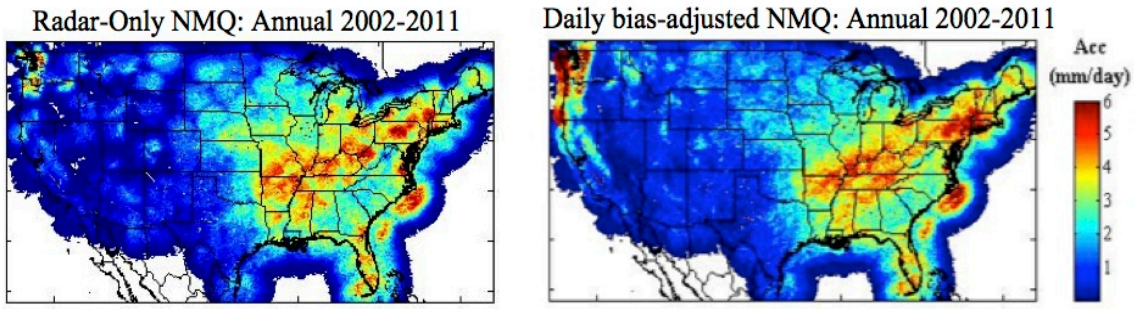


Figure 2. Annual precipitation for the period 2002-2011 derived from NMQ radar-only product (left) and bias-adjusted product using daily precipitation in situ data (GHCN-D) and an inverse distance weighting (IDW) approach. The effect of the bias adjustment is particularly visible over the Western U.S. with more realistic precipitation patterns for the bias-adjusted NMQ.

Current work consists of extending the IDW procedure at the hourly scale using in situ HADS data. Different adjustment procedure including kriging method and its variants, such as simple kriging (SK), ordinary kriging (OK), and conditional bias-penalized Kriging (CBPK), among others are also being developped.

PLANNED WORK

- Perform the IDW bias-adjustment at the hourly scale using in-situ HADS data for the entire period of record (2002-2011).
- Implement and test different adjustment procedures including the kriging method and its variants.
- Determination of the optimal bias-adjustment procedure (IDW, kriging and variants).

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).
- A measure of uncertainty associated with the bias-adjusted QPE over CONUS.
- A manuscript summarizing the bias-adjustment procedure and presenting the final long-term high-resolution bias-adjusted QPE.

PRESENTATIONS

- 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, D.-J. Seo, and B. Kim 2014. Long-term large-scale bias-adjusted precipitation estimates at high spatial and temporal resolution derived from the National Mosaic and Multi-sensor QPE (NMQ/Q2) precipitation reanalysis over CONUS. *2014 AGU fall meeting*, December 15-19 2014, San Francisco, CA, USA.

- Nelson, B.R., O.P. Prat, S.E. Stevens, D.-J. Seo, J. Zhang, and K. Howard 2014. Assessment of bias in the National Mosaic and Multi-Sensor QPE (NMQ/Q2) reanalysis radar-only estimate. *2014 AGU fall meeting*, December 15-19 2014, San Francisco, CA, USA.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

The radar-only NMQ precipitations estimates at the daily were bias-adjusted with in situ rain gauge data using an Inverse Distance Weighting approach (1). The bias-adjusted product is still under development at the hourly scale. Three presentations have been made or co-authored on the project (3).

Toward the development of Climate Data Records for precipitation: Characterization of CONUS rainfall using a suite of satellite, radar, and rain gauge QPE products

Task Leader	Olivier Prat
Task Code	NC-CDR/SDS-14-NCICS-OP
NOAA Sponsor	Ed Kearns
NOAA Office	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 task uses a suite of quantitative precipitation estimates (QPEs) derived from satellite, radar, surface observations, and models to derive long-term precipitation characteristics at fine spatial and temporal resolution over CONUS for the period 2002-2012. This work is part of a broader effort to evaluate long-term multi-sensor QPEs from the perspective of developing Climate Data Records (CDRs) for precipitation.

BACKGROUND

The comparison effort includes satellite multi-sensor datasets of TMPA, CMORPH-ADJ, and PERSIANN-CDR along with their respective unadjusted/near-real time version (TMPA-RT, CMORPH, PERSIANN). The satellite based QPEs are compared over the concurrent period with the NCEP Stage IV product, which is a near real time product providing precipitation data at the hourly temporal scale gridded at a nominal 4-km spatial resolution. In addition, remotely sensed precipitation datasets are compared with surface observations from the Global Historical Climatology Network (GHCN-Daily) and from the PRISM (Parameter-elevation Regressions on Independent Slopes Model), which provides gridded precipitation estimates that are used as a baseline for multi-sensor QPE products comparison.

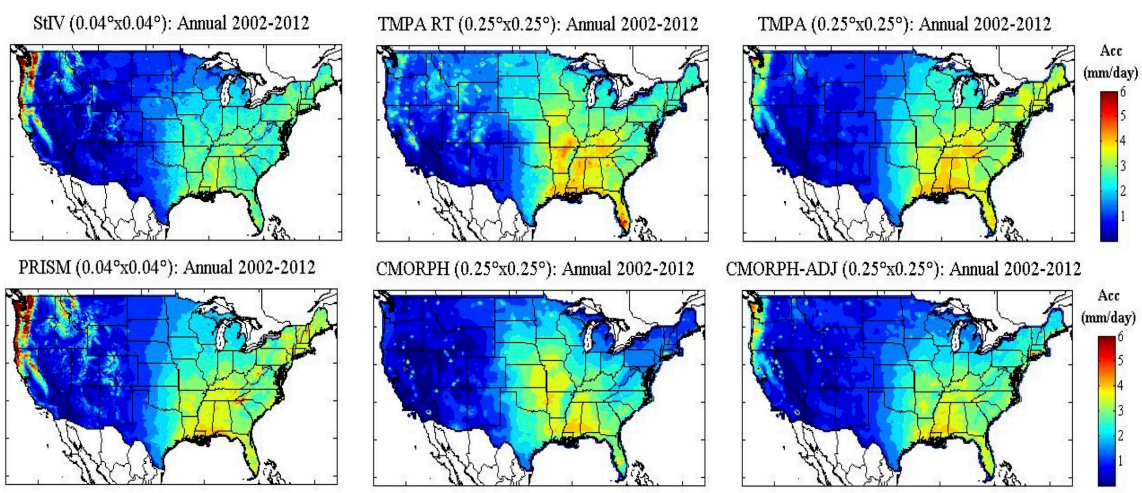


Figure 1. From top left to bottom right. Annual precipitation for the period 2002-2012 derived from Stage IV, TMPA-RT (Real Time), TMPA, PRISM, CMORPH, and CMORPH-ADJ (Adjusted).

Figure 1. displays the annual precipitation derived from radar (Stage IV), surface observation and model (PRISM), unadjusted (TMPA-RT, CMORPH) and adjusted (TMPA, CMORPH-ADJ) satellite QPEs.

ACCOMPLISHMENTS

The comparisons were performed at the annual, seasonal, monthly, and daily scales and at the river forecast center level (major river basins) (*Fig. 2*).

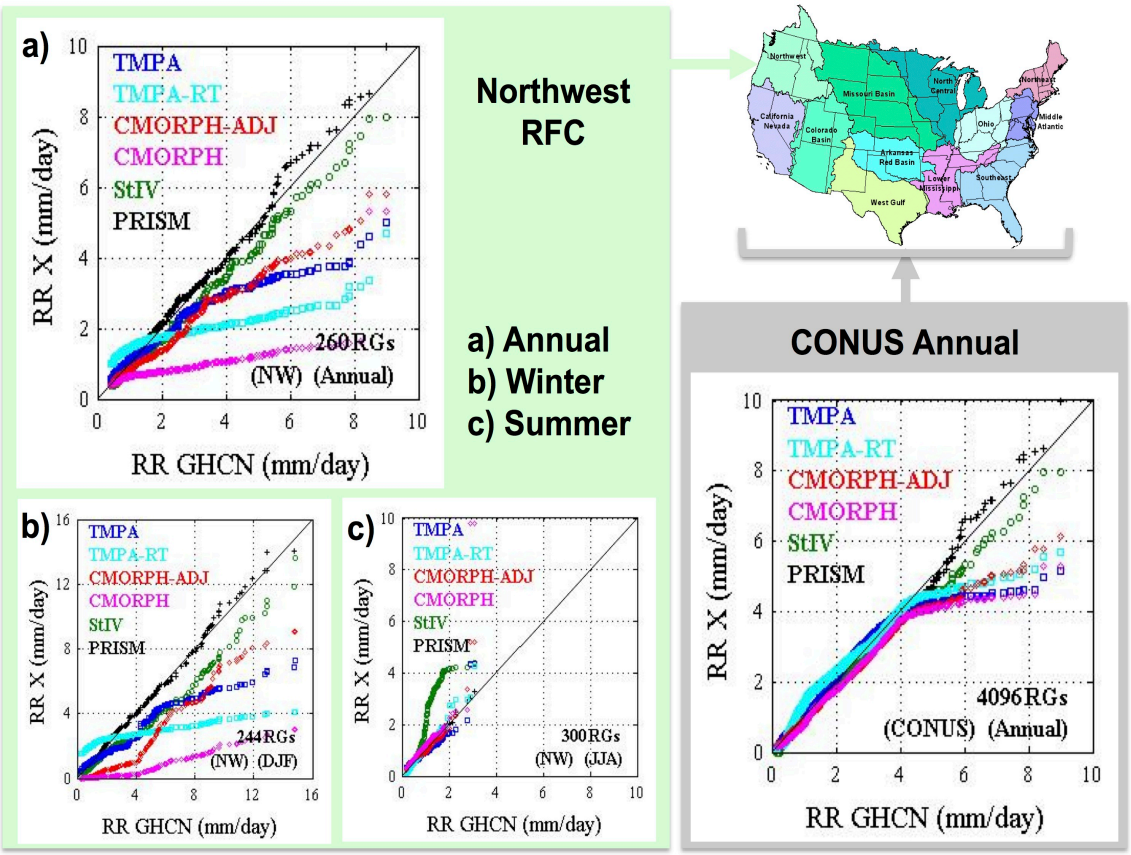


Figure 2. Comparison (Quantile-Quantile plot) of TMPA, TMPA-RT, CMORPH-ADJ, CMORPH, St-IV, and PRISM with surface observations from GHCN-daily for the annual precipitation over CONUS. While a good agreement is found for PRISM (expected because incorporate surface observation including GHCN) and TMPA and CMORPH-ADJ present a severe underestimation at higher rain rates (R>4 mm/day). Differences can be even more important when looking at the river basin scale (or River Forecast Center: RFC) in particular in the West (Fig. a) and at the seasonal scale (Winter: Fig. b; Summer: Fig. c). Please note the different scales for the figures.

The most widely used satellite QPEs have been compared at the annual, seasonal, and daily scales. The research group completed the satellite QPE evaluation over CONUS: Uncorrected (TMPA-RT, CMORPH, PERSIANN) and bias-adjusted (TMPA, CMORPH-ADJ, PERSIANN-CDR) satellite QPE with radar (Stage IV) and surface stations (GHCN-D, PRISM). The impact of differing spatial and temporal resolutions with respect to the datasets ability to capture extreme rainfall was investigated and results illustrated the challenge of

retrieving those extreme (top 1% percentile) from remote sensing. We are currently extending this effort to other precipitation products (CPCP, GPCC).

PLANNED WORK

- Use this work as a benchmark for the comparison of the newly available NMQ/Q2 reanalysis with surface observations and satellites QPE. This includes bias-assessment and bias-adjustment of the radar only NMQ/Q2.
- Extend this work by including other precipitation QPEs (GPCP, GPCC); and
- Prepare a manuscript that will compare the aforementioned real-time and bias-adjusted satellite QPE products at the global scale. Analysis parameters will include performance assessment at various time scales and as a function of the geography type and elevation.
- Coordinate effort with CICS-MD (R. Ferraro, S. Rudlosky) to extent the ground validation/QPE products comparison to additional datasets (Hydro-Estimator, SCaMRP, MIRS, MSPPS, GPI).
- Other possible directions include the development of new functionalities for the Satellite Product Evaluation Center (SPEC) to help with QPE products comparison (L. Vasquez). This task is pending on funding and time availability.

PUBLICATIONS

- Nelson, B.R., O.P Prat, D.-J. Seo, and E. Habib, 2015. Assessment and implications of Stage IV QPE for product inter-comparisons. *Weather and Forecasting*, under revision.
- Prat, O.P., and B.R. Nelson, 2015. Evaluation of precipitation estimates over CONUS derived from satellite, radar, and rain gauge datasets at daily to annual scales (2002-2012). *Hydrology and Earth System Sciences,* in press.
- Ashouri, H, K. Hsu, S. Sorooshian, D. Braithwaite, K.R. Knapp, L.D. Cecil, B.R. Nelson, and O.P. Prat, 2015. PERSIANN-CDR: Daily precipitation climate data record from multi-satellite observations for hydrological and climate studies. *Bulletin of the American Meteorological Society*, 96, 69-80, doi:10.1175/BAMS-D-13-00068.1.

DELIVERABLES

- Complete assessment of the differences between all the QPE products for the period 2002-2012 at the annual, seasonal, and daily scale. The study performed to CONUS is currently being extended to a global scale;
- Metrics quantifying each dataset ability to capture precipitation patterns and extreme precipitation events;
- 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. This last point is depending on resources and time availability.

PRESENTATIONS

- Prat, O.P., B.R. Nelson, L. Vasquez, R. Ferraro, S. Rudlosky, and J.J. Wang 2014. Evaluation of satellite based Quantitative Precipitation Estimates (QPEs) over CONUS (2002-2012): Comparison with surface and radar precipitation datasets. *7th Workshop of the International Precipitation Working Group (IPWG)*, November 17-21 2014, Tsukuba, Japan.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	3
# 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

PERFORMANCE METRICS EXPLANATION

We coauthored one journal article describing the PERSIANN-CDR algorithm and applications (1). One journal article on the evaluation of multi-sensor QPE products was published (1). One journal article on the Stage IV evaluation is under revision (1). One presentation has been made at the IPWG conference (1).

Mapping the World's Tropical Cyclone Rainfall Contribution Over Land Using Satellite Data: Precipitation Budget and Extreme Rainfall

Task Leader	Olivier Prat
Task Code	NC-CDR/SDS-15-NCICS-OP
NOAA Sponsor	Ed Kearns
NOAA Office	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: 60%; Goal 2: 0%; Goal 3: 0%; Goal 4: 40%; Goal 5: 0%

Highlight: This work examines the over-land rainfall contribution originating from tropical cyclones for basins around the world for the period 1998-2009. Using the global database IBTrACS and satellite precipitation data from the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) product 3B42, the precipitation budget and extreme rainfall were determined for different TC basins around the world.

BACKGROUND

Tropical cyclones constitute one of the major natural disasters around the world as well as an important source of fresh water over areas prone to tropical cyclones. Annually, an average of 119 million people are exposed to tropical cyclone hazards (United Nation Development Program 2004). In this work, we estimated the over-land rainfall contribution of tropical cyclones for basins around the world, using NOAA's NCDC global database IBTrACS and satellite precipitation data from the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA 3B42V7).

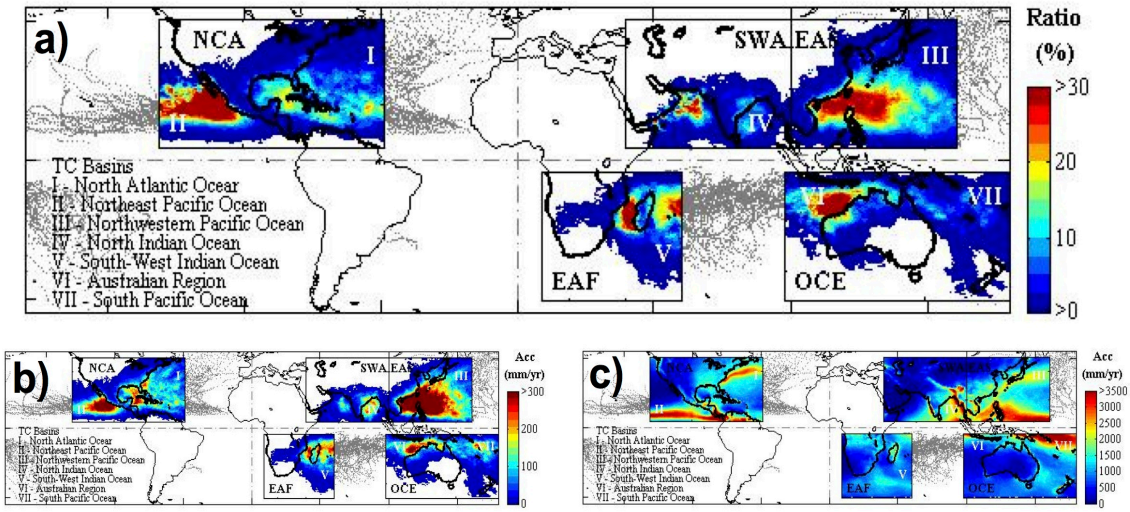


Figure 1. Tropical cyclone (TC) contribution (a), tropical cyclone rainfall (b), and total rainfall (c) for North and Central America (NCA), East Asia (EAS), South and West Asia (SWA),

Oceania (OCE) and East Africa (EAF) for 1998-2009. The TC tracks are from the IBTrACS database (Knapp et al. 2010). TC Contribution (a) = 100 x TC Rainfall (b) / Total Rainfall (c).

Results showed that TCs accounted for 6-10% of the annual rainfall over areas prone to cyclonic activity for the different basins (*Fig. 1a*). At the local scale, tropical cyclones contributed to more than 25% and up to 60% (Baja California Sur) of the average annual rainfall over very different climatic areas with arid or tropical characteristics (*Fig. 1a*). East Asia (EAS) presented the higher and most constant tropical cyclone rainfall, while East Africa (EAF) displayed the highest year-to-year variability, and the Americas (NCA) exhibited the lowest average (*Fig. 1b*). Throughout the year, the maximum monthly contribution (8-11%) was found later in the TC season and depended on the peak of cyclonic activity, the cyclone associated rainfall, and the transition between dry and wet regimes if any. Current work consists of quantifying precipitation extremes in relation with cyclonic activity.

ACCOMPLISHMENTS

A comparison between two versions of the algorithm: TMPA 3B42V7 (version 7: used in Prat and Nelson 2013, *Water. Resour. Res.*) and TMPA 3B42V6 (version 6: used in Prat and Nelson 2013, *J. Climate*) was performed. The differences between V7 and V6 were mostly significant in terms of total and non-TC rainfall with a negative bias for V6 when compared to V7 (linear regression coefficient: 0.77<a<0.94). The largest differences were observed for the NCA (a=0.77: Fig. 2) and the SWA (a=0.79) domains. The differences in terms of TC rainfall (0.85<a<1.03) and TC contribution (0.93<a<1.08) were less important.

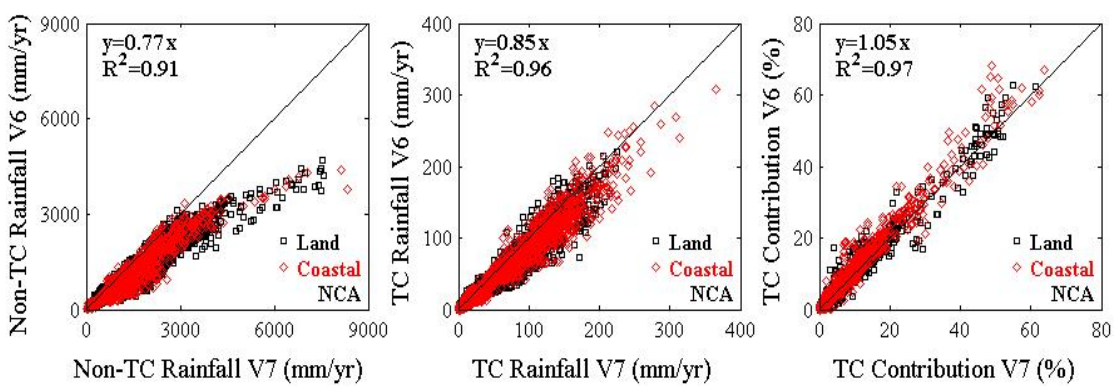


Figure 2. Comparison between TMPA 3B42V7 (version 7) and TMPA 3B42V6 (version 6) for the North and Central America (NCA) domain.

This study was the first that quantifies the tropical cyclone rainfall contribution over land for the different basins around the world. Current work consists of quantifying precipitation extremes in relation with cyclonic activity. Annual and monthly precipitation extremes have been extracted from TMPA 3B42V7 and the period of study was extended to 1998-2012. A manuscript summarizing the findings is currently being finalized for publication.

PLANNED WORK

- Finalize the manuscript on precipitation extremes associated with cyclonic activity.

PUBLICATIONS

- Prat, O.P., and B.R. Nelson, 2015. On the link between tropical cyclones and extreme rainfall. *Geophysical Research Letters*, to be submitted.

DELIVERABLES

- Manuscript summarizing the findings on tropical cyclone rainfall and extreme rainfall.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

One manuscript on the link between tropical cyclones and extreme rainfall is still under preparation and should be submitted by early summer 2015 (1).

Dual-Pol signature of microphysical processes in warm rain

Task Leader	Olivier Prat
Task Code	NC-CDR/SDS-16-NCICS-OP
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: 100%; Theme 2: 0%; Theme 3: 0%.
Main CICS Research Topic	Surface Observing Networks
Contribution to NOAA Goals (%)	Goal 1: 0%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: This work combines an explicit bin microphysical model with an electromagnetic scattering model. The goal is to assess the signature of microphysical processes (settling, coalescence, drop breakup, evaporation) on radar dual-polarization variables: the reflectivity factor at horizontal polarization (Z_H), the differential reflectivity (Z_{DR}), and the specific differential phase (K_{DP}).

BACKGROUND

Since spring of 2013, all the WSR-88D Nexrad have been upgraded to a dual-polarization technology. Conventional radars, such as the previous generation of Nexrad, are only able to provide a one-dimensional information on the relative size of objects (i.e. hydrometeors) within the control volume. On the other hand, dual-pol radars provide two-dimensional (horizontal, vertical) information and thus allow accessing the size, the shape, and the variety of object within the control volume. The impact on the polarimetric radar variables—reflectivity factor (Z_H), differential reflectivity (Z_{DR}), and specific differential phase shift (K_{DP})—of selected microphysical processes in warm rain is investigated. This collaboration is between Dr. Olivier Prat from CICS-NC and Dr. Matthew Kumjian from Pennsylvania State University (PSU). It proposes combining two theoretical models that were developed separately. The project group uses the one-dimensional version of a bin-microphysical model (Prat et al. 2012) that resolves explicitly the evolution of the drop size distribution (DSD) under the influence of microphysical processes throughout the rain column. The computed transient and equilibrium DSDs are used as an input for an electromagnetic scattering model (Kumjian and Ryzhkov 2012) that emulates the evolution of the polarimetric radar variables (Z_H, Z_{DR}, K_{DP}). The fingerprint of each individual microphysical processes (drop settling, drop coalescence, aerodynamic breakup, collisional breakup, bounce, evaporation, etc.) as well as the full physics configuration (all processes included with/without updraft/downdrafts) is quantified as a function of the shape of the initial DSD and for different values of the nominal rain rate (RR). *Figure 1* displays the vertical profiles of the polarimetric variables (Z_H; Z_{DR}, K_{DP}) under the influence of selected microphysical processes. In the case of aerodynamic breakup, a slight decrease towards the ground is observed for Z_H, Z_{DR}, and K_{DP} due to the breakup of large drops (d>5 mm). For collisional breakup, the sharp decrease in the vertical profiles (Z_H, Z_{DR}, K_{DP}) is due to drop collisions and subsequent breakup resulting in the creation of a large number of small drops (d<0.5mm). Conversely, for coalescence-only vertical profiles (Z_H, Z_{DR}, K_{DP}), the increase toward the ground as mass from smaller drops (d<1 mm) is shifted to larger sizes. Finally, the full physics configuration displays a decrease in Z_H and Z_{DR}, while K_{DP} exhibits a non-

monotonous behavior and first decreases (*breakup of large drops aloft*) then increases toward the ground (*coalescence of drops 0.6<d<1.7 mm with increase in drops 1.7<d<3.1 mm*).

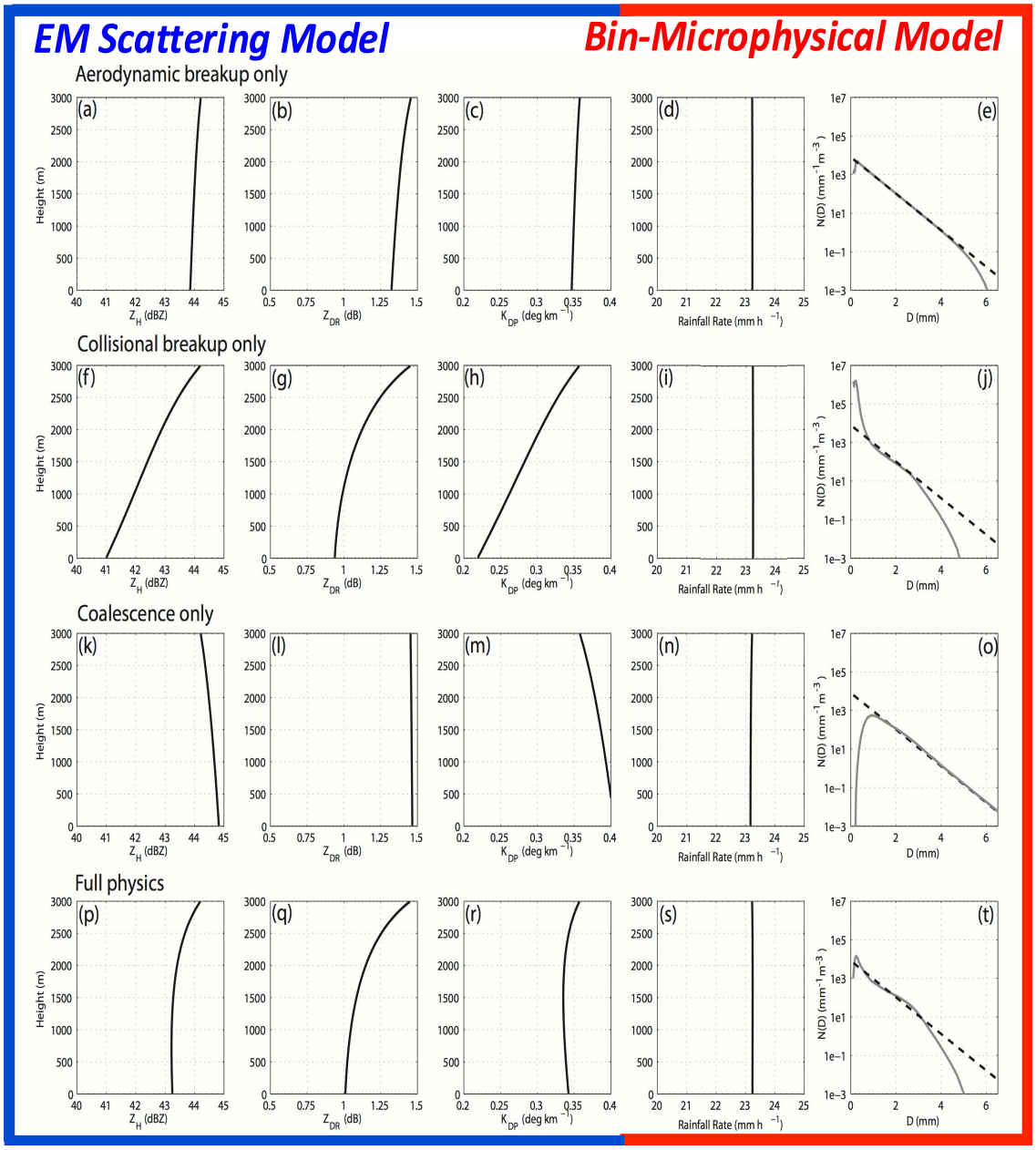


Figure 1. Vertical profiles of the polarimetric variables (Z_H: first column; Z_{DR}: second column: K_{DP}: third column) for selected microphysical processes: aerodynamic breakup (a-c), collisional breakup (f-h), coalescence (k-m), and full physics (p-r). The profiles are established after 60 min. of simulation and for an initial exponential DSD aloft with a nominal rain rate of 20 mm h^{-1}. The forth column shows the rain rate throughout the column as a mass conservation indicator. The last column shows the initial DSD aloft (black dashed line) and the final DSD at the ground (gray solid curves).

ACCOMPLISHMENTS

A few key findings were derived from this work. First, it was found that each individual microphysical process displays a particular signature of Z_H, Z_{DR}, and K_{DP} as indicated in Figure 1 (1). In addition, the polarimetric fingerprints of collisional processes depended on the radar wavelength (S, C, and X bands) as shown in Figure 2 (2). Another interesting finding is that the signal for evaporation (increase in Z_{DR} and decrease in Z_H (K_{DP})) did not overlap with the signal from collisional processes (Fig. 2). This may allow for accurate diagnoses of the physical process dominating the signal in radar observations, particularly in the case of radars operating at multiple frequencies (3). Finally, when compared with radar and disdrometer observations collected for a variety of storm environments (stratiform, convective), theoretical DualPol profiles (Z_H, Z_{DR}, K_{DP}) suggested that the parameterizations of drop breakup were too aggressive for the largest rainfall rates, resulting in very "tropical" DSDs heavily skewed towards smaller drops (4). More importantly, we found an unequivocal dependency between microphysical processes and polarimetric radar variables, which suggests that real-time radar rainfall field observations could help improve microphysical parameterization of drop-drop interactions via inverse problem modelling techniques (5).

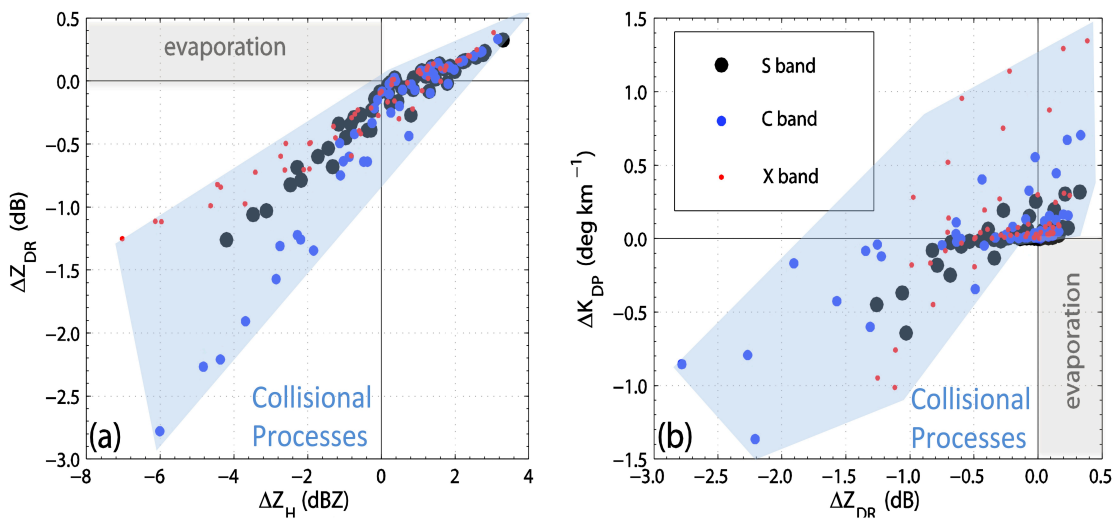


Figure 2. Change in the polarimetric variables in the spaces (Z_H, Z_{DR}) and (Z_{DR}, K_{DP}) over the 3-km rainshaft for a variety of initial DSDs. Calculations are performed for S, C, and X bands. The quadrant marked "evaporation" indicates the region expected for evaporation.

Currently, the project group is investigating the transient behavior of the polarimetric variables. Synthetic and real rainfall events, including stratiform/convective cases covering a wide range of rainfall intensity and duration, are used as input to the microphysical model. The transient behavior of the dual-pol variables is quantified as a function of different parameters (shape of the initial DSD, nominal rain rate, type of event, microphysical parameterizations).

PLANNED WORK

- Due to competition with other projects, this work is currently put on hold pending availability of external funding. One proposal was submitted to DOE as Co-I that was

declined. We are currently identifying other possible sources of funding to develop the microphysical model.

PUBLICATIONS

- Kumjian, M.R., and O.P. Prat, 2014. The impact of raindrop collisional processes on the polarimetric radar variables. Journal of the Atmospheric Sciences, 71, 3052-3067.

DELIVERABLES

- A manuscript was published in August 2014 and several conference presentations were delivered. The continuation of this work is pending the availability of external funding and a proposal to be submitted.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

One journal article on the signature of raindrop collisional processes on the polarimetric radar variables was published (1).

Identifying Tropical Variability with CDRs

Task Leader	Carl Schreck
Task Code	NC-CDR/SDS-17-NCICS-CS
NOAA Sponsor	Ed Kearns
NOAA Office	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 water management and the energy sector.

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

A manuscript was recently accepted to the *Bulletin of the American Meteorological Society* illustrating how CDRs can be used to anticipate changes in natural gas prices. It examines these relationships through recent winters. Volatility in the natural gas markets can be linked to large temperature variability over the United States in recent winters. A positive Arctic Oscillation is linked to warm temperatures in 2011/12 when prices fell. Strong ridging in the Gulf of Alaska in 2013/14 led to cold temperatures and rising prices. This study demonstrates how energy traders and meteorologists use weather and climate data, including Climate Data Records, to anticipate that variability.

Dr. Schreck (CICS-NC) served as science advisor for three terms of NASA DEVELOP interns at NCEI. Each team consisted of 2–4 interns ranging from undergraduate students to post-Masters. They applied CDRs to long-range forecasting. The first two terms examined the impacts of teleconnections on precipitation over the southwestern U.S. using the PERSIANN CDR. Figure 1 provides a sample of the results. It shows the enhanced probability of high precipitation days within most climate divisions in the region during El Niño years.

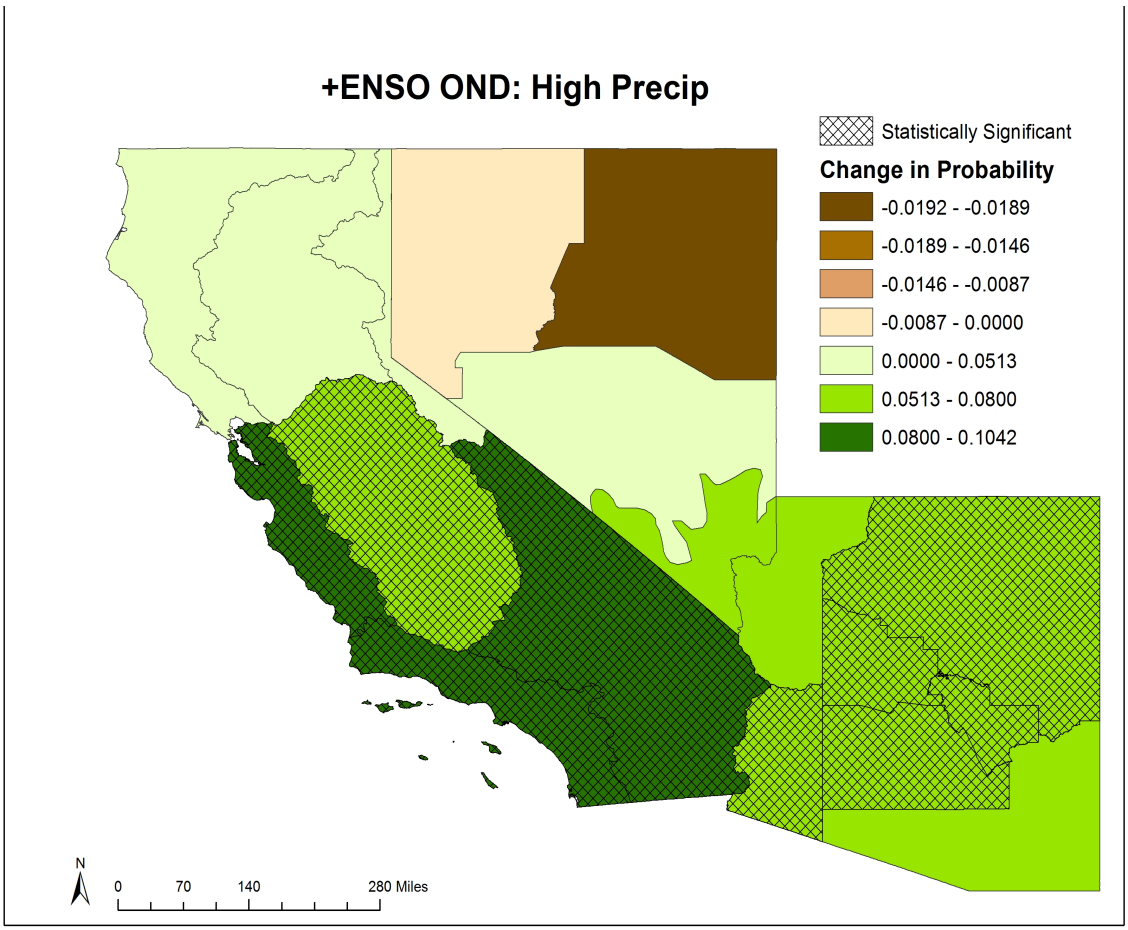


Figure 1. Changes in probability of a high precipitation day during the months of October – December when the ONI ENSO index is greater than 1.0. Statistically significant changes are crosshatched.

The third NASA DEVELOP term 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 United States, 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 intraseasonal time scales. Furthermore, the impact of other extratropical teleconnections was modulated by the phase of the MJO.

The newly developed OLR-daily CDR was also compared with a similar dataset available from NOAA/ESRL that is widely used in the tropical community. Some highlights of the new dataset include:

- Higher spatial resolution (1.0°)
- Better handling of the diurnal cycle, which reduces spectral ringing from the orbital precession of the satellites
- More sensitivity to water vapor, which helps identify signals in cloud-free regions
- Minor geolocation errors in the ESRL dataset are absent in the CDR version

PLANNED WORK

- Revise monitor.cicsnc.org/mjo to leverage the new interim CDR of daily OLR
- Prepare manuscript comparing the new OLR-daily CDR with the previous dataset.

PUBLICATIONS

Peer-reviewed

- Kruk, M. C., C. J. Schreck, and T. Evans, 2014: [The Tropics] Eastern North Pacific basin [in "State of the Climate in 2013"]. *Bull. Amer. Meteor. Soc.*, **95**, S90–S92, doi:10.1175/2014BAMSStateoftheClimate.1.

Other publications

- Bodeker, G., and Coauthors, 2014: *Outcomes of the GRUAN network expansion workshop*. GRUAN-RP-4. GRUAN Lead Center, DWD, 60 pp.

DELIVERABLES

- monitor.cicsnc.org/mjo served CDR-based diagnostics to an average of 320 unique visitors every month

PRESENTATIONS

Invited

- Schreck, C. J., 2015: Improving agricultural forecasts with large satellite datasets. *Data4Decisions Conference*, 24-26 March 2015, Raleigh, NC.

Other presentations

- Schreck, C. J., and Coauthors, 2015: Natural gas prices and the extreme winters of 2011/12 and 2013/14. *Sixth Conference on Weather, Climate, and the New Energy Economy*, 4-8 January 2015, Phoenix, AZ.
- Schreck, C. J., H.-T. Lee, and K. Knapp, 2015: A new daily OLR dataset for identifying the MJO and tropical waves. *Third Symposium on Prediction of the Madden–Julian Oscillation,* 4-8 January 2015, Phoenix, AZ.
- Schreck, C. J., H.-T. Lee, and K. Knapp, 2014: A new daily OLR dataset for identifying the MJO and tropical waves. *39th Climate Diagnostics and Prediction Workshop*, 20-23 October 2014, St. Louis, MO.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# of non-peered reviewed papers	1
# of invited presentations	1
# of graduate students supported by a CICS task	0
# of graduate students formally advised	1
# of undergraduate students mentored during the year	0

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

Task Leader	Soroosh Sorooshian
Task Code	NC-CDR/SDS-18-UCI
NOAA Sponsor	Ed Kearns
NOAA Office	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 December 2014. 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*.

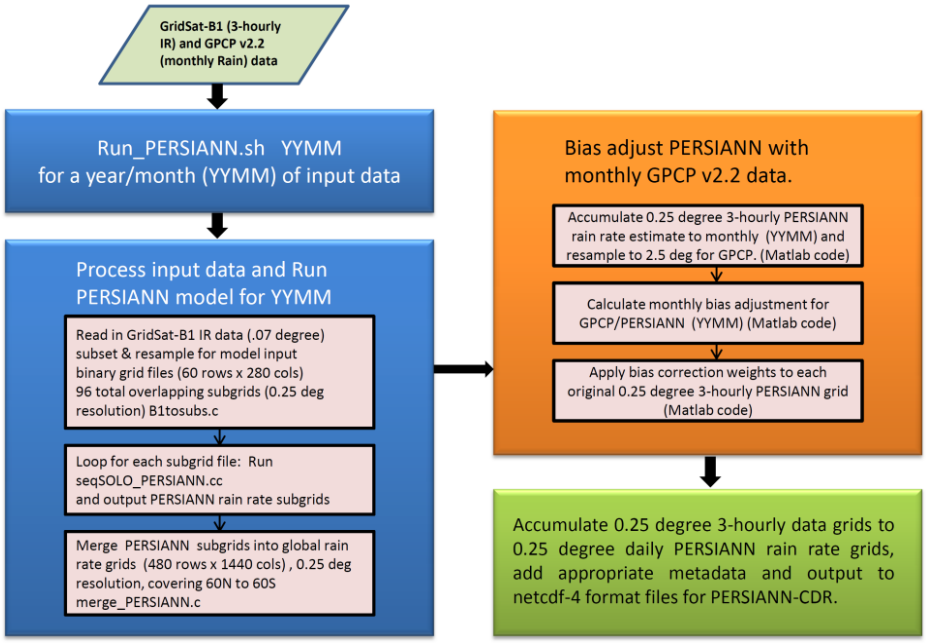


Figure 1. The PERSIANN-CDR flowchart

ACCOMPLISHMENTS

PERSIANN-CDR daily data is processed up to December 2014. During this report period, the performance of PERSIANN-CDR in capturing the behavior of precipitation extremes over China is evaluated using the East Asia (EA) gauge-based data set ((ftp://ftp.cpc.ncep.noaa.gov/precip/xie/EAG/EA_V0409/) (Xie *et al*., 2007). Some indices (SDII, R20mm, R10mm, R20mmTOT, & R10mmTOT) described in Table 1 are calculated (Klein Tank *et al*., 2009) for the 1983-2006 period.

Category	ID	Definition	Unit
Absolute threshold indices	SDII	Annual precipitation from wet days	mm/day
	R20mm	Annual count of days when daily precipitation ≥ 20mm	Days
	R10mm	Annual count of days when daily precipitation ≥ 10mm	Days
	R20mmTOT	Annual total precipitation when daily precipitation ≥ 20mm	mm
	R10mmTOT	Annual total precipitation when daily precipitation ≥ 10mm	mm

Table 1. Extreme precipitation indices used in the analysis

Figure 2 shows the five threshold indices for PERSIANN-CDR and the EA data set. It shows that PERSIANN-CDR exhibits good agreement with the EA gridded-gauge data in depicting the spatial distributions of those threshold indices. With respect to the correlation coefficients between PERSIANN-CDR and the EA data set, high correlations are observed in the south and east regions of the country where rain-gauge networks are much denser, and where most of the heavy rainfall events occur. Over the entirety of China, the significant correlations at 95% confidence interval for SDII, R20mm, R10mm, R20mmTOT and R10mmTOT covers 63%, 60%, 70%, 62%, and 70% of total area, respectively. However, the percentages are increased to 85%, 76%, 95%, 79%, and 95% respectively in the monsoon area. The daily precipitation in parts of northwestern China is below the threshold (20 mm and 10 mm), resulting in blank spaces in the map of annual correlation analysis. Compared to percentile indices, PERSIANN-CDR shows closer agreement with the EA data set in the eastern China monsoon region for the indices. The correlation of annual absolute threshold indices between PERSIANN-CDR and the EA data set is significant in most of the eastern China monsoon regions.

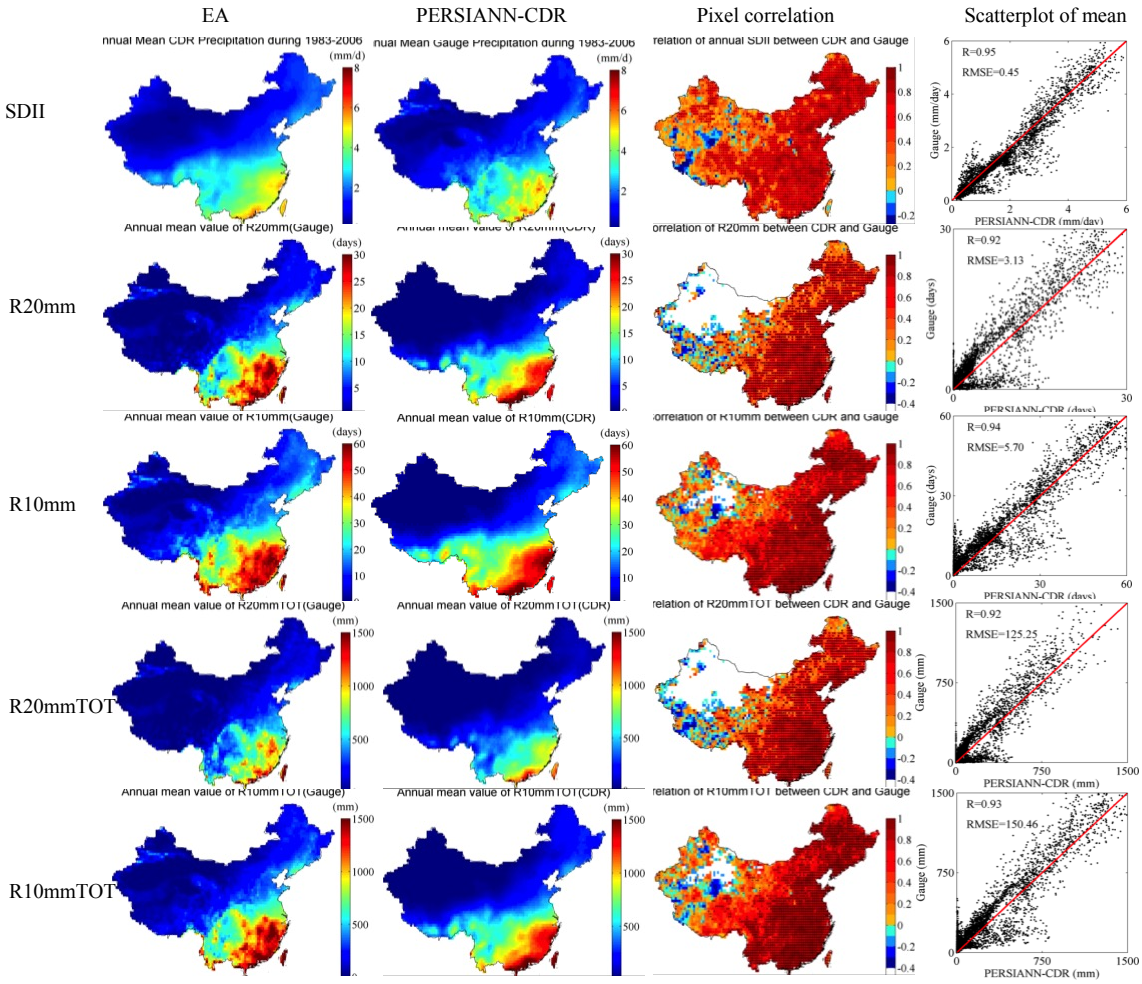


Figure 2. The indices of extreme daily precipitation from the EA data set (1st column) and PERSIANN-CDR (2nd column). The spatial correlation distribution and the scatterplots of the indices from the EA and PERSIANN-CDR data sets are shown in the 3rd and 4th columns, respectively.

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

PUBLICATIONS

- Ashouri H., K. Hsu, S. Sorooshian, D. Braithwaite, K. R. Knapp, L. D. Cecil, B. R. Nelson, O. P. Prat, 2015: PERSIANN-CDR: Daily Precipitation Climate Data Record from Multi-Satellite Observations for Hydrological and Climate Studies, Bull. Amer. Meteor. Soc., doi: http://dx.doi.org/10.1175/BAMS-D-13-00068.1
- 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, 2014. (Accepted)

PRESENTATIONS

- Hsu, K., H. Ashouri, D. Braithwaite, and S. Sorooshian, PERSIANN-CDR: A Daily Precipitation Data Record, 17-21 November, 2014, Tsukuba, Japan.
- Ashouri H., P. Nguyen, A. Thorstensen, K. Hsu, and S. Sorooshian, 2014: Long-Term Historical Rainfall-Runoff Modeling Using High-Resolution Satellite-based Precipitation Products, Fall Meeting, American Geophysical Union; 2014 Dec 15-19; San Francisco, California, USA.
- Nguyen, P., A. Thorstensen, K. Hsu, A. AghaKouchak, B. Sanders, and S. Sorooshian. 2014. Simulation of the 2008 Iowa Flood using HiResFlood-UCI model with remote sensing data. Poster session presented at the annual meeting of the American Geophysical Union; 2014 Dec 15-19; San Francisco, California, USA.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	1
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	2
# 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

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

Task Leader	Scott Stevens
Task Code	NC-CDR/SDS-19-NCICS-SS
NOAA Sponsor	Ed Kearns
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: 10%; Goal 2: 60%; Goal 3: 0%; Goal 4: 30%; Goal 5: 0%

Highlight: The project group has generated eleven years of a high-resolution gridded precipitation product for the entire continental United States at CICS-NC. We continue to work closely with our partners toward quality assurance and the transfer of this very large dataset.

BACKGROUND

This report summarizes the year-5 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.

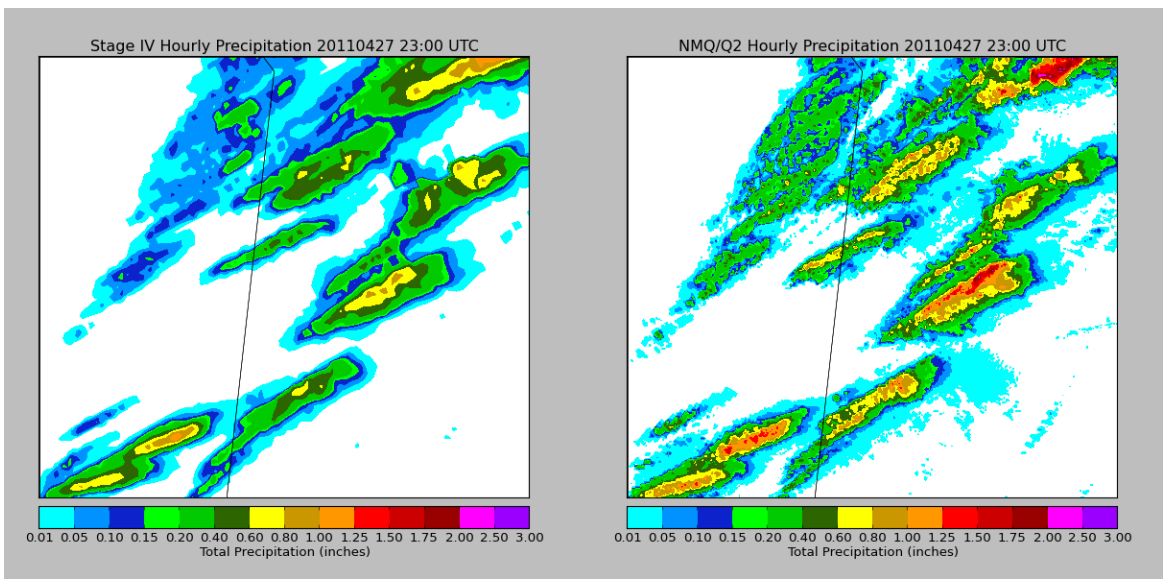


Figure 1. Comparison of spatial resolution in the operational Stage IV gridded precipitation product (left), and the NMQ/Q2 reanalysis product (right).

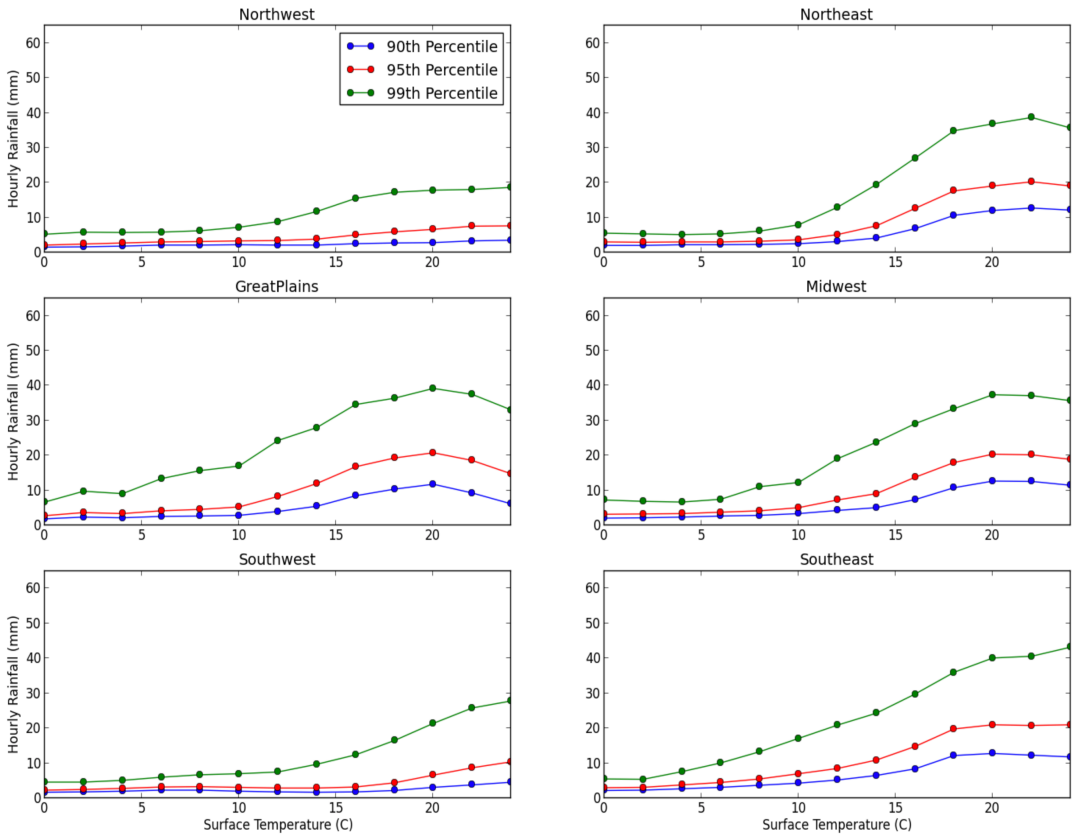


Figure 2. Regional relationships between surface temperature and hourly rainfall.

ACCOMPLISHMENTS

The reprocessing effort was largely completed during year 5, and a continuous record of precipitation information now exists from 2001-2011. Efforts have begun to organize the output data and identify gaps that occurred during processing in an attempt to create the most complete record possible. So far, the project has held closely to established timelines for completion, and efforts have begun to include the output in the NCEI data archives.

With the processing effort nearing completion, this has allowed for some scientific exploration of the product. The reanalysis was used this year to investigate the relationship among temperature, atmospheric moisture, and extreme rainfall. The greatly increased spatial resolution allows us to examine the most extreme precipitation, which is often dampened by spatial averaging in coarser products. Figure 2 shows the values for the highest percentiles of rainfall as a function of surface temperature. The data suggest that the relationship between temperature and heavy rainfall is largely dependent on region, with some areas of the U.S. showing a much stronger correlation than others. This research was presented at the 2014 Fall Meeting of the American Geophysical Union in San Francisco, CA.

PLANNED WORK

- Work with NSSL to assess the quality of the product

- Coordinate transfer of this very large dataset between partners in North Carolina and Oklahoma
- Explore necessary steps to expand into more recent years, including dual-polarization radar

DELIVERABLES

- Gridded precipitation dataset for continental US for years 2001-2011

PRESENTATIONS

- Stevens, S., B. Nelson, K. Kunkel, O. Prat, and T. Karl, 2014: Relationship among high rainfall rates, atmospheric moisture, and temperature based on high-resolution radar-based precipitation estimates, American Geophysical Union Fall Meeting, San Francisco, CA (Dec 15-19).

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	1

PERFORMANCE METRICS EXPLANATION

This year a presentation was given at the fall meeting of the American Geophysical Union in San Francisco, CA, focusing on the application of this dataset to advance research into precipitation processes. In addition, CICS-NC Scientist Scott Stevens served as mentor to undergraduate student Kelly Gassert, whose undergraduate research project focused on radar-derived precipitation estimates and was also presented at the aforementioned meeting in San Francisco.

Ingest Archive System Agile Development Team

Task Leader	Lou Vasquez
Task Code	NC-CDR/SDS-20-NCICS-LV
NOAA Sponsor	Ed Kearns
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 100%; Theme 3: 0%
Main CICS Research Topic	Climate Data and Informaiton 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: Implemented agile development methodologies for the rejuvenation of the Ingest Archive System.

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. The system is configurable to allow data to be pushed to the local system and to pull data from remote systems. The 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.

To facilitate the stabilization and rejuvenation of the system, we instituted the Agile Scrum methodology for the software 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.

An agile Scrum team was convened to initially address stabilization issues concerned with the Ingest-Archive System (IAS), and further to develop improvements to support the ongoing ingest and archive of data at NCEI-NC. Lou Vasquez and Linda Copley joined five additional NCEI participants in the formation of this team.

ACCOMPLISHMENTS

Standing up an agile Scrum team in the NCEI environment has been a significant accomplishment. Adopting agile requires a culture change, among the developers as well as the other stakeholders. Although the Scrum methodology is clearly defined, we put in place the processes to implement it in our environment. Team roles were assigned and defined. We organized all of the work being considered for the team into a product backlog, with priorities assigned to the top items. As a self-organized team, the team worked together to

determine how to accomplish the work, divided up into two-week sprints. At the completion of each sprint the developed products were demonstrated for interested stakeholders. A sprint retrospective is conducted among the team to identify areas of success and areas for improvement. The short cycle time gives us plenty of opportunity to refine the process, and each sprint has seen several refinements to the process.

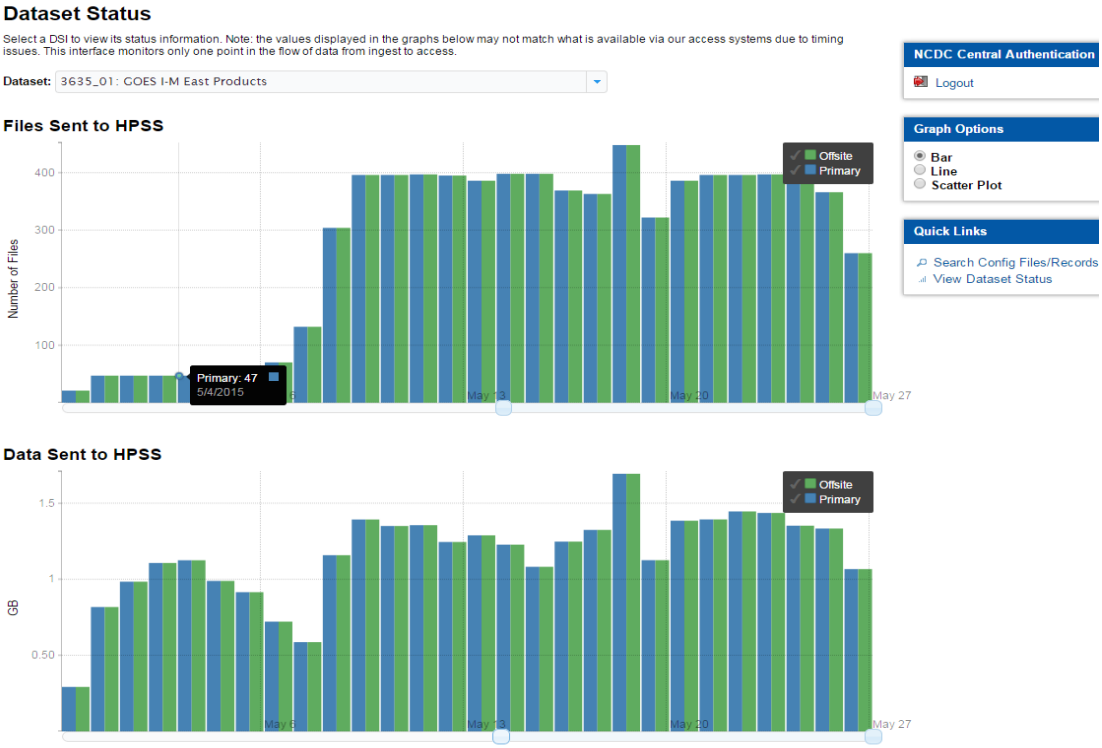
Overcoming pressing operational issues has been a constant theme. Operational issues impact the centers' ability to perform the primary function of data archive and provision, in addition to ingest of new datasets, and development of new capabilities. For these reasons it becomes important for this development group that the system be fully operational, and a great deal of effort was placed towards this goal.

Issues encountered and resolved in this task can be broken down into three categories: external, internal, and fallout. External items include systemic disk failures, NCEI tape system outage, and radar service data corruption. Internal items typically included system configuration or software changes that created unexpected results for the system. Fallout items occurred where external or internal issues left data in unknown states and special understanding of the data and system operation were required to post process data not handled during the issue, and bring the system state back to normal operations. All of these items required analysis, development, and debugging skills within the team for recovery—benefitting the center and development team goals.

An initial goal for the project team was the stabilization of the existing system. Given the number of Ingest system issues, its dynamic nature, and marginal stability of the system, the first step to was to improve feedback via observability. The multitude of operational problems was keeping us from being able to move forward on improving the system, so we made it a priority to develop tools that allow us to discover system issues proactively.

Three monitoring tools were developed: Server Status Notifications, SIPGenSys System Monitor, and Dataset Monitor. The Server Status Notifications system provides emails and text messages based on the status of various operating system components, hardware components, and third-party system components. The SIPGenSys (Submission Information Packet Generation System) System Monitor (*Figure 1*) is a graphical interface that utilizes the Logstash-Kibana stack to display near-real-time operational statistics for system load, file movement, and archive of files. The Dataset Monitor (*Figure 2)* is a web interface that shows the number of files and volume of data archived for each data set on a daily basis. The use of these three tools has allowed the operations and development teams to detect and correct system issues well before the user community becomes aware of the problem.

Figure 1. SIPGenSys System Monitor Tool



Moving the SIPGenSys system towards an architecture that supports long-term goals of virtualization, minimal data moves, and code modernization, we co-designed and vetted a future architecture. This architecture meets system owner needs of flexible resources, reduced data copies, and an environment that supports a more robust codebase. It also meets NCEI IT infrastructure requirements, including security, maintainability, and platform requirements.

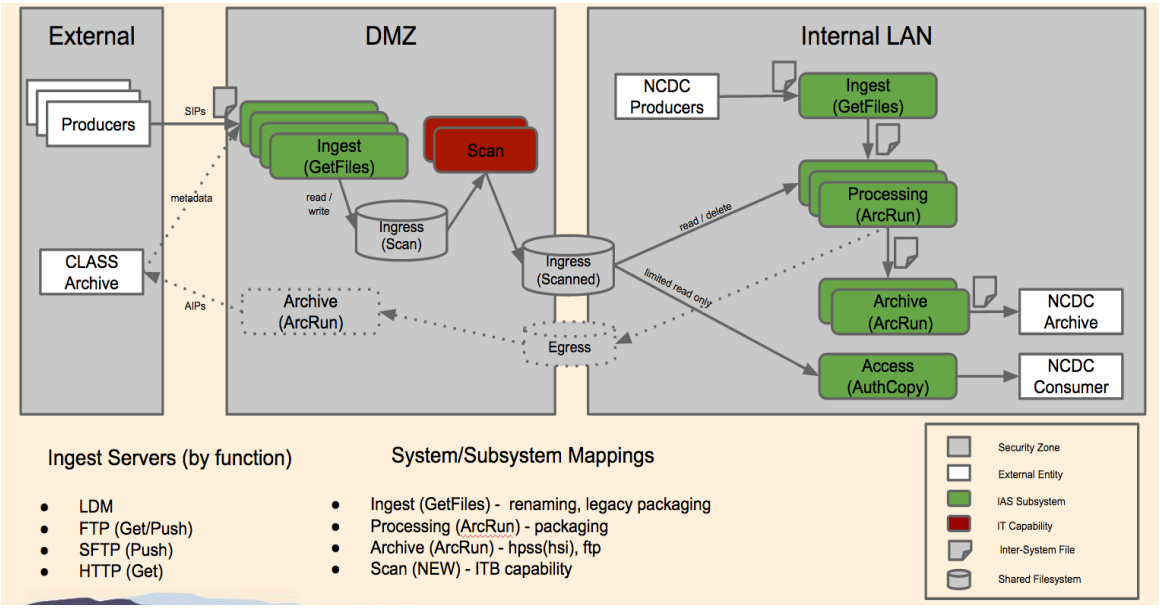


Figure 3. IAS Future Architecture Design

PLANNED WORK

- Ingest system future architecture implementation
- Expand agile development product breadth

DELIVERABLES

- Ingest Proposed Architecture
- Ingest Real-Time Monitoring
- Ingest Dataset Statistics

PRESENTATIONS

- NCEI Branch Seminar, NCEI, Asheville, NC: “Key West Agile Team: Implementation and Successes” L. Copley; May 5, 2015

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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-01-NCICS-JD
NOAA Sponsor	Tim Owen
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme 1: 40%; Theme 2: 40%; Theme 3: 20%
Main CICS Research Topic	Climate Literacy, Outreach, Engagement, and Communications
Contribution to NOAA Goals (%)	Goal 1: 40%; Goal 2: 0%; Goal 3: 0%; Goal 4: 40%; Goal 5: 20%

Highlights: 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.

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, including presentations, lectures, development science, and active engagement initiatives. These activities are often in conjunction with CICS-NC partners, which include NCEI's Information Services Division, NOAA's Climate Program Office, and other cooperative institutes. Broad areas for discussion when engaging with stakeholders are framed under these areas:

- 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 in research purposes by academia, legislative staff, and the general public
- Increase awareness of climate datasets and products anddiscuss 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 and operational needs
- 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, and providing ongoing operational support to NOAA organizations.

ACCOMPLISHMENTS

To advance climate literacy activities across public, private, and academic partners on climate data, information, and application opportunities, several activities were completed from October 2014 to June 2015. These include developing an engagement strategy and frameworks, engaging in seminars and presentations, engaging in relationship building and capacity-building activities, enabling catalytic support of innovation in uses of climate data, and ongoing operational support to NCEI. Key accomplishments in this past year included:

- Advancing literacy and outreach in education with the K-12 audiences and supporting undergraduate and graduate areas
- Engaging in meaningful dialogue on uses, applications, and requirements of climate information with business and industry partners through workshops
- Providing operational support to NCEI's 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
- With support from other CICS-NC staff, conducting interdisciplinary engagement and outreach and engagement activities to other stakeholder communities (e.g., public policy/legislative groups, local non-profit groups, and economic development groups)

Advancing Literacy and Outreach in Education

CICS-NC engages with K-12 students and teachers as well as the general public to help advance climate science, literacy, and education particularly focusing on the STEM skillsets. In the past year, various members of the CICS –NC team have given presentations, led lectures, taught courses, developed curricula, lent equipment, and mentored high-school students.

During the fall of 2014, three members of CICS-NC (Ronald Leeper, Jared Rennie, and Carl Schreck) mentored two local area high school students (Charlie Pugh and Sean Feirstein). The two students were introduced to teleconnections such as the Madden-Julian Oscillation (MJO) and how they relate to global temperatures. In addition, the students became familiar with weather observations incorporated in both the US Climate Reference Network (USCRN) and the Global Historical Climatology Network (GHCN). Using these two networks, the students compared weather conditions for the Midwest before and during the 2012 drought.

Figure 1. Theresa Stone, Laura Stevens, and Scott Stevens represented CICS-NC at WeatherFest on the UNC-Charlotte campus on March 21, 2015.

Theresa Stone, Laura Stevens, and Scott Stevens participated in WeatherFest on March 21, 2015, hosted by the local AMS chapter at UNC-Charlotte. AMS describes WeatherFest as "an interactive four-hour science and weather fair designed to instill a love for math and science in children of all ages and to spark a young person's interest in this area so they may consider a career in these and other science and engineering fields." CICS-NC showcased the Cyclone Center, the National Climate Assessment, and NOAA educational materials to approximately 500 attendees.

Jared Rennie, Bobby Taylor, Jim Biard, and Tom Maycock represented CICS-NC at the Entrepreneurship, Science, Technology, Engineering, Art, & Math (ESTEAM) Expo, a K-12 outreach event in Asheville, NC, on March 28, 2015, demonstrating Cyclone Center storm analyses and information about the National Climate Assessment to approximately 800 attendees.

Theresa Stone, Laura Stevens, and Jared Rennie supported CICS-NC's participation in the *Mountain Science Expo* for approximately 2600 K-12 students, families, and area educators, on April 11, 2015, at the NC Arboretum, showcasing the Cyclone Center citizen science project and the National Climate Assessment in cooperation with NCEI's Outreach program. The *Mountain Science Expo* was part of the larger North Carolina Science Festival activities taking place across the state "showcasing science and technology." The NC Science Festival "highlights the educational, cultural, and financial impact of science in our state. Through hands-on activities, science talks, lab tours, nature experiences, exhibits and performances, the Festival engages a wide range of public audiences while inspiring future generations."[1]

Theresa Stone and Scott Stevens traveled to Isothermal Community College (ICC) on April 17, 2015, to represent CICS-NC at ICC's *Science and Technology Expo*, also part of the NC Science Festival activities. At this event, Theresa and Scott were able to engage with

[1] http://www.ncsciencefestival.org/about-us/mission/

approximately 150 6th grade students from Rutherford and Polk counties in a classroom setting. Each group of students learned how to classify tropical cyclones using the Cyclone Center website and gained an understanding of the purpose of the National Climate Assessment and how climate change impacts North Carolina.

Figure 2. Laura Stevens demonstrating a tropical cyclone classification during WeatherFest at UNC-Charlotte on March 21, 2015.

Figure 3 (l) & 4 (r). Jim Biard and Jared Rennie representing CICS-NC at the ESTEAM Expo on March 28, 2015, at the WNC Agriculture Center. Laura Stevens and Theresa Stone at the shared CICS-NC/NCDC display table at the Mountain Science Expo on April 11, 2015.

CICS-NC supports outreach in education to university-level students by providing internship opportunities for graduating college seniors and graduate student researchers who have a strong desire to enhance their research and analysis skills by working with NOAA and CICS. CICS-NC is closely linked to the State Climate Office of North Carolina, North Carolina State University's Marine Earth and Atmospheric Sciences Department, and the UNC Asheville

Atmospheric Sciences and Applied Mathematics Department. Many of the CICS-NC staff also gave guest lectures and talks at local universities on various climate research topics.

In 2014, four new undergraduate interns joined the CICS-NC internship program (additional details in the *Workforce Development* section). Jenny Dissen provided support and occasional mentorship to William Clark, an undergraduate student from UNC Asheville who worked on two projects examining economic impacts of climate change.

Several CICS-NC staff (Carl Schreck, Jared Rennie, and Jenny Dissen) also provided mentorship support to graduate students visiting NCEI as part of the NASA DEVELOP program for undergraduate and graduate students, a capacity building program within NASA's Applied Sciences Program. Most recently, Carl Schreck supervised and mentored several graduate students in this program. Participants in the program work closely with end users to address environmental issues using satellite data. Carl was involved in the Regional U.S. Energy project that uses GHCN daily data and the Outgoing Longwave Radiation CDR to examine the relationship between atmospheric teleconnections and temperature anomalies in the eastern half of the United States.

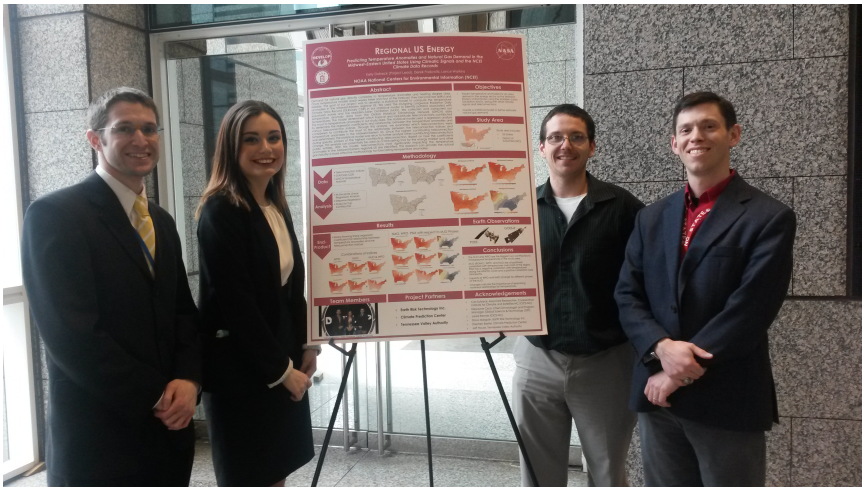


Figure 5. NASA DEVELOP Spring Presentations held on March 27th with Kelly Dobeck (NASA Develop), Derek Podowitz (NASA Develop), Jared Rennie (CICS-NC), and Carl Schreck (CICS-NC).

In February 2015, Ronald Leeper and Jared Rennie gave an invited talk at the UNC Asheville Department of Atmospheric Sciences titled “The Evolution of In Situ Climate Observations and Impacts on Observations and Climate Metrics” where they discussed the evolution of both the US Climate Reference Network (USCRN) and the Global Historical Climatology Network (GHCN) and its potential impact on weather and climate data to undergraduate and graduate students and department faculty.

CICS-NC continues to support the State Climate Office (NCSCO) at NC State University to enhance the communication abilities of their weather and climate-monitoring network (ECONet). In their effort to expand this network and enhance data collection from its 39 locations, CICS-NC supports the State Climate Office by enabling the capability to further the

collection of climate data (e.g., by providing technology such as cellular modems). The continued collaboration with NCSCO builds public engagement of climate observations and their role in understanding our society's sensitivity to climate.

Outreach and engagement to K-12, undergraduate/graduate levels, select associations, and the general public has been further advanced in the past several months through various presentations conducted by the CICS-NC team. This includes:

- **Durham Public Schools Weather Chat:** Presentation to students across the country about weather and climate. Hosted by Durham Public Schools and broadcast across to the country to approximately 1,000 students in middle school. **October 2014** (Jared Rennie): https://www.youtube.com/watch?v=vrWiCx7U0kw
- **"Climate Change Impacts in the United States"** to AB Tech Environmental Biology students at NCDC, Asheville, NC, **Nov 3, 2014** (Laura Stevens)
- **"Climate change and risk?** - How variable are climate projections and implications for disturbance risk", invited talk, Southern Forests Economic Issues Forum. Raleigh, NC, **November 4, 2014** (Ken Kunkel)
- **Asheville Middle School:** Presentations to 6th and 7th graders at Asheville Middle School on weather, climate, and what we do at CICS-NC / NCEI. **November 2014** (Jared Rennie)
- **"Teaching Climate Using the Third National Assessment"** at the AGU Geophysical Information For Teachers (GIFT) Workshop, San Francisco, CA, **December 15, 2014** (Laura Stevens)
- **"Climate Change Impacts in the United States"** to Environmental Biology students at AB Tech, Asheville, NC, **March 10, 2015** (Laura Stevens)
- **"Climate Change Impacts in the United States"** to Environmental Biology students at AB Tech, Asheville, NC, **March 16, 2015** (Robert Taylor)

Engaging with Business and Industry Sectors

Jenny Dissen is currently engaging with Facebook, particularly the data center located in Forest City, North Carolina, on the development of a case study that intends to elaborate how the engineering and system designers used climate information as a key decision driver in the siting and operations of this data center. Facebook uses an innovative evaporative cooling system instead of a chiller system and is concerned with maintaining certain temperature and humidity conditions in order to establish an efficient and effective power utilization effectiveness ratio. The location in Forest City is considered one of the most energy efficient data centers in the world.

In addition to direct engagement and seminars, CICS-NC has also established a more formal mode of engagement to build collaborations with business and industry. The program, titled Executive Forum on Business and Climate, is a groundbreaking approach to bringing together academic researchers, business leaders, and federal science experts to examine how recent weather and climate trends are impacting industry and how information is being used by business decision-makers in their strategy and operations.

CICS-NC held its third Executive Forum on Business and Climate on March 19 – 20, 2015. This forum focused on "Private Property, Climate Information Disclosure, and the Roles of Insurance and Government" and was conducted in collaboration with the UNC-Chapel Hill School of Law, Georgetown, and other partners. Nearly 50 representatives from the science, policy and legal academic, and private sectors as well as state insurance commissioners attended the discussion. The goal was to examine opportunities for insurance companies to disclose climate related risks, explore the role of climate data in these disclosures and analysis, and report out recommendations to the commissioners associations who can assess opportunities for improving private sector climate change adaptation as well as field requests for climate data. CICS-NC attendees included Otis Brown, Ken Kunkel, Jenny Dissen, Paula Hennon, and Amanda Rycerz; Ken Kunkel and Otis Brown led a discussion on "State of the climate science in identification of risks; presentation and use of data from national climate center and affiliates." NCEI's Adam Smith was integrally involved in the planning phase, particularly with incorporating outcomes from the various NOAA Reinsurance Engagement Strategy activities that have taken place in the past year. The Forum information and outcomes are available on the website: http://www.cicsnc.org/events/forum3/.

Figure 6: Discussion and interactions between business leaders, government, scientists and academics at the recent Executive Forum on Business and Climate: "Private Property, Climate Information Disclosure, and the Roles of Insurance and Government," March 19-20, 2015, Chapel Hill, USA

CICS-NC also engaged with private sector companies through collaboration and partnership with Acclimatise to pursue research opportunities in the area of climate adaptation. An informal partnership has also been established with The Brattle Group to jointly develop innovative options for addressing climate adaptation opportunities.

Engagement and Outreach in Collaboration with NCEI

In addition to engagement and outreach across academia and business and industry, Jenny Dissen supported various strategic and operational customer/stakeholder engagement

activities with the NCEI Center for Weather and Climate Information Services (CWCIS), formerly the NCDC's Climate Services and Monitoring Division (CSMD).

As part of a broader effort throughout NCEI to maximize awareness, understanding, and use of appropriate NCEI products and services, and to capture feedback, Jenny Dissen supported various strategic divisional activities initiated in 2013 and well underway today. This is part of a larger endeavor to help capture customer engagement information and includes activities such as:

- Strategic plan and an implementation roadmap
- Process documents on how customers engage with NCEI and how information is captured, stored, and analyzed
- Customer information catalog/repository
- Support various market analysis reports in collaboration with subcontracting companies to NCEI
- Developing interim solutions to catalog customer requests, engagement requests, and feedback/recommendations from customers
- Capturing, reviewing, and prioritizing requirements to help inform options for a Customer Relationship Management tool that will ultimately serve as a repository of customer information.

Another key area of support to the NCEI CWC Engagement team includes reshaping how the division partners with the Regional Climate Services Directors to engage with stakeholders in various sectors. This involves a review and reassessment of the sectoral engagement strategy. This activity includes a suggestion towards mapping NCEI CWC sectoral activities to the U.S. Census NAICS code, and the toal is to have this recommendation be considered for all NCEI.

Jenny Dissen, along with many NCEI staff, created an active working engagement activity called Climate Data and Applications Workshops (formerly referred to as Dataset Discovery Day). These two-day workshops allow NCEI staff to discuss their data products, CICS-NC staff to discuss research and application opportunities in various sectors, and users from public and private sector to discuss applications and their requirements. In an effort to continue the engagement workshop series, NCEI worked with their subcontracting partner GST and CICS-NC for a "Workshop on Water Resources and Drought Information in the Southwest U.S.: Facilitating Collaboration to Increase Access to Relevant Drought Information" that took place January 2015 in conjunction with the annual American Meteorological Society meeting. As drought continues to be a significant challenge that causes enormous societal and water-related impacts, this workshop was intended to foster a cross-sectorial collaboration with stakeholders from federal, state and local government, academia, and the research community, as well as affected businesses, industry, and information providers to not only raise awareness but also capture key requirements related to the drought data and access related issues. Workshop information and a detailed summary can be accessed here: http://www.cicsnc.org/events/water-drought-sw/.

Support to NCEI is ongoing, as these efforts to build a robust customer engagement activity is a multi-year effort.

Supporting Innovation and Economic Development

CICS-NC outreach and engagement activities are under the purview of NC State's Office of Research, Innovation, and Economic Development. To that end, Jenny Dissen collaborates with the local Asheville Chamber of Commerce and the Buncombe County Economic Development Coalition to identify and support opportunities that will increase STEM skills and capabilities, particularly in climate science, within the region. Otis Brown and Dissen led various discussions to promote the growth of the science and technology sector in the Western North Carolina region, specifically in the weather/climate sciences arena.

CICS-NC supports access to climate information through its partnership with the Asheville Buncombe Sustainable Community Initiatives (ABSCI), an NC 501 (c) 3 with a mission to support and catalyze a resilient and enduring prosperity for the community within the context of a rapidly evolving and increasingly complex world. ABSCI has a long history of projects that support sustainability of the long-term economic, environmental, and cultural values that make North Carolina vital and unique. The ABSCI project portfolio includes the Callen Center, where ABSCI manages and runs The Collider, an innovative catalytic environment for building relationships and collaborations across economic and community sectors, specifically in the theme of climate data and applications. Otis Brown, Paula Hennon, and Dissen are providing various advisory level support to ABSCI in the cultivation, construction, and build-out of the Collider innovative space, which is targeted to open late fall of 2015.

In 2013, ABSCI and CASE Consultants supported an initiative called the *National Partnership for Resilience* (NPfR). The NPfR aimed to fill a major gap in the climate services landscape: the need for sustained engagement among climate-sensitive businesses, climate adaptation providers, public agencies, and academic institutions. NPfR explored the feasibility of a public-private-academic-nonprofit entity, and has now evolved into a broader endeavor called *the Partnership for Resilience*, an activity of North Carolina Institute for Climate Studies (NCICS).

Since fall of 2014, the *Partnership for Resilience* has been developing and establishing a vision and methodology for its formation and how it will engage with its members across public, private, academic, and non-profit organizations. The *Partnership for Resilience* will carry out an active program of technology and information transfer and economic development, supported by funds the North Carolina Institute for Climate Studies and Partnership for Resilience members. The goal is to foster collaboration across these stakeholders to disseminate climate science, data technology, and information available in the public domain about climate change adaptation and risk analysis/opportunities. The program aims to cover topics and projects, which cover the following spectra and are spearheaded by the Partnership Working Groups:

- Climate Adaptation & Mitigation
- Regional Climate Analysis
- Climate Modeling

- Climate Data Usability
- Climate Decision-Support Tools & Services
- Climate Change Risk Modeling
- Economic Development Strategies and Opportunities
- Stakeholder Engagement
- Organizational Best Practices
- Government & Public Sector Data and Information Dissemination Activities

Dissen currently supports Paula Hennon and Otis Brown in this activity under NCICS. Since September 2014, PfR has established a vision statement, a mission statement, an implementation plan, and a business plan. In April 2015, the staff worked with key strategic advisors to address several formation-related activities and are currently collaborating with North Carolina ORIED Office of Technology Transfer (OTT) to address compliance and intellectual property topics.

Additional details of this activity are included in Paula Hennon's section of the report.

PLANNED WORK

- Continue activities in the Executive Forum on Business and Climate
- Continue efforts in the development and working group activities of the Partnership for Resilience
- Hold additional Climate Data and Applications workshops (e.g., regional snowfall index, international surface temperature dataset, newly available radar products, updated climate normals data information)
- Support the implementation activities of NCEI's engagement strategy; assist in incorporating various recommendations; design, develop, and implement a new approach to sectoral engagement; deploy customer engagement information requests forms; and develop processes that improve customer information analysis.

PUBLICATIONS

- Schreck, C., S. Bennett, J. Cordeira, J. Crouch, J. Dissen, A. Lang, D. Margolin, A. O'Shay, J. Rennie, and M. Ventrice, 2015: Natural Gas Prices and the Extreme Winters of 2011/12 and 2013/14: Causes, Indicators, and Interactions. *Bull. Amer. Meteor. Soc.* doi:10.1175/BAMS-D-13-00237.1.

DELIVERABLES

- Execution of three forums called the Executive Forum on Business and Climate
- Supported activities related to the 2015 AMS Workshop on Drought
- Development of a NCEI CWC IS Center-wide Engagement Strategy, as well as framework and methodologies for NCEI Implementation Plans, Customer Engagement Forms, Process Design and Documentation, review of various recommendations and requirements, and a strategic approach to sectoral engagement

PRESENTATIONS

- Dissen, J., Houston, T., Margolin, J. (2014). Climate Change & Variability – Data Sources, Accessibility, and Use. Georgia Environmental Conference. Jekyll Island, GA.
- Privette, J.L., T. G. Houston, D. P. Brown, J. Dissen, K. Gleason, and R. A. Leduc Clarke. A New Approach to Climate Services at NOAA's National Climatic Data Center (NCDC). January 7, 2015 AMS Annual Meeting

OTHER

- Co-chair of American Meteorological Society Committee on Effective Communication of Weather and Climate Information
- Panel Moderator for 2014 American Meteorological Society on "Challenges and Opportunities in Communicating Weather and Climate Information"
- Key participant in the and a voting member of AMS Energy Committee and the new member of the newly proposed AMS International Committee
- Key lead and contributor in the cultivation of the Asheville Climate Cluster Group, in collaboration with the Asheville-based local nonprofit ABSCI
- Contributor and supporter to the ABSCI efforts on the Collider Space at the Callen Center Building in Asheville, which aims to focus on climate related activities in Asheville
- Completing a certificate course on Climate Change and Society through UNC Asheville

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	1
# 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	1

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

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

BACKGROUND

Recent activities focused on highlighting research findings of CICS-NC scientists and their NOAA/NCEI colleagues, improving 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

CICS-NC Communications

- Wrote and distributed the second edition of CICS-NC's newsletter, *Trends.*
- Wrote and posted 12 press releases/website stories on new scientific papers and other CICS-NC staff, all with NCDC co-authors or NCDC-related content.
- Provided editorial support for two research papers, both of which have since been accepted for publication.
- Established a Twitter account and worked to build Twitter and Facebook audiences
- Prepared flyer highlighting K-12 outreach activities
- Worked with graphic designer Jessicca Griffin to develop several retractable banners for use at CICS-NC outreach activities, including two banners presenting key findings and climate change trends from the Third National Climate Assessment and two banners that present information on CICS-NC and its outreach and engagement activities.
- Provided feedback on CICS-NC staff presentations.
- Helped coordinate staffing for the joint Asheville AMS chapter/CICS-NC booth at the 2014 annual meeting of the American Meteorological Society.

NOAA NCEI Communications

- Provided quick-turnaround copyedit of forthcoming NOAA California Drought Service Assessment.
- Contributed science communication expertise, including writing several Frequently Asked Question responses related to updates to NOAA NCEI surface temperature records and providing editorial input on an important press release.
- Revised Greenhouse Gas Frequently Asked Questions content (awaiting deployment).

- Improved coordination between CICS-NC and NCEI communications staff, sharing workload of developing web stories and integrating social media posts.
- Several of the CICS-NC web stories were also posted in modified form on NCEI's web site and mentioned in NCEI social media posts, which greatly extended the reach of these stories.

PLANNED WORK

- Continue to highlight and promote work done by CICS-NC and the institute as a whole
- Continue to assist with developing communication skills of CICS-NC staff
- Build reach of Facebook and Twitter accounts
- Provide expanded communications support for NCEI, including editorial work on the forthcoming Explaining Extreme Events report and other science communication tasks.

DELIVERABLES

- One issue of CICS-NC Trends newsletter
- Twelve web stories and press releases
- Four retractable banners
- Flyer on K-12 outreach
- Six FAQs related to surface temperature records and related paper in *Science*
- Significantly updated 15 FAQs on global warming for NCEI website (awaiting deployment).

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	21
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	18
# of products or techniques transitioned from research to ops without NOAA guidance	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

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 NCDC-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 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 E. Bell
Task Code	NC-SON-01-NCICS-JB
NOAA Sponsor	Howard Diamond
NOAA Office	NCEI/USCRN
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%

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 US Climate Reference Network is a series of climate monitoring stations maintained and operated by NOAA. To increase the network's capability of monitoring soil processes and accurately estimating drought, it was decided to add soil observations to the list of USCRN instrumentation. In the summer of 2011, the USCRN team completed the installation of all soil observational probes in the contiguous 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 NOAA's National Centers for Environmental Information, while installation and maintenance is performed by NOAA's Atmospheric Turbulence and Diffusion Division (ATDD). In order to improve the ability of the network, multiple projects were started to analyze soil moisture variability and change: 1). An analysis of the 2012 drought using soil moisture observations from 2011-2013, and 2) Spatial representativeness of USCRN soil observations using a dense temporary network.

ACCOMPLISHMENTS

USCRN soil observations were fully installed in 2011, which does not allow much time for performing any 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.

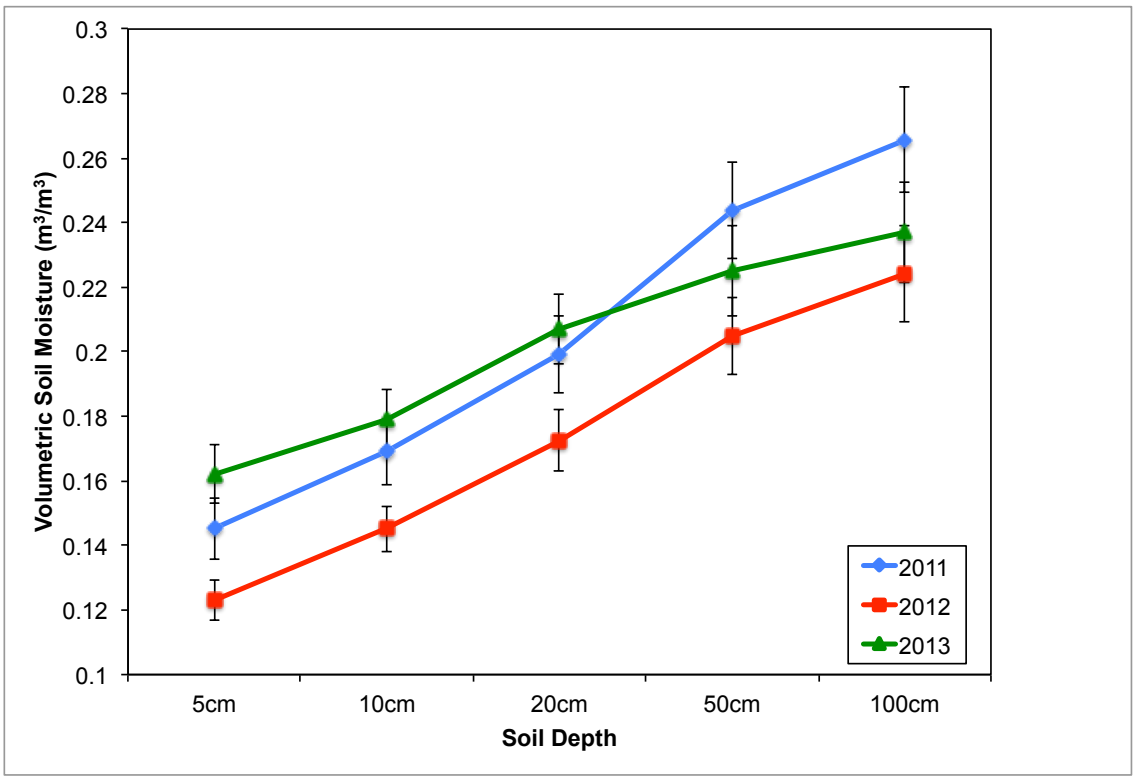


Figure 1. National soil moisture signal for each soil depth of the USCRN soil observations during the summers of 2011, 2012, and 2013. The top three levels experienced full recovery from the 2012 drought, but the bottom two levels never completely recovered.

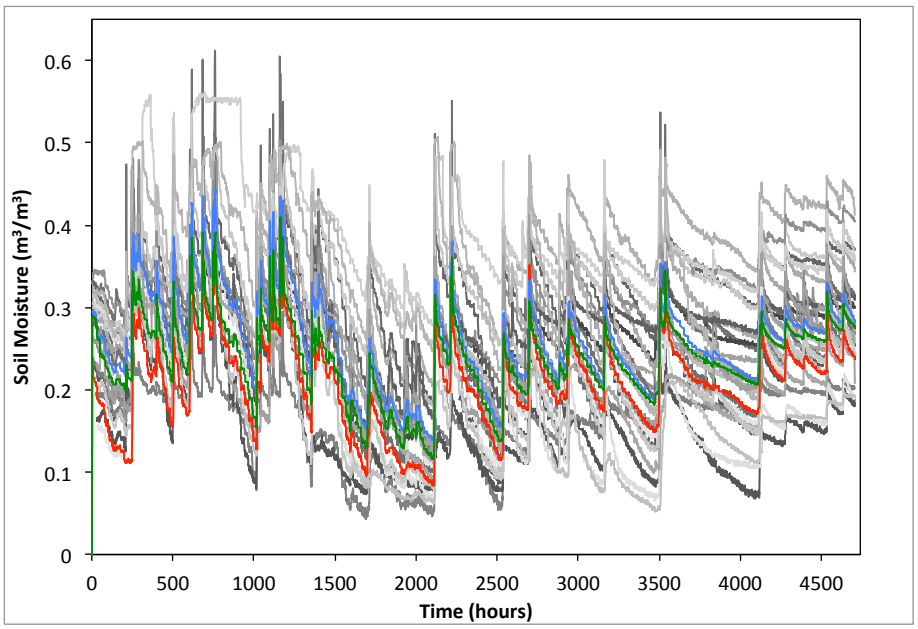


Figure 2. Mean soil moisture variability of the temporary network at Millbrook, NY. Red line is the USCRN value, blue line is the 9km average, and green line is the 3km average. The various shades of grey represent the individual probe values for the temporary network.

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.

PLANNED WORK

- Make revisions to the 2012 drought manuscript.
- Use USCRN observations to evaluate California drought.
- Submit manuscript for the Millbrook and Crossville study.
- Evaluate ways to continue expand the analysis of the spatial study.

DELIVERABLES

Instrumentation development for scaling and calibration.

PRESENTATIONS

- Bell, J.E. Preparation of NOAA's USCRN for NASA's SMAP Mission. NASA/JPL SMAP CAL/VAL Meeting, Pasadena, CA. October 2014.
- Bell, J.E. Evaluation of the California Drought with USCRN Soil Observations. Irvine, CA. AGU Chapman Conference on California Drought. April 2015

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

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

Task Leader	Jesse E. Bell
Task Code	NC-SON-02-NCICS-JB
NOAA Sponsor	Howard Diamond
NOAA Office	NCEI/USCRN
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%

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

BACKGROUND

The soil instrumentation that was recently added to the United States Climate Reference Network (USCRN) 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, while also providing 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

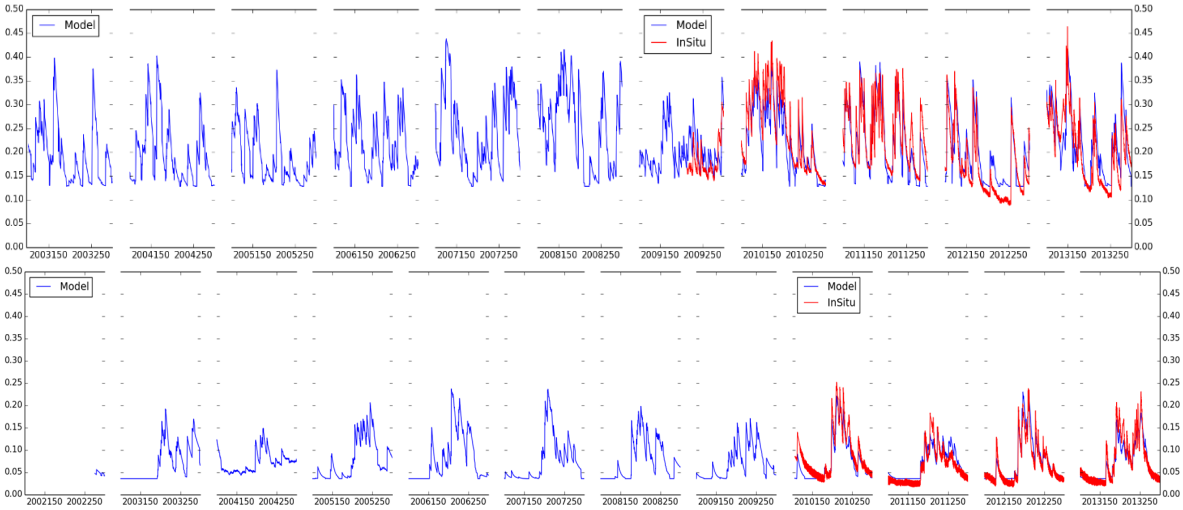


Figure 1 (top). USCRN #1003, Nebraska. In Situ (2009-2013), Historical Extension (2003–2009). Figure 1 (bottom). USCRN #1010, Arizona. In Situ (2010-2013), Historical Extension (2002-2009)

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 for improving this situation 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 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.

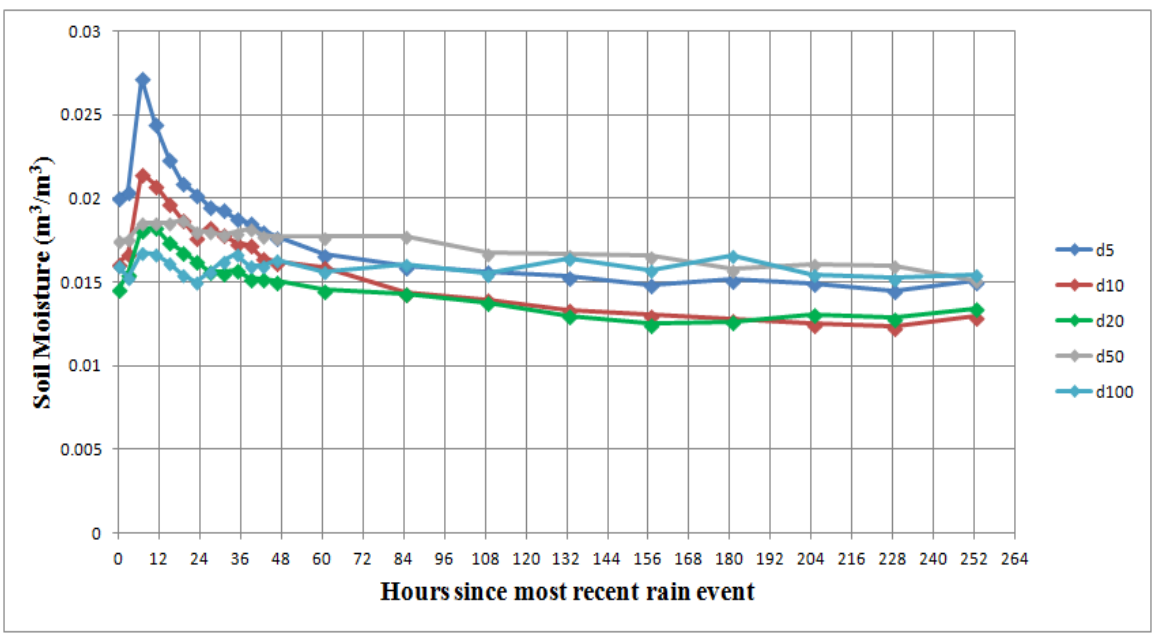


Figure 2: Random errors calculated by triple-collocation (m^3/m^3) as a function of hours after precipitation events at 5cm 10cm, 20cm, 50cm, and 100cm depths

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 in the past decade that 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.
- Develop index from modeled historical soil moisture record.
- Develop a manuscript that uses historical soil moisture record for drought monitoring.

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*, Accepted pending minor revisions.

DELIVERABLES

Extended soil moisture record for improved drought monitoring.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

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	Howard Diamond
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

During the last reporting period, there were three new installations in Alaska bringing the total to 16 broadcasting sites. The site names are AK Deadhorse 3 S (at the airport approximately 5 miles south of Prudhoe Bay, Alaska), AK Ivotuk 1 NNE (at the Arctic Slope Regional Corporation, Ivotuk Airstrip), and AK Ruby 44 ESE (on the Nowitna National Wildlife Refuge).

Deadhorse and Ruby stations are solar powered, supplemented by a methanol fuel cell during the winter months. Ivotuk is powered by a solar, wind, and diesel generator system previously installed at this National Science Foundation research location.

Figure 1. Alaska CRN Site near Ruby in the Nowitna National Wildlife Refuge.

PLANNED WORK

The Alaska USCRN network is projected to have a total of 29 sites. With FY 2015 funding from the CICS program, 2 of the 13 remaining installations are scheduled for mid-August 2015 at Denali National Park and Selawik National Wildlife Refuge.

The first weather-observing mission for a NOAA Unmanned Aerial System (UAS) within the Continental US will use ATDD's DJI S-1000 octocopter, a small UAS.

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

Flight-testing is expected to be conducted in mid-June near Oak Ridge, Tennessee. From July to September 2015, the sUAS will make approximately 120, 10-minute flights to measure the spatial variability of both the thermal infrared and visible wavelengths reflected from the Earth's surface surrounding surface flux towers in the 2015 portion of the Convective Initiation (CI) experiment near Belle Mina, Alabama. More detailed information can be found at http://www.arl.noaa.gov/sUAS_CIstudy.php.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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 US Climate Reference Network (USCRN) Quality Assurance Methods

Task Leader	Ronald Leeper
Task Code	NC-SON-04-NCICS-RL
NOAA Sponsor	Howard Diamond
NOAA Office	NCEI/USCRN
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: Manuscripts documenting the new automated quality assurance (QA) algorithm for precipitation and comparisons with the existing approach have been accepted in the Journals of Atmospheric and Oceanic Technology and Atmospheric Measurement Techniques. Reports have been complied that describe implementation plans of the algorithm necessary for operational deployment as well as manual QA efforts to further improve the quality of station data.

BACKGROUND

The US Climate Reference Network (USCRN) monitors the U.S. climate from over 124 well representative (obstacle-free) locations across the United States, including Alaska and Hawaii. Climate variables of interest (e.g., temperature and precipitation) 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

Studies evaluating the recently developed QA algorithm for precipitation have been accepted for publication in the *Journal of Atmospheric and Oceanic Technology* (JTECH) and the European Geophysical Union (EGU) journal *Atmospheric Measurement Techniques* (AMT). These studies highlight improvements of the new algorithm performance from station data in the first publication, and a gauge evaporation field campaign over the summer of 2013 in the second manuscript.

Documentation and reports on the QA algorithm's performance (validation and verification) and strategies for implementation, maintenance, and reprocessing have been completed for the National Centers for Environmental Information (NCEI) operational readiness review (ORR); required to deploy the algorithm operationally. In addition, manual QA approaches to identify environmental factors affecting the quality of station data that pass automated QA checks (i.e. brush fires, electrical issues, animal infestations, and snow-capped gauge; see figure 1) have been devised to further improve the quality of station precipitation prior to algorithm deployment.

Figure 1. Frog infestation of the Geonor gauge at Titusville, FL

PLANNED WORK

- Complete operational readiness review (ORR)
- Deploy new precipitation algorithm for public dissemination
- Utilize USCRN new precipitation dataset in hydrological investigations

PUBLICATIONS

- **Leeper, R. D.**, and J. Kochendorfer, 2015: Evaporation from weighing precipitation gauges: Impacts on automated gauge measurements and quality assurance methods. *Atmospheric Measurement Techniques*, **8,** 2291-2300, doi:10.5194/amt-8-2291-2015. Available online at: http://dx.doi.org/10.5194/amt-8-2291-2015
- **Leeper, R. D.**, M. A. Palecki, and E. Davis, 2015: Methods to calculate precipitation from weighing bucket gauges with redundant depth measurements. *Journal of Atmospheric and Oceanic Technology*, **32,** 1179-1190, doi:10.1175/JTECH-D-14-00185.1. Available online at: http://dx.doi.org/10.1175/JTECH-D-14-00185.1

DELIVERABLES

- Operational Readiness Review (ORR) Documents
- Analysis of network precipitation extremes

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	2
# of non-peered reviewed papers	3
# 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

PERFORMANCE METRICS EXPLANATION

- The development of manual QA scripts that identify suspicious observations for manual review and further improve the quality of USCRN gauge data
- Completed three reports that described the production, maintenance, and reprocessing plans

Collocated US Climate Reference Network (USCRN) and Cooperative Observer Network (COOP) Comparisons

Task Leader	Ronald Leeper and Jared Rennie
Task Code	NC-SON-05-NCICS
NOAA Sponsor	Howard Diamond/Jay Lawrimore
NOAA Office	NCEI/USCRN
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: 30%; Goal 2: 70%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: A manuscript that describes network differences between USCRN and COOP networks has been accepted for publication in the Journal of Atmospheric and Oceanic Technology.

BACKGROUND

The United States Climate Reference Network (USCRN) was specifically engineered to detect and attribute climate signals over the next 50 years. From station placement, sensor selection and shielding, calibration standards, and redundancy, this network was designed to limit the effect of observational biases on data records. As USCRN data becomes increasingly utilized in climate-focused tasks, differences between traditional cooperative observer (COOP) and modern USCRN networks will become increasingly relevant. The purpose of this study is to compare USCRN and COOP temperature and precipitation measurements and attribute observational discrepancies to station architecture.

ACCOMPLISHMENTS

USCRN and COOP stations had varying perspectives on atmospheric temperature and precipitation measurements. For temperature, network differences were mostly attributed to local radiative biases (i.e. land cover, thermistor type, and method of sensor aspiration). Precipitation differences were sensitive to gauge shielding, which was more discernable for colder (snowy) precipitation events. In addition, network observations varied in time with changes in station observer and instrumentation; however, USCRN and homogenized monthly COOP data had similar national temperature trends (*figure 1*). These results are presented in a peer-reviewed publication in the *Journal of Atmospheric and Oceanic Technology.*

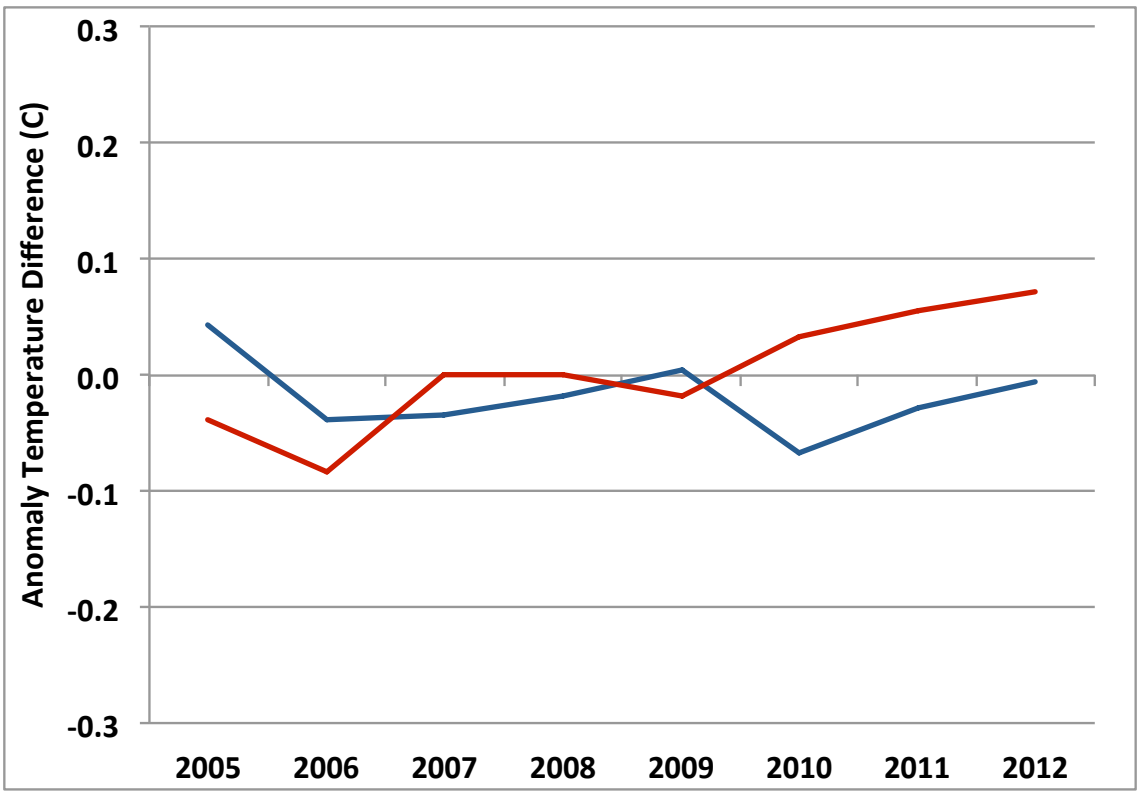


Figure 1. Annual USCRN and USHCNv2.5 maximum (red) and minimum (blue) anomalous National temperature differences

PUBLICATIONS

- Leeper, R. D., J. Rennie, M. A. Palecki. Observational Perspectives from U.S. Climate Reference Network (USCRN) and Cooperative Observer (COOP) Network: Temperature and Precipitation Comparison. *J. Atmos. Oceanic Tech.* **32**, 703-721, doi:10.1175/JTECH-D-14-00172.1

PRESENTATIONS

- Leeper, D. R., and Rennie, J. The Evolution of In Situ Climate Observations and Impacts on Observations and Climate Metrics. UNC Asheville Department of Atmospheric Sciences, Asheville, NC, February 2015.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

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	NCEI/USCRN
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: 0%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Initiated hydrological studies linking surface precipitation and sub-surface soil moisture measurements involving high school and under graduate interns. In addition, a cumulative distribution function was applied to station soil moisture observations so soil conditions across the U.S. can be monitored on the same scale. This approach was applied to the California drought.

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. Precipitation and soil conditions are important hydrological variables particularly during hydrological extreme events- droughts and floods. Over the few years that USCRN has monitored soil conditions nationally (since 2011), there has been a number of drought (i.e. 2012-drought and California-drought) and flood (Colorado, 2011) events affecting the U.S. The USCRN provides a unique opportunity to investigate these hydrological events over sub-daily time scales.

ACCOMPLISHMENTS

Two high school student interns conducted an exploratory analysis of soil moisture response to precipitation events with co-mentors Carl Schreck and Jared Rennie. Results revealed that precipitation intensity alone did not explain the total variance in soil moisture response. Soil moisture change was greatest for precipitation events with initially drier soil conditions (figure 1). The lack of a soil response to precipitation events with initially wetter soil conditions may be an indication of surface runoff and or localized flooding. How moist initial soil conditions are before the response to precipitation is lessened (saturation point) will likely change from station to station depending on soil profile and soil characteristics.

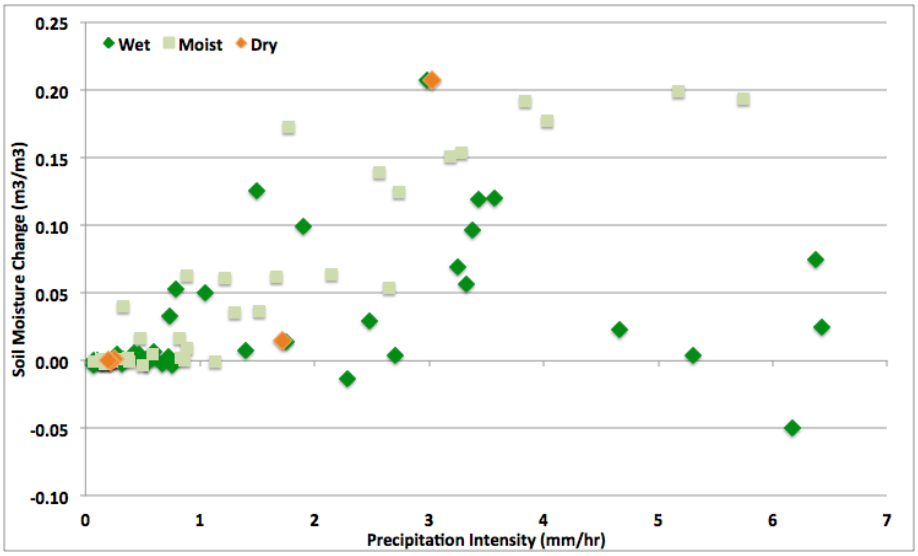


Figure 1. Volumetric 5cm soil moisture change by mean precipitation event intensity for initially dry (SM < 25% of all observations; orange-diamond), moist (25% >= SM <= 75% of all observations; light green-square), and wet (SM > 75% of all observations; dark green-diamond) soil conditions from the Lincoln 11 SW USCRN station between summer months May-Nov of 2011 and 2012.

An undergraduate Educational Partnership Program scholar analyzed the evolution of the 2012 drought from ground based in situ and modeling perspectives. The surface (precipitation) and sub-surface (soil moisture) conditions from North American Regional Reanalysis (NARR) was compared with USCRN observations from 2011 to 2013. Results revealed that while NARR based soil and precipitation data captured first order differences (drying to wetting trends) the magnitude of simulated surface and sub-surface conditions were biased with respect to USCRN observations (figure 2). The magnitude and direction NARR biases varied by climate region.

Further analysis with colleague Dr. Jesse Bell using a cumulative distribution function (CDF) on station soil observations was necessary to compare USCRN soil conditions across the network for any given time. The CDF functions rank station observations of soil moisture from 0 (driest) to 1 (wettest) by the station's historical set of soil data. These rankings make station observations of soil conditions comparable across the network as shown in figures 3a and b.

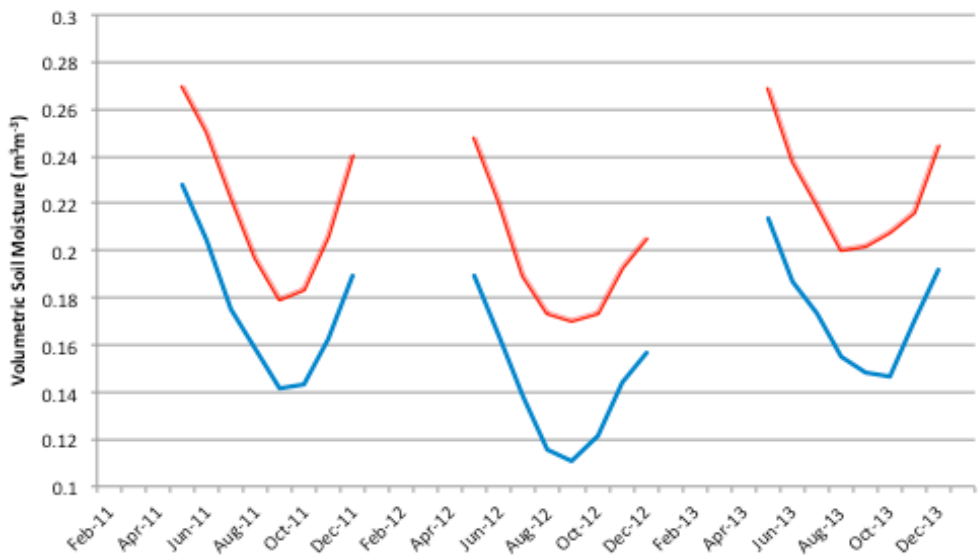


Figure 2. USCRN (blue) and NARR (red) national average 5cm volumetric soil moisture.

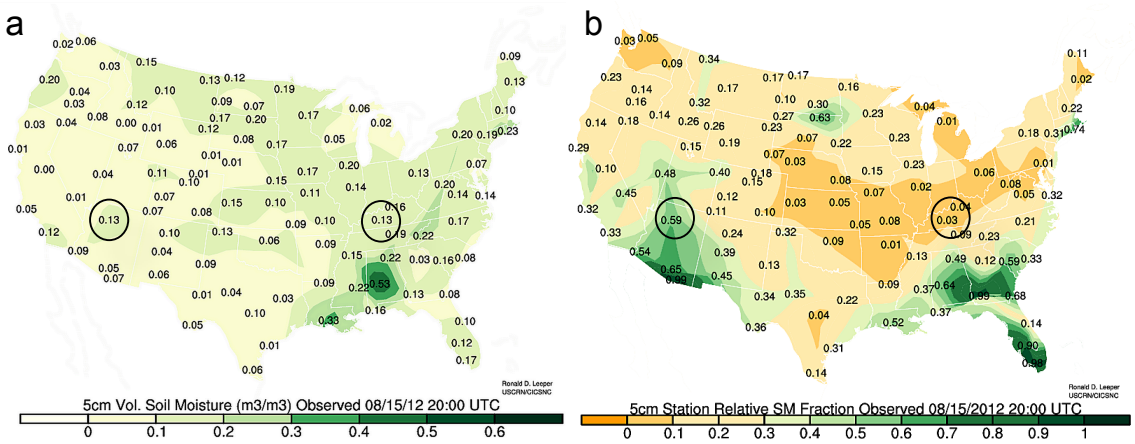


Figure 3. Contiguous U.S. USCRN observations of 5cm (a) volumetric soil moisture and (b) cdf-based station relative soil moisture fraction during the 2012 drought on Aug. 15th 2012 at 20:00 UTC. Identified (black circle) stations (eastern) Bowling Green, KY, and (western) Williams, AZ, have similar volumetric soil moisture observations that are dissimilar for their respective location and soil profiles.

PLANNED WORK

- Develop a soil moisture product based on station cumulative distribution function
- Complete USCRN and NARR comparison study

DELIVERABLES

- A National soil moisture product highlighting wet and dry conditions across the U.S.
- An overview of the North American Regional Reanalysis (NARR) simulated soil conditions for the 2012 drought.

PRESENTATIONS

- Vines C., Leeper R., and Palecki M. Evaluating the 2012 Drought using Modeled and Observed Datasets. Annual Biomedical Research Conference for Minority Students, San Antonio, TX. November 2014.
- Leeper, R. D. and Bell, J. E. Evaluating the Evolution of the California Drought and Monitoring Societal Risks with NOAA's U.S. Climate Reference Network. Annual Meeting of the American Meteorological Society, January 2015.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	3

PERFORMANCE METRICS EXPLANATION

- High School interns Charlie Pugh and Sean Feirstein (co-mentors: Jared Rennie and Carl Schreck) completed a preliminary analysis of soil moisture response to precipitation
- Chante' Vines (co-mentor Michael Palecki) was an Educational Partnership Program scholar from Morgan State University whom evaluated the evolution of the 2012 drought from modeled and observed perspectives.
- Chante' Vines presented her work at the Annual Biomedical Research Conference for Minority Students in San Antonio, TX.

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	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: A new land surface temperature Databank has been operational since June 2014, with openness and transparency as one of its highlights. This product has laid the groundwork for the next iteration of NOAA's global temperature product, which will include more stations, along with updates to its quality assurance and bias correction 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.

While there have been tremendous advances in the understanding of climate change since its release, there remain substantial spatial and temporal gaps in GHCN-M due to deficiencies in global collections of data. In addition, there has been limited success at completely documenting the provenance and implementing version control from the point measurement through dissemination and data sharing pathways, quality control, bias correction, and archive and access. To address these concerns, scientists from both CICS-NC and NOAA established the International Surface Temperature Initiative (ISTI) in 2010. In 2014, the Initiative surpassed its first major goal by releasing the first version of the Global Land Surface Databank. This Databank includes multiple stages including the original paper record (known as Stage Zero), keyed data in its native format (Stage One and Two), and a merged dataset with duplicate source data reconciled (Stage Three).

Since its initial release, the Databank Working Group has worked to provide a near-real-time update system. Each month, sources with the latest, most complete data are updated and appended to the existing stations in the Databank. A monthly update is then released to the public and then archived through a submission agreement by NOAA. These monthly updates have been used as the starting point for creating the next version of GHCN-M (version 4), which is currently underway.

ACCOMPLISHMENTS

The first version of the Databank (v1.0.0) was released on June 30th, 2014. Since then, members of the Databank Working group have been engaging with the public to use the product and provide feedback. Members of ISTI also met in Boulder, Colorado, in July 2014 to use the dataset for analysis in benchmarking, homogenization, and spatial gridding routines. After useful suggestions from both ISTI members and the public, a small update to the Databank was applied and released in August 2014 (v1.0.1.)

Because of the need to have the latest data, a near-real-time (NRT) update system was established. This NRT system looks for new data from four of the most up-to-date sources and runs through the stages of the Databank. It first pulls the data from its original location (known as Stage One), converts it to a common format defined by ISTI (Stage Two), and then appends existing data to stations that exist in the merged product (Stage Three). A map of the locations of all the stations updated each month is in Figure 1.

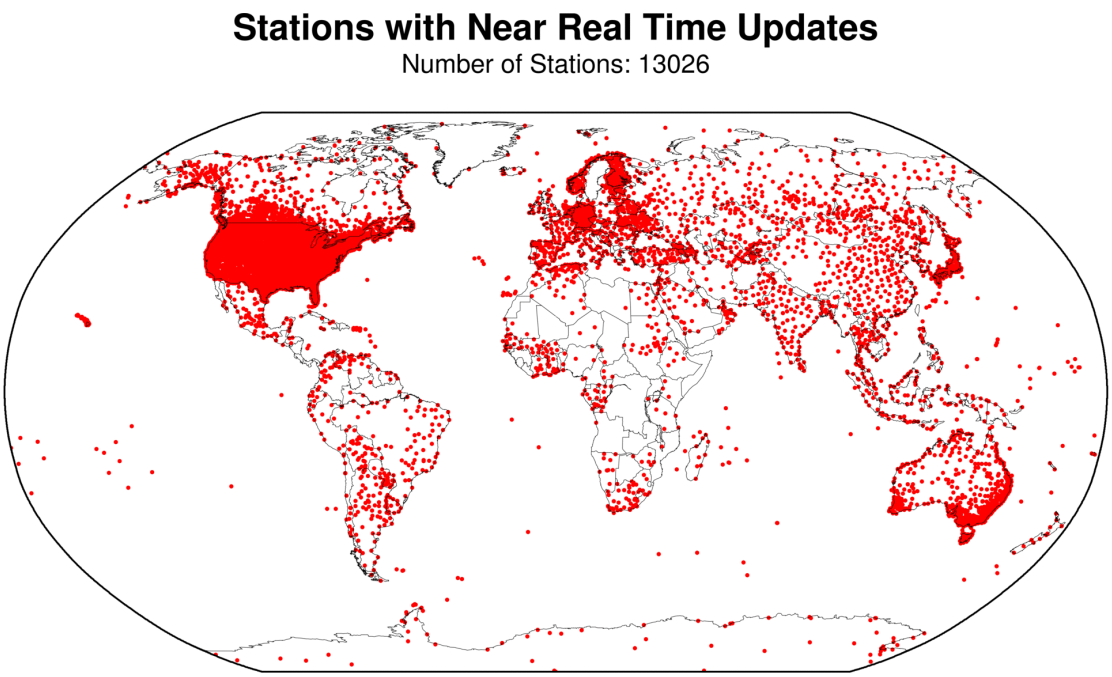


Figure 1. Location of stations that have new data each month in the ISTI Databank.

The latest version of the ISTI Databank lays the groundwork for the next version of GHCN-M. Because of this, the GHCN-M team has worked into setting up an end-to-end process on an internal development server. Once the latest Databank data are compiled in ISTI format, they are also converted into a format that is similar to the GHCN-M format. From there, it is then run through a suite of quality control algorithms, and then through the Pairwise

Homogeneity Algorithm (PHA) to remove non-climatic influences such as station moves and instrument changes. The result is an alpha version of GHCN-M (called v4.a.1). A dataflow diagram of the entre process is located in Figure 2.

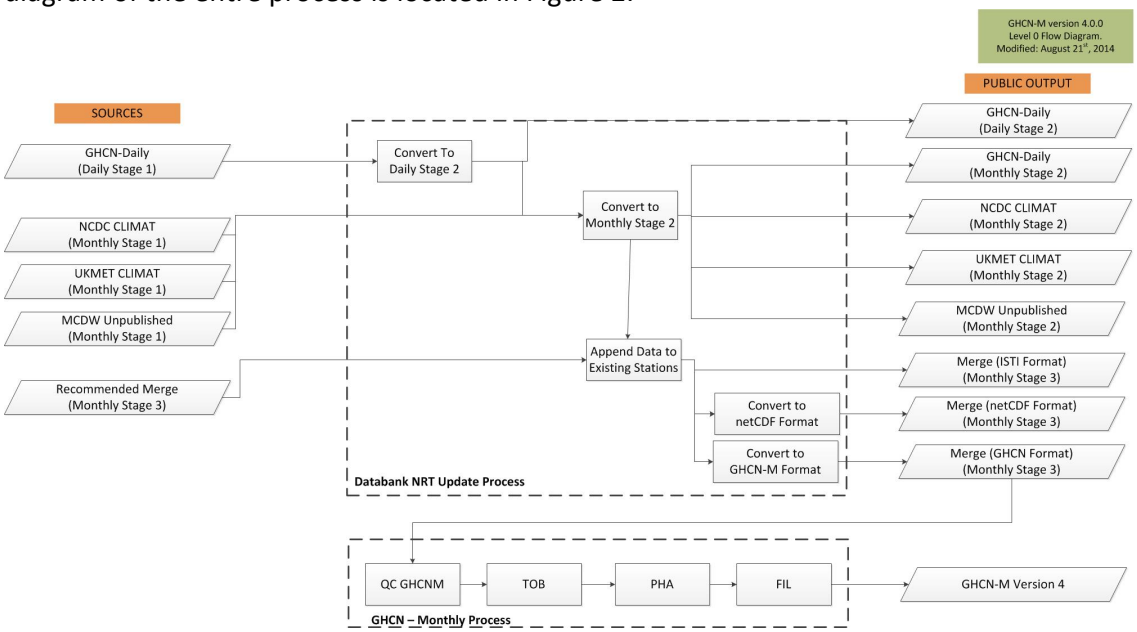


Figure 2. Level 0 Flow Diagram of the Databank near real time (NRT) update process, along with the GHCN-Monthly process, currently in alpha form.

GHCN-M v4.a.1 is run each night on the development server, and 5-degree gridboxes are generated to make comparisons with the operational product (v3.2.2). These comparisons have explained how the state of climate changes by not only increasing stations in existing gridboxes, but also adding new gridboxes, especially in the Polar Regions. An example of gridbox differences can be seen in Figure 3. These comparisons will help determine where changes will be needed in the NRT update, quality control, or PHA procedures.

PLANNED WORK

- Continue to engage with public on feedback regarding the Databank and provide updates to processing as needed.
- Continue development of GHCN-M Version 4, including updating quality control and bias correction algorithms used in GHCN-M version 3 to account for an increase in station count.
- Continue to evaluate gridbox differences between version 3 and 4, including checking for consistency with NOAA's Global Temperature Product, which includes both global land and ocean data.
- Release GHCN-M version 4 as a public beta and collaborate on writing journal article.

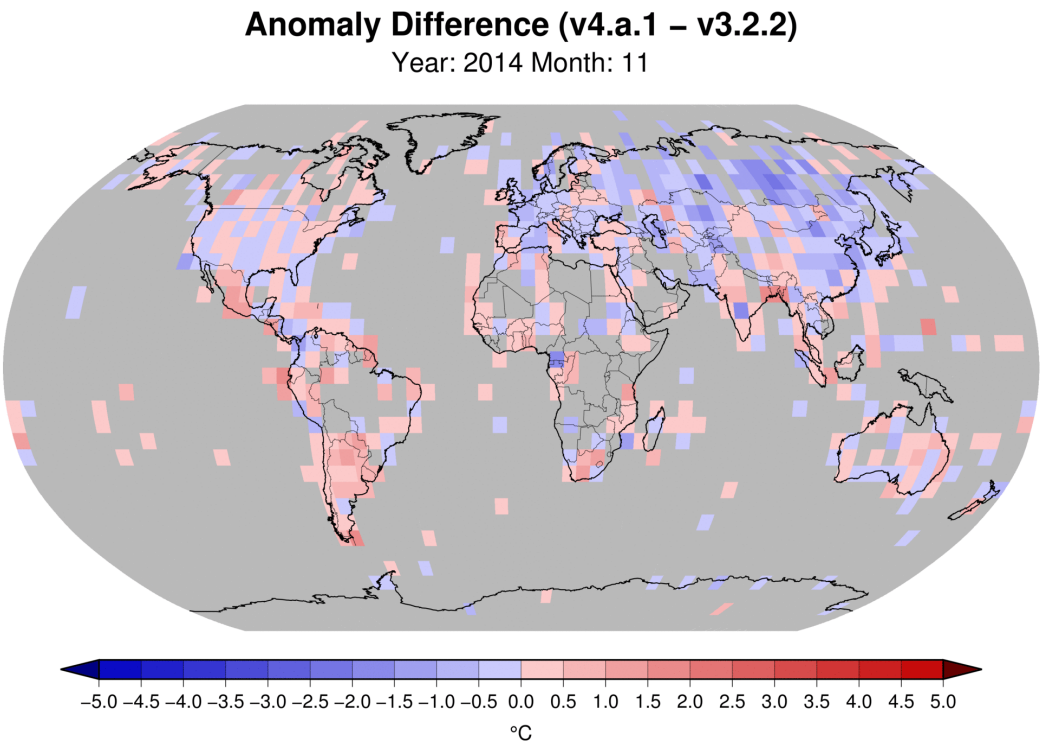


Figure 3. Difference in 5 deg gridbox anomalies for November, 2014 between the operational version of GHCN-M (v3.2.2) and the developmental version, known as v4.a.1

DELIVERABLES

- Update to ISTI Databank (v1.0.1) after addressing feedback from community.
- Created near-real-time update system of the Databank, which incorporates the latest data.
- Established end-to-end process for GHCN-M version 4, compared with operational version for consistency.

PRESENTATIONS

- Rennie, J.J. (2014) The ISTI Databank – Its construction, its formats, its metadata and its data characteristics, SAMSI IMAGe Summer Program: The International Surface Temperature Initiative, Boulder, CO, 8 Jul 2014

OTHER RELEVANT INFORMATION

- Location of latest GHCN-M version 3 dataset: http://www.ncdc.noaa.gov/ghcnm/v3.php
- The International Surface Temperature Initiative: www.surfacetemperatures.org
- FTP site of the Global Databank: http://www.gosic.org/GLOBAL_SURFACE_DATABANK/GBD.html

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	2
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

This year, we have worked on improving our ISTI Databank Product and provided updates on a monthly timescale. In addition, we have developed an alpha version of GHCN-M version 4 for internal use. These both will lead to the eventual beta and operational release of GHCN-M version 4. A presentation was given on the status of the Databank at a workshop in Boulder, CO.

Development of an Experimental Homogenized Sub-Monthly Temperature Monitoring Tool

Task Leader	Jared Rennie and Ken Kunkel
Task Code	NC-SON-08-NCICS
NOAA Sponsor	Jay Lawrimore/David Easterling
NOAA Office	NCEI/CPO
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 in house, station data is aggregated on the state, NCA region, and contiguous US levels to analyze current temperatures against its period of record. A dataset has been produced internally and has 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 solely by chance (for example, sharp changes due to synoptic conditions). Since there is a high 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. A flow chart of the process is shown in Figure 1 and an example of daily anomaly data is provided in Figure 2. 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.

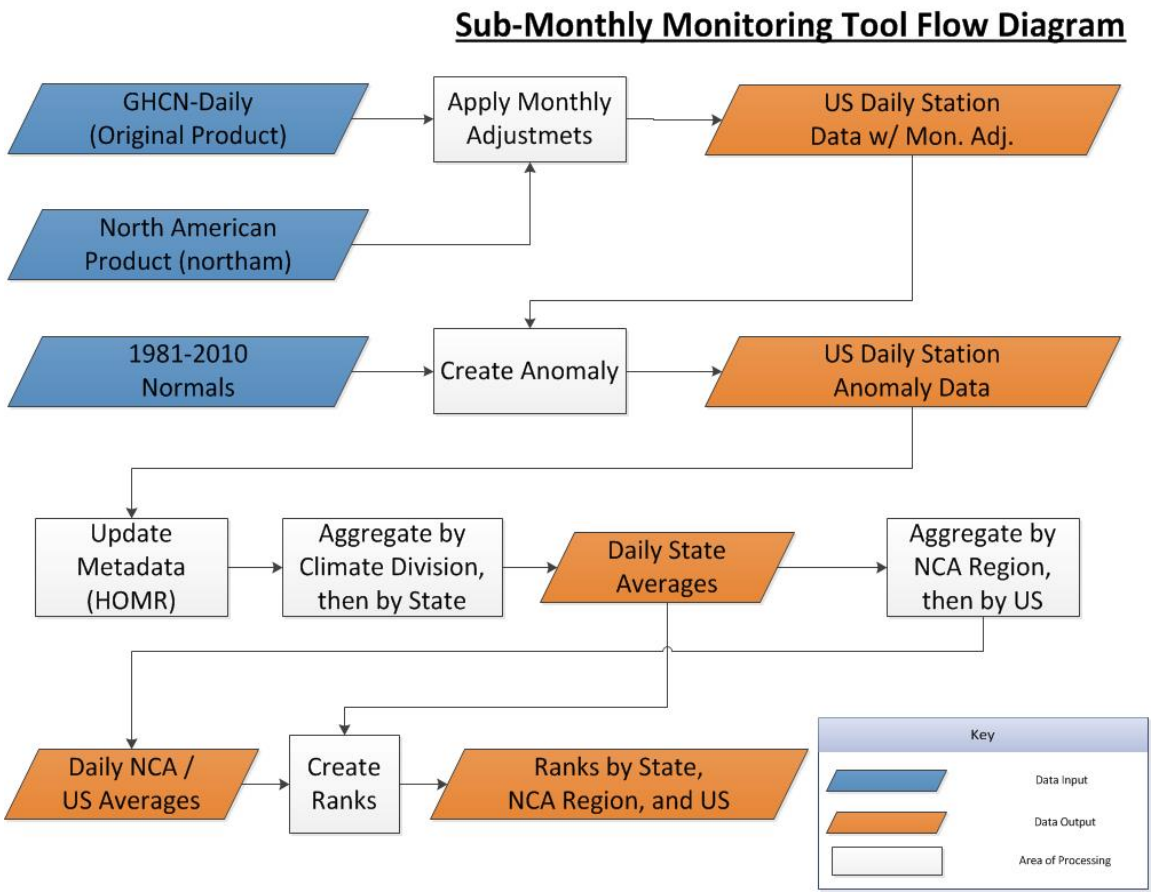


Figure 1. Data Flow Diagram of the Sub-Monthly Monitoring Tool Process. Input data is in blue and output data is in orange

PLANNED WORK

- Engage with users internal at CICS-NC and NOAA
- Include divisions in Alaska and Hawaii
- Address uncertainty parameters
- Set up nightly processing system to update and archive ranks and statistics
- Create website to display maps and ranks
- Publish journal article on processing and results

DELIVERABLES

- A new, state of the art monitoring tool for sub-monthly data for the lower 48 states

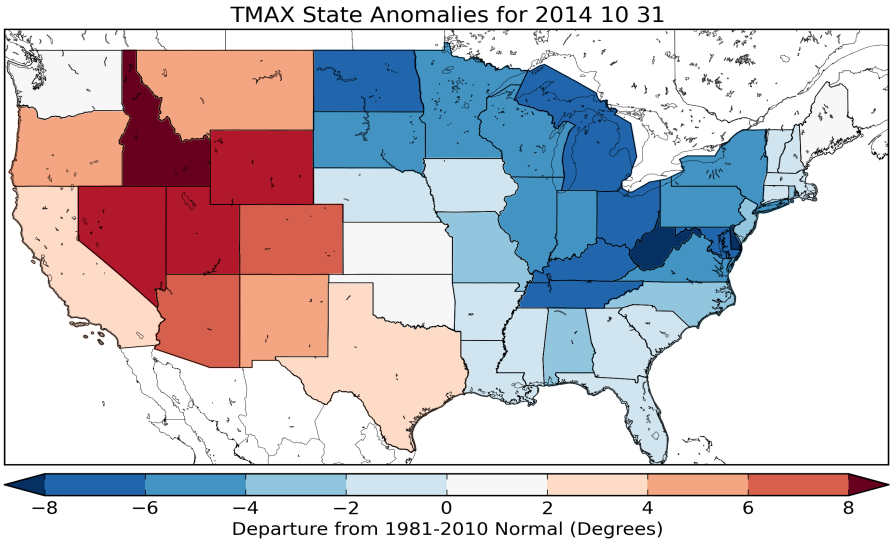


Figure 2. State Averaged Maximum Temperature Anomaly for October 31st, 2014. Anomalies are compared with the 1981-2010 Normals

PRESENTATIONS

- Rennie, J.J. (2015) Computation, Analysis and Visualization of In-Situ and Remote Sensing Data using Python, 95th Annual Meeting of the American Meteorological Society, Phoenix, AZ, 5 Jan 2015
- Rennie, J.J. (2015) Steps towards an experimental homogenized sub-monthly temperature monitoring tool, Branch Seminar, Asheville, NC, 28 Apr 2015

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	1
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

This work has been part of CICS-NC research day, and while it uses NOAA data, no NOAA people are on the team. Was invited to give poster at AMS Annual Meeting to describe processing and visualization techniques using the Python scripting language. Asked to give presentation to NOAA employees at the weekly branch seminar.

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 Science (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 departments to gain experience and exposure with their academic peers. 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 fellows working on applied research topics in Climate Data Records and Surface Observing Networks. Senior scientists from NOAA and CICS-NC provide mentoring for these fellows. 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 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.

- William Clark is an Atmospheric Sciences w/ Concentration in Weather Forecasting major at the University of North Carolina-Asheville. As an undergraduate intern, William is working closely with the Technical Support Unit and the National Climate Assessment to learn about climate modeling and gain knowledge in Python. During the reporting period, William Clark worked on two projects examining economic impacts to climate change: The first project was an inundation impact model using a Geographic Information System (GIS) in New Hanover County, NC. This model shows 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. William also supported economic research and analysis, specifically looking at U.S. Census sectors and their economic value added to the U.S. economy. This research will enable support to NCEI as they begin to redesign their engagement with various sectors.

- Kelly Gassert completed a second bachelor's degree in Atmospheric Sciences at the University of North Carolina-Asheville in May 2015. She interned with CICS-NC in the summer of 2013, working with Jenny Dissen and Dr. Kenneth Kunkel on the examination of precipitation trends throughout the Southeastern United States and throughout Brazil. She then participated in another CICS-NC internship, where she developed a project in support of the next National Climate Assessment. Under the guidance of Dr. Paula Hennon, Scott Stevens, Andrew Buddenberg, and others, she analyzed radar data, gained knowledge in Python, and continued a more detailed study of climate science.
- 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. As an undergraduate CICS-NC intern, Tiffany worked closely with the Technical Support Unit and the National Climate Assessment learning the process of climate modeling with computer applications.
- Dr. Elsa Nickl completed her Ph.D. in 2012 at the University of Delaware. In her dissertation, she analyzed the spatial and temporal patterns of annual land-surface precipitation over 100-plus years using three sets of available estimates (CRU, GPCC and University of Delaware datasets). Substantial differences among precipitation variability estimates were found, especially within mountainous regions. This encouraged her to develop a new spatial interpolation method for precipitation, which takes into account topographic influences. Her interests are climate variability and change with emphasis in mountainous regions. Dr. Nickl 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.
- Steve Stegall received his undergraduate degrees in meteorology and applied math from Metro State College of Denver and his Master of Science in atmospheric science from the University of Arizona. He recently completed his Ph.D. from North Carolina A & T State University in atmospheric science. For his dissertation, Steve analyzed surface winds in the Chukchi/Beaufort Seas and North Slope Alaska region and created a 31-year surface wind climatology as well as analysis of the Chukchi–Beaufort High-Resolution Atmospheric Reanalysis (CBHAR) dataset establishing an inverse correlation and relationship between wind speed and SST in the Chukchi/Beaufort Seas region due to strong cold air advection from wind flow off ice onto the warmer ocean water and cloud/radiation properties. Steve Stegall joined the CICS-NC team in May 2014 as a Post Doctoral Research Scholar. During this funding period, Dr. Stegall began 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 degree in Atmospheric Sciences with a concentration in Climatology and minor in mathematics at the University of North Carolina-Asheville in May 2015. As an undergraduate CICS-NC intern, he gained a greater understanding of the intersection between climate science and policy, as well as developing strategies for public outreach and engagement surrounding the

National Climate Assessment. Mr. Taylor worked with NCA lead science writer Susan Hassol and copy editor Tom Maycock on the NCA3 *Highlights* Document and contributed to the TSU's support of the USGCRP's National Climate Indicators System through his understanding of climate science and geographic information systems. In addition to his work with the National Climate Indicators, Mr. Taylor participated in several outreach and engagement efforts related to the National Climate Assessment.

GLOBAL SURFACE TEMPERATURE PORTFOLIO:
Data gap impacts on global surface temperature anomalies trends using GFDL CM3-CMIP5 model

Task Leader	Elsa Nickl
Task Code	NC-WFD-01-NCICS-EN
NOAA Sponsor	Russ Vose
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme1: 100%, Theme2: 0%, Theme3: 0%
Main CICS Research Topic:	Climate Data and Information Records and Scientific Data Stewardship
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: %; Goal 3: %; Goal 4: %; Goal 5: %

Highlight: Data gaps from US NOAA Temp/MLOST and UK HadCRUT4 were applied to NOAA GFDL CM3-CMIP5 model to analyze the impacts on temperature trends for different periods and for future scenarios. We found a decrease on surface temperature trends when data gaps are taking into account.

BACKGROUND

Despite the improvement in the observation network and in the estimations of air surface temperature in regions where observations are not available, the spatial coverage of surface temperature remains incomplete, especially in regions of complex geography (e.g., cold polar regions, mountains, deserts, rainforests).

In 2010 David Wuertz (NOAA/NCEI) analyzed the impacts of interpolation over the poles on the estimation of global surface temperature using GFDL CM2.1 model, finding little difference in trends between interpolated and non-interpolated data. Based on these results, and as part of the project plan to improve the NOAA Temp/MLOST Global Surface Temperature Dataset, Zhang et. al. analyzed in 2014 the impacts of gaps on global surface temperature trends using various datasets, finding potentially reduced warming rates during the recent decades when taking into account data gaps.

In order to complement these previous studies, we analyzed the impacts of NOAA Temp/MLOST and HadCRUT4 data gaps on global temperature trends using climate model simulations (1880-2005) and future projections (2005-2100) based on two Representative Concentration Pathways (RCP) scenarios (2.6 and 8.5) from the NOAA GFDL CM3-CMIP5 model.

ACCOMPLISHMENTS

A decrease was found in surface temperature anomalies and trends when data gaps from NOAA Temp/MLOST and HadCRUT4 are taken into account. The cooling effect caused by the data gaps is larger for the periods 1975-2000, 1997-2012, and for future scenarios (2000-2100) with RCP 8.5 (*Figures 1 and 2*).

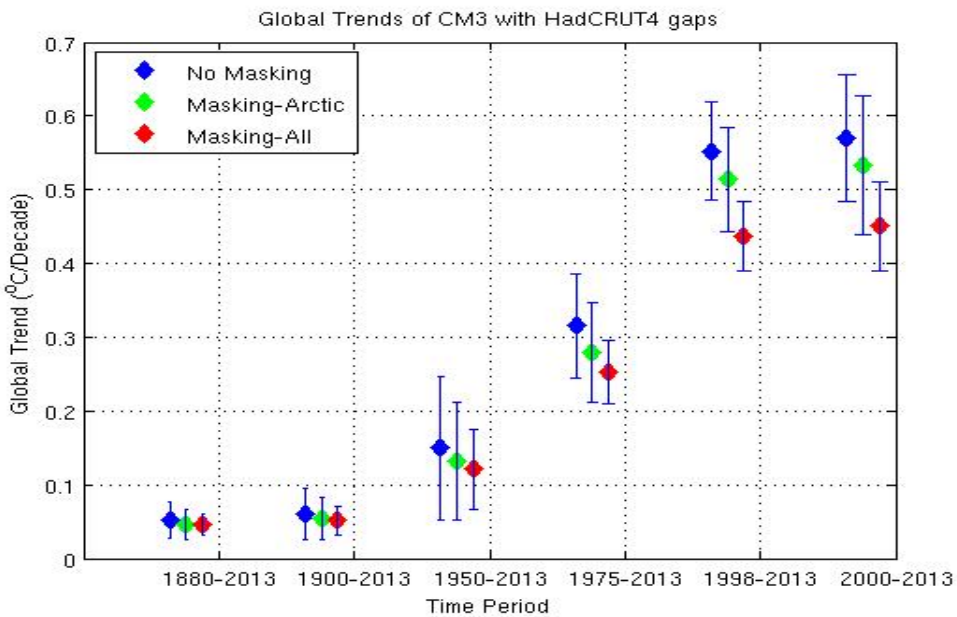


Figure 1. Surface temperature anomalies trends (^{o} C /Decade) from CM3 model (period 1880-2012) for full coverage (blue), taking into account all gaps (red) and taking into account only Arctic region gaps (green), for different periods of time.

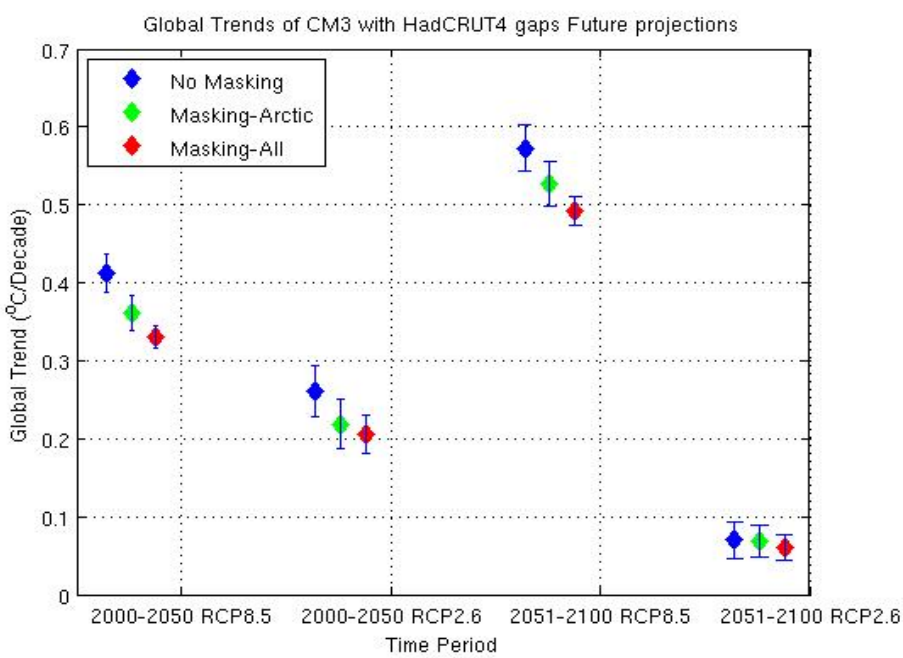


Figure 2. Surface temperature anomalies trends (^{o} C /Decade) from CM3 model (period 2000-2100) for full coverage (blue), taking into account all gaps (red) and taking into account only Arctic region gaps (green), for different periods of time and RCPs.

The impacts of data gaps from NOAA Temp/MLOST and HadCRUT4 are quite similar although the spatial distribution of gaps is different in the topics (more gaps in the tropics with HdCRUT4).

Future scenarios show an increase in trends of surface temperature anomalies for the period 200-2100 considering RCP8.5. Trends decrease when taking into account RCP 2.6 especially after the year 2050.

Trend error estimation shows values between +/-0.02 to 0.09 at 90% confidence level.

PUBLICATIONS

In preparation:

- Nickl, E., H.-M.Zhang and D. Wuertz, 2015. Data Gap Impacts on Global Surface Temperature Anomalies Trends using GFDL CM3-CMIP5
- Zhang, H.-M., D. Wuertz, E.Nickl, V.Banzon, B.Gleason, B.Huang, J.L.Lawrimore, M.Menne, P.THorne, and C.Williams, 2015. Data Gap Impacts on Global Surface Temperature Trends from Various Reconstructed Datasets

PRESENTATIONS

- Zhang, H.-M., D. Wuertz, E. Nickl, P.V. Banzon, B. Gleason, B. Huang, J.H. Lawrimore, M. Menne, J. Rennie, P. Thorne and C. Williiams: A Data Gap Analysis and efforts towards improving NOAA's Global Surface Temperature. AGU Fall Meeting, Poster Presentation (GC51D-0448), San Francisco, December 15-19, 2014.
- Nickl, E., H.M. Zhang and D. Wuertz: Data Gap Impact Analysis on Global Surface Temperature Trends using GFDL CM3-CMIP5 model. SAMSI IMAGe Summer Program: The International Surface Temperature Initiative, Poster Session, Boulder, July 8-16, 2014.
- Zhang H.M., D. Wuertz, E. Nickl, J.H. Lawrimore, M. Menne and C. Williiams: Data Gap Impacts on Global Surface Temperature Trends from Various Datasets. SAMSI IMAGe Summer Program: The International Surface Temperature Initiative, Poster Session, Boulder, July 8-16, 2014.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	2
# 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

PERFORMANCE METRICS EXPLANATION

Two journal publications on data gap impact analysis are under preparation. Three posters were presented to show preliminary and final results of data gap impact study.

GLOBAL SURFACE TEMPERATURE PORTFOLIO: Evaluation of global surface temperature methods

Task Leader	Elsa Nickl
Task Code	NC-WFD-02-NCICS-EN
NOAA Sponsor	Russ Vose
NOAA Office	NCEI
Contribution to CICS Themes (%)	Theme1: 0%, Theme2: 100%, Theme3: 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 evaluate the strengths and limitations of the best-known existing global surface temperature datasets (NOAA Temp/MLOST, UK HadCRUT4, NASA GISTEMP, University of York, and Berkeley BEST).

BACKGROUND

One of the principal tasks included in the Project Plan for the Improvement of NOAA Temp/MLOST Surface Temperature dataset is the assessment and benchmark of various product generation methods. Previous research (Zhang et al. and Nickl et. al. in 2014) shows the importance of addressing data gaps in order to enhance the estimation of surface temperature trends.

Some researchers started to evaluate interpolation methods for regional areas (Dodd et al., 2015 and Hofstra et al., 2008) and for specific methods (Rhode, 2013 and Cowtan and way, 2014).

This task aims to assess the strengths and limitations of the interpolation methods used for NOAATemp, UKHadCRUT4, NASA GISTEMP, University of York, and BEST Berkeley using ERA Interim as a benchmark dataset for recent decades and the GFDL CM3 model as benchmark dataset for historical analysis (the use of this model is still under discussion).

ACCOMPLISHMENTS

As a first stage of the research, we compared the temporal and spatial variability of global surface temperature trends for different datasets and identified the regions and periods of discrepancies. Trend maps for periods 1880-2013, 1901-2000, 1950-2000, 1975-2000, and 1997-2012 were performed using monthly surface temperature. The principal regions of discrepancies identified are the west part of Arctic region (Alaska, Greenland), South America (Andes and Amazon Basin), Africa (Western and South Africa), western Antarctica, and East Asia (*Figure 1*).

ERA Interim monthly anomalies were estimated based on a 10-year climatology (1990-99) for the period 1979-2014. ERA Interim data will be used as input anomalies, treated as if they were meteorological station data. During the last two months, the temperature team

has been discussing the enhancement of NOAATemp MLOST estimation over the poles and we decided to focus the evaluation on this dataset.

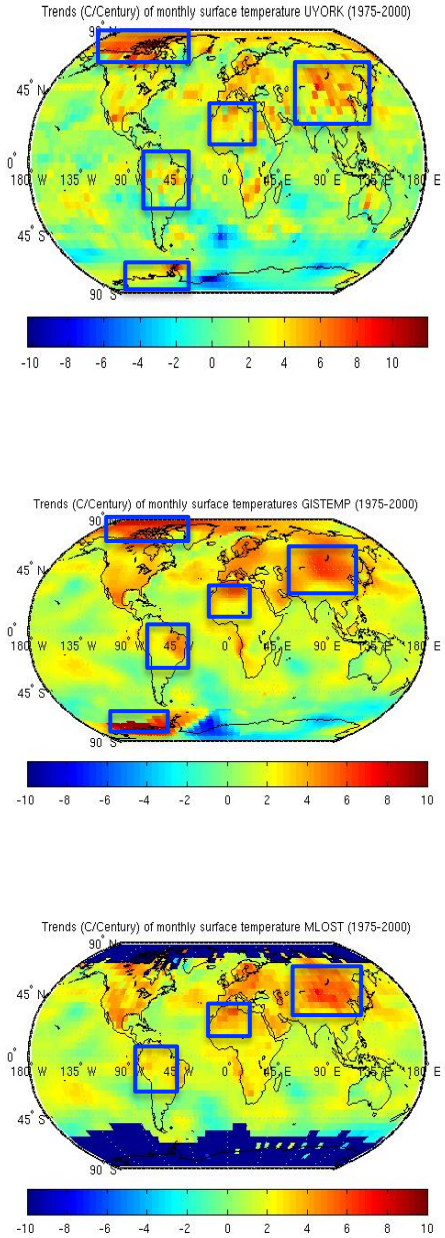


Figure 1. Trends (^{o} C /Century) of monthly surface temperature from University of York, GISTEMP, and NOAATemp/MLOST datasets for the period 1975-2000. Boxes show differences.

The NOAA Temp/MLOST method takes into account sea surface temperature (SST) and ice in addition to land surface temperature (LST) observations, as well as the use of modes for

both SST and LST high-frequency analysis trough Empirical Orthogonal Teleconnections (EOT). In order to evaluate the possibility that ERA Interim could be used as an input for NOAA Temp/MLOST evaluation, the first step of the process is to estimate EOTs for ERA Interim and compare the modes with EOTs for gridded LST from GHCN (applying Optimum Interpolation).

ERA Interim anomalies were estimated at 5 degrees resolution (to match NOAA Temp/MLOST grids) and EOTs (42 modes) were estimated using the period 1982-2014. As EOTs from gridded GHCN are being estimated, ERA Interim EOTs are compared with MLOST EOTs. It has been found that Mode 4 and Mode 7 from NOAA Temp MLOST are similar to Mode1 and Mode 4 from ERA Interim and (*Figure 2*).

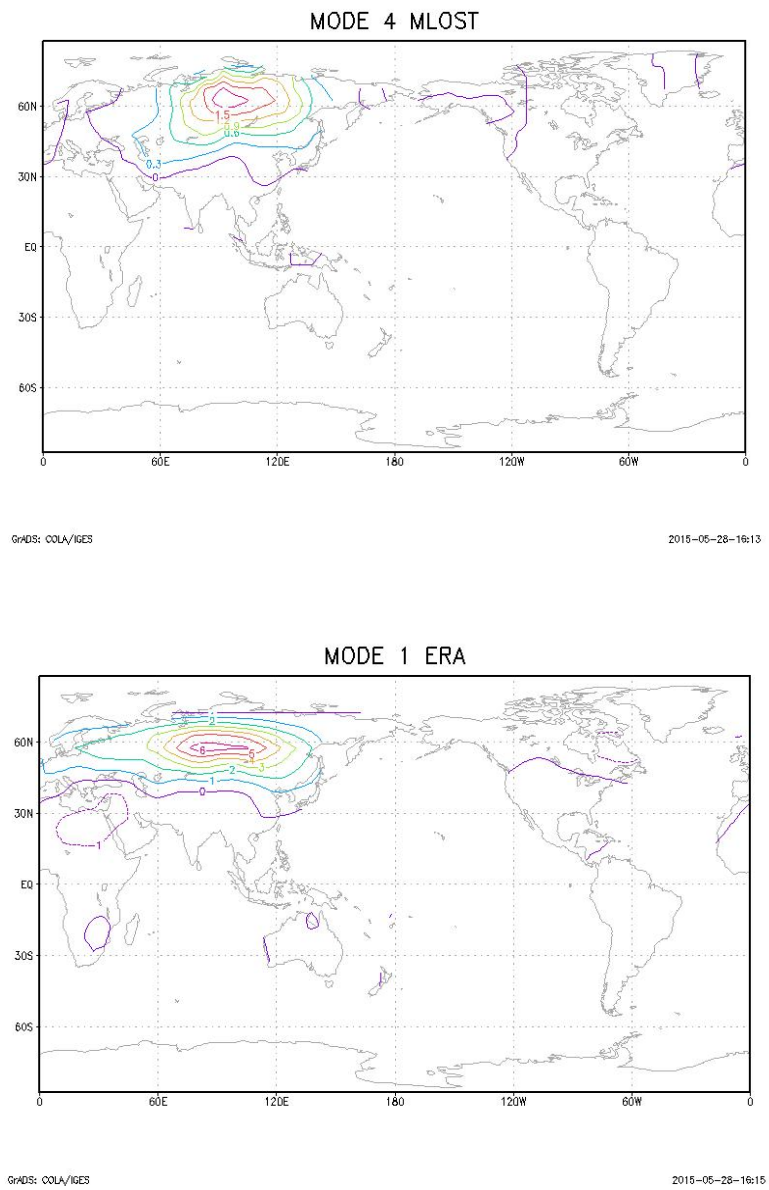


Figure 2. Mode 4 from Noaa Temp/MLOST and Mode 1 from ERA show similar patterns

PLANNED WORK

- Estimate errors using ERA Interim as a dataset benchmark
- Prepare a journal article based on results

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

The task is in process and we plan to prepare a journal article when we have results from the methods evaluation.

Estimation of land surface precipitation for contiguous U.S. using a new spatial interpolation method

Task Leader	Elsa Nickl
Task Code	NC-WFD-03-NCICS-EN
NOAA Sponsor	Russ Vose
NOAA Office	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: A new spatial interpolation method that takes topography into account is applied to estimate monthly land surface temperatures for the United States and compared with NOAA/NCEI and PRISM estimated precipitation fields.

BACKGROUND

In 2012, Nickl presented a new spatial interpolation method of land surface precipitation estimation. The method was developed during her PhD program with the contribution of her advisor Cort Willmott. The 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. Adjustable-scale ellipses with different orientations and sizes are used for estimating orographic scales (resolution of topography at which the relationship with precipitation is optimal). These ellipse allow better capturing of the topographic patterns associated with precipitation (e.g., the area exposed to winds). The method was tested for the area of San Joaquin Valley (Western U.S.) producing lower errors when compared to traditional interpolation.

In order to tune and test the method for a larger area, it is applied to the contiguous U.S. region and compared with NOAA/NCEI and PRISM datasets to evaluate the possibility of using some aspects of new methodology in the gridding process of the NOAA/NCEI land surface precipitation.

ACCOMPLISHMENTS

In the initial stage of the research some differences were found when comparing monthly precipitation from NOSS/NCEI and PRISM for period 1895-2012 and taking into account elevations greater than 500m. The differences were found after the 1950s when analyzing the spatial means and upper geographic percentiles.

Correlations between precipitation errors and topographic variables show moderate to high values in most of the stations within the mountains regions (Figure 1). 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. These correlation values remain moderate and high when analyzing climatologies, specific months, specific days, and lower station densities.

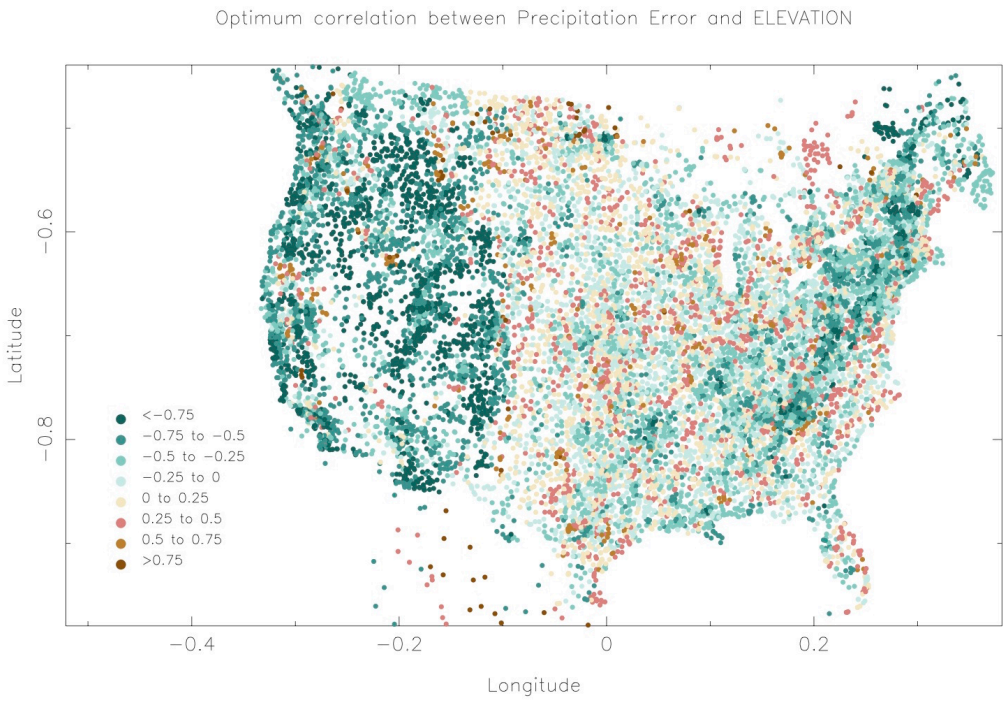


Figure 1. Optimum correlations (best correlation selected at each point from eight orographic scales) between precipitation errors and elevation.

For high and moderate density of stations (14,000 and 4,000 stations) and climatologies, the interpolator performs well and the spatial patterns are similar to NOAA/NCEI maps, with most differences in mountainous regions (Figure 2). When testing for lower station densities (200 stations) and daily data (lots of zero-value precipitation observations) there is a problem of sensitivity of parameters when applying the MLR, causing extreme low and high values.

Crossvalidation was applied for the different periods of time for both traditional and new interpolator, and it was found that for climatologies (JFM, AMJ, JAS, OND) the errors decrease in many stations of the mountainous regions when applying the spatial interpolation method.

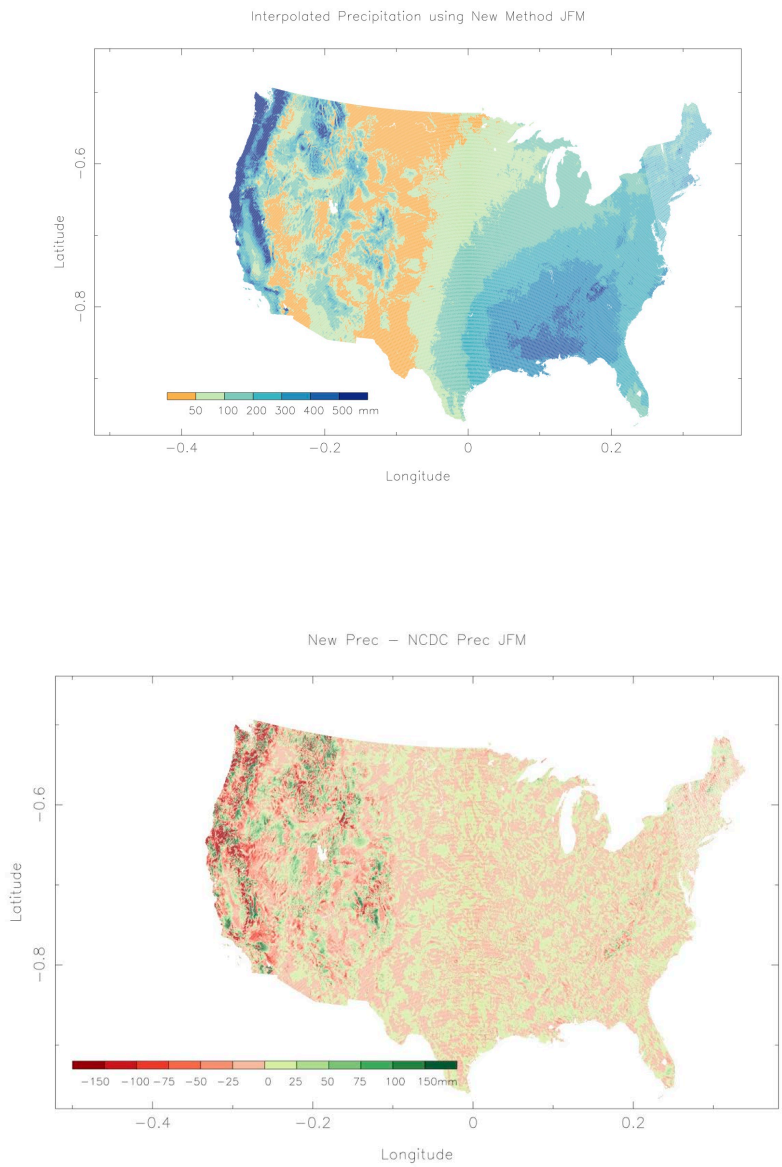


Figure 2. Estimated precipitation for JFM climatology (1981-2010) using new interpolator and differences between new estimates and NOAA/NCEI

In addition to the method application, Nickl interacted with Oliver Prat (CICS-NC) in order to exchange ideas and information. Topographic variables at different orographic scales were estimated for Prat's research station network in order to do bias analysis. He found interesting bias associations between radar and surface observations and topography (eastern/western orientation). Some of these results were presented in a poster session at AGU 2014. Nickl and Prat are considering an article about the application of this topographic information at global scale.

PLANNED WORK

- Prepare an article about the results found
- Evaluate possibility of writing and article with Olivier Prat about relationship of bias between radar and surface observations and topographic variables at global scale.

DELIVERABLES

- Topographic dataset generation at different orographic scales for US and global using an adjustable-scale ellipse
- Estimation of land surface precipitation using a new spatial interpolator method

PRESENTATIONS

- Nickl, E., C. Willmott, and R. Vose. Estimation of land surface precipitation using a new spatial interpolator method. Peruvian Geophysical Institute, Lima, February 18, 2015
- Prat, O.P., B.R. Nelson, S.E. Stevens, D.J. Seo, B. Kim, and E. Nickl. Long-term large-scale bias adjusted precipitation estimates at high spatial and temporal resolution derived from the national mosaic and multi-sensor QPE (NMQ/Q2) precipitation reanalysis over CONUS. AGU Fall Meeting, Poster Presentation (GC51D-0448), San Francisco, December 15-19, 2014

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	1
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

The new spatial interpolator method developed during my dissertation was used to estimate new precipitation fields taking into account topographic variables.

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 and global reanalysis datasets (ERA-40, ERA-Interim, MERRA, and NCEP/NCRA). Results show that the bias and RMSE are low when compared to USCRN, especially for nighttime temperatures.

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 sources of surface temperature data 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 or each USCRN station for each day from 2009 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, bias schemes can be derived and applied to the HIRS data, and improvements made to the quality of the HIRS surface temperature.

The above is 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 NRA) that are downscaled to 0.5° lat/lon and interpolated to hourly output from 1979-2009 (Wang and Zhang, 2013). This will provide bias and RMSE on a long-term global scale for all HIRS satellites from 1979-2009. Also, interannual variability and teleconnections will be analyzed with the surface temperatures as well as the bias and RMSE.

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 United States vs. the eastern United States. This is most likely due to the heterogeneous topography and land

surface types in the western United States vs. the more homogenous land surface types and topography in the Eastern United States. Further investigation is currently being conducted with HIRS skin temperature data.

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 (figure 1), the results show good performance for each. Both satellites show similar bias and RMSE for both the day and nighttime with -0.5°C and 2.25°C respectively (figure 1a and 1b). 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 (figure 1c and 1d). Both daytime and nighttime standard deviations of the respective HIRS and USCRN temperatures show very similar results (figure 1e and 1f). Overall the HIRS daytime and nighttime temperatures perform well vs. the USCRN temperatures, with higher bias and RMSE for the daytime temperatures. For the M02 satellite daytime temperatures, the bias increases slightly from 2.25°C to 2.5°C from 2009 to 2013. Similarly, the RMSE for the M02 increases from 4.0°C to ~5.2°C from 2009 to 2013.

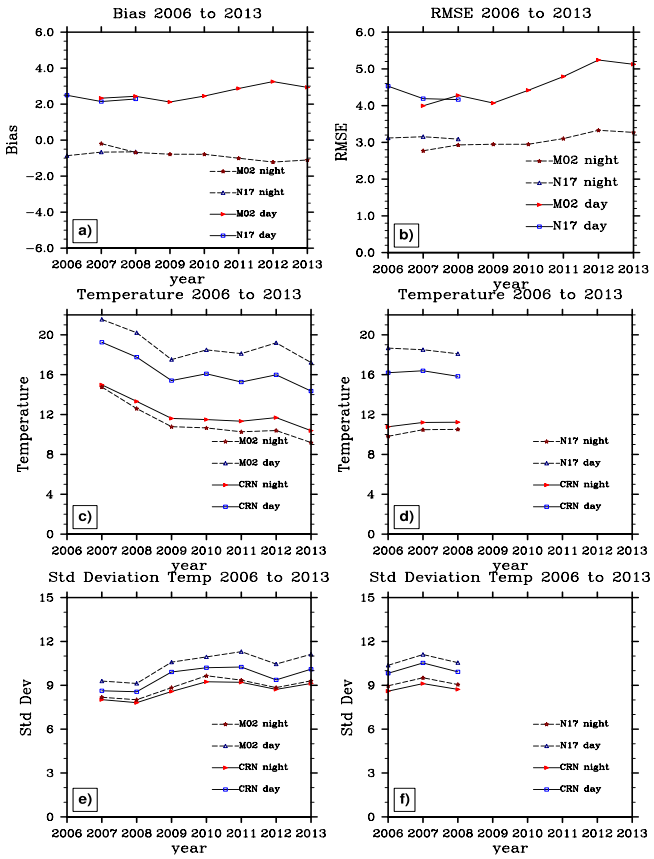


Figure 1. Annual bias and RMSE (both day and night) of HIRS M02 and N17 satellites surface temperatures. Each year represents the average bias and RMSE of the stations. Bias is

defined here as USCRN minus HIRS. Annual temperature (both day and night) of M02 and N17 and the associated collocated CRN temperatures. Also included are the annual standard deviation of the temperatures (both day and night) of the M02 and N17 temperatures and associated collocated standard deviation of CRN temperatures.

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. The collocation is parallelized for efficiency. The results are preliminary but give a very clear global view of bias between HIRS and each of the datasets. For most of Eurasia including Greenland and North Africa there is negative bias. Most positive bias occurs over the western U.S., Mexico, and Central America and also includes Western and Southern South America and Eastern Australia. Also, the lowest number of collocations for 2009 occurs over the Amazon and African rainforest as well as Southeast Asia and Malaysia. The results are very similar for all three datasets for 2009.

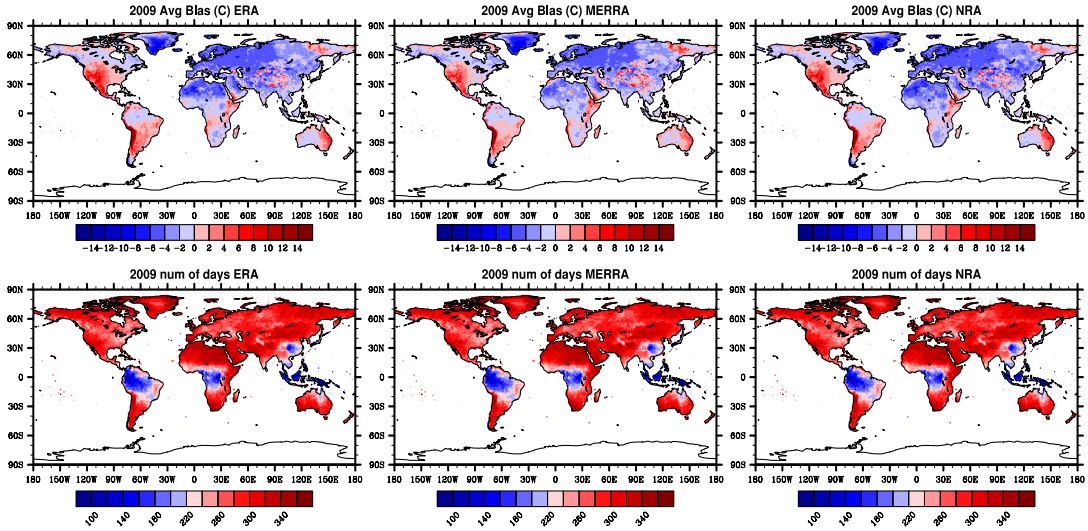


Figure 2. 2009 average bias of HIRS surface temperatures collocated to ERA-interim, MERRA, and NRA land surface datasets. Included is the number of collocations for 2009 of HIRS surface temperatures to each dataset.

PLANNED WORK

- Write and publish research in a peer-reviewed journal.
- Continue to collocate and analyze data both on the global scale and with USCRN.
- Produce similar HIRS collocation on global scale with surface temperature over ocean.
- Using HIRS skin temperature, investigate the higher bias and RMSE in the western U.S. vs. the Eastern U.S.
- Expand the land surface HIRS collocation to cover the period of 1979-2009.

- Collaborate and publish research in a pee-reviewed journal with the Arctic Surface Flux Evaluation project.

PRESENTATIONS

- Stegall, S., L. Shi, and H. Zhang, 2014: Assessment of High Resolution Infrared Radiation Sounder (HIRS) Satellite Air Temperature Data to with U.S. Climate Reference Network (USCRN) Station Air Temperature Data, *American Geophysical Union, Fall Meeting*, 15-19 December, 2014, San Francisco, California.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

Other CICS PI Projects

In addition to NCEI support tasks, CICS-NC scientists participate in other sponsored research programs awarded through competitive proposal solicitations. CICS-NC scientists have submitted individual and collaborative climate science proposals through NCSU to federal solicitations from NASA, NSF, NOAA, DOE, and DOD and to various other non-federal entities.

Trends in Extra-tropical Cyclone and Blocking High Occurrence

Task Leader	Kenneth Kunkel
Task Code	NC-OTH-01-NCICS-KK
NOAA Sponsor	David Easterling
NOAA Office	NCEI/CPO
Contribution to CICS Themes (%)	Theme 1: 0%; Theme 2: 0%; Theme 3: 100%.
Main CICS Research Topic	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Analysis of uncertainties in extra-tropical cyclone (ETC) occurrence have identified periods when the analyzed temporal variations can be considered reliable, including 1891-present for mid-latitude land areas and the North Atlantic, 1921-present for the North Pacific, and 1931-present for high latitude land areas. Analysis of blocking high frequency points to a similar early period high bias.

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 that, 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 equatorward in the cold season. For certain types of extreme weather, most notably heat waves and droughts, a phenomenon know 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 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 1871-2011. We have also performed a preliminary analysis of blocking high occurrence, including long-term trends.

ACCOMPLISHMENTS

Previous work found some notable trends in ETC activity. From 1871 to 2010, statistically significant trends in high latitude ETC activity were found in the Pacific sector (downward) and in the Europe and Asia sectors (upward). Upward, statistically significant trends were found for all mid-latitude sectors (bottom panels). These results imply a substantial equator-ward shift over the North American and Pacific sectors. The main focus of the ETC effort this year was to address issues of uncertainty. Specifically, how robust are these observed trends in the context of changes over time in the availability of pressure observations to drive the reanalysis model.

The availability of a 56-ensemble set of reanalysis output provides an opportunity to quantify the uncertainties. To further explore the spatial dependence of uncertainty, the grid point variability was quantified as the standard deviation of monthly mean pressure among ensemble members. The variability values were aggregated to the regional level by averaging the grid points in each sector weighted by the cosine of the latitude. The temporal variations in the regional averages are shown in Fig. 1a. Variability values are very low for all of the regions after 1950. Going back in time from 1950, levels rise in all regions. However, the values are rather low for all of the mid-latitude sectors, except for the Pacific, back to the late 19th Century. For the Pacific, the 1940s rise is obvious. Also, a rapid rise in variability back in time from 1950 is seen for the high-latitude sectors of North America and the Pacific. This uncertainty was examined in a different way by determining "consensus" tracks. If tracks in two or more different ensemble members were within 200 km of each other for at least one time during the duration of the track, they were considered a single common track, and counted as just one track. If there were no uncertainty in determination of the tracks, then a track in one ensemble member would be duplicated exactly in time and space in each of the other 55 members and counted as a single track. Linkages were determined for all tracks across all 56 members. The number of individual tracks was then counted for each year. Time series of these counts for each sector are shown in Fig. 1b. The number of ETC tracks is higher earlier in the record for all sectors. This is most notable for the mid-latitude Pacific. Early in the record, there are many tracks that do not link with tracks in the other members. The reduction of ETC counts over time reflects increasing consensus (decreasing uncertainty) in track location.

These results reinforce some of our tentative conclusions and cast doubt on others. For the Pacific, the peak in uncertainty in the early 1940s correlates exactly with a peak in the number of ETCs, strongly suggesting that this peak is not real. This appears to confirm the model tendency to produce an excess of ETCs in the absence of constraining surface pressure observations. Thus, the high number of Pacific ETCs in the late 19th and early 20th Centuries cannot be considered reliable. However, the mid-latitude Pacific upward trend from about 1930 to the 1970s followed by a decline to present should be reliable based on the low surface pressure uncertainty during this time period (Fig. 1). For North America, the mid-latitude upward trend from the early 20th Century to mid-Century followed by a decline also should be reliable based on low surface pressure uncertainty. However, the high latitude behavior of increases in the late 19th Century followed by decreases in the early 20th Century should be viewed as uncertain based on very high surface pressure uncertainty. For Europe, the mid-latitude surface pressure uncertainty is low through the entire period of

record and the corresponding ETC temporal variations should be reliable. The high latitude increase in the very early part of the record corresponds with higher uncertainty and thus is not reliable. For Asia, the surface pressure uncertainty is moderately high in the late 19th Century, casting some doubt on the overall slight upward trends.

Our tentative overall conclusion that since 1871 ETC activity has increased and shifted equatorward in the Northern Hemisphere requires revision. The high level of surface pressure uncertainty in the late 19th and early 20th Centuries in some sectors suggests that conclusions about trends for the entire North Hemisphere can only be made for a shorter period, perhaps around 1930 onward for high latitudes and 1910 onward for mid latitudes. In that context, there appears to be a robust upward trend in ETC numbers but little evidence of any shift in latitude.

Preliminary analysis of the frequency of blocking highs (*Fig. 2*) suggests a similar bias in the early number of such events. There is a substantial downward trend from 1871 to the early part of the 20th Century. While it may be premature to dismiss a real downward trend, the high uncertainties in surface pressure point to an artificial influence.

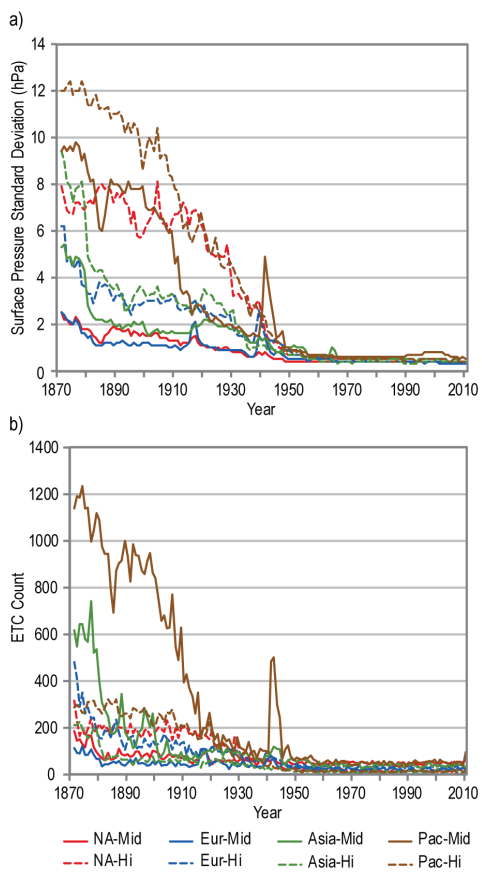


Figure 1. Time series of two metrics of uncertainty: a) the sector average grid point standard deviation of monthly surface pressure for eight different regions; and b) the number of independent ETC tracks counted over all 56 ensemble members for the eight regions.

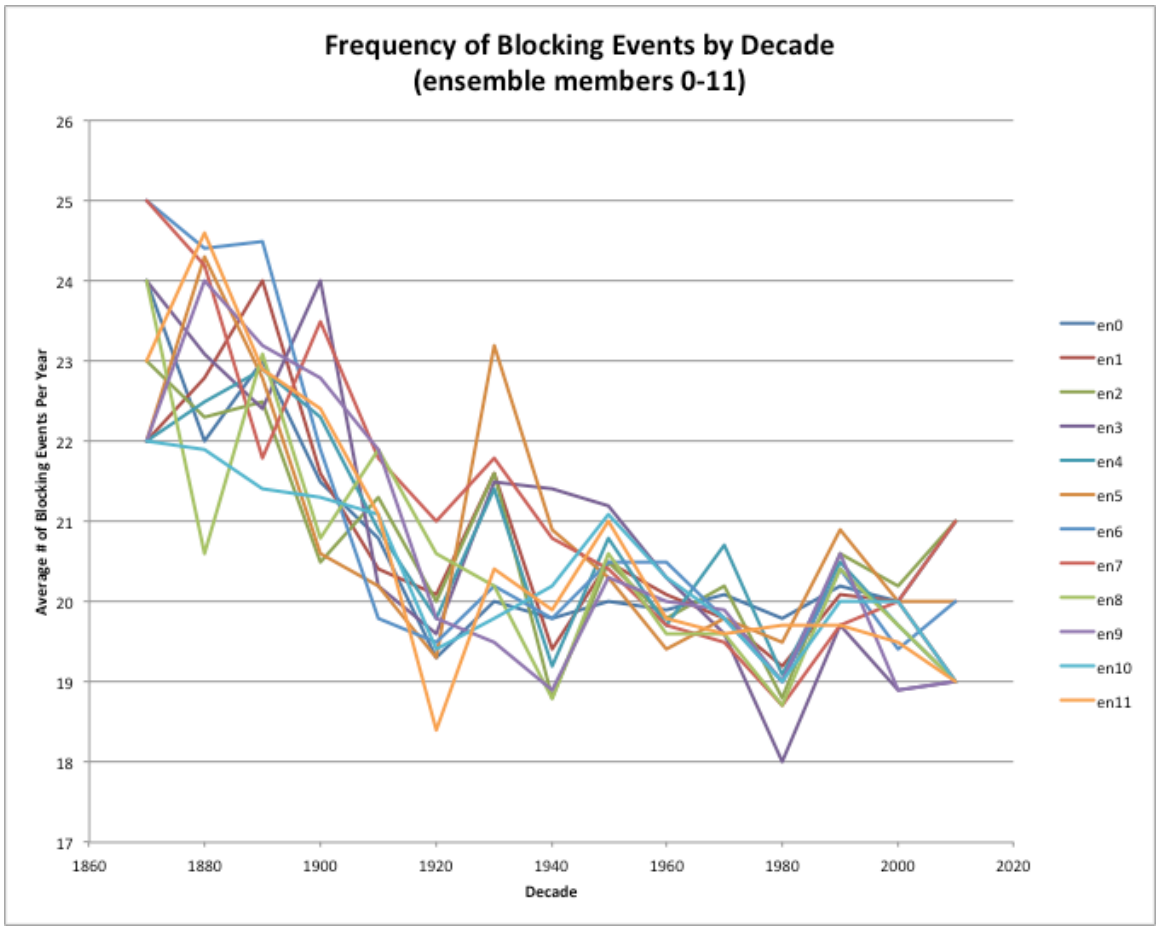


Figure 2. This graph shows preliminary results of the frequency of blocking highs from the first 12 ensemble members of the 20CR dataset. All ensemble members show an overall decreasing trend in the number of blocking high events over the period of record (1875-2011).

PLANNED WORK

- Update the ETC analysis to include a newly-released version of the 20CR
- Complete and submit a paper on reliable periods of ETC trends
- Complete analysis of blocking highs in the 20CR
- Apply the ETC and blocking high algorithms to CMIP5 simulations

DELIVERABLES

- Completion of uncertainty analysis of ETCs
- Completion of basic analysis of blocking high frequency and trends

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	1
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

PERFORMANCE METRICS EXPLANATION

A new blocking high dataset has been generated from the 20CR.

Research Dealing with the Impacts of Climate on Health

Task Leader	Jesse E. Bell
Task Code	NC-OTH-02-NCICS-JB
Other Sponsor	CDC/NCEI
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%

Highlights: This report illustrates the collaboration and interaction with the CDC's Climate and Health Program. The goal of this interaction is to increase the understanding of the effects of climate change 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 will likely have increased impacts 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 (CDC) has dedicated time and resources to addressing the issues that will arise from global climate change. The CDC has formed the Climate and Health Program to focus solely on preparing for climate change and the impacts on the health of U.S. residents. Besides leading climate and health research, the Climate and Health Program is responsible for providing funding to state and city health departments to prepare for the adverse effects of climate change.

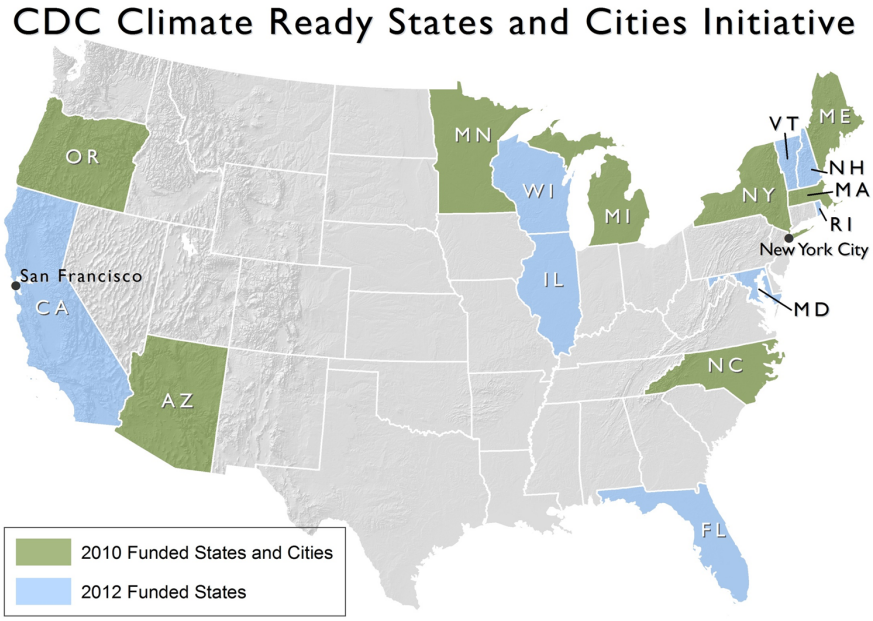


Figure 1. List of states and cities being funded by CDC's Climate-Ready States and Cities Initiative.

ACCOMPLISHMENTS

In order to develop projects dealing with climate and health, Jesse E. Bell has extended his role in the Climate and Health Program (located in CDC's National Center for Environmental

Health) as a Climate Science Advisor. His role is to serve has a conduit to between climate observations from NOAA and 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 and has helped CDC gain access to National Climate Assessment climate change projections and NIDIS drought data for the National Environmental Health Tracking Network.

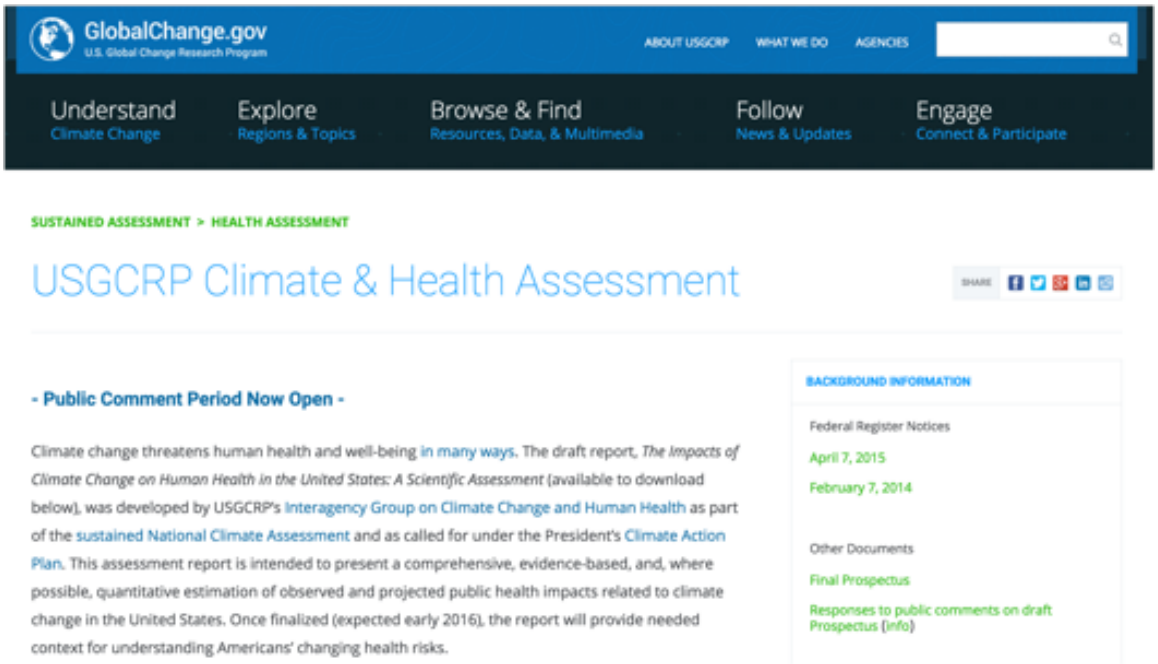


Figure 2. Webpage for public comments of the USGCRP Climate and Health Assessment.

Dr. Bell was also a lead author of the extremes chapter of the USGCRP Climate and Health Assessment. His chapter evaluated the impacts of extreme events on human health. The draft report assessed: 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; 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 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.

PLANNED WORK

- Finish student projects and submit for publication.

- Lead and complete the USGCRP – Interim Report on Climate and Health chapter on Extremes and Human Health.
- Continue to serve as a mentor to MPH students at Emory University.
- Continue to develop CICS connections to health community.

PRESENTATIONS

- Bell, J.E. The Health Consequences of a Changing Climate. 2014 Second S-NPP Applications Workshop, Huntsville, AL. November 2014.
- Bell, J.E. NOAA Climate Data Sources for Health. 2014 Water and Health Conference, Raleigh, NC. October 2014.
- Bell, J.E. Intersection of Climate and Health. Invited talk at the AMS Asheville Chapter, Asheville, NC. September 2014.

OTHER

Dr. Bell, through his Adjunct Professor Position in the Rollins School of Public Health at Emory University, has mentored and graduated four Masters of Public Health students that are interested in working on topics dealing with climate and health.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	4
# of undergraduate students mentored during the year	0

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	National Climate Assessments
Contribution to NOAA Goals (%)	Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0%

Highlight: Model simulations from the CMIP5 hindcast experiment were found to generally reproduce observed regional trends in the number of monthly temperature extremes for the period 1981-2010.

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 six 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 multimodel 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 hydroclimatic and hydro-ecological system dynamics with the management of water infrastructure systems, a two-level agent-based modeling framework will explicitly simulate adaptive behaviors and feedbacks between policy and consumers.

This interdisciplinary project involves collaboration between three universities, North Carolina State University (NCSU), Arizona State University (ASU), and Florida International University (FIU). Findings from the CMIP5 retro-analyses will evaluate and recommend societal options (i.e. supply augmentation vs. demand reduction) for promoting future (2015-2034) freshwater sustainability across the Sunbelt. Cross-regional synthesis of policies

and media sources for the targeted basins will identify de/centralized adaptive strategies that have been employed independently and collectively to maintain flows, increase supplies, or reduce demands. Utilizing the near-term hydroclimatic projections, we will quantify how current policies on reservoir operations and groundwater extraction could impact the reliability of future water supplies for cities and also alter the key attributes of hydrographs that are critical for maintaining freshwater biodiversity. In doing so, the project will also investigate the degree to which regions have pursued 'hard path' (i.e. supply augmentation) vs. 'soft path' (i.e. demand reduction) strategies by explicitly modeling potential societal interventions for water sustainability.

ACCOMPLISHMENTS

The major objective for this period was to perform an analysis of trends in monthly extremes. Monthly temperature and precipitation data for thirteen models from the CMIP5 30-yr hindcast experiment for 1980-2010 were used. Most of these models have more than one ensemble member. The total number of ensemble members for these thirteen models was 75. An extreme index was constructed by calculating standardized monthly anomalies of temperature and precipitation for the observations and models for individual grid points. This index is then divided into two parts: a positive index for values that are $>+1.5\sigma$ (σ is the standard deviation of the standardized monthly anomalies) and a negative index for values that are $<-1.5\sigma$. The index is then aggregated into six regions of the United States: the Southeast, Southwest, Northeast, Northwest, 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

Figure 1 shows the positive (warm) number of extreme temperature events for the 1981 to 2010 time period for each region. With the exception of the NW, each of the regions show increasing trends for both the observations and the model mean. The NE shows almost identical trends for the observations and the model mean. The NW region indicates a decreasing observed trend with the model mean showing an increasing trend. Clearly in each plot in Fig. 1, the observations show much more interannual variability than the model mean, mainly due to the averaging of the 77 ensemble members in calculating the model mean, which will dampen the variability. The correlations of the observed series with the model means are low for all regions, except the NE region, which has a correlation of 0.41. Thus the trends of the observations and model means of extreme temperature (positive, i.e. extreme high) show good agreement, except the NW; however the interannual variability is not in good agreement. A good example is the large number of observed positive extreme temperatures for 1998 is the GP and MW, probably coinciding with the strong 1997-1998 El Nino. Notice the failure of the model mean to capture this large number of extreme events for the same year and regions. But that is attributable to the nature of the models; there is no expectation that a coupled (ocean-atmosphere) climate model would reproduce the timing of El Nino events.

Figure 2 is the number of negative (cold) extreme temperature events. Unlike Fig. 1, there is good agreement for the trends for all the regions as well as higher correlations of the observed and model mean series. The model mean also captures the Mount Pinatubo

eruption in the early 1990's with a large peak for all the regions. The observations show a much smaller peak in these regions, except the MW and the GP, where the observations and the model mean show good agreement. This difference between the model mean and observations could be the result of some of the models explicit treatment for volcanoes.

Comparing Figs. 1 and 2, it is evident that the number of warm events overall are increasing and the number of cold events are decreasing over the 1981-2010 time period.

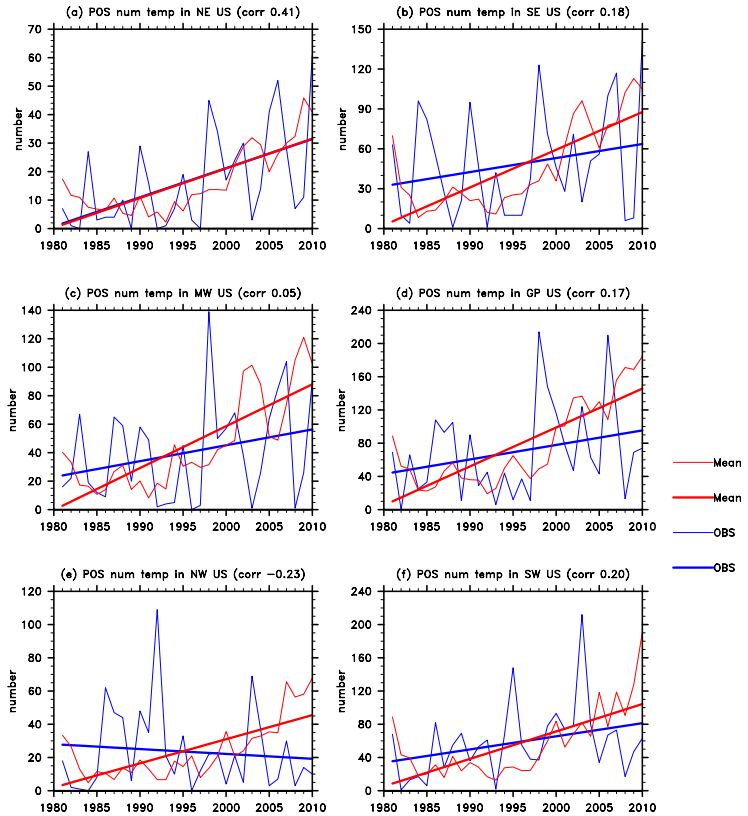


Figure 1: Time series and trends (1981–2010) of the positive (warm) extreme temperature index for observations and the model mean for the NE, SE, MW, GP, NW, and SW. The correlation between the obervational series and the model mean series are in parentheses.

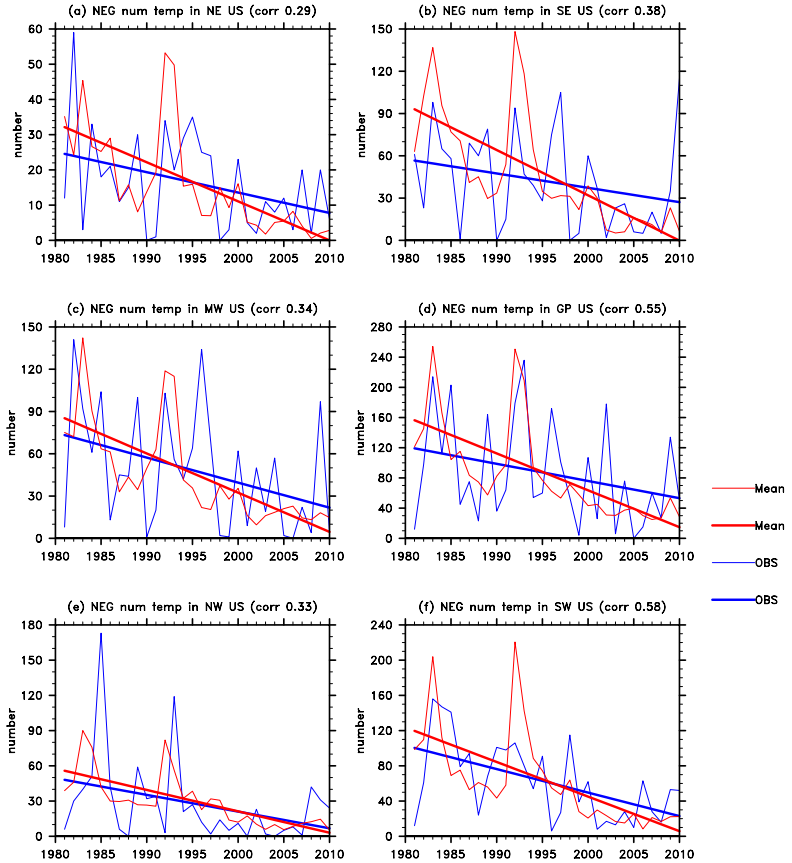


Figure 2. Time series and trends (1981–2010) of the negative (cold) extreme temperature index for observations and the model mean for the NE, SE, MW, GP, NW, and SW. The correlation between the obervational series and the model mean series are in parentheses.

PLANNED WORK

- Complete and submit a paper on CMIP5 hindcast simulations
- Analyze daily data from CMIP5 hindcast simulations for extremes

PRESENTATIONS

- Stegall, S. T., K. E. Kunkel, 2015: Long-Term U.S. Regional Trends of Extreme Temperature In the Coupled Model Intercomparison Project (CMIP5) Hindcast Data, American Meteorological Society 95th Annual Meeting, Phoenix, AZ (January 4-8).

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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	1
# of undergraduate students mentored during the year	0

PERFORMANCE METRICS EXPLANATION

Kenneth Kunkel serves on the Ph.D. committee of North Carolina State University Ph.D. candidate Rajarshi Das Bhowmik. Two papers were presented at the 2014 AGU Fall meeting and the 2015 Annual Meeting of the American Meteorological Society.

Role of Kelvin Waves in Tropical Cyclogenesis	
Task Leader	Carl Schreck
Task Code	NC-OTH-04-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 are shown to significantly affect the formation of tropical cyclones in all basins through interactions with the Madden–Julian Oscillation and 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 multisatellite 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 multisatellite 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.

These preliminary results were presented at the AMS Conference on Hurricanes and Tropical Meteorology. Forecasters from the National Hurricane Center showed interest in the results. They suggested binning the storms by time-lags from the most convective (crest) part of the wave, rather than by phase of the wave. This lag-based view has been used in previous studies and was more adaptable for the forecasters. For the remainder of Year 2, we revised our methodology following these suggestions. Consistent with previous work, we found a suppression of tropical cyclogenesis in the days leading up to wave passage (negative lags) and an increase following wave passage.

Figure 1 summarizes the results of the Kelvin wave composites. The tropical cyclone generally forms outside of the wave's enhanced convection and moisture. Instead, it develops with enhanced outflow at 200-hPa (Fig. 1a) and cyclonic vorticity (Fig. 1b), both of which persist on time scales longer than that of the wave. The Kelvin wave is embedded within the MJO and affects the greatest change in the zonal wind anomalies (Fig. 1c). The

easterly wave initiates or intensifies within the Kelvin wave and enhances the westerly anomalies until genesis occurs around 2.5 days after the interaction with the Kelvin wave crest. The results have been submitted to Monthly Weather Review.

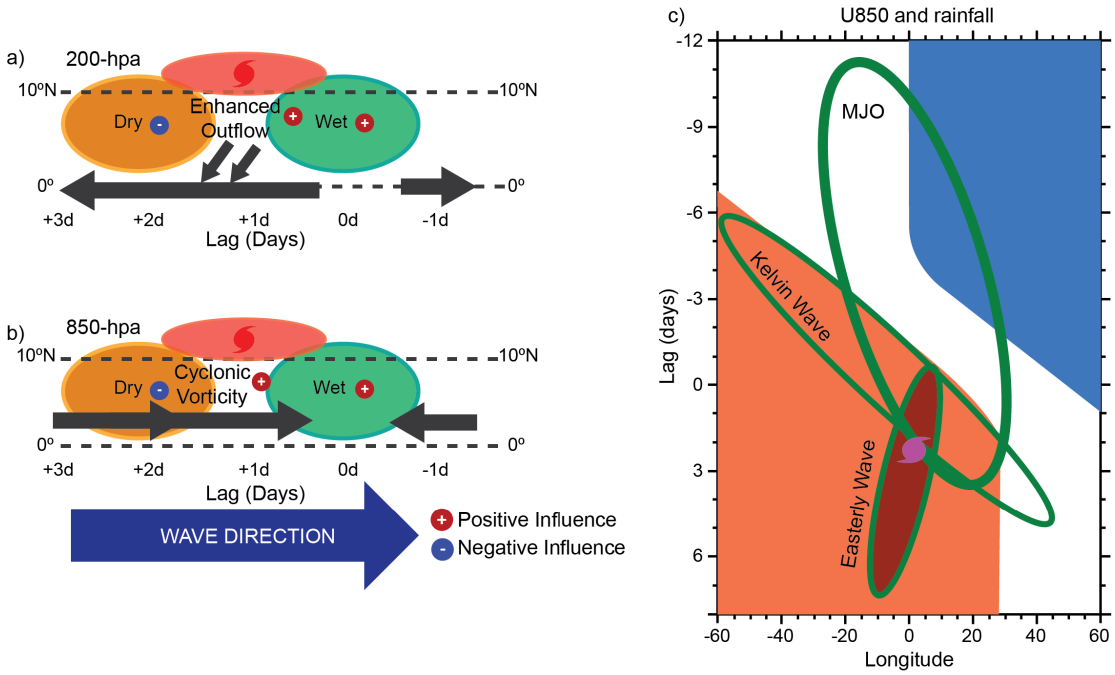


Figure 1. Schematic summarizing the relationships between the Kelvin waves and tropical cyclogenesis observed in this study at a) 200-hPa and b) 850-hPa. The horizontal axis is time in days from the wave crest, but it could also be viewed as longitude. c) Time–longitude Hovmöller schematic of 850-hPa zonal wind anomalies and rainfall anomalies associated with the Kelvin wave, the MJO, and the pregenesis easterly wave.

PLANNED WORK

- Analyze the developing tropical cyclones in a Lagrangian framework to determine the impacts of Kelvin waves on the developing storms

PRESENTATIONS

Invited presentations

- Schreck, C. J., and J. P. Kossin, 2014: A global survey of Kelvin waves and tropical cyclogenesis. *NASA Precipitation Measurement Mission Science Team Meeting*, 4-8 August 2014, Baltimore, MD.

Other presentations

- Schreck, C. J., and J. P. Kossin, 2015: A global survey of Kelvin waves and tropical cyclogenesis. *Third Symposium on Prediction of the Madden–Julian Oscillation,* 4-8 January 2015, Phoenix, AZ.

- Schreck, C. J., and J. P. Kossin, 2014: A global survey of Kelvin waves and tropical cyclogenesis. *39th Climate Diagnostics and Prediction Workshop*, 20-23 October 2014, St. Louis, MO.
- Schreck, C. J., and J. P. Kossin, 2014: A global survey of Kelvin waves and tropical cyclogenesis. *31st Conf. on Hurricanes and Tropical Meteorology*, 31 March-4 April 2014, San Diego, CA.

PERFORMANCE METRICS

	FY15
# of new or improved products developed following NOAA guidance	0
# of products or techniques transitioned from research to ops following NOAA guidance	0
# of new or improved products developed without NOAA guidance	0
# of products or techniques transitioned from research to ops without NOAA guidance	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

	FY15
# of new or improved products developed following NOAA guidance	87
# of products or techniques transitioned from research to ops following NOAA guidance	11
# of new or improved products developed without NOAA guidance	23
# of products or techniques transitioned from research to ops without NOAA guidance	0
# of peer reviewed papers	33
# of non-peered reviewed papers	5
# of invited presentations*	58
# of graduate students supported by a CICS task	2
# of graduate students formally advised	8
# of undergraduate students mentored during the year	17

Appendix 2: CICS-NC Publications 2014–2015

Ashouri, H., K.-L. Hsu, **S. Sorooshian**, D. K. Braithwaite, K. R. Knapp, L. D. Cecil, B. R. Nelson, and **O. P. Prat**, 2015: PERSIANN-CDR: daily precipitation Climate Data Record from multi-satellite observations for hydrological and climate studies. *Bulletin of the American Meteorological Society*, **96,** 69-83, doi:10.1175/BAMS-D-13-00068.1. Available online at: http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-13-00068.1

Bilotta, R., **J. E. Bell**, E. Shepherd, and A. Arguez, 2015: Calculation and evaluation of an air-freezing index for the 1981–2010 climate normals period in the coterminous United States. *Journal of Applied Meteorology and Climatology*, **54,** 69-76, doi:10.1175/JAMC-D-14-0119.1. Available online at: http://dx.doi.org/10.1175/JAMC-D-14-0119.1

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, doi:10.1016/j.advwatres.2015.02.006. Available online at: http://dx.doi.org/10.1016/j.advwatres.2015.02.006

Huang, B., V. F. Banzon, E. Freeman, J. Lawrimore, **W. Liu**, T. C. Peterson, T. M. Smith, P. W. Thorne, S. D. Woodruff, and H.-M. Zhang, 2015: Extended Reconstructed Sea Surface Temperature Version 4 (ERSST.v4). Part I: Upgrades and intercomparisons. *Journal of Climate*, **28,** 911-930, doi:10.1175/JCLI-D-14-00006.1. Available online at: http://dx.doi.org/10.1175/JCLI-D-14-00006.1

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*, **In press**, doi:10.1175/JTECH-D-14-00040.1. Available online at: http://journals.ametsoc.org/doi/abs/10.1175/JTECH-D-14-00040.1?af=R

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*, **In press**, doi:10.1016/j.crm.2015.03.002. Available online at: http://dx.doi.org/10.1016/j.crm.2015.03.002

Kilpatrick, K. A., G. Podestá, S. Walsh, E. Williams, V. Halliwell, M. Szczodrak, **O. B. Brown**, P. J. Minnett, and R. Evans, 2015: A decade of sea surface temperature from MODIS. *Remote Sensing of Environment*, **165,** 27-41, doi:10.1016/j.rse.2015.04.023. Available online at: http://dx.doi.org/10.1016/j.rse.2015.04.023

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*, **In press**, doi:10.1175/BAMS-D-14-00261.1. Available online at: http://dx.doi.org/10.1175/BAMS-D-14-00261.1

Kunkel, K. E., R. S. Vose, **L. E. Stevens**, and R. W. Knight, 2015: Is the monthly temperature climate of the United States becoming more extreme? *Geophysical Research Letters*, **42,**

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Leeper, R. D., and J. Kochendorfer, 2015: Evaporation from weighing precipitation gauges: Impacts on automated gauge measurements and quality assurance methods. *Atmospheric Measurement Techniques*, **8,** 2291-2300, doi:10.5194/amt-8-2291-2015. Available online at: http://dx.doi.org/10.5194/amt-8-2291-2015

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Leeper, R. D., **J. Rennie**, and M. A. Palecki, 2015: Observational perspectives from U.S. Climate Reference Network (USCRN) and Cooperative Observer Program (COOP) Network: Temperature and precipitation comparison. *Journal of Atmospheric and Oceanic Technology*, **In press**, doi:10.1175/JTECH-D-14-00172.1. Available online at: http://dx.doi.org/10.1175/JTECH-D-14-00172.1

Liu, W., B. Huang, P. W. Thorne, V. F. Banzon, H.-M. Zhang, E. Freeman, J. Lawrimore, T. C. Peterson, T. M. Smith, and S. D. Woodruff, 2015: Extended Reconstructed Sea Surface Temperature Version 4 (ERSST.v4): Part II. Parametric and Structural Uncertainty Estimations. *Journal of Climate*, **28,** 931-951, doi:10.1175/JCLI-D-14-00007.1. Available online at: http://dx.doi.org/10.1175/JCLI-D-14-00007.1

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Miao, C., H. Ashouri, K.-L. Hsu, **S. Sorooshian**, and Q. Duan, 2015: Evaluation of the PERSIANN-CDR daily rainfall estimates in capturing the behavior of extreme precipitation events over China. *Journal of Hydrometeorology*, doi:10.1175/JHM-D-14-0174.1. Available online at: http://dx.doi.org/10.1175/JHM-D-14-0174.1

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

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, doi:10.5194/hess-19-2037-2015. Available online at: http://www.hydrol-earth-syst-sci.net/19/2037/2015/

Santer, B. D., S. Solomon, C. Bonfils, M. D. Zelinka, J. F. Painter, F. Beltran, J. C. Fyfe, G. Johannesson, **C. Mears**, D. A. Ridley, J.-P. Vernier, and F. J. Wentz, 2015: Observed

multivariable signals of late 20th and early 21st century volcanic activity. *Geophysical Research Letters*, **42,** 500-509, doi:10.1002/2014GL062366. Available online at: http://dx.doi.org/10.1002/2014GL062366

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*, **In press**, doi:10.1175/BAMS-D-13-00237.1. Available online at: http://dx.doi.org/10.1175/BAMS-D-13-00237.1

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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, 2014: Cyclone Center: Can citizen scientists improve tropical cyclone intensity records? *Bulletin of the American Meteorological Society*, **In press**, doi:10.1175/BAMS-D-13-00152.1. Available online at: http://dx.doi.org/10.1175/BAMS-D-13-00152.1

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Kruk, M. C., **C. J. Schreck, III**, and T. Evans, 2014: [The Tropics] Eastern North Pacific basin [in "State of the Climate in 2013"]. *Bulletin of the American Meteorological Society*, J. Blunden, and D. S. Arndt, Eds., American Meteorological Society, S90-S92. Available online at: http://journals.ametsoc.org/doi/pdf/10.1175/2014BAMSStateoftheClimate.1

Kumjian, M. R., and **O. P. Prat**, 2014: The impact of raindrop collisional processes on the polarimetric radar variables. *Journal of the Atmospheric Sciences*, **71,** 3052-3067, doi:10.1175/JAS-D-13-0357.1. Available online at: http://dx.doi.org/10.1175/JAS-D-13-0357.1

Lawrimore, J., T. R. Karl, M. Squires, D. A. Robinson, and **K. E. Kunkel**, 2014: Trends and variability in severe snowstorms east of the Rocky Mountains. *Journal of Hydrometeorology*, **15,** 1762-1777, doi:10.1175/JHM-D-13-068.1. Available online at: http://dx.doi.org/10.1175/JHM-D-13-068.1

Meier, W. N., **G. Peng**, D. J. Scott, and M. Savoie, 2014: Verification of a new NOAA/NSIDC passive microwave sea-ice concentration climate record. *Polar Research*, **33**, doi:10.3402/polar.v33.21004. Available online at: http://www.polarresearch.net/index.php/polar/article/view/21004

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Rennie, J. J., J. H. Lawrimore, B. E. Gleason, **P. W. Thorne**, C. P. Morice, M. J. Menne, C. N. Williams, W. G. de Almeida, J. R. Christy, M. Flannery, M. Ishihara, K. Kamiguchi, A. M. G. Klein-Tank, A. Mhanda, D. H. Lister, V. Razuvaev, M. Renom, M. Rusticucci, J. Tandy, S. J. Worley, V. Venema, W. Angel, M. Brunet, B. Dattore, H. Diamond, M. A. Lazzara, F. Le Blancq, J. Luterbacher, H. Mächel, J. Revadekar, R. S. Vose, and X. Yin, 2014: The International Surface Temperature Initiative global land surface databank: Monthly temperature data release description and methods. *Geoscience Data Journal*, **1,** 75-102, doi:10.1002/gdj3.8. Available online at: http://dx.doi.org/10.1002/gdj3.8

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Appendix 3: CICS-NC Presentations 2014–2015

- **Bell, J.E.** Intersection of Climate and Health. Invited talk at the AMS Asheville Chapter, Asheville, NC. September 2014.
- **Bell, J.E.** NOAA Climate Data Sources for Health. 2014 Water and Health Conference, Raleigh, NC. October 2014.
- **Bell, J.E.** Preparation of NOAA's USCRN for NASA's SMAP Mission. NASA/JPL SMAP CAL/VAL Meeting, Pasadena, CA. October 2014.
- **Bell, J.E.** The Health Consequences of a Changing Climate. 2014 Second S-NPP Applications Workshop, Huntsville, AL. November 2014.
- **Bell, J.E**. Evaluation of the California Drought with USCRN Soil Observations. Irvine, CA. AGU Chapman Conference on California Drought. April 2015
- **Brown, O**. and Kunkel, K.E., 2015: State of the Climate Science in Identification of Risks; Presentation and Use of Data from National Climate Center and Affiliates, invited talk, Executive Forum on Business and Climate Workshop: Private Property, Information Disclosure, and the Roles of Insurance and Government, Chapel, NC, (20 March).
- **Champion, S.**, and Kunkel, K. 2015: Data Management and the National Climate Assessment: Best Practices, Lessons Learned, and Future Applications. *95TH Annual Meeting the American Meteorological Society*, Phoenix, AZ
- **L. Copley**; NCEI Branch Seminar, NCEI, Asheville, NC: "Key West Agile Team: Implementation and Successes", May 5, 2015.
- **Dissen**, J., Houston, T., Margolin, J. (2014). Climate Change & Variability – Data Sources, Accessibility, and Use. Georgia Environmental Conference. Jekyll Island, GA.
- Privette, J.L., T. G. Houston, D. P. Brown, **J. Dissen**, K. Gleason, and R. A. Leduc Clarke. A New Approach to Climate Services at NOAA's National Climatic Data Center (NCDC). January 7, 2015 AMS Annual Meeting
- **Hennon, C.** C., K. R. Knapp, C. J. Schreck, S. E. Stevens, J. P. Kossin, P. W. Thorne, P. A. Hennon, M. C. Kruk, and J. Rennie, 2014: Toward a homogeneous global tropical cyclone intensity record. *31st Conf. on Hurricanes and Tropical Meteorology*, 31 March-4 April 2014, San Diego, CA.
- **Hennon, C**. C., K. R. Knapp, C. J. Schreck, S. E. Stevens, J. P. Kossin, P. W. Thorne, P. A. Hennon, M. C. Kruk, and J. Rennie, 2014: Cyclone Center: Using citizen science to reconcile global tropical cyclone intensity. *Eighth International Workshop on Tropical Cyclones (IWTC-VIII),* 2-10 December 2014, Jeju, Republic of Korea.
- **Hennon, C.** C., K. R. Knapp, C. J. Schreck, J. P. Kossin, and S. E. Stevens, 2015: Cyclone Center: A crowd sourcing application of the HURSAT-B1 data record. *20th Conference on Satellite Meteorology and Oceanography*, 4-8 January 2015, Phoenix, AZ.
- **Paula A Hennon**, Andrew Buddenberg, et al 2015: Technial Support for Climate Assessment Data Services, Joint Assembly (AGU), Montreal, Canada (4 May 2015).
- **Kunkel, K.E.**, 2014: Climate Change: Regional Climate Scenarios, invited paper, Climate Change Adaptation Planning Workshop, National Exercise Program, The White House, Washington, DC, (7 May).

- **Kunkel, K.E.**, 2014: NOAA Climate Data in the National Climate Assessment, invited paper, Workshop on Sources, Uses and Access to Regional Climate Forecasts and Projections, U.S. Department of Agriculture, Washington, DC, (14 May).
- **Kunkel, K.E**., 2014: Climate change and risk? - How variable are climate projections and implications for disturbance risk, invited talk, Southern Forests Economic Issues Forum. Raleigh, NC, (4 November).
- **Kunkel, K.E.**, 2014: Regional Climate Model Simulation of Extreme Precipitation in North America", invited talk, Fall Meeting of the American Geophysical Union, San Francisco, CA, (December 19).
- **Kunkel, K.E.**, 2014: Science Issues Associated with Precipitation and Storm Extremes, Fall Meeting of the American Geophysical Union, San Francisco, CA, (19 December).
- **Kunkel, K.E.**, 2015: Science and Communication Issues Associated with Precipitation in the NCA, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (5 January 5).
- **Kunkel, K.E.**, 2015: Data Management and the National Climate Assessment: Best Practices, Lessons Learned, and Future Applications, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (5 January).
- **Kunkel, K.E.**, 2015: Overview of the National Climate Assessment, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (5 January).
- **Kunkel, K.E.**, 2015: Looking back on NCA3 and forward to NCA4, Town Hall Meeting: Developing Climate Scenarios for the 4th National Climate Assessment and the Sustained Assessment Process, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (6 January).
- **Kunkel, K.E.**, 2015: Historical Perspective on Recent Hot and Cold Extremes, poster paper, Annual Meeting of the American Meteorological Society, Phoenix, AZ, (7 January).
- **Kunkel, K.E**., 2015: Future Projections of Extreme Climate Conditions from the National Climate Assessment: Implications for Food Security, invited paper, Annual Meeting of the American Association for the Advancement of Science, San Jose, CA, (15 February).
- **Kunkel, K.E**., 2015: Projected Effects of Climate Change on Extreme Weather, invited talk, Kickoff Meeting, Effects of Climate Change on Dam-Related Health and Safety Interagency Assessment Team, Washington, DC, (25 February).
- **Kunkel, K.E.,** 2015: Extreme Climate Conditions Past and Future: Implications for Food Security and Water Resources, 13th Annual Climate Prediction Applications Science Workshop, Las Cruces, NM, (25 March).
- Vines C., **Leeper R**., and Palecki M. Evaluating the 2012 Drought using Modeled and Observed Datasets. Annual Biomedical Research Conference for Minority Students, San Antonio, TX. November 2014.
- **Leeper, R. D**. and Bell, J. E. Evaluating the Evolution of the California Drought and Monitoring Societal Risks with NOAA's U.S. Climate Reference Network. Annual Meeting of the American Meteorological Society, January 2015.
- **Leeper, D. R**., and Rennie, J. The Evolution of In Situ Climate Observations and Impacts on Observations and Climate Metrics. UNC Asheville Department of Atmospheric Sciences, Asheville, NC, February 2015.

- **Matthews, J.L**. 2014 Land surface albedo climate data record from a constellation of geostationary satellites. *EUMETSAT visiting scientist seminar*, 4 October 2014, Darmstadt, Germany.
- Lattanzio, A., **J. Matthews**, M. Takahasi, K. Knapp, J. Schulz, R. Roebeling, R. Stoeckli. 2014. 30 years of land surface albedo from GEO satellites: Status of the SCOPE-CM LAGS Project. *The Climate Symposium 2014*, 13-17 October 2014, Darmstadt, Germany.
- **Matthews, J.L**., 2014. Research applications at the National Climatic Data Center*, North Carolina State University Mathematics Department First Year seminar*, Raleigh, NC (14 Nov.).
- **Matthews, J.L.** 2015. Land surface albedo from a constellation of geostationary satellites compared and fused with polar-orbiting data. *Annual meeting of the American Meterological Society*, 4-8 January 2015, Phoenix, AZ, USA.
- **Matthews, J.L**. 2015. Land surface albedo from a constellation of geostationary satellites compared and fused with polar-orbiting data. *Annual meeting of the American Meteorological Society*, 4-8 January 2015, Phoenix, AZ, USA.
- Shi, L., **J.L. Matthews,** Q. Yang, S.-P. Ho. 2015. HIRS-Derived temperature and humidity profiles and comparisons with GPS R0 derived profiles, *Annual meeting of the American Meteorological Society*, 4-8 January 2015, Phoenix, AZ, USA.
- **Nickl, E.**, H.M. Zhang and D. Wuertz: Data Gap Impact Analysis on Global Surface Temperature Trends using GFDL CM3-CMIP5 model. SAMSI IMAGe Summer Program: The International Surface Temperature Initiative, Poster Session, Boulder, July 8-16, 2014.
- Zhang H.M., D. Wuertz, **E. Nickl**, J.H. Lawrimore, M. Menne and C. Williiams: Data Gap Impacts on Global Surface Temperature Trends from Various Datasets. SAMSI IMAGe Summer Program: The International Surface Temperature Initiative, Poster Session, Boulder, July 8-16, 2014.
- **Nickl, E**., C. Willmott, and R. Vose. Estimation of land surface precipitation using a new spatial interpolator method. Peruvian Geophysical Institute, Lima, February 18, 2015
- **Peng, G**., 2014: Introduction to scientific data stewardship maturity matrix. NCDC/CICS-NC Branch Seminar. November 13, 2014, Asheville, NC, USA.
- Jones, P. R., N. A. Ritchey, **G. Peng**, V. A. Toner, H. Brown, and K. Roberts, 2014: ISO, FGDC, DIF and Dublin Core – making sense of metadata standards for Earth Science data. AGU Fall meeting, 15 – 19 December 2014, San Francisco, CA, USA.
- **Peng, G.,** 2015: NOAA/WHOI Climate Data Record of Ocean Surface Bundle, v1.0 (Sea Surface Temperature, Ocean Near-Surface Properties, and Heat Fluxes) (DSI – 371201). NCDC User & Engagement Services Branch Briefing. January 8, 2015. Asheville, NC, USA.
- **Peng, G.,** 2015: Towards a consistent measure of stewardship practices. NCEI Archive Branch Briefing. May 6, 2015, Asheville, NC, USA.
- **Prat, O.P.,** B.R. Nelson, L. Vasquez, R. Ferraro, S. Rudlosky, and J.J. Wang 2014. Evaluation of satellite based Quantitative Precipitation Estimates (QPEs) over CONUS (2002-2012): Comparison with surface and radar precipitation datasets. *7th*

Workshop of the International Precipitation Working Group (IPWG), November 17-21 2014, Tsukuba, Japan.

- **Prat, O.P**., B.R. Nelson, S.E. Stevens, D.-J. Seo, and B. Kim 2014. Long-term large-scale bias-adjusted precipitation estimates at high spatial and temporal resolution derived from the National Mosaic and Multi-sensor QPE (NMQ/Q2) precipitation reanalysis over CONUS. *2014 AGU fall meeting*, December 15-19 2014, San Francisco, CA, USA.
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