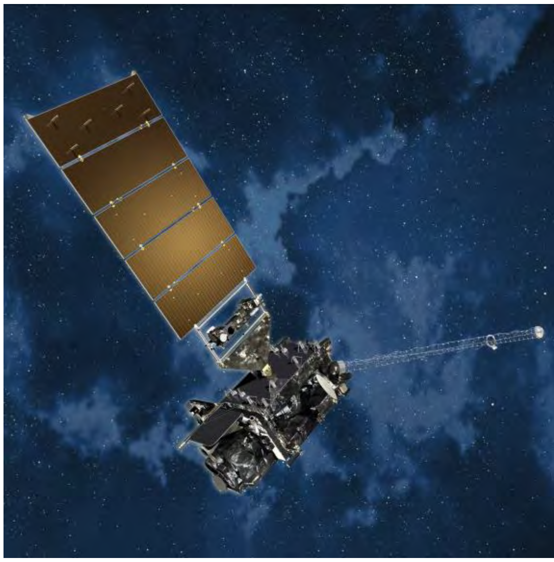

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# COOPERATIVE INSTITUTE FOR CLIMATE and SATELLITES (CICS)

## Annual Scientific Report

# VOLUME II: CICS-NC TASK REPORTS

For the period:
July 1, 2014 – March 31, 2015
NOAA Grant NA14NES4320003

**Dr. Fernando Miralles-Wilhelm, Director**

April 30, 2015

# Table of Contents

# CICS-NC Intro Statement

***CICS-NC***

The Cooperative Institute for Climate and Satellites-North Carolina (CICS-NC) is 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 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 within the NOAA/NESDIS National Climatic Data Center (NCDC) 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 NCDC.

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 atmospheric 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 which were not originally envisaged in the original proposal, thus, a number of additional partners were added to the CICS Consortium. New partners include: University of Michigan, Center for Climate and Energy Solutions (C2ES), 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-NC anticipates adding Stanford University, University of Pennsylvania, and Harvard University as partners to enhance business and industry climate links over the next five years.

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 NCDC; 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.

# Highlights

### CICS-NC

CICS-NC highlights are arranged by topic with funders noted at the end of the highlight. CICS' primary NOAA funding comes from NESDIS/NCDC, but CICS also receives grants from OAR's Climate Program Office (CPO), the NWS Office of Science and Technology (OST), NESDIS/NODC, OAR/ATDD, NESDIS/JPSSO, the National Ocean Services (NOS), and the OAR's Earth System Research Laboratory (ESRL). Other funding comes from the National Science Foundation (NSF), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA) and *EarthRisk*.

### Administration

*Communications:* This task promoted the Cooperative Institute for Climate and Satellites–North Carolina (CICS-NC) to its stakeholders and advanced the National Climatic Data Center's external and internal communications. **[NCSU and NCDC]**

*Information Technology Systems Improvement, Management, and Maintenance*: 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. **[NCDC/NCSU]**

### Climate Literacy, Education, Outreach, and Engagement

*Research Activities in Advancing Climate Literacy, Outreach, and Engagement across Public, Private, and Academic Institutions*: Education, literacy, and outreach are all important elements of the broader CICS mission. CICS-NC engages in the improvement of both formal and informal education 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, the general public, and other interdisciplinary stakeholder groups. **[NCDC]**

### Climate Data and Information Records and Scientific Data Stewardship

*Climate Data Record (CDR) Integrated Product Team (IPT) Support*: Climate Data Record (CDR) IPTs are multi-disciplinary teams comprised of members from offices and organizations supporting the transition of research-grade CDRs into an initial operational capability (IOC) status. The IPTs are formed for the purpose of efficient and effective collaboration, coordination, and execution and reporting of member's office/organization tasks required to transition the CDR to an IOC state. Several CICS-NC scientists serve as Products and Operations Branch representatives on multiple CDR IPTs. **[NCDC]**

*Expansion of CDR User Base (e.g., Obs4MIPs)*: 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). Several CICS-NC scientists have worked on a project to make observational products more accessible for climate model intercomparisons. **[NCDC]**

*SNPP VIIRS Climate Raw Data Record Production Software Development*: The VIIRS Climate Raw Data Record production software development and test were completed, and operational production began on October 19, 2013. **[NCDC]**

*Graph Database Proof-of-Concept Federated Archive Search Tool (FAST)*: Created a proof-of-concept tool that demonstrates search capabilities across multiple, disparate datasets. **[NCDC]**

*Suomi-NPP VIIRS Climate Raw Data Record System Infrastructure Development*: Completed transition of the VIIRS Climate Raw Data Record into the NCDC operational environment while helping to define the processes for the 3-tier software development environment. **[NCDC]**

*Transfer NOAA/NASA Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Sea Surface Temperature (SST) Processing to National Oceanographic Data Center (NODC)*: The Pathfinder Sea Surface Temperature (SST) time series has been extended to include NOAA-19 observations. This is a continuation of the previously submitted time series that covered the Advanced Very High Resolution Radiometer (AVHRR) sensors NOAA-7 through NOAA-18. In addition, the coverage period of NOAA-7 was expanded to include September and October of 1981 through cooperative work with NCDC/RSAD and National Oceanographic Data Center (NODC) to provide the augmented Reynolds OI reference SST fields that are required to process the Pathfinder time series. **[NCDC, NODC]**

*Net Surface Radiation Budget at High Spatial and Temporal Resolution from Multi-Sensor Data Fusion:* A successful technique to estimate net surface solar radiation from geostationary earth orbit (GEO) satellites has been developed by adapting an algorithm developed for the NASA-operated Clouds and Earth's Radiant Energy System (CERES) instrument on board the EOS/Terra and Aqua. Comparison of results with ground site measurements revealed excellent agreements comparable to or better than other sophisticated methods or even CERES-parameterized flux products. **[NCDC]**

*Independent Evaluations of the Calibration of the Visible Channel in the International Satellite Cloud Climatology Project (ISCCP) B1 Data*: Calibration of the Geostationary Earth Orbit (GEO) visible channel in the ISCCP B1 data stream has been completed for all meteorological satellites for the period 1979-2009, through employing AVHRR channel 1 reflectance in the Pathfinder Atmospheres Extended (PATMOS-x) data and validated through other independent results. Separately, the pre-GVAR GOES data (prior to GOES-8) has been reprocessed to conform to a more consistent format with less noise and these reprocessed data files will soon replace the present ISCCP B1 data in the archive. **[NCDC/JPSSO]**

*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. **[NCDC]**

*Uncertainty Quantification for Climate Data Records*: Uncertainty quantification in climate research is a multidisciplinary area of increasing importance. 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. **[NCDC]**

*Comparison of ground-based temperature measurements with satellite-derived phenology:* This research is a comparison of satellite-derived phenology measurements with ground-based temperature metrics. The goal of this project is to determine which of air or soil temperatures are better for estimating the growing season and will serve to improve U.S. Climate Reference Network (USCRN) drought monitoring. **[NCDC]**

*High-resolution Infrared Radiation Sounder (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. Applying neural networks to High-resolution Infrared Radiation Sounder (HIRS) data produces the data for this project. **[NCDC]**

*Maintenance and Production of CDR's for Microwave Sounding Unit (MSU) and AMSU Atmospheric Temperatures and NCDC Special Sensor Microwave Imager (SSM/I) Brightness Temperatures*: MSU/AMSU brightness temperatures have been updated and transferred to CDR Archive at NCDC. SSM/I Version 7 brightness temperatures have been updated and transferred to CDR Archive at NCDC. **[NCDC]**

*Evaluation and Characterization of Satellite Products***:** With the NOAA/NSIDC passive microwave sea ice concentration climate data record (CDR) successfully transferred into operations, and evaluation of the CDR was performed and and a global characterization of decadal trends of sea ice extents in the Arctic and Antarctic Oceans was performed. Also evaluated the NCDC blended sea surface winds. **[NCDC]**

*The scope and the framework of long-term scientific stewardship for CDRs*: Defined the scope of long-term stewardship for NOAA digital climate environmental data products based on U.S. laws and expert bodies' recommendation and associated functional areas. Also developed a unified framework for assessing the vigor of stewardship practice applied to individual environmental data products. Submitted a manuscript to a peer-review journal. **[NCDC]**

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

*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. **[NCDC]**

*Dual-Polarization 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 ($K_{DP}$). **[NCDC]**

*Reanalyzing Tropical Cyclones Imagery with Citizen Scientists: CycloneCenter.org* is a web-based interface through which citizen scientists have already produced more than 300,000 classifications of tropical cyclone intensity and structure. Preliminary research has shown that these classifications can help address uncertainties in the historical record of these storms. **[NCDC, NCSU]**

*Satellite Data Support for Hydrolic and Water Resource Planning and Management:*
A new daily precipitation climate data set was developed. The PERSIANN Precipitation Climate Data Record (PERSIANN-CDR) is a precipitation dataset with product resolution at daily $0.25^0$ lat-long scale. The product covers from 60°S to 60°N and 0° to 360° longitude, from 1983 to near current time. **[NCDC]**

*Reanalysis of archived NEXRAD data using NMQ/Q2 algorithms to create a high-resolution precipitation dataset for the continental United States*: This project has generated four years of a high-resolution gridded precipitation product for the entire continental United States at CICS-NC, with an additional seven years being produced at the National Severe Storms Laboratory/CIMMS in Norman, OK. The project group continues to work closely with these partners toward quality assurance and the transfer of this very large dataset. **[NCDC]**

*Satellite Product Evaluation and Near Real Time Monitoring:* This project applies the Satellite Product Evaluation Center (SPEC) tool to the Surface Fluxes and Analysis (SurFA) project used to generate a Near Real-Time Monitoring (NRTM) website. Ingest operations were supported with modifications to manifest creation in support of multiple archive site common manifest generation. **[NCDC]**

## National Climate Assessment

*National Climate Assessment Technical Support Unit (TSU)*: 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.

*Trends in Extra-tropical Cyclone (ETC) 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.

*Development of Geospatial Visualizations, Online resources, and Decision Support Tools for the National Climate Assessment:* Staff from UNC Asheville's NEMAC created maps and products for the National Climate Assessment; co-developed digital resource environments and interactive and static graphics for users of the Climate Assessment and Indicators team; and researched and presented a decision framework for use by the Climate Assessment. These new products support the overall advancement and progression of the National Climate Assessment program. **[CPO]**

Contributions of CICS-NC staff at the TSU to the release of the Third National Climate Assessment include:

- *Software Engineering Services*: 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 were created and continue to be developed as part of the continuing assessment process.
- *Graphical Services*: CICS staff provided editorial, graphics, and production support for the National Climate Assessment, making significant contributions to the release of the NCA in May 2014.
- *Program Support:* Implementing new production processes and maintaining a supportive workforce are ongoing priorities. Coordinating TSU/USGCRP activities and delivering the Third National Climate Assessment report and website were primary accomplishments of the TSU in 2014.
- *Web Development*: Made major contributions to the development and delivery of the website for the Third NCA. Designed and implemented a new web site for CICS-NC. Concluded a performance evaluation of the NCA Comment and Review system. Completed web development support for Dataset Discovery Days and the Executive Forum on Business and Climate websites.

- *Copy Editor*: Provided editorial and production support for the NCA, contributing to multiple drafts and the final approved document. Facilitated delivery to layout and website production and contributed to the development of the shorter "*Highlights*" summary of the NCA.
- *Metadata Collection and Management*: TSU built a sustainable process and technical infrastructures to collect, curate, and display the metadata of the National Climate Assessment. The effort satisfies compliance with the Information Quality Act and includes 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. TSU has completed approximately 75% of the collection.
- *Analysis of Observational and Modeled Climate Data*: Analysis of several observational and model datasets was performed and 23 figures were produced for the Third NCA report, along with the compilation of associated metadata.
- *Science Editor/Publication Support*: Provided editorial, graphics, and production support for NOAA's Technical Support Unit to the National Climate Assessment, making significant contributions to the development and delivery of the full report and accompanying *Highlights* document.
- *Scientific Support Activities*: Scientific analysis of Coupled Model Intercomparison Project, Phase 5 (CMIP5) and CMIP3 data was performed to support the development of the Third National Climate Assessment (NCA). **[CPO/NCDC]**

**Surface Observing Networks**

*Validation 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. **[NCDC]**

*Research Dealing with the Impacts of Climate on Health***:** 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 climate change on human health and assist with projects that can further this knowledge. **[NCDC]**

*Climate Monitoring and Research Support for NOAA's Air Resources Laboratory (ARL) Atmospheric Turbulence and Diffusion Division (ATDD):* Additional USCRN stations were installed in Alaska, continuing the expansion of the Alaska Climate reference Network (ACRN). **[ATDD]**

*Investigating the Hydrological Impacts of Tropical Cyclones over the Carolinas from Observational and Modeling Based Perspectives*: Four Tropical cyclones (Floyd 1999, Isabel 2003, Frances 2004, and Irene 2011) that impacted the Carolinas were simulated using the Weather Research and Forecasting model (WRF) for an ensemble of microphysical parameterizations. Modeling results were compared against surface and remotely sensed observations to assess the model's ability to capture such extreme events and their impacts on local communities. **[NCDC]**

*Development and verification of US Climate Reference Network (USCRN) Quality Assurance Methods*: A field campaign was initiated this year with NOAA's Air Resources Laboratory (ARL) precipitation testbed in Marshall, CO. The field study focused on gauge evaporation over the summer of 2013, which showed USCRN gauges were prone to evaporative losses. However, preliminary results indicate that evaporative losses had little impact on total precipitation. In addition, a website was developed to both improve the dissemination of USCRN climate-quality data and serve as a spatial check for manual quality control (QC). A manuscript describing the new precipitation algorithm for the USCRN network was drafted and is currently being reviewed by the USCRN Project Science Manager. **[NCDC, CPO]**

*Collocated US Climate Reference Network (USCRN) and Cooperative Observer Network (COOP) Comparisons*: A manuscript describing network differences between USCRN and COOP networks was completed and submitted for internal review. Pending reviewer responses to revised manuscript, the document will be submitted for publication in a peer-reviewed journal. **[NCDC]**

*Maintenance and Streamlining of the Global Historical Climatology Network – Monthly (GHCN-M) Dataset*: A new land surface temperature Databank has been publically available through beta releases and work is underway to transition from research to operations. This product will lay the groundwork for the next iteration of GHCN-M, which will include updates to quality assurance and bias correction. **[NCDC]**

**Workforce Development**

*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. We found a decrease on surface temperature trends when data gaps are taking into account. **[NCDC]**

*GLOBAL SURFACE TEMPERATURE PORTFOLIO-Evaluation of global surface temperature methods:* 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). **[NCDC]**

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

*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 NRA). Results show that the bias and RMSE are low when compared to USCRN, especially for nighttime temperatures. **[NCDC]**

### Consortium Projects

*Improving Prediction of Heavy Precipitation Events in the Eastern US:* This project utilized the NOAA GEFS Reforecast database to develop a model-error climatology for heavy precipitation in the eastern US. Comparison of reanalysis and reforecast data, for event-relative composites stratified by precipitation character and synoptic weather setting, is providing insight in to model error sources during heavy precipitation. **[ESRL]**

*Programming and Applications Development for NOAA's Climate Services Portal (NCSP):* Staff from UNC Asheville's National Environmental Modeling and Analysis Center (NEMAC) assisted with the enhancement and launch of the Multigraph website, the development of the Climate Explorer application, and the design and development of the U.S. Climate Resilience Toolkit. These products support the overall advancement and progression of the NOAA's Climate Services Portal (NCSP) program. **[NCDC]**

*Spatio-Temporal Patterns of Precipitation and Winds in California*: Precipitation frequency as a function of altitude in northern California does not correspond to the standard idealized relationship. It is widely variable with respect to both basin and storm type. **[ESRL]**

### Other CICS PI Projects

*Water Sustainability and Climate Change: a Cross-Regional Perspective*: Model simulations from the CMIP5 hindcast experiment were found to reproduce observed temperature trends for the southeast and southwest U.S. for the period 1981-2010. Trends in the number of extreme monthly temperatures are simulated well for most regions, but not for the northwest. **[NSF]**

*Identifying Tropical Variability with CDRs*: Climate Data Records are being leveraged to develop new diagnostics for tracking and predicting the MJO and equatorial waves. These diagnostics are tested in near-real time on monitor.cicsnc.org/mjo where they are served to hundreds of users in the public and private sectors every month. **[NCDC]**

# 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 Climatic Data Center (NCDC) administration and leadership.

**BACKGROUND**

Under the NOAA Cooperative Agreement, CICS-NC serves as the second of the dual-location campuses for CICS and is collocated with NCDC 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 NCDC 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 an IT operations and support specialist. There is travel support for administration and research facilitation purposes and a substantial investment in IT infrastructure associated with the dual 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

| | |
|---|---|
| **Communications** | |
| **Task Leader** | Tom Maycock, Geraldine Guillevic |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 promoted the Cooperative Institute for Climate and Satellites (CICS-NC) to its stakeholders and advanced the National Climatic Data Center's external and internal communications efforts.

**BACKGROUND**

With the fast growth of CICS-NC, a strong communications plan was needed to reach out to its audiences and potential partners. The approach was to understand what the key messages were and how they should be delivered by determining which channels should be used for the different audiences. With more than 300 employees in the center and a growing need for internal, open lines of communications, an impactful approach to understanding and engaging both employees and management was also needed to increase motivation for improved performance.

Building on the CICS-NC communications plan, recent activities focused on highlighting research findings of CICS-NC scientists and their NOAA/NCDC 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 NCDC/NCEI.

**ACCOMPLISHMENTS**

*CICS-NC Communications*

- Developed and implemented an effective communications strategic plan:
  - Define a proper brand identity aligned with the Institute's core values and assets
  - Create a visual cohesion for all CICS-NC communications
  - Create a Vision Statement which resonates with the core mission and key-messages to use in all CICS communications
  - Build a bridge between CICS-NC and its various partners and stakeholders to promote the Institute's activities by creating powerful messages and using the adapted channels
  - Strengthen the Institute's social media voice
  - Increase the Institute's presence in the media

- 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 NCDC Communications*
Developed an impactful internal communications strategy:
- Conducted center-wide interviews to identify the needs of various segments of the employee audience
- Analyzed and improved existing internal channels and/or developed new channels when necessary
- Determined and implemented the most effective methods and channels to achieve internal communications objectives
- Collaborated with the Director's office and management to define appropriate processes to ensure smooth, consistent, and successful workflows and strategic message delivery
- Built strong relationships with management and employees to understand their organizational functions and develop appropriate strategies for their internal communication needs

External Communications Activities:
- Provided quick-turnaround copyedit of forthcoming NOAA California Drought Service Assessment.
- Revised Greenhouse Gas Frequently Asked Questions content (awaiting deployment).
- Improved coordination with 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 NCDC’s web site and mentioned in NCDC social media posts.

**PLANNED WORK**
- Continue to highlight and promote work done by CICS-NC and the institute as a whole
- Build reach of Facebook and Twitter accounts
- Provide expanded communications support for NCDC, including editorial work on the forthcoming Explaining Extreme Events report and communications related to new surface temperature products.

**DELIVERABLES**

- CICS-NC brochure
- 30 facts sheets, available on www.cicsnc.org
- CICS-NC Communications Plan
- Press releases, available on cicsnc.org
- NOAA NCDC Internal Communications plan: an audit with 80 interviews led internally to a short-term actions plan and mid-term actions plan
- Management pagers to help improve performance
- Trends newsletter
- Twelve web stories and press releases
- Four retractable banners
- Flyer on K-12 outreach
- Significantly updated 15 FAQs on global warming for NCED website (awaiting deployment).

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 67 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 6 |
| # 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 |

**Information Technology Systems Improvement, Management, and Maintenance**

| | |
|---|---|
| **Task Leader** | Jonathan Brannock, Scott Wilkins |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 head node is a powerful server where users can prototype ideas and perform light work tasks, including coding and testing. The head node can then queue heavy workloads onto the cluster where a number of different 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.

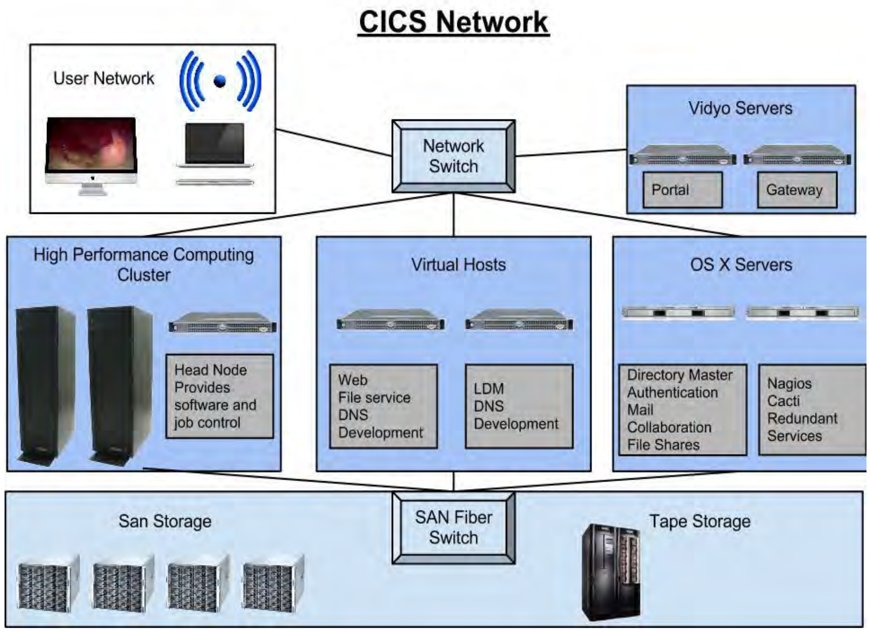



*Figure 1: Network, and system diagram.*

CICS-NC provides a distributed file system for concurrent system-wide access to high-speed storage. The Quantum Storenext file system is attached to three Promise SANs providing 600 Terabytes of online disk storage. This offers our users high-speed redundant storage for large projects and data sets. Of the total disk storage, 550 Terabytes is managed using Quantum's Storage Manager which makes 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 NCDC. CICS-NC currently has 10 blade centers with 600 processing cores and 2.3 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 NCDC partners.

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.

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.

**ACCOMPLISHMENTS**

Upgrades were made to distributed-file system controllers. Stornext metadata controllers were upgraded to latest software. This upgrade increased metadata performance by 35%. 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 Management 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 impending release of Stornext 5.

Upgrades were made to our Promise SAN controllers. A new SAN controller was installed with 72 4tb drives. This increased our storage capacity. We also evenly distributed the storage trays between the two newer SAN controllers. This doubled the potential throughput of each file system.

Building-wide Wi-Fi access was planned, updated, and deployed. Wi-Fi coverage was improved from 19 access points covering two floors and select areas on 3 other floors to 30 access points covering new areas on the 1st floor, fitness center, and NCDC archive. The most populous areas were upgraded to 802.11AC or gigabit Wi-Fi. Heat maps and simulations were used to place the access points in optimal locations. CICS-NC also extended the wired network with an additional POE switch in the basement.

Virtualization support was improved by setting up a shared storage using logical volume management (LVM) for the VM data. This improvement also gives us the ability to migrate, load balance, and failover VM's between the different host servers. This also improves our ability to scale this platform as needs increase.

The *Vidyo* system was improved by adding two new services. The first is *VidyoReplay*. *VidyoReplay* gives CICS-NC the ability to record meetings for later viewing or dissemination. The *VidyoReplay* also provides the ability to webcast a meeting to as many as 300 additional participants. The second addition is *VidyoVoice*. *VidyoVoice* allows a toll-free telephone number to be used to dial into any of the meetings. This allows an additional 10 participants to connect via telephone.

New tools were implemented for daily monitoring and control of IT resources, including *Casper Suite*, *Puppet OSE*, and *Splunk*. The *Casper Suite* by JAMF was implemented to provide an all-in-one configuration management, auditing, inventory, remote support, and employee self service. This has allowed IT to track and enforce patches and other security threats, track and distribute licensed software, and to provide asset tracking via automated inventory updates. *Casper* also provides centralized package management and package creation tools. This allows software to be customized and configured then distributed by policy or the self-service portal. CICS-NC has also implemented *Puppet Open Source Edition*. This provides configuration management and enforcement on Linux and Unix platforms. CICS-NC IT staff can write or download configuration modules and then enforce them on any number of servers. This provides unified configuration templates, reduces configuration skew, simplifies new server configuration, and prevents unauthorized or unintended changes to configuration files on the servers. CICS-NC IT has also implemented *Splunk*. *Splunk* provides unified log management, searching, and reporting and gives CICS-NC better visibility into IT operations as a whole with the ability to search for specific events quickly and easily.

CICS-NC IT has migrated authentication services from *Apple Open Directory* to *Microsoft Active Directory*. This provides a more stable and sustainable infrastructure for authentication services.

CICS- NC maintains three data subscriptions from NCDC Comprehensive Large Array-data Stewardship System (CLASS) that provide VIIRS and AVHRR data to our collaborators in Miami. The IT group completely redesigned the processes used to move this data because the previous provider (NOAA/CLASS) will no longer be able to push the files to CICS-NC. This redesign resulted in a 50% reduction in the amount of data we are required to transfer and store. CICS-NC maintains 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, the IT group renegotiated the CICS-NC 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. They increased both the number of virtual servers we can support and the performance and memory capacity of the virtual server platform.

**PLANNED WORK**

- Expected upgrades (e.g. server migration, VM improvements, ldm upgrades, OS updates)
- Continuous tasks (maintenance)
- System integration of hardware and software from RSMAS to continue OISST Processing

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 10 |
| # 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, Education, Outreach, and Engagement

Climate literacy, education, outreach, and engagement efforts are focused on improving the public's knowledge and understanding of climate science, variability, change, its impacts, and opportunities for adaptation and mitigation. In response to the demand from NCDC's users, CICS-NC engagement activities provide climate data and information to help build a climate-smart and resilient nation. The broader goal is to engage in activities that support NCDC's strategic plan for engagement and foster a climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions.

**Background**

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's 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 affect weather patterns today and into the future. As the discussion on reducing emissions shifts into mainstream awareness, considered as climate mitigation pathways, the question remains of 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, higher 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 which utilizes effective, science-based problem-solving skills (e.g., STEM based learning) in education. Working collaboratively with other academic and public partners, stakeholders, and the private sector, CICS-NC supports and engages in various educational, engagement, and outreach-related activities that:

- Advance the development of strong and comprehensive education and outreach activities related to 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 NCDC climate datasets and products and how educational leaders can make use of climate data products for teaching climate science
- 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 NCDC in advancing their outreach with the Sectoral Engagement Team, communication with the Communications Officer, and literacy with the Education Lead
- Support outreach and engagement activities on climate applications to local economic development groups and non-profits

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

**Task Leader** Jenny Dissen
**Task Code** NC-CLOE-05-NCICS-JD
**NOAA Sponsor**
**NOAA Office**
**Contribution to CICS Themes (%)** Theme 1: 40%; Theme 2: 40%; Theme 3: 20%.
**Main CICS Research Topic** Climate Literacy, Education, Outreach, and Engagement
**Contribution to NOAA Goals (%)** Goal 1: 40%; Goal 2: 0%; Goal 3: 0%; Goal 4: 40%; Goal 5: 20%
**Highlight**: Education, literacy, and outreach are all important elements of the broader CICS mission. CICS-NC engages in the improvement of both formal and informal education 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, 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. During our first five years, CICS-NC engaged in several meaningful climate literacy, engagement, and outreach activities for business and industry, as well as members of the general public, through education initiatives. These activities were developed in conjunction with CICS-NC partners, which include NCDC's Customer Services and Monitoring Division, NOAA's Climate Program Office, and CICS-MD. Broad areas of key topics or themes for discussion when engaging with the stakeholders were 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 and discuss areas of uses and applications of these climate data products
- Increase business and industry sector understanding and use of climate data and information for their strategic and operational purposes
- Demonstrate capacity building on the various impacts of climate change across public, private, and academic arenas

Climate literacy 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 like NCDC, NODC, and CPO.

**ACCOMPLISHMENTS**

To advance climate literacy activities across public, private, and academic partners on climate data, information, and application opportunities, there were several activities accomplished in our first five years. These included developing an engagement strategy and framework, 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 NCDC. Key accomplishments included:

- Advancing literacy and outreach in education with the K-12 audiences and supporting undergraduate and graduate students
- Engaging in meaningful dialogue on uses, applications, and requirements of climate information with business and industry partners
- Providing operational support to NCDC's activities in advancing their sectoral engagement, outreach, and communications activities
- Conducting interdisciplinary engagement and outreach activities with 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 engaged with the 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.

CICS-NC partnered with NOAA's NCDC and the NC State University Science House to provide K-12 educational outreach for climate and Earth system science several times during our first funding period. The Science House serves over 5,000 teachers and over 36,000 students annually from six offices spread across the state of North Carolina. As part of our collaboration with The Science House, CICS-NC supported the *ESTEAM Girls and Boys Conferences* on March 24th and 26th, 2015, at A-B Tech, providing western North Carolina 7th graders an opportunity to participate in an adult-like science conference. The Science House describes the conferences as "an annual event for 7th grade students of western North Carolina…[that allows] students to participate in an adult-like conference in which they experience hands-on, informative sessions from local professionals working in related ESTEAM fields. The conferences are held at the Business Acceleration Site in Enka (BASE) at A-B Tech and are by invitation only."[1]

CICS-NC also engaged in various modes of outreach and engagement activities in the community to support local K-12 and undergraduate audiences:

[1] http://www.thesciencehouse.org/k-12-students/esteam.php

Jared Rennie gave talks to 6th and 7th grade students at Asheville Middle School (about 250 students total). The talks included an overview of CICS-NC, its role within the National Climatic Data Center, and the volume of digital as well as paper climate data archived at NCDC. Jared showed off some weather instruments and some historical weather observations. Jared also participated in a Google Hangout and talk about weather and climate for Durham Public Schools. While the hangout was hosted by DPS, over 1,000 students nationwide also viewed it.


*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 ~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 ~800 attendees.

Theresa Stone, Laura Stevens, and Jared Rennie supported CICS-NC’s participation in the *Mountain Science Expo* for ~2,600 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 NCDC’s Outreach program. The *Mountain Science Expo* was part of the larger North Carolina Science Festival activities taking place across the state. “The North Carolina Science Festival is a multi-day celebration showcasing science and technology. The 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."[2]

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 ~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 supported outreach in education to university-level students by providing internship opportunities for graduating college seniors and graduate student researchers

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

who have a strong desire to enhance their research and analysis skills by working with NOAA and CICS-NC. Recently, CICS-NC has provided mentorship support to the NASA DEVELOP program, where several CICS-NC staff members (Carl Schreck, Jared Rennie, and Jenny Dissen) have mentored projects and students that were part of the NASA DEVELOP activity.

In 2014, four new students from UNC Asheville's Atmospheric Sciences and Applied Mathematics department joined the CICS-NC internship program (please refer to additional details in the *Workforce Development* area). Jenny Dissen provided support and occasional mentorship support to William Clark, an undergraduate student from UNC Asheville who worked on two projects examining economic impacts of climate change. The first project was an inundation impact model using a Geographic Information System for 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 help NCDC as they begin to redesign their engagement with various sectors.

Ronald Leeper mentored an Educational Partnership Program (EPP) scholar on a research project comparing the evolution of soil conditions from in situ and modeled perspectives over the 2012 drought. Chante' Vines came to NCDC from Morgan State University in Maryland for a nine-week internship over the summer of 2014. During her tenure, she furthered her coding expertise using the statistical software R and ESRI's Geographic Information System (GIS) program ArcGIS in addition to working with modeled climate data for the first time. She presented results from her completed project to NCDC staff, at the 2014 NOAA OEd Student Science and Education Symposium in Silver Springs, MD, and at the Annual Biomedical Research Conference for Minority Students in San Antonio, TX.

Carl Schreck worked closely with NASA DEVELOP, a capacity building program within NASA's Applied Sciences Program. He has supervised and mentored 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 tele-connections and temperature anomalies in the eastern half of the United States.

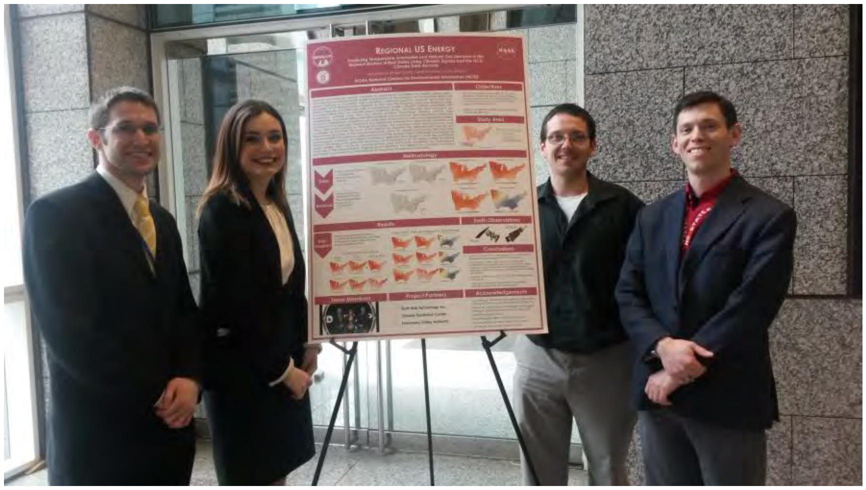


*Figure 5. NASA DEVELOP Spring Presentations held on March 27, 2014 with Derek Podowitz (NASA Develop), Kelly Dobeck (NASA Develop), Jared Rennie, and Carl Schreck.*

Outreach and engagement to K-12, undergraduate/graduate levels, select associations, and the general public were advanced through various presentations conducted by the CICS-NC team. These include:

- **“Climate Change Impacts in the United States**” as part of the North Carolina Arboretum seminar series at the NC Arboretum, Asheville, NC, **July 31, 2014.** (Laura Stevens)
- **“Climate Change Impacts in the United States”** to French Broad Mensa, Asheville, NC, **September 13, 2014** (Laura Stevens)
- **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 ~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 / NCDC. **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)

- **"Climate Change Impacts in the United States" - 20 minute radio interview with Jess Messer on WPEK-AM, Asheville NC (July 29,2014)** (Laura Stevens)

***Engaging with Business and Industry Sectors***

Jenny Dissen continued engaging with Facebook, particularly the data center located in Forest City, North Carolina, on a development case study related to their experience of using NCDC climate data for the siting and operations of their data farm. Engagement with Facebook has also led to collaborations with the NC State Climate Office, Isothermal Community College (ICC), and NOAA NCDC. In August 2014, this collaboration led to the installation and deployment of a new weather station on Isothermal's campus in Spindale, NC. The new station is part of the State Climate Office's Environment and Climate Observing Network, or ECONet, which provides critical weather and climate data from observing stations across the state of North Carolina. Data from this new station will contribute to the array of benefits provided by the ECONet throughout the state, including improvements in economic development, planning, and emergency response. The project was made possible through matching grants from Facebook's Community Action Grant program and the National Oceanic and Atmospheric Administration (NOAA), as well as contributions from CICS-NC.

CICS-NC continued to support the North Carolina State Climate Office (NCSCO) at NC State University to enhance the communication abilities of their ECONet network. CICS-NC also works to enhance NCSCO's capabilities to collect of climate data (e.g., by providing technology such as cellular modems). The continued collaboration with NCSCO builds public engagement of climate observations and NCSCO's role in understanding our society's sensitivity to climate.

Engagement with business and industry occurs in various other modes as well. Jenny Dissen frequently provides access to the latest climate information through seminars and webinars with various private sector companies, through both formal and informal process. Informally, CICS-NC presents and leads various webinar sessions to advance access to climate data and information to different solutions providers, such as:

- Booz Allen Hamilton Climate Change Community of Practice
- Booz Allen Hamilton Sustainability Community of Practice
- StatWeather Energy Summit (Fall 2012, Spring 2013, Fall 2013)
- Asheville Leadership
- Asheville HUB and Economic Development Coalition
- Air and Waste Management Association (Regulatory Update - Georgia Regional Meeting)
- Air and Waste Management Association – Climate Change Conference
- Tokio Marine Technology Insurance Conference
- Fortune Brainstorm Green (2012 and 2013)
- Facebook Data Center
- CDM Smith (Environmental Engineering Company) – Webinar

- Georgia Environmental Conference (Aug 2014); in collaboration with Environ International

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. In 2013-2014, CICS-NC established a program called the Executive Forum on Business and Climate, a new and groundbreaking approach to bringing together academic researchers, business leaders, and federal science experts to examine how recent weather and climate trends are affecting industry and how climate information is used by business decision-makers in their strategy and operations.

Following two successful Executive Forums in 2013 and 2014, CICS-NC held another 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 community, policy and legal academics, the private sector, and 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 recommendations to the commissioners associations, who can assess opportunities for improving private sector climate change adaptation and 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." NCDC's Adam Smith was integrally involved in the planning phase, particularly to incorporate outcomes from the various NOAA Reinsurance Engagement Strategy activities taken place in the past year. The Forum outcomes will also be provided to this team to incorporate levels of feedback that meets the team's engagement goals.

*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,"*

Other engagement with business and industry includes:

- **"Climate Impacts in the United States: An Overview from the National Climate Assessment"**, Ken Kunkel invited presentation, Climate Impacts and Resilience Workshop, Business Environmental Leadership Council, Washington, DC, **July 16, 2014.** Type of group: business leaders. CICS-NC
- **"NOAA Climate Data for Public Health",** Jesse Bell invited presentation, Air & Waste Management Association (AWMA) Annual Meeting in Long Beach, CA. Bell served as a panelist and gave a presentation on NCDC data being used at the Centers for Disease Control and Prevention (CDC). July 2014

***Engagement and Outreach in Collaboration with NCDC***

As part of the merging of NOAA's data centers into the new National Centers for Environmental Information (NCEI), the former NCDC's Climate Services and Monitoring Division (CSMD) is being reorganized as the Center for Weather and Climate Information Services division (CWCIS) at NCEI. In collaboration with the CSMD, NCDCs Communications team, and Narayan Strategies, Jenny assisted in developing a perspective on the new NCEI Center for Weather and Climate Engagement strategic plan, an internal document developed to assess the current engagement-related activities and build future activities that support the NCEI CWC Engagement vision and mission. The strategic perspective included elements on stakeholders, on how to improve and evolve engagement activities with the current users, and on what the next five years could look like.

As part of a broader effort to help NCEI maximize awareness, understanding, and use of products and services and capture feedback, Jenny supported the new NCEI Center for Weather and Climate Information Services Division in both strategic and operational context as they form new methods for enhancing customer engagement. This includes developing a usable and robust engagement team implementation plan that captures the activities necessary to arrive at a future state vision.

Jenny Dissen provided input to key business contacts in the energy industry as part of an *Acclimatise* market analysis. Jenny also assisted in designing the process-related activities to help map and document how customer information is received, tracked, and managed at the Center, and how engagement requests are appropriately catalogued. Working closely with the NCEI engagement team, Jenny supported and developed methodologies for examining the existing process that the former NCDC undertakes to engage its users. This includes interviewing people involved in engaging with customers, developing process maps, and assessing the findings to provide recommendations. In addition, support to the NCEI engagement team included developing "interim" solutions to capture customer, data, and engagement requirement needs by capturing, reviewing, and prioritizing requirements. This effort will help inform options for a Customer Relationship Management tool that will ultimately serve as a repository of customer information.

Other support to the NCEI CWC Engagement team included review and reassessment of the sectoral engagement strategy in an effort to map to the U.S. Census category of the NAICS code.

Support to NCEI is ongoing, as 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 collaborated with the local Asheville Chamber of Commerce and the Buncombe County Economic Development Coalition to identify and support opportunities in growing the region's STEM skills and capabilities, particularly in climate science. Jenny and Otis Brown 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.

A *National Partnership for Resilience* (NPfR) workshop, held in March 2014, focused on the feasibility and the formation of what has now evolved into a broader endeavor called the *Partnership for Resilience*, an activity of North Carolina Institute for Climate Studies (NCICS). The goal of the *Partnership* is to promote resilience in businesses and communities by adapting to changing climate. Dissen currently supports Paula Hennon and Otis Brown in this activity under NCICS.

***Outreach with the Legislative/Policy Making Community***

Jared Rennie was selected to participate as a volunteer in the American Meteorological Society's "Weather, Water, and Climate Day on Capitol Hill" workshop in Washington, DC (May 2014). Jared met with many members of Congress to discuss what we do as a society and offered our services for queries that may came up in the future regarding weather, water, and climate. He and his team met with staffers from the offices of Senator Bill Burr and Representative Mark Meadows, and with Senator Kay Hagan.

Other engagement activity with the legislative group:

- **"Climate Projections-Southern U.S.**", Ken Kunkel invited talk, Innovation in Water Treatment and Conservation webinar, Southern Legislative Conference, **July 17, 2014.**

**PLANNED WORK**

- Continue additional 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.

**DELIVERABLES**

- Execution of three forums called the Executive Forum on Business and Climate
- Led and developed the Climate Data and Applications Workshop Series; completed the workshop called Precipitation Data and Applications; supported activities related to the 2014 AMS Drought Workshop
- 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, and review of various recommendations and requirements
- Support of NCDC and CICS-NC enterprise and administrative activities

**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.

**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, and a voting member of, the AMS Energy Committee, and a 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**

| | |
|---|---|
| # 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 | N/A |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 4 |

# Climate Data and Information Records and Scientific Data Stewardship

Climate Data Records (CDRs) provide climate-quality satellite and in situ observing datasets that document the Earth's climate.

### Background

CICS-NC supports efforts at the National Climatic Data Center (NCDC) 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 algorithm and product | Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation; quantified errors | Record is publicly available from Long-Term archive; Regularly updated | Used in published applications; may be used by industry; assessments demonstrating positive value |

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

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

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

### Work Plan

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 NCDC.
- 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** | Art Burden, Anand Inamdar, Jessica Matthews, Ge Peng, Olivier Prat, Carl Schreck |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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.

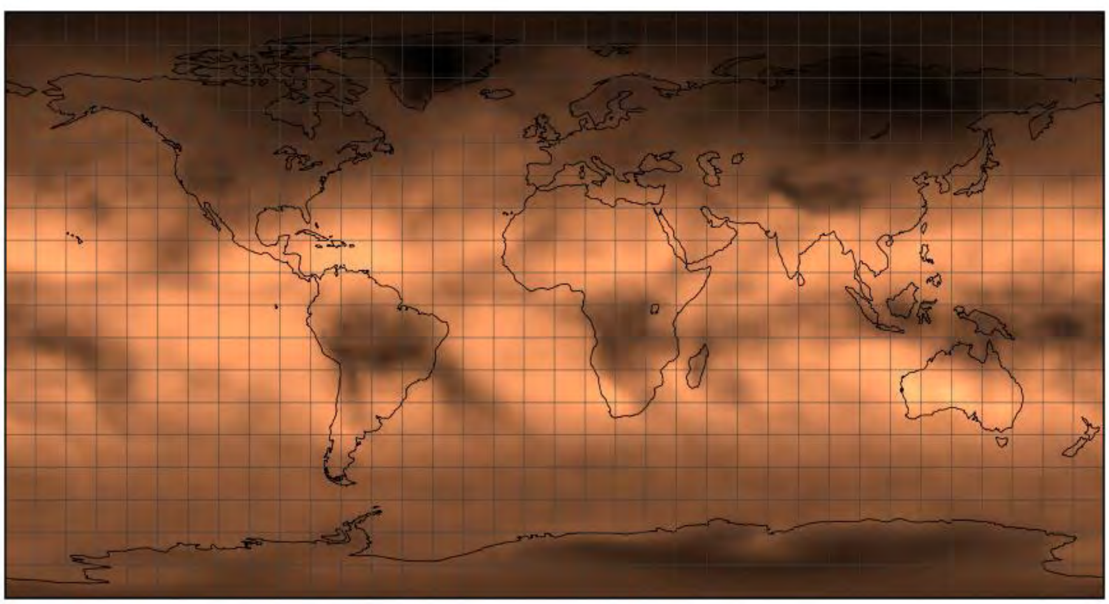


*Figure 1. A sample image for the Outgoing Longwave Radiation-Monthly CDR.*

**ACCOMPLISHMENTS**

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

- Atmospheric Temperature Bundle: MSU and AMSU FCDR (Burden)
- Atmospheric Temperature Bundle: MSU and AMSU TCDR (Burden)
- Cryosphere Bundle: APP and APP-x (Burden)
- Cloud/Moisture Bundle: Cloud Top Pressure, TPW (Burden)
- Cloud Bundle: AVHRR Radiances, Cloud properties (Burden)
- Total Solar Irradiance (Inamdar)
- Solar Spectral Irradiance – Composite (Inamdar)
- Calibration of MSRI using the Moon (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 NCDC 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 NCDC systems as requested by CDRP, PI, and/or other IPT members,
- Assisting with ingest and archiving 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.

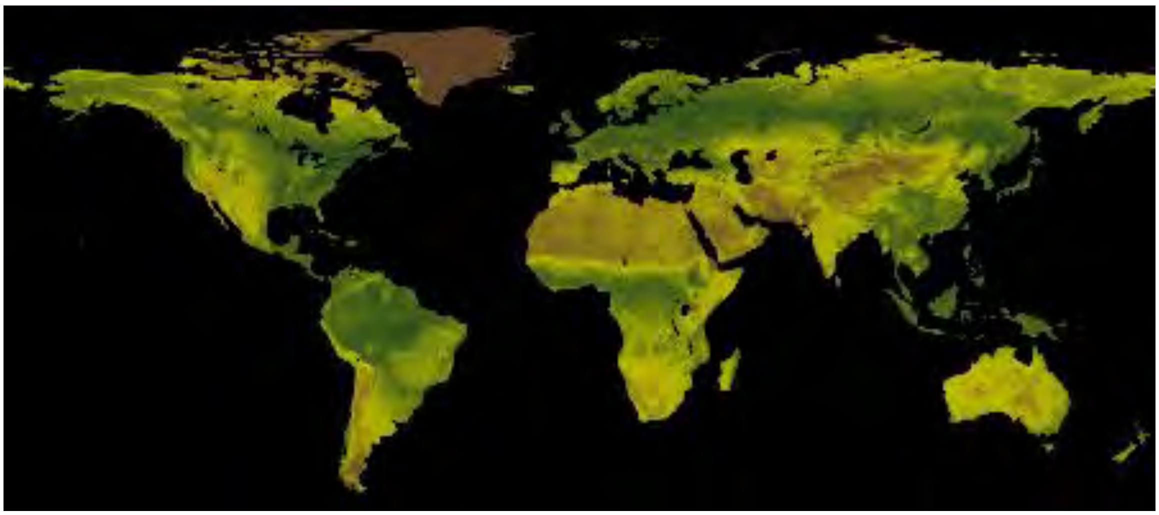


*Figure 2. An example image of Normalized Difference Vegetation Index (NDVI) for the Land Surface Bundle CDR.*

**PLANNED WORK**

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

**DELIVERABLES**

N/A

**PUBLICATIONS**

- Ashouri, H, K. Hsu, S. Sorooshian, D. Braithwaite, K.R. Knapp, L.D. Cecil, B.R. Nelson, and O.P. Prat, 2014. 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.

**PRESENTATIONS**

- Prat, O.P., 2014. Overview of satellite quantitative precipitation estimates. *NCDC-NODC-NGDC-CICS-AFCCC Internal Seminar,* July 8 2014, Asheville, NC, USA.

- Prat, O.P., 2014. Toward the development of Climate Data Records (CDR) for precipitation: Evaluation and applications of radar, satellite, and ground based QPE product. *CICS-MD Seminar,* April 11 2014, College Park, MD, USA.
- Prat, O.P., B.R. Nelson, and L. Vasquez, 2014. Characterization of CONUS rainfall using a multi-sensor approach: Evaluation of radar-based, satellite-based, and ground-based QPE products. *International Weather Radar and Hydrology symposium*, 7-9 April 2014, Washington, DC, USA.
- Prat, O.P., and B.R. Nelson, 2014. Toward the development of an evaluation framework of Climate Data Records for precipitation: A characterization of CONUS rainfall using a suite of satellite, radar, and rain gauge QPE products. *94^th annual meeting of the American Meteorological Society,* 2-6 February 2014, Atlanta, GA, USA.

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 1 |
| # 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 | 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**

Olivier Prat (OP) participated in the PERSIANN-CDR adjustment to comply with CDR requirements. The Atmospheric Temperature Bundle: MSU and AMSU FCDR, Precipitation – PERSIANN-CDR, and Land Surface Bundle CDR have been transitioned to IOC status. OP coauthored one journal article describing the PERSIANN-CDR algorithm. OP gave presentations (2) and seminars (2) using precipitation CDRs.

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

| | |
|---|---|
| **Task Leader** | Jim Biard, Jessica Matthews, Ge Peng, Carl Schreck |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**

This project kicked off in July 2014 and the team made several key accomplishments by the end of CICS-NC's first 5-year award. Most of the tasks to date have focused on planning and analysis. In particular:

- Assessed the effort to incorporate obs4MIPS-compliant uncertainty estimates for selected operational CDRs
- Determined a methodology for temporal and spatial upscaling, downscaling, and averaging of CDRs to meet Obs4MIPs requirements
- Submitted Obs4MIPs Data Set Proposal Forms for selected CDRs

- Started development of a software tool capable of creating Obs4MIPs-compliant version of CDRs from operational CDRs

**PLANNED WORK**

- Complete development of a software tool capable of creating Obs4MIPs-compliant version of CDRs from operational CDRs
- Verify output from this tool with original CDRs
- Validate that all metadata compliances are met in the Obs4MIPs version of CDRs
- Produce complete period of record in Obs4MIPs-compliant resolutions and formats for selected operational CDRs
- Compose required Technical Note documentation to accompany each Obs4MIPs CDR

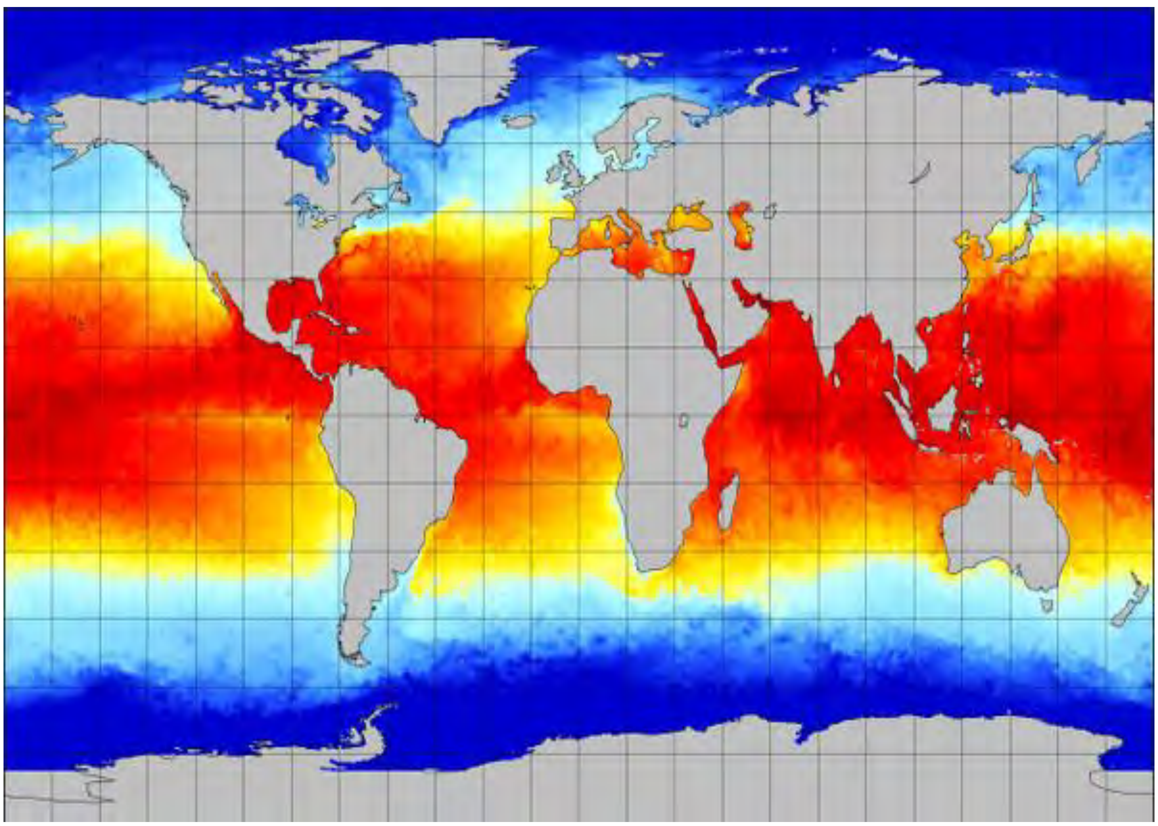


*Figure 1. A sample image of the Optimal Interpolation Sea Surface Temperature CDR prepared for Obs4MIPs.*

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 |

| **SNPP VIIRS Climate Raw Data Record Production Software Development** | |
|---|---|
| **Task Leader** | Jim Biard |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **Contribution to CICS Themes (%)** | Theme 1: 100% |
| **Main CICS Research Topic** | Climate Data and Information Records and Scientific Data Stewardship |
| **Contribution to NOAA Goals (%)** | Goal 5: 100% |

**Highlight**: The VIIRS Climate Raw Data Record production software development and test were completed and operational production began on October 19, 2013.

**BACKGROUND**

The Climate Raw Data Record (C-RDR) Project is a part of the Climate Data Record Program. The C-RDR Project is responsible for developing a system to acquire, reformat, and enhance the Suomi National Polar-orbiting Partnership (SNPP) Raw Data Records (RDRs) and support data to facilitate the production of Climate Data Records (CDRs).

CDRs are fully calibrated, long-term time series of climate variables that have the consistency and continuity required for the climate research community. The production of CDRs requires the reprocessing of extensive data sets as algorithms are improved and the sensor performance is better understood. To produce CDRs**,** the raw data are required as input for each iteration of the reprocessing.

The goal of the C-RDR system is to provide the SNPP raw data and supporting data in a format that is enhanced for utilization in research, the production of CDRs, and long-term stewardship. There will be a C-RDR for each science instrument on the SNPP satellite. The C-RDRs contain the raw measurements from the RDRs, decoded and decompressed so they are easily accessible. Each C-RDR file also contains extensive provenance, discovery, and usage metadata. The C-RDR files use the established, platform-independent, community standard netCDF-4 data format.

The C-RDR system produces C-RDR files from SNPP RDR granules on an operational basis, and will do so for the life of the SNPP mission. The C-RDR files are being archived and are available to the user community.

The C-RDR for the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument was the first chosen for development.

**ACCOMPLISHMENTS**

Over the last year, the coding of the applications that makes up the VIIRS C-RDR production system was completed. Internal testing, both within CICS-NC computer systems and in the development system within NCDC's 3-Tier Development Environment, was performed and successfully completed. The VIIRS C-RDR production system applications and associated libraries, scripts, and configuration files were then deployed in the test system within the NCDC 3-Tier Development Environment where they underwent and passed an NCDC security review. The system acceptance test was then performed with successful results. Once the VIIRS C-RDR production system had passed the acceptance test, an Operational Readiness Review was held and stakeholders agreed that the system was ready for production. The NCDC Information Technology Branch (ITB) deployed the production system within the NCDC 3-Tier Development Environment.

The high-level data flow in the core production system is described in *Figure 1*.

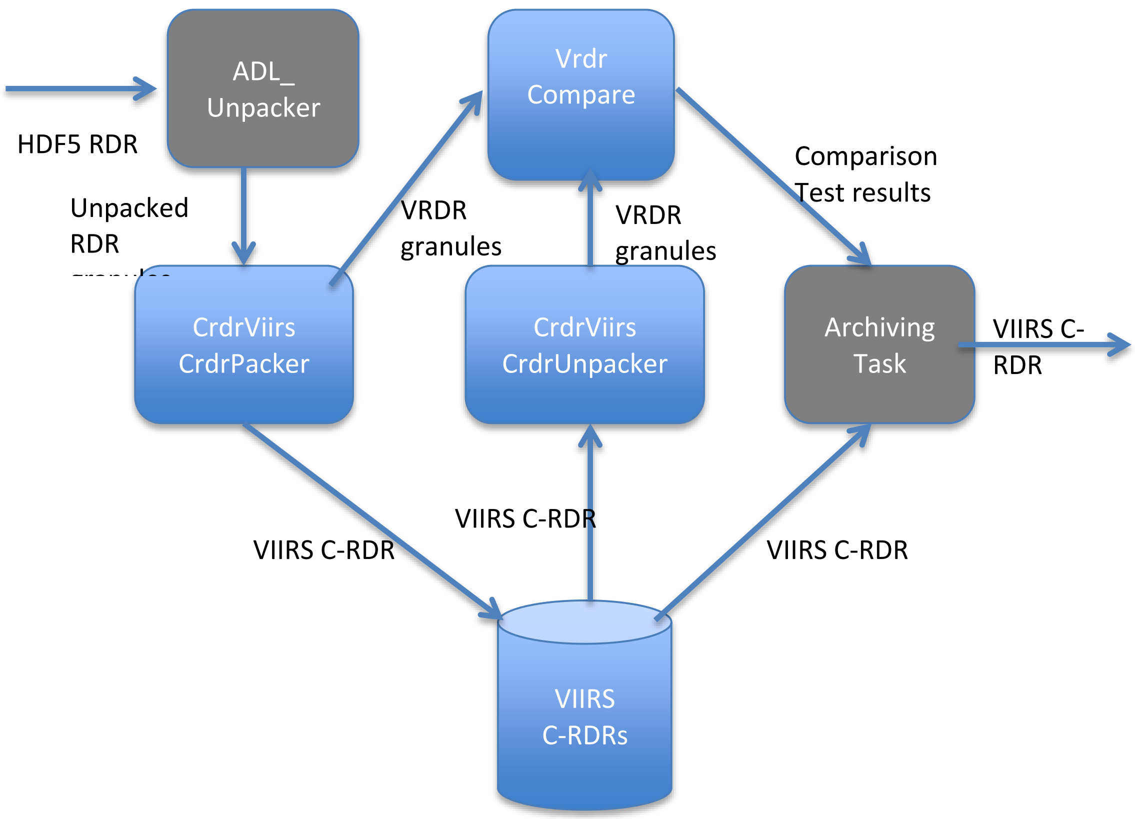



*Figure 1: Primary data flow in the VIIRS C-RDR production system*

Files containing VIIRS RDR granules, packaged together using the HDF5 format, are retrieved on an ongoing basis from the NOAA Comprehensive Large Array-data Stewardship System (CLASS) and fed into the VIIRS C-RDR production system. The ADL_Unpacker application (provided by the SNPP program) extracts the individual binary RDR granules and their associated metadata, which are passed to the CrdrViirsCrdrPacker application.

The CrdrViirsCrdrPacker application takes the contents of the RDR granules and constructs a C-RDR file. It also constructs Verified RDR (VRDR) granules-one per RDR granule, with metadata, using code provided by the SNPP program. VRDR granules are created as the first step in SNPP operational production of VIIRS Sensor Data Records (SDRs) in the NOAA Interface Data Processing Segment (IDPS). A VRDR is similar to a C-RDR, but it contains a subset of all the data available in an RDR.

Once the CrdrViirsCrdrPacker application has completed its task, the CrdrViirsCrdrUnpacker application is run to create VRDR granules and metadata from the C-RDR file just created. The two sets of VRDR granules and metadata are then passed to the VrdrCompare application, which checks to see if there are any differences in the two sets, and records the success or failure of the test. If there are no differences found, the archiving task (part of the production system executive) feeds the validated VIIRS C-RDR file out to the NCDC archive ingest system. The archive-ingest system delivers the files to the HDSS Access System (HAS) where they are made available for time-based search and download.

Ongoing production of the VIIRS C-RDR began on October 19, 2013. Since that time, analysis of the processing logs has shown that the error rates are well within the success margins specified for the operational system. Further analysis of the logs uncovered a defect in the CrdrViirsCrdrUnpacker application that was causing it to produce faulty VRDR granules under certain rare conditions, which then cause the validation test of the source C-RDR file to fail. This defect was corrected.

As part of the development effort, procedures for the system acceptance test and procedures for configuring a system were written so that it is ready for development and operation of the VIIRS C-RDR production software (including required 3rd party applications and libraries). A document was written to describe the VIIRS C-RDR contents (the VIIRS C-RDR Data Product Specification). A User's Guide for the applications and the system executive was also written. Work was begun on a software design description document.

**PLANNED WORK**

The two main focuses in the project for the coming award period will be monitoring and maintenance of the software and completing the documentation. If processing errors are uncovered through monitoring, the responsible code defects will be corrected and the operational software updated.

Another part of the maintenance task is identifying gaps in the VIIRS C-RDR time coverage relative to the available VIIRS RDR granules and filling in those gaps by ordering the missing RDR granules from CLASS and processing them. This will be done on a low-rate basis to extend the VIIRS C-RDR coverage back to the beginning of the available VIIRS RDR coverage, as well as to recover C-RDR files lost on account of data transmission problems or VIIRS C-RDR production system errors.

The Software Design Description document should be completed during FY2015.

**DELIVERABLES**

- VIIRS C-RDR production system software
- VIIRS C-RDR System Acceptance Test
- VIIRS C-RDR production system configuration procedures

**PRESENTATIONS**

- Biard, J.C., Copley, L.B., Saunders, D. and Privette, J., 2014: Easy Access to the VIIRS Science Raw Data Record, *STAR JPSS Annual Science Team Meeting,* College Park, MD (13 May).
- Biard, J.C., 2014: The VIIRS Climate Raw Data Record, *STAR JPSS Annual Science Team Meeting,* College Park, MD (14 May). (Poster)

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**Graph Database Proof-of-Concept Federated Archive Search Tool (FAST)**

| | |
|---|---|
| **Task Leader** | Linda Copley |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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.

This proof-of-concept implements a NoSQL graph database to collect descriptive information for the data in different unrelated systems, and demonstrates the capabilities of linking associated datasets into a new search and discovery interface. The extremely flexible data model inherent in 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.

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.

The goal of this proof-of concept is to determine the utility of this solution to provide search and discovery across disparate datasets, while applying enhanced search capabilities to support a diverse community of users.

**ACCOMPLISHMENTS**

Created a proof-of-concept application 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).

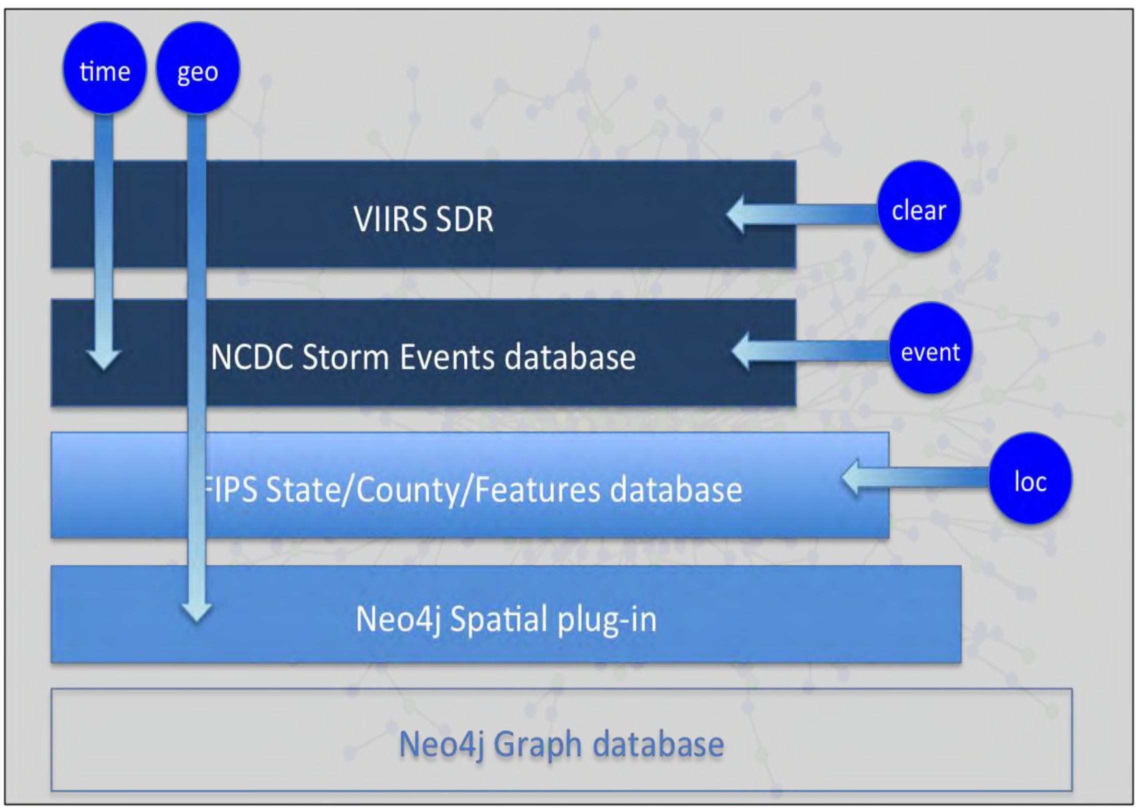



*Figure 1: Graph Database Stack*

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 date tree in the graph database to allow for temporal searches.

Additional descriptive data for the datasets was also incorporated into the graph. For Storm Events, the variables included storm type, damage type, and wind speed. The VIIRS SDRs included variables such as percent cloud cover, day/night flag, and percent error.

The strong relationship properties of the graph database were exploited to provide for rapid and unique queries over these two datasets. A significant strength of graph databases is the ability to discover relationships among data, without the recursive joining of data required in relational databases. Where a relational database would require the multiply-recursive loading of entire data stores while performing map-reduce operations, the graph database follows a linked list type structure to traverse to nearest neighbors in a single hop. This allows for rapid traversal of friends-of-friends type queries.

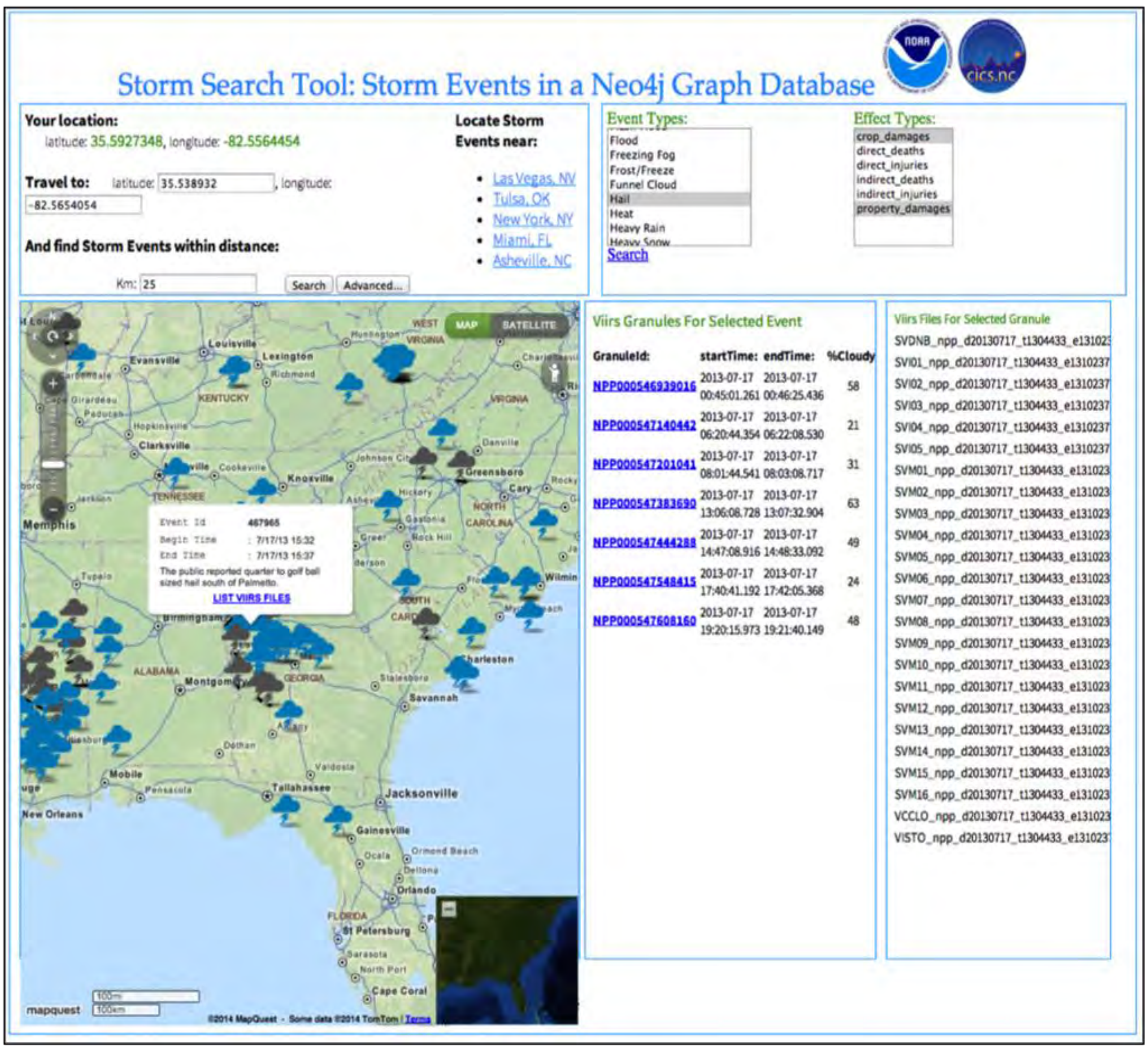



*Figure 2: Storm Search Tool*

The FAST group created a demonstration application that allows the user to quickly and easily discover data that crosscuts the datasets and satisfies multiple search requirements, such as finding all of the data for a specified date in a geographic area with a given qualitative measure. This application allows the user to query for Storm Events based on several criteria, including geographic location, event type, and storm effect. The zoom-able map allows narrowing of the results set to a geographic area. Hovering over a storm event displays the storm date and time along with a descriptive narrative. When a specific storm is selected the applicable VIIRS SDR granules are listed; and for a selected granule the available VIIRS SDR product files are displayed.

**PLANNED WORK**

- Create a tool for discovery of CDR metadata using a graph database.
- Integrate additional NCDC datasets into discovery tool.

**DELIVERABLES**

- FAST (Federated Archive Search Tool) application proof-of-concept

**PRESENTATIONS**

- Copley, L., 2014: Graph Databases Conceptual Overview. Presentation to NCDC Metadata Working Group, 7 March 2014.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | N/A |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**Suomi-NPP VIIRS Climate Raw Data Record System Infrastructure Development**

| | |
|---|---|
| **Task Leader** | Linda Copley |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**: Completed transition of the VIIRS Climate Raw Data Record into the NCDC operational environment while helping to define the processes for the 3-tier software development environment.

**BACKGROUND**

The VIIRS Climate Raw Data Record (C-RDR) Project is a sub-system of the Climate Data Record (CDR) Project. The C-RDR Project is responsible for developing a system to acquire, reformat, and enhance the Suomi National Polar-orbiting Partnership (NPP) Raw Data Records (RDRs) and support data required for the production of Climate Data Records (CDRs).

CDRs are fully calibrated, long-term time series having the consistency and continuity required for the climate research community. The production of CDRs requires the reprocessing of extensive datasets as algorithms are improved and the sensor performance is better understood. To produce CDRs, the raw data are required as input for each iteration of the reprocessing.

The goal of the C-RDR system is to provide the NPP and JPSS raw data and supporting data in a format that is enhanced for utilization in research, the production of CDRs and long-term stewardship. The C-RDRs contain the raw measurements from the CCSDS packets, decoded and decompressed so they are easily accessible in an established data format, netCDF-4. The C-RDRs are quality controlled and assembled into data files, which include information for the computation of earth location and calibration values.

The C-RDR system reformats the NPP and JPSS raw measurements into easily accessible C-RDR files. The C-RDRs contain the information required for the production of CDRs and Climate Information Records (CIRs). The C-RDR system disseminates these C-RDRs to the user community on a routine and operational basis.

This task is focused on developing the system infrastructure to support the production of C-RDRs. The Processing Director system controls the flow of ingested Raw Data Records (RDRs) from the NOAA CLASS archive, sets up the processing into C-RDRs, and tracks and controls the status of processing. The system is being developed with a generic architecture to provide a framework that allows other processing streams to be inserted into the workflow in place of the C-RDR.

**ACCOMPLISHMENTS**

The production of the VIIRS C-RDR was transitioned into the operational environment at NCDC. Ongoing production of the VIIRS C-RDR began on October 19, 2103. C-RDR's are now being produced routinely as soon as they are downlinked from the NPP satellite and made available in NOAA's Comprehensive Large-Array Storage System (CLASS). The C-RDR's are archived at NCDC in the Hierarchical Data Storage System (HDSS) Access System, and are available for download there.

Each C-RDR is validated to ensure that it contains data equivalent to the original bit-based Raw Data Record (RDR). A comparator tool has been created to validate that the raw data contained in the RDR is faithfully replicated in the final C-RDR product. This comparison tool is integrated into the product workflow so that each C-RDR is validated prior to archive.

The transition of the C-RDR into operations at NCDC represented the first transition of a product using virtual machines and the 3-tier development environment.

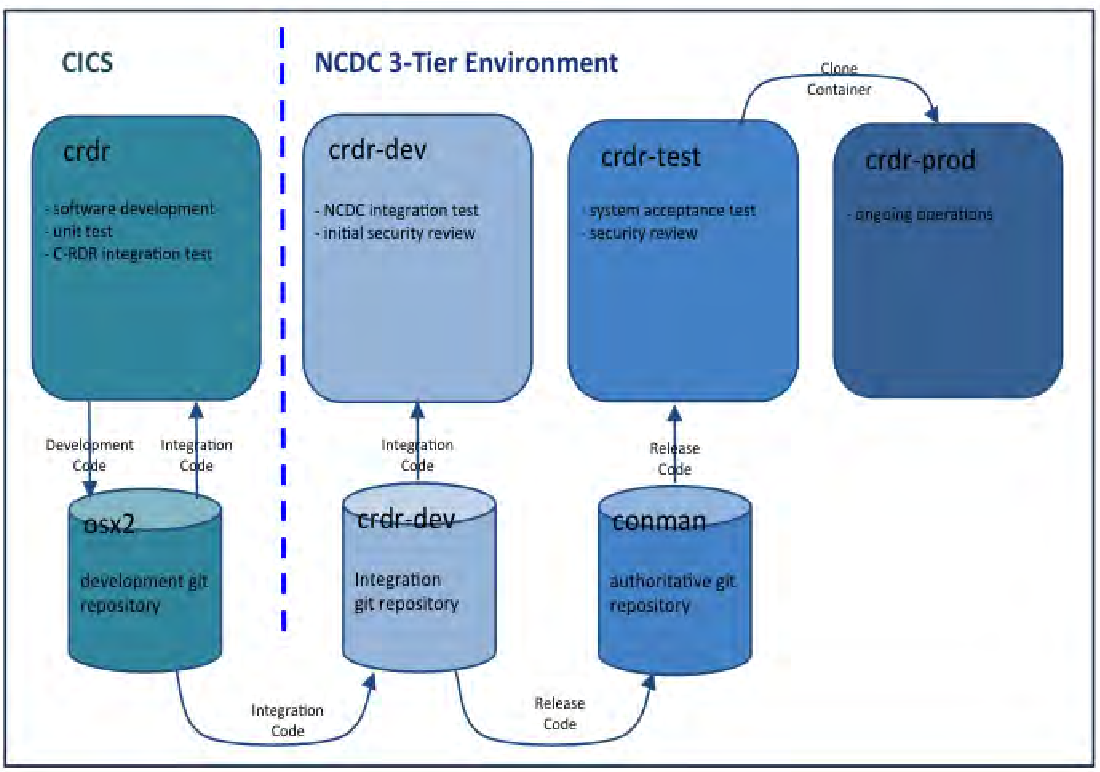



*Figure 1. NCDC 3-tier development environment as integrated with the CICS-NC development environment.*

As the first product to be developed using this paradigm, the processes and requirements for development and transition in this environment were developed collaboratively with NCDC personnel. We determined the requirements for each phase transition as imposed by the Information Technology, Information Security, Operations, Archive, and User Engagement entities at NCDC. Each requirement was satisfied and documented through a series of defined documents and reviews.

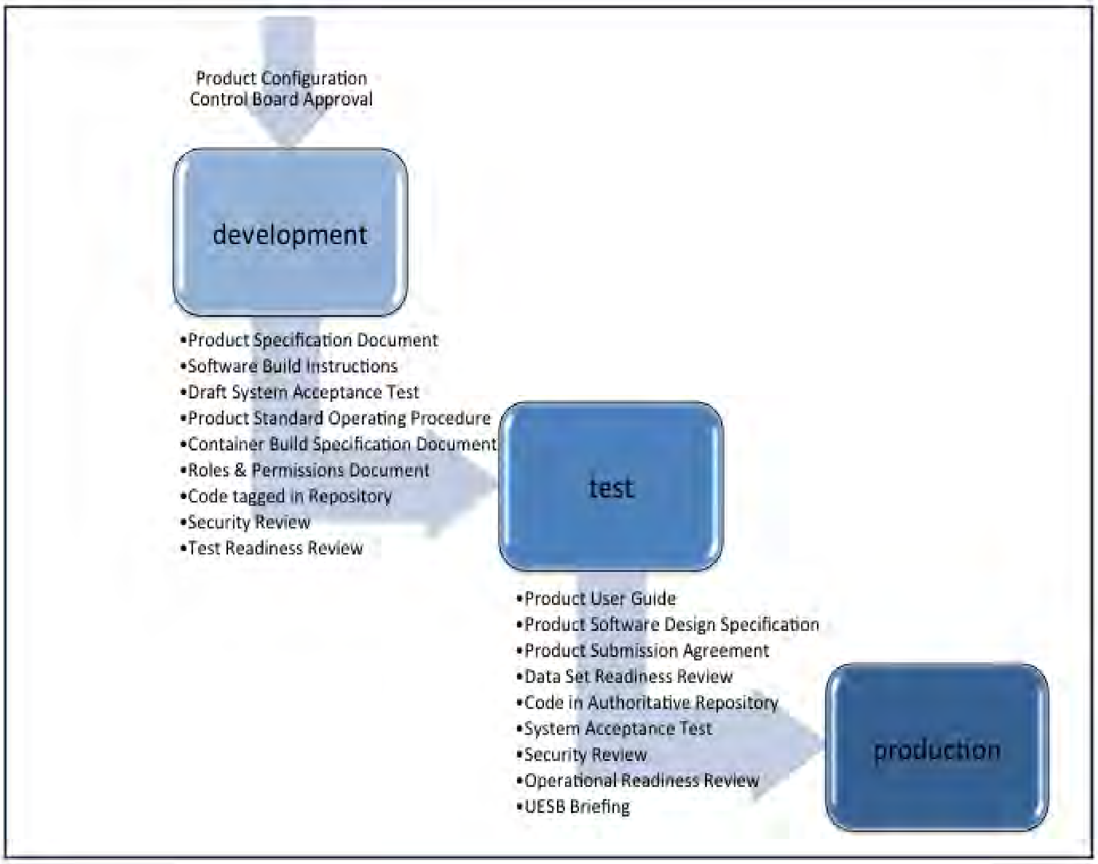



*Figure 2. Phase-transition requirements in the NCDC 3-tier development environment.*

Some components of the process necessitated the implementation of tools to support the processes. Git was installed as our development version management system, and Gerrit was implemented for initial and ongoing code review support. Additionally, we developed and implemented a Configuration Management Plan and Configuration Management Process to handle both deployed software and the associated documentation.

**PLANNED WORK**

- Develop operations status and reporting functions for the Processing Director.
- Integrate additional NCDC products into the Processing Director environment.

**DELIVERABLES**

- VIIRS C-RDR version 1.0 Processing Director

- VIIRS C-RDR CCB Charter Rev 1.0
- VIIRS C-RDR Configuration Items Rev 1.0
- VIIRS C-RDR Configuration Management Plan Rev 1.0
- VIIRS C-RDR Configuration Management Process Rev 1.0
- VIIRS C-RDR Software Change Request Form Rev 1.0
- VIIRS C-RDR Development to Production Checklist Rev 1.0
- VIIRS C-RDR Standard Operating Procedure Rev 1.0
- VIIRS C-RDR User Guide Rev 1.0

**PRESENTATIONS**

- Biard, J.C., Copley, L.B., Saunders, D. and Privette, J., 2014: Easy Access to the VIIRS.
- Science Raw Data Record, STAR JPSS Annual Science Team Meeting, College Park, MD (13 May).

**OTHER**

- Database architect and database developer for Submission Information Package Generation System (SIPGenSys) configuration subsystem.
- Member of NCDC Metadata Working Group (NMWG).
- Supported 'Hour of Code' at Jones Elementary as part of Computer Science Education Week.
- Supported 'Wave Day' science exploration at Asheville Middle School.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | N/A |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**Transfer NOAA/NASA Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Sea Surface Temperature (SST) Processing to National Oceanographic Data Center (NODC)**

| | |
|---|---|
| **Task Leader** | Robert Evans |
| **Task Code** | NC-CDR- - UM |
| **NOAA Sponsor** | NESDIS/NCDC |
| **NOAA Office** | |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 100%; Theme 3: 0% |
| **Main CICS Research Topic** | Climate Data and Information Records and Scientific Data Stewardship |
| **Contribution to NOAA Goals (%)** | Goal 1: 100%; Goal 2: 0%; Goal 3: 0%; Goal 4: 0%, Goal 5: 0% |

**Highlight**: The Pathfinder Sea Surface Temperature (SST) time series has been extended to include NOAA-19 observations. This is a continuation of the previously submitted time series that covered the Advanced Very High Resolution Radiometer (AVHRR) sensors NOAA-7 through NOAA-18. In addition, the coverage period of NOAA-7 was expanded to include September and October of 1981 through cooperative work with NCDC/RSAD and National Oceanographic Data Center (NODC) to provide the augmented Reynolds OI reference SST fields that are required to process the Pathfinder time series.

**BACKGROUND**

The primary goal of this work is to assemble Advanced Very High Resolution Radiometer (AVHRR) Sea Surface Temperature (SST) retrieval algorithms into a robust code package to produce a Climate-Quality Data Record (CDR) for the AVHRR SST time series, NOAA-7 (September 1981) through NOAA-19 (2013) and deliver the package to NODC to support on-going production of the AVHRR Pathfinder SST time series. This work was based on the Pathfinder 5.2 approach, originally published in Kilpatrick et. al, 1999 (Pathfinder 5.0). Final efforts this year focused on implementing a Pathfinder 5.3 update that added a quality test tree for NOAA-7 and NOAA-19 equivalent to that provided for NOAA-9 through NOAA-18 data set processing. Group for High Resolution Sea Surface Temperature (GHRSST) Version 2.0 file specification and formatted in the GHRSST NetCDF4 files format.

**ACCOMPLISHMENTS**

Accomplishments to project end included:

- Implementation of updated AVHRR SeaDAS 6.4 retrieval codes
- Inclusion of data quality tests for NOAAA-7 and NOAA-19, now Pathfinder 5.3
- Update of C-ATBD to reflect inclusion of NOAA-7 and -19 quality tests
- Processing the entire NOAA-7 through NOAA-19 observations using Pathfinder 5.3
- Transfer of Pathfinder 5.3 data sets to NODC for conversion to NetCDF4 format and delivery to NCDC
- Transfer Pathfinder 5.3 code base to NCDC and NODC
- Provision of support to NODC to implement Pathfinder processing on the cluster environment
- Update of documents provided to CDR reflecting Pathfinder 5.3 version
- Provision of reference Pathfinder 5.3 data sets for NODC (for validation of NODC in-house processing of the entire Pathfinder 5.3 time series)

- Transfer of Pathfinder SeaDAS 6.4 implementation to NODC and NCDC
- Production of Pathfinder 5.3 SST dataset for all NOAA 5 channel sensors
- Transfer of updated NOAA dataset to NODC for NetCDF file conversion
- Transfer of Pathfinder on-going production to NODC
- Update Pathfinder documentation and provide to NCDC
- Transfer of Pathfinder processing code to NCDC and NODC

**-- All work was completed and this is the final report for this task/project. ---**

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 0 |
| # 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 | 1 |
| # of peer reviewed papers | 0 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 0 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**Net Surface Radiation Budget at High Spatial and Temporal Resolution from Multi-Sensor Data Fusion**

| | |
|---|---|
| **Task Leader** | Anand Inamdar |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**: A successful technique to estimate net surface solar radiation from geostationary earth orbit (GEO) satellites has been developed by adapting an algorithm developed for the NASA-operated Clouds and Earth's Radiant Energy System (CERES) instrument on board the EOS/Terra and Aqua. Comparison of results with ground site measurements revealed excellent agreements comparable to or better than other sophisticated methods or even CERES-parameterized flux products.

**BACKGROUND**

Net surface radiation controls the energy and water exchanges between the biosphere and the atmosphere and has major influences on the Earth's weather and climate. Therefore, the ability to better monitor each of the shortwave and longwave radiative components at the surface at high spatial and temporal resolution is vital to better understand existing feedbacks between the surface energy and hydrological cycles and the past and current Earth's climate, and to better assess future effects of climate change. NASA-operated Clouds and Earth's Radiant Energy System (CERES) instrument on board the EOS platform has been making measurements of net radiation budget (top-of-atmosphere and surface) for over a decade now, but the spatial and temporal resolution lacks what is needed for certain applications like water management in agriculture. However, with a wide array of sensors (like Moderate Resolution Imaging Spectroradiometer (MODIS), the suite of geostationary-orbit meteorological satellites, etc), there is potential to use optimized data fusion techniques to fill in the spatial and temporal gaps.

**ACCOMPLISHMENTS**

A technique was developed to derive net surface radiation in the shortwave domain from GOES-10 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) sites yields very good agreement comparable to, or many times better than, other sophisticated methods, including the CERES products (see *Fig. 1*). An advantage of this product is a significantly extended spatial and temporal coverage than that offered by the CERES instrument. A journal paper describing this study was submitted to the IEEE Transactions on Geoscience and Remote Sensing.

The reviews for the submitted Journal paper to the IEEE TGRS were received more than 8 months after the initial submission. Following reviewer's comments for a major revision, the research group extended the analysis including additional months and years to represent all seasons.

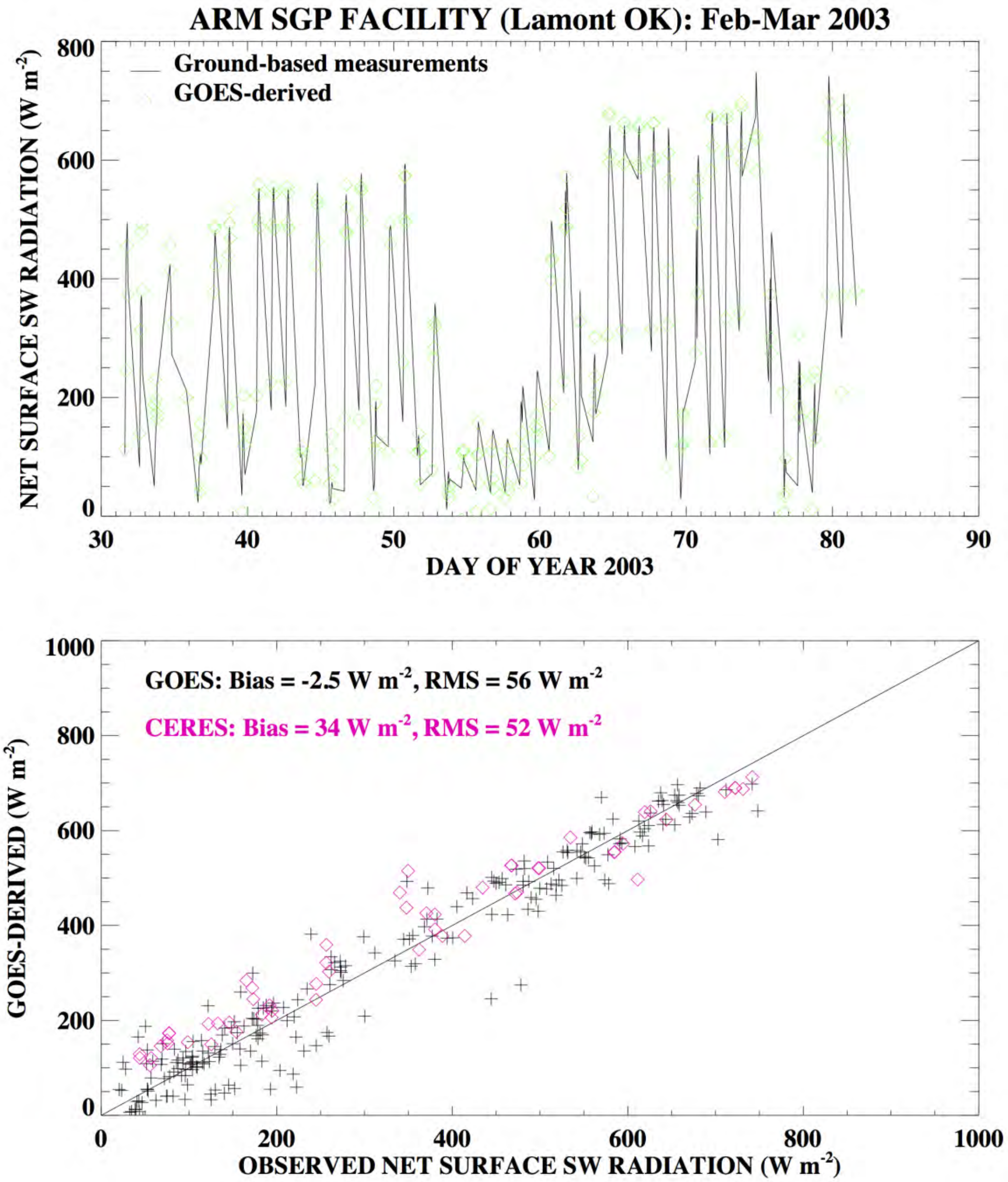



*Fig. 1. Top: Time series of net surface SW flux measured at ground (continuous solid line) and those retrieved from GOES-10 (green symbols). Bottom: Scatter plot of matched pairs of observed and modeled values from top panel. Magenta diamond symbols show the comparison with CERES products (Model B in the CERES sub-system).*

**PLANNED WORK**

- Extension of the work to other meteorological satellites around the globe

- Top-of-atmosphere and surface LW radiation from MODIS imager
- Extend the present SW scheme to long wave spectral region for the GEO imagery
- A proposal, "Estimation of top of canopy net radiation using observations from MODIS on-board TERRA and AQUA satellites", has been submitted to NASA with Anand Inamdar as the lead PI and Pierre Guillevic is the Co-I. Decision on award is still pending.

**PUBLICATIONS**

- Inamdar, A. K., and P. Guillevic, 2014: Estimation of net surface shortwave radiation from GOES imagery. Submitted to *IEEE Trans. Geosci. Remote Sensing*.
- Inamdar, A. K., and P. Guillevic, 2014: "A new approach to monitor net surface solar radiation from geostationary imagery". Proc. of AMS 95$^{th}$ Annual Meeting held at Atlanta Feb 2-6 2014.

**PRESENTATIONS**

***Invited***

- "A new approach to monitor net surface solar radiation from geostationary satellites." Earth System Science Inter-disciplinary Center (ESSIC), University of Maryland, College Park MD Sep 9 2013.

***Conference***

- 28$^{th}$ Hydrology Conference, American Meteorological Society 94$^{th}$ Annual Meeting, Atlanta. Feb 3 2014.

| **Performance Metrics** | |
|---|---|
| # 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 | 1 |

**Independent Evaluations of the Calibration of the Visible Channel in the International Satellite Cloud Climatology Project (ISCCP) B1 Data**

| | |
|---|---|
| **Task Leader** | Anand Inamdar |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 has been completed for all meteorological satellites for the period 1979-2009, through employing AVHRR channel 1 reflectance in the Pathfinder Atmospheres Extended (PATMOS-x) data and validated through other independent results. Separately, the pre-GVAR GOES data (prior to GOES-8) has been reprocessed to conform to a more consistent format with less noise and these reprocessed data files will soon replace the present ISCCP B1 data in the archive.

**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. For accurate retrieval of these geophysical parameters, it is vital to have a good calibration. The visible channel calibration is currently managed by the Meteorological Center in France through normalization with the concurrent Advanced Very High Resolution Radiometer (AVHRR) solar channel on the afternoon NOAA polar-orbiting satellite at the same viewing geometry. However, there are several gaps in the present calibration. For example, data prior to 1983, suffers from too much noise for certain GEO sensors. The main objective of the present project is to fill in these calibration gaps and perform a uniform calibration for all the geostationary satellite visible channels from 1979 until present, through cross-calibration with the MODIS-quality AVHRR visible channel Climate Data Record (CDR) product available at NOAA/NCDC.

**ACCOMPLISHMENTS**

Cross-calibration of the GEO visible channel counts with the AVHRR PATMOS-x has been performed through direct linear regression, using domain-averaged count values for the GEO, instead of the cumulative histogram matching technique that was used and reported previously. The former scheme has been found to yield better results than the histogram approach as evidenced by comparisons with the ISCCP calibration and also other calibration results. Time variation of the calibration coefficient is derived in terms of a quadratic function of the time lapsed since launch of the satellite. Results for the time series of the calibration coefficients have been validated independently. These include calibration using views of the moon (lunar) which were made available from Thomas Stone of the USGS Lunar Observatory at Flagstaff AZ, and observation of pseudo-invariant stable targets on earth.

Data provided from each Satellite Processing Center (SPC) have been treated separately for calibration purposes. An example of the time variation of the calibration coefficient using different methods is shown in *Figure 1* for the GOES and Meteosat Second Generation 2 (MTS-2) satellite series. A journal paper describing this study has been submitted to the AMS Journal of Atmospheric and Oceanic Technology.

An additional comparison of calibrations with Lunar were performed in the extension period of this award. The ISCCP transition from NY GISS Center to Asheville is moving in full swing with Quality Control processing of ISCCP B1U images.

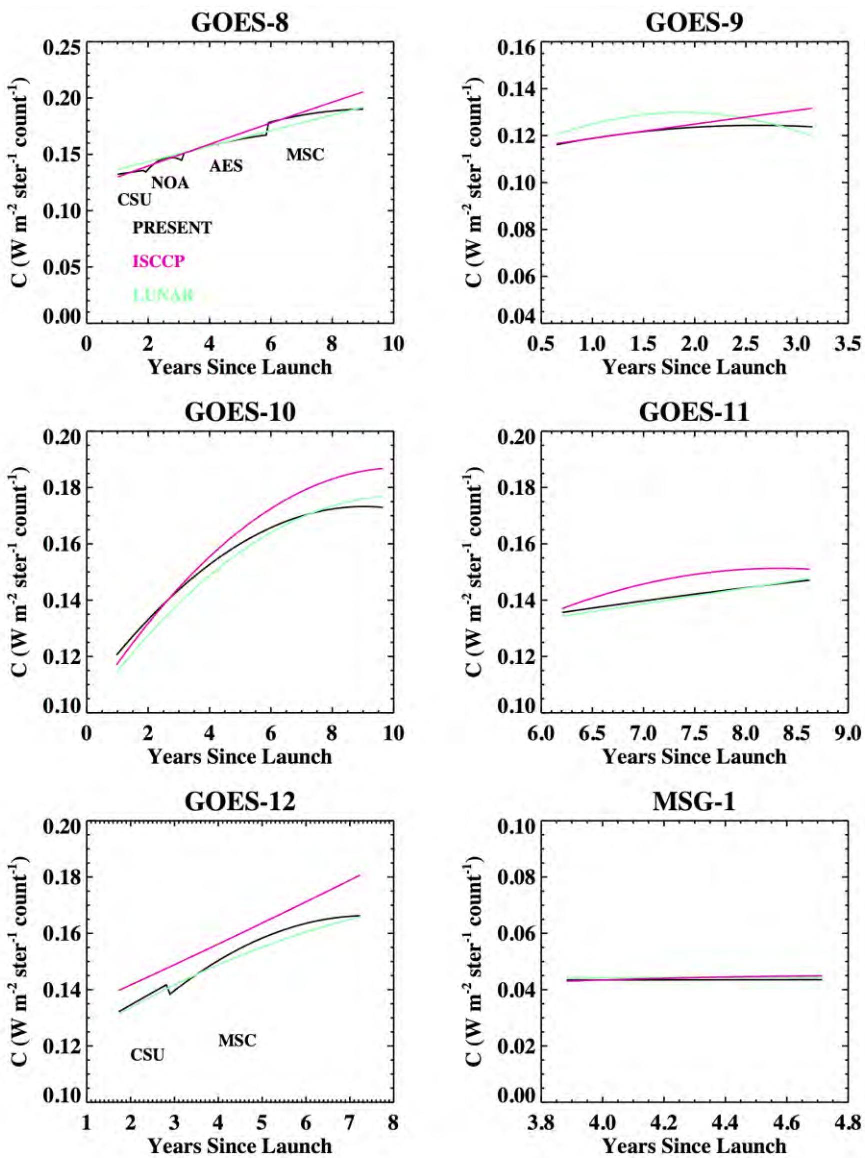



*Fig. 1. Comparison of the time variation of the calibration coefficient, derived from ISCCP, present study and lunar calibration for GOES-8 to GOES-12 and also Meteosat Second Generation 2 (MSG-2) satellites. Satellites with multiple SPC data providers (GOES-8 and*

*GOES-12) are identified. The color codes for different curves follow the same pattern shown in the top left corner panel.*

**PLANNED WORK:**

- Quality check of all ISCCP B1 images manually before they are employed in ISCCP cloud processing;
- Comparison with additional calibration results from Lunar and other studies as they become available;
- Re-calibration of the reprocessed pre-GVAR ISCCP B1U data;
- Implementation of the full ISCCP processing at NCDC;
- Processing of ISCCP cloud properties at high spatial resolution using the newly calibrated ISCCP B1U data at NCDC.

**PUBLICATIONS**

- Inamdar, A. K., and K. Knapp, 2014: Inter-comparison of Independent Calibration Techniques Applied to the Visible Channel of the ISCCP B1 data. Submitted to *J. Atmos. Ocean. Tech*.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 |

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

| | |
|---|---|
| **Task Leader** | Jessica Matthews |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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), NCDC 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, NCDC 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 NCDC 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.

**ACCOMPLISHMENTS**

This project was one of only 10 selected by the SCOPE-CM Executive Panel from the 2014 competition. We proposed to extend the international collaboration into Phase 2 which is planned to last 5 years and includes activities such as: a common cloud mask approach, a common inter-calibration method, exploration of different temporal resolutions and formats of output, and validation of Level 2 products. In August 2013, Alessio Lattanzio and

Joerg Schulz of EUMETSAT visited NCDC and we made plans for the work to be accomplished by both EUMETSAT and NCDC in 2014.

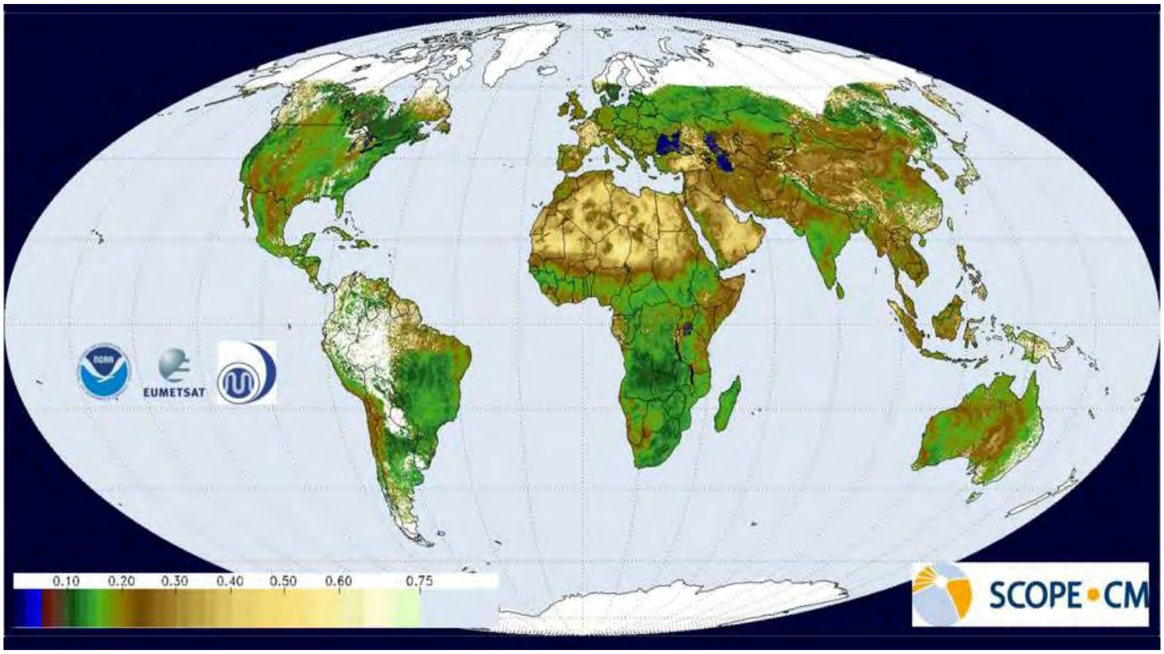



*Figure 1. Broadband black sky albedo spatial composite product for the period 1-10 May 2001.*

One of the main tasks for 2014 was to create a unified approach to calibration. It was decided that we would use the GSICS approach of deep convective cloud (DCC) method. Because the Global Space-based Inter-Calibration System (GSICS) community is already pursuing this, the CICS-NC group will not duplicate their efforts. Jessica Matthews made contact with the NOAA representative working with GSICS for GOES calibration, Fang Fang Yu, who agreed to share calibration information for GOES.

Another main task for 2014 was to use the same global data set for total column ozone and water vapor inputs into the algorithm. Previously, each agency used their reanalysis dataset. All agencies have now agreed to use the ECMWF ozone and water vapor reanalysis data, and this code has been implemented and tested as core code by all agencies.

In January of 2014, Jessica Matthews began collaborating with Brian Reich and Elizabeth Mannshardt of the Statistics Department at North Carolina State University to develop a validation framework for this data set. To date the group has 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.

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.

**PLANNED WORK**

- Update algorithm code to store daily products
- Implement and test cloud mask as developed by the Satellite Application Facility on Climate Monitoring
- 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

**OTHER**

Selected as SCOPE-CM Phase 2 project.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 |

| | |
|---|---|
| **Uncertainty Quantification for Climate Data Records** | |
| **Task Leader** | Jessica Matthews |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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.

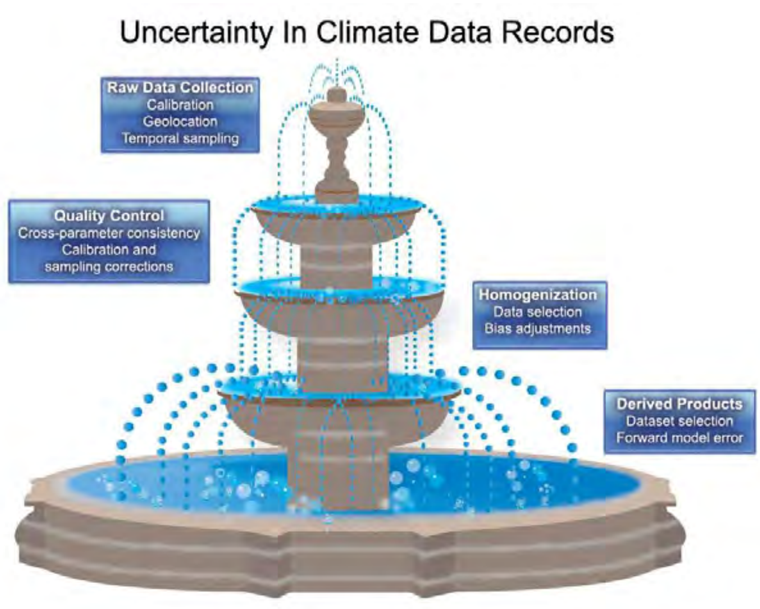


*Figure 1. Uncertainties in climate data records; it is necessary to understand all the uncertainties in the observing system and data manipulation processes. Additional uncertainties are introduced at each level leading to an uncertainty cascade.*

**ACCOMPLISHMENTS**

As chairperson of the Climate Working Group for SAMSI's 2012-2013 Program on Statistical and Computational Methodology for Massive Datasets, Jessica Matthews organized virtual weekly meetings throughout the academic year. The participants in the working group included graduate students, postdocs, and scientists from various governmental agencies and academic institutions from across the country and world. This activity has introduced CICS-NC as an entity in the mathematics/statistics for climate community network. Project topics researched by the group included: detection and attribution when comparing climate model output with observational data, uncertainty quantification for the global carbon cycle, and spatial statistics on distributed data.

Collaboration with Sandia National Laboratories started in February 2014 to apply uncertainty quantification technology based on random fields to a NCDC Climate Data Record. In particular, the Pathfinder SST 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. Pending successful implementation of UQ methodologies to the Pathfinder SST 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 are 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.

Collaboration with NCDC 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. Matthews and Smith plan to research the sensitivity of contributing factors and an overall uncertainty quantification methodology to apply to these loss estimates.

**PLANNED WORK**

- Continue to bridge between NCDC 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.
- Submit manuscript on US Billion Dollar Disaster loss estimate uncertainty
- Utilize North Carolina State University Mathematics Department Adjunct faculty appointment to engage students in this field.

**PRESENTATIONS**

- Matthews, J.L., 2013: Research applications at the National Climatic Data Center*, North Carolina State University Statistics Department Environmental seminar*, Raleigh, NC (17 Oct.).
- Matthews, J.L. and Lei Shi, 2014: Validation of satellite-derived temperature and humidity profiles, *SIAM Conference on Uncertainty Quantification*, Savannah, GA (31 Mar).

**OTHER**

- Scientific committee member for Next Generation Climate Data Products Workshop, Boulder, CO, July 15-19, 2013

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 |

**Comparison of ground-based temperature measurements with satellite-derived phenology**

| | |
|---|---|
| **Task Leader** | Jesse Bell and Jessica Matthews |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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: 50%; Goal 2: 50%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0% |

**Highlight**: This research is a comparison of satellite-derived phenology measurements with ground-based temperature metrics. The goal of this project is to determine which of air or soil temperatures are better for estimating the growing season and will serve to improve USCRN drought monitoring.

**BACKGROUND**

Climate observations of growing season are essential for understanding plant phenology and physiological development. Air temperature, as it is one of the most commonly recorded climate variables, is traditionally used to define the onset and end of the growing season when phenology measurements are not available. Because belowground activity has been shown to be a predominant indicator of vegetative growth, research was con-ducted to determine if soil temperature is a better metric for calculating plant phenology than air temperature. Using start of season (SOS) estimates derived from remotely-sensed MODIS normalized difference vegetation index (NDVI) data, comparisons were made with SOS estimates derived from air and soil temperature as measured by the U.S. Climate Reference Network (USCRN).

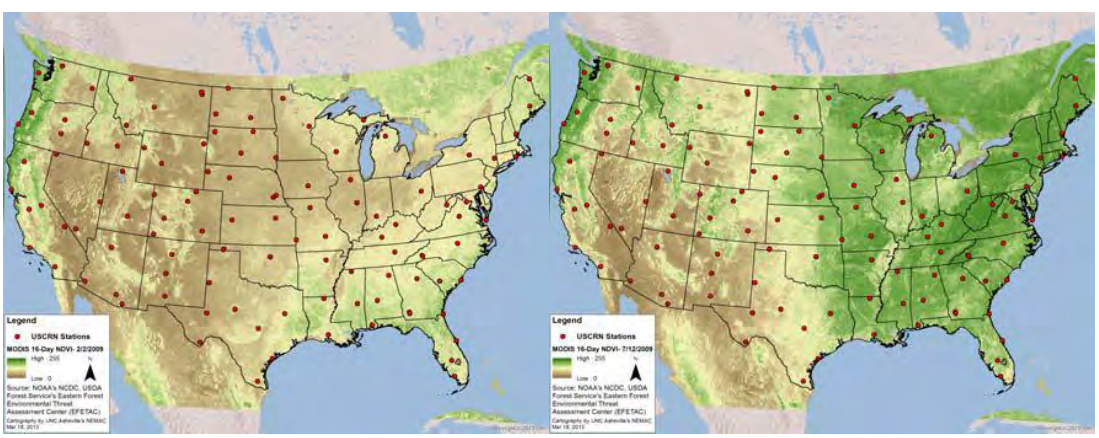


*Figure 1. MODIS NDVI data for winter 2009 (left panel) and summer 2009 (right panel) as overlaid with locations of USCRN stations.*

**ACCOMPLISHMENTS**

Different temperature thresholds were investigated to determine which in situ temperature variable (of air, surface, or soil) and which threshold (of 0C, 5C, or 10C) provides the most accurate correlation with the start date of the growing season. Our approach includes an investigation of 39 USCRN stations that have three complete years (2010-2012) of air, surface and soil (5, 10, 20, and 50 cm) temperature data.

16-day MODIS NDVI data at 250-meter spatial resolution, from both AQUA and TERRA, were used to estimate SOS for each USCRN station in the study. The pixels containing each station were examined for all of 2010-2012. *Figure 1* illustrates the seasonal change of NDVI data along with the USCRN station locations. Two different methods for calculating SOS were applied to the NDVI data: a local threshold based on yearly minimum and maximum NDVI values (ratio) and slope based estimates from exponential functional fits to NDVI data (exponential).

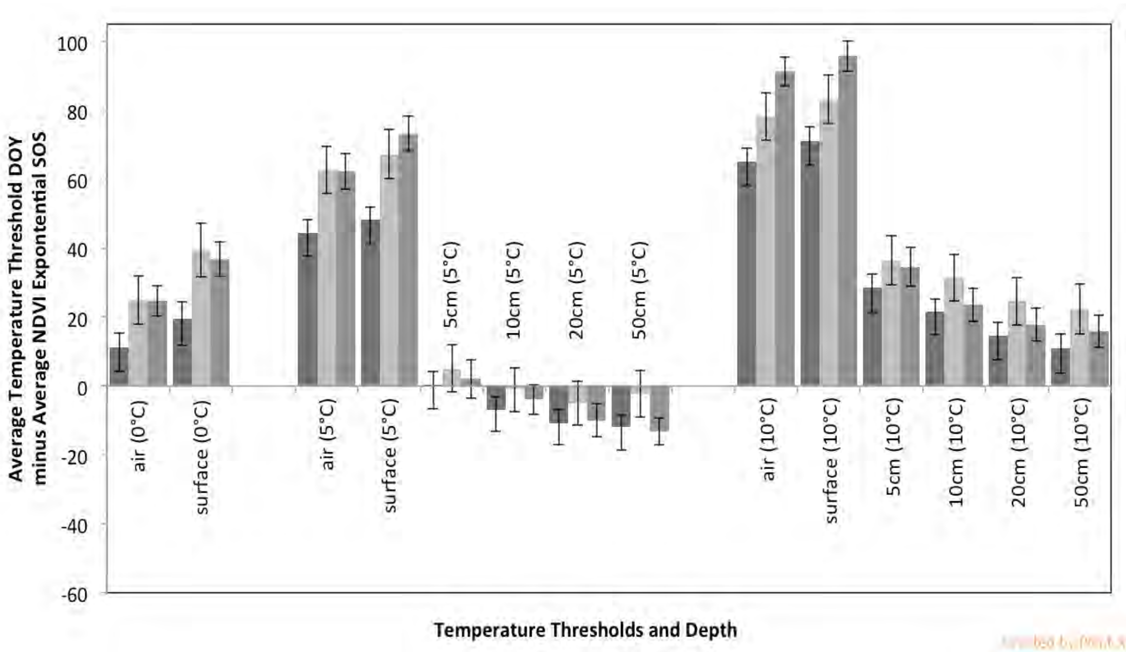



*Figure 2. Comparison of the average difference between temperature-derived SOS at various depths and temperature thresholds with NDVI-derived SOS using the exponential method. Dark grey bars indicate 2010, light grey bars indicate 2011, and medium grey bars indicate 2012. Soli temperatures using the 5C threshold are the closest tot the NDVI-derived SOS.*

The NDVI-based SOS estimates were then compared to the SOS estimates for each of the air and soil temperature thresholds from the ground-based measurements. The best RMSE correlations were with the soil temperature thresholds at 5C and the exponential method (see Figure 2). Assuming that the NDVI-based SOS using the exponential method is a surrogate for truth in the absence of actual phenology data, these results are the first to show large-scale patterns of soil temperature thresholds as an indicator of phenological development. This research provides a new methodology for determining the climatic growing season that will assist in more accurate predictions of plant growth and development for monitoring and modeling purposes.

**PLANNED WORK**

- Extend research to include analysis of 2013 data with a focus on the impact of different eco-regions
- Pursue funding to extend the USCRN to include web-based camera technology in order to validate this methodology.

**PUBLICATIONS**

- Bell, J.E. and J.L. Matthews. Evaluation of air and soil temperatures for determining the onset of the growing season. Submitted.

**PRESENTATIONS**

- Bell J.E., and J.L. Matthews, 2013. Growing Season Analysis during *NCDC Dataset Discovery Day: Frost and Freeze Data and Impacts to the Agriculture, Construction, and Transportation Industry*, 20 March 2013, Asheville, NC.
- Meyer J., 2013. Evaluation of Air and Soil Temperatures for Determining Onset of Growing Season. *NCDC Internal Seminar*, 26 March 2013, Asheville, NC.

**OTHER**

- The analysis for 2012 data was contributed to by UNC-Asheville undergraduate Mathematics major Jennifer Meyer.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 |

**HIRS Temperature and Humidity Profiles**

| | |
|---|---|
| **Task Leader** | Jessica Matthews |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 for this project.

**BACKGROUND**

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

For the temperature profiles HIRS Channels 2-12 were used, while for the humidity profiles HIRS Channels 4-8 and 10-12 were used as inputs. These selections were based on the known relations of the channel information to the different physical variables. The HIRS data coupled with $CO_2$ data were used as inputs to a neural network. The neural networks were calibrated according to surface pressure bins. There were three different neural nets, one each for: surface pressures less than 700 mb, greater than 850 mb, and those in between 700 and 850 mb. Radiative Transfer for Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) (RTTOV) data were used as inputs of profile data for calibration purposes.

The resultant neural networks were applied to produce global temperature and humidity profiles using a series of 13 satellites during the 1978-2013 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 same RTTOV training data sets as used to calibrate the neural networks for the specific humidity and temperature profiles were used to calibrate neural networks for relative humidity profiles. A Monte Carlo scheme was developed to find the optimum neural network by perturbing such variables as: number of layers, number of nodes per layer, and transfer function relating the layers. The process was implemented in Matlab and parallelized for efficiency.

The existing temperature and specific humidity data sets were processed through 2011. We detected a bug in the 2011 data set. The data set was thusly corrected and also extended to include 1978-2013.

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 hr of overpass. To date comparisons have been done with Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) and Constellation Observing System for Meteorology Ionsphere and Climate (COSMIC) observations, which are both largely based on radiosonde measurements.

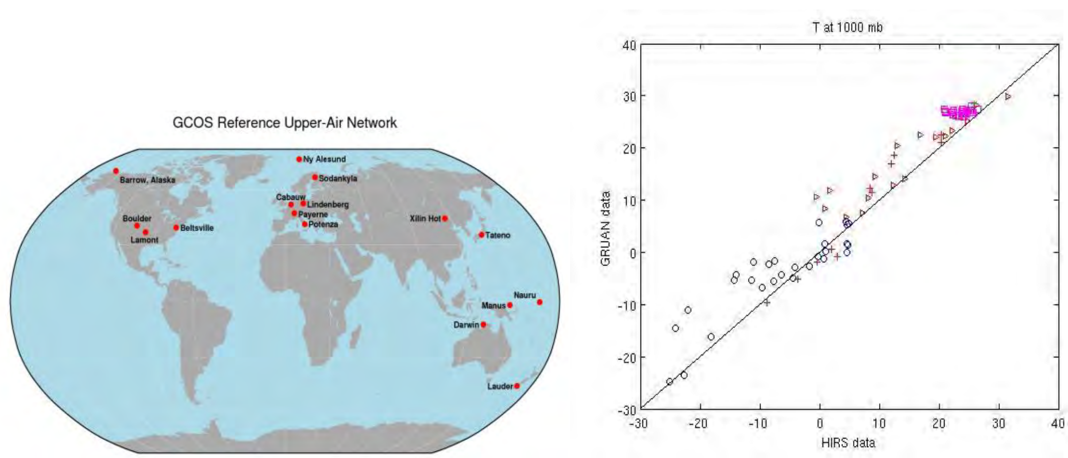



*Figure 1. Locations of available GRUAN stations (left panel). Comparisons of retrieved temperature values based on HIRS data to GRUAN radiosonde observations at a pressure level of 1000 mb (right panel).*

As a result of analyzing these comparisons, a bias correction methodology was developed. It is a two-tier approach. Researchers first leverage information from the AVHRR Reflectance - PATMOS-x CDR to identify cloud coverage of the HIRS pixels, and then optimize based on COSMIC observations.

**PLANNED WORK**

- Continue validation work to assess the performance of the algorithms, including comparisons with surface observations from Hadley Integrated Surface Database (HadISD) and U.S. Climate Reference Network (USCRN)
- Continue implementation of bias correction methodology
- Explore implementing bootstrap methodology to provide associated uncertainty estimates

**DELIVERABLES**

- Corrected and extended temperature and specific humidity profile data

**PRESENTATIONS**

- Matthews, J.L. and Lei Shi, 2014: Validation of satellite-derived temperature and humidity profiles, *SIAM Conference on Uncertainty Quantification*, Savannah, GA (31 Mar).

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 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 a new relative humidity product (1). We also corrected and extended the temperature and specific humidity products (2).

**Maintenance and Production of CDR's for Microwave Sounding Unit (MSU) and AMSU Atmospheric Temperatures and NCDC Special Sensor Microwave Imager (SSM/I) Brightness Temperatures**

| | |
|---|---|
| **Task Leader** | Carl Mears |
| **Task Code** | NC-CDR - -RSS |
| **NOAA Sponsor** | NESDIS/NCDC |
| **NOAA Office** | |
| **Contribution to CICS Themes (%)** | Theme 1: %; Theme 2: 100%; 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**: MSU/AMSU brightness temperatures updated and transferred to CDR Archive at NCDC. SSM/I Version 7 brightness temperatures updated and transferred to CDR Archive at NCDC.

**BACKGROUND**

NOAA's National Climatic Data Center (NCDC) Climate Data Record Program (CDRP) leads NOAA's development and provision of authoritative satellite climate data records (CDRs) for the atmospheres, oceans, and land. This project addresses CDRP's current need to sustain and maintain two specific CDRs derived from satellite microwave radiometers:

1. Atmospheric temperatures at multiple layers derived from the Microwave Sounding Units (MSUs) and Advanced Microwave Sounding Units (AMSUs)
2. Top of the atmospheric (TOA) brightness temperature ($T_B$) derived from the SSM/I on the F15 spacecraft and from the SSM/IS on the F17 spacecraft

The air temperature measurements began in late 1978 with the launch of the first Microwave Sounding Unit (MSU), and the SSM/I brightness temperature measurements began in 1987 with the launch of the first SSM/I on the DMSP F08 spacecraft. Both types of measurements will continue to be recorded with the ongoing operation of various Advanced Microwave Sounding Units (AMSUs) on NOAA, NASA, and EUMETSAT platforms and with the four SSM/IS on F16, F17, F18, and F19.

These measurements have been an important part of national (Climate Change Science Program (CCSP)) and international (Institute of Geophysics, Planetary Physics, and Signatures (IGPP)) assessments of climate change, as well as providing a basis for a number of independent studies of climate change. The continuation, validation, and improvement of these datasets are of fundamental importance to our ability to continue to monitor long-term changes in atmospheric temperature. The goal of this proposal is to ensure the continued production of high quality CDRs from both MSU/AMSU and SSMI/SSMIS.

## ACCOMPLISHMENTS

The main focus of this project was to transition the MSU/AMSU and SSM/I brightness temperature products from research to operations. The transition is complete and the focus of the project is now routine updates and transfers of data to NCDC as well as ongoing monitoring of the data stream. The two sections below summarize progress for each of the data products.

### *MSU/AMSU*

The group has completed the following tasks for MSU/AMSU.

- Completion and approval of Quality Control and Quality Assurance Description Document.
- On-going data production for AMSU instruments on NOAA-15, NOAA-16, NOAA-18, NOAA-19, and METOP-A satellites.
- On-going routine transfers of the MSU/AMSU data in CF 1.6 compliant netcdf to NCDC on a monthly basis.
- Developed simple automated validations tools for MSU/AMSU brightness temperatures
- Completed production, reformatting and transfer of MSU/AMSU data to NCDC through project end
- Ongoing monitoring and quality assurance of these data streams

An example of the monthly atmospheric temperature anomalies from this dataset is shown below.

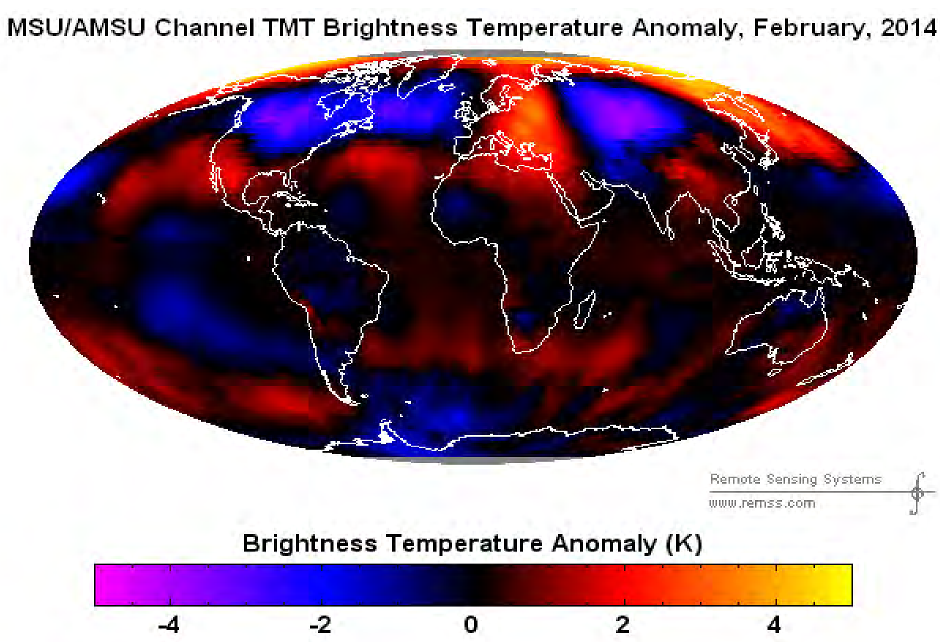



*Figure 1. Temperature Anomaly in the lower troposphere for February 2014. The large positive anomaly over Eastern Europe contributed to poor snow conditions at the 2014 Olympics in Sochi, Russia.*

***SSM/I – SSMIS***

We have completed the following tasks for SSM/I – SSMIS.

- Completion and approval of Quality Control and Quality Assurance Description Document.
- Completion of code to write F17 data in netcdf4 format with approved CF-1.6 metadata.
- Conversion of the dataset to netcdf4.
- Transfer of all previous F17 data to NCDC.
- Ongoing production of data from F17
- Routine transfer of SSMIS F17 data to NCDC in netcdf4 format.
- Developed simple automated validations tools for SSM/I brightness temperatures
- Completed production, reformatting and transfer of SSM/I data to NCDC through project end
- Ongoing monitoring and quality assurance of these data streams

A daily map of the 37 GHz H-Pol brightness temperatures is shown below.

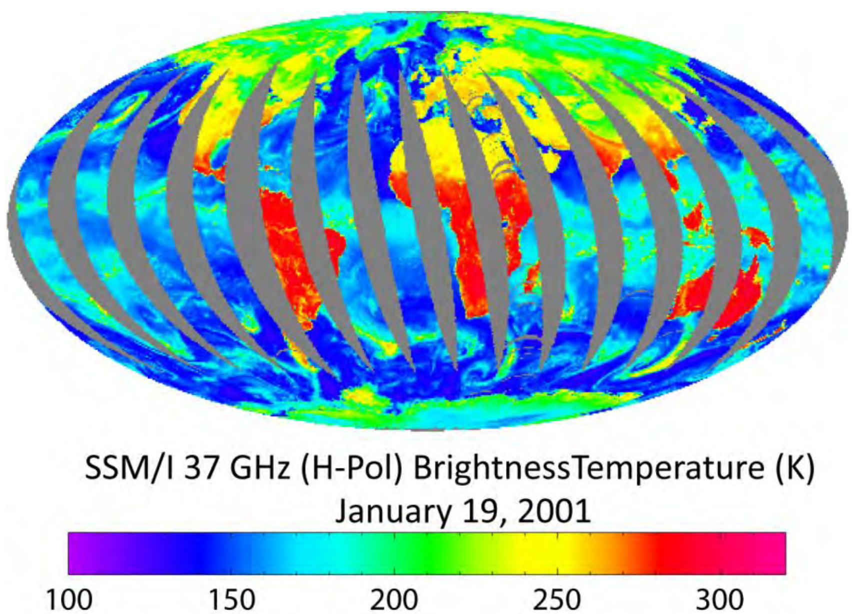



*Figure 2. SSM/I 37 GHz H-Pol brightness temperatures for January 19, 2001. These data were obtained from the DSMP F13 satellite. Variations in the brightness temperatures are due to a combination of surface (temperature, emissivity) and atmospheric (water vapor, clouds, and rain) effects.*

**DELIVERABLES (completed)**

- Monthly Updates to the MSU/AMSU datasets, completed by the 10th of the following month
- Monthly Updates to the SSMIS F17 dataset, completed by the 10th of the following month

**-- All work was completed and this is final report for this task/project. ---**

**PUBLICATIONS**


- Santer, B. D., et al. (2014), Volcanic contribution to decadal changes in tropospheric temperature, *Nature Geoscience*, *7*, 185-189.
- Santer, B. D., et al. (2015), Observed multivariable signals of late 20$^{th}$ and early 21st century volcanic activity, *Geophys. Res. Lett.*, *42*, 500–509, doi:10.1002/2014GL062366.


**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**Evaluation and Characterization of Satellite Products**

| | |
|---|---|
| **Task Leader** | Ge Peng |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**: With the NOAA/NSIDC passive microwave sea ice concentration climate data record (CDR) successfully transferred into operations, and evaluation of the CDR was performed and and a global characterization of decadal trends of sea ice extents in the Arctic and Antarctic Oceans was performed. Also evaluated the NCDC blended sea surface winds.

## BACKGROUND

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

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

The NOAA/NSIDC passive microwave sea ice concentration climate data record (CDR) has been evaluated comparing to other passive microwave sea ice concentration products. The characterization of the global decadal trends was established in term of sea ice extent (*Figure 1*).

- One paper is published in the proceeding of the 2013 IEEE Geoscience and Remote Sensing Symposium (IGARSS).
- One peer-reviewed paper is published in the Earth System Science Data journal (doi:10.5194/essd-5-311-2013).
- One peer-reviewed paper submitted to the Polar Research journal and is currently under revision.

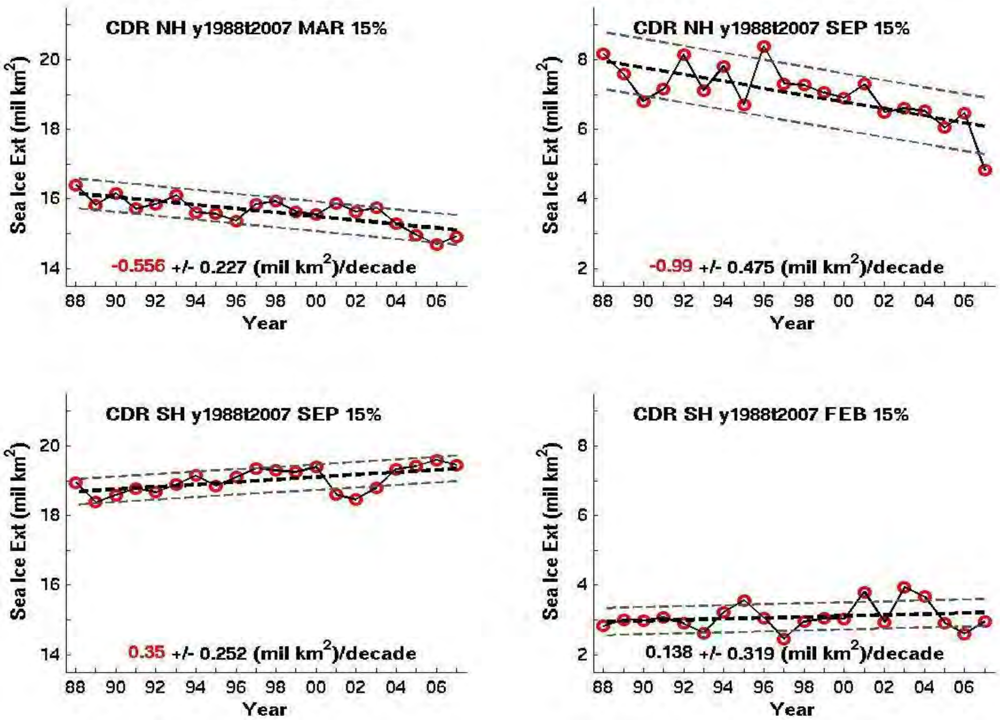



*Figure 1. Annual maximum (left panels) and minimum (right panels) CDR sea ice extent from 1988 to 2007 (red circles), with the linear regression ±1 standard deviation of the annual mean sea ice extent (black and grey dashed lines, respectively) for the Northern (top) and Southern (bottom) Hemispheres with the decadal trend and its margin of error - trend in red is significant at the 95% confidence level. It shows that significant trends of depletion are observed in the Arctic region - a stronger decadal trend of annual minimum sea ice extent than that of annual maximum. At the same time, sea ice coverage undergoes slight increase with that of annual maximum being statistically significant at the 95% confidence level.*

The NCDC satellite-based blended sea surface wind product has been evaluated along with short-range forecast winds from three international numerical weather prediction NWP) model centers (ECMWF - the European Center for Medium range Weather Forecasting, DWD - the German Weather Service "Deutscher Wetterdienst", and JMA - the Japan Meteorological Agency) and NCEP Climate Forecast System Reanalysis (CFSR) winds using high-quality in situ reference time series for year 2009.

- One peer-reviewed paper is published by the AMS Weather and Forecasting journal.
- Recommendations of utilizing single pixel filtering and wind directions from a high-resolution NWP model have been provided to the NCDC scientist and developed a detailed improvement plan for the next version.
- A by-product of this study is the uncovering of a systematic directional bias at one of the TAO buoy array from November 2008 to January 2010 (Figure 2). A peer-reviewed paper is published by the Data Science journal.

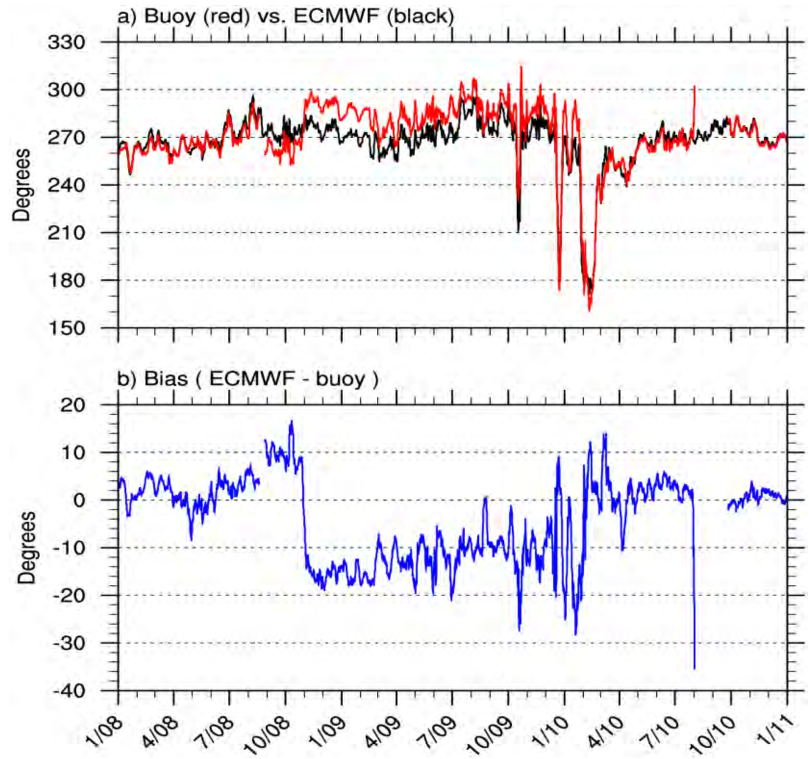



*Figure 2. a) Wind directions from the 7-day running means of 6-hourly wind components from ECMWF (black) and the WMO 51010 buoy located at 0°N, 170°W in the central equatorial Pacific Ocean (red) from January 2008 to January 2011 and b) the difference between the two. It shows a sudden shift in buoy wind direction in the early November of 2008.*

**PLANNED WORK**

- Examine regional decadal variability of sea ice extent in the Arctic Ocean using the NOAA/NSIDC sea ice concentration CDR
- Evaluate satellite-based surface fluxes products that are under transition or to be transitioned from research to operation in the Polar regions

**PUBLICATIONS**

- Peng, G., W.N. Meier, D. J. Scott, and M. Savoie, 2013A Long-Term and Reproducible Satellite-Based Passive Microwave Sea Ice Concentration Data Record for Climate Study and Monitoring. *Earth System Science Data Journal*. **5**, 311–318, doi:10.5194/essd-5-311-2013.
- Meier, W. N., G. Peng, D. J. Scott, and M. Savoie, 2014: Verification of a new sea ice concentration climate data record. *Revision submitted to Polar Research*.
- Peng, G. and W. Meier, 2013: Characterization of a satellite-based passive microwave sea ice concentration climate data record. *Proc. International Geoscience and Remote Sensing Symposium (IGARSS)*, 232 – 235, IEEE International, 21 – 26 Jul, 2013, Melbourne, Australia.
- Peng, G., H.-M. Zhang, H.P. Frank, J.-R. Bidlot, M. Higaki, S. Stevens, and W.R. Hankins, 2013: Evaluation of various surface wind products with OceanSITES buoy

measurements. *Weather and Forecasting*, **28**, 1281–1303, doi:10.1175/WAF-D-12-00086.1.

- Peng, G., J.-R. Bidlot, H.P. Freitag, C.J. Schreck, III, 2014: Identifying directional bias of TAO daily wind vectors in the central equatorial Pacific Ocean from November 2008 to January 2010. *Data Science Journal, 13, 79-87. doi: 10.2481/dsj.14-019.*

**PRESENTATIONS**

- Peng, G., L. D. Cecil, and B. Cramer, 2014: An End-to-End Framework for Probabilistic Uncertainty Characterization of Climate Satellite Data and Products. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS 2014 annual meeting, February 2- 6, 2014, Atlanta, GA, USA.
- Zhang, H.-M., G. Peng, L. Vasquez, W. Hankins, C.W. Fairall, R. Weller, and A. Brown, 2013: The SURFA Project: Towards Near-Real-Time Quality Monitoring of NWP Forecasts and Historical Analysis. 4$^{th}$ WGNE workshop on systematic error in weather and climate models. 15-19 April 2013, Exeter, UK.

**OTHER**

- Co-PI for the NCDC Ocean Data Management Project.
- Served as a mentor to a NOAA EPP summer intern who has participated in the implementation of a near-real-time product quality monitoring web portal.
- Served as NCDC scientific steward for S-NPP Cal/Val data and reviewed 5 S-NPP Cal/Val findings
- Designed and coordinated the implementation of a near-real-time product quality monitoring web portal that has been test-released to collaborators in model centers, surface fluxes and TAO project management.
- Identified an anomalous behavior of sea winds at one of TAO buoy sites utilizing the aforementioned near-real-time product quality monitoring portal and notified our collaborators in the TAO project at NOAA's Pacific Marine Environmental Laboratory, which prompted an analysis of the buoy wind measurements at the site and resulted in re-categorization of the buoy data quality flag to reflect low data quality for users in a more timely fashion.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 4 |
| # of non-peered reviewed papers | 1 |
| # of invited presentations | 0 |
| # of graduate students supported by a CICS task | N/A |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 1 |

**The Scope and Framework of Long-Term Scientific Stewardship for CDRs**

| | |
|---|---|
| **Task Leader** | Ge Peng |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**: Defined the scope of long-term stewardship for NOAA digital climate environmental data products based on U.S. laws and expert bodies' recommendation and associated functional areas. Developed a unified framework for assessing the vigor of stewardship practice applied to individual environmental data products. Submitted a manuscript to a peer-review journal.

**BACKGROUND**

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

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

Currently, there is no systematic framework for assessing the quality of stewardship practices applied to environmental datasets and providing consistent data integrity and usability information to users and stakeholders.

**ACCOMPLISHMENTS**

- Coordinated more than 15 informal focus group discussions among 30 subject matter experts in the fields of archive, access, user service, system engineering and architecture, software engineering, IT security, data management, configuration management, satellite data product development, and research-to-operation transition at or affiliated with NOAA's National Climate Data Center (NCDC), now a part of NOAA's National Centers for Environmental Information (NCEI).
- Drafted and refined the scope of long-term stewardship for NOAA digital climate environmental data products (*Figure 1*).
- Developed a unified framework of assessing stewardship practices applied to NOAA climate environmental data products in term of stewardship maturity matrix with a five-level graduated maturity scale for each component, representing Ad Hoc, Minimal, Intermediate, Advanced, and Optimal stage (*Figure 2*).
- Presented the stewardship maturity matrix at the AMS annual and ESIP summer meeting to scientific and data management community to introduce the framework to the Earth Science community and provide an opportunity for them to provide us with feedback to improve its consistency.

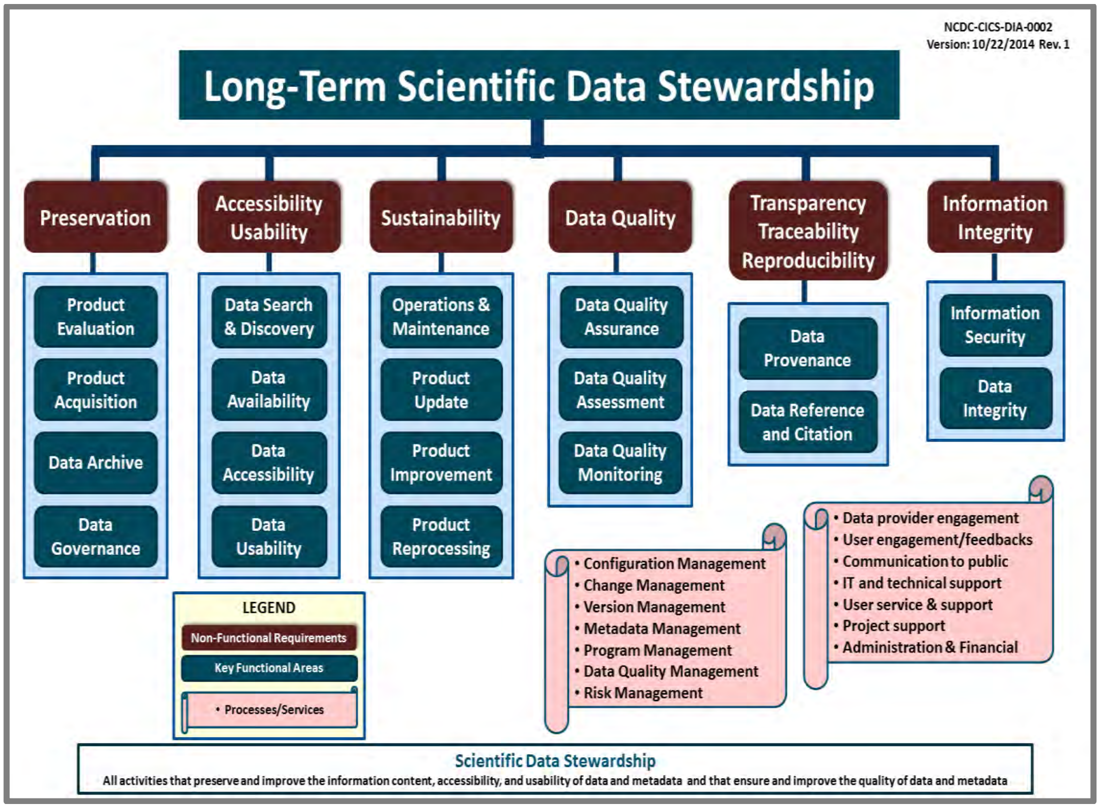
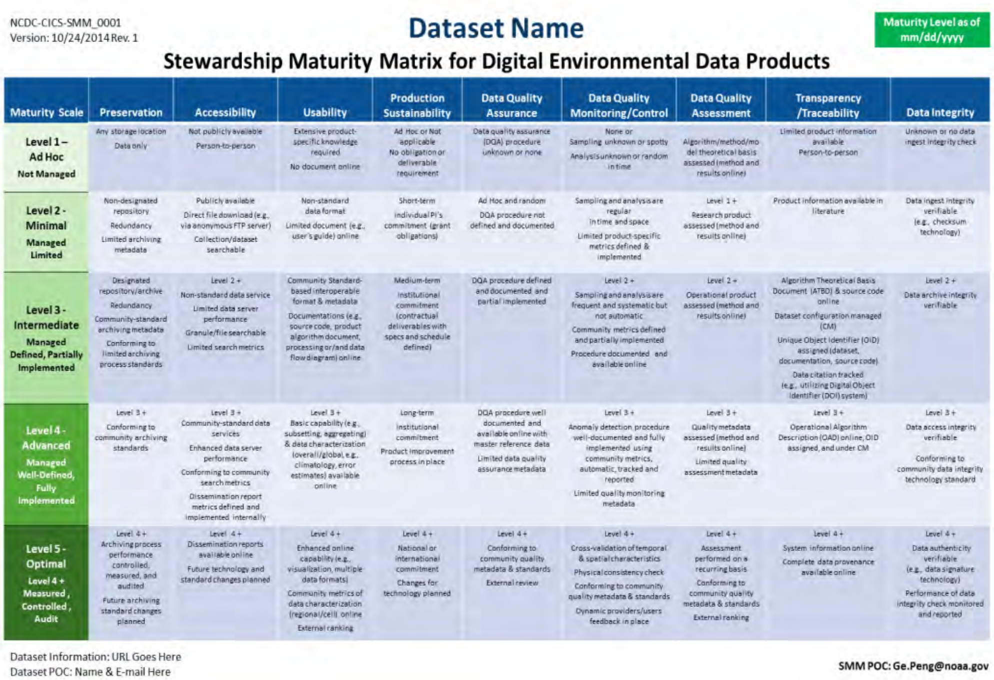



*Figure 1. Diagram of the scope of long-term stewardship for NOAA digital climate environmental data products.*



NCDC-CICS-SMM_0001
Version: 10/24/2014 Rev. 1

**Dataset Name**

Maturity Level as of mm/dd/yyyy

**Stewardship Maturity Matrix for Digital Environmental Data Products**

| Maturity Scale | Preservation | Accessibility | Usability | Production Sustainability | Data Quality Assurance | Data Quality Monitoring/Control | 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 document 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 searchable | Non-standard data format Limited document (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 repository/archive Redundancy Community-standard archiving metadata Conforming to limited archiving process standards | Level 2 + Non-standard data service Limited data server performance Granule/file searchable Limited search metrics | Community Standard-based interoperable format & metadata Documentations (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 partial 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 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 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 + 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 2. A pdf version of the NCDC/CICS-NC Scientific Data Stewardship Maturity Matrix.*

**PLANNED WORK**

- Use case studies with various types of datasets, collaborating with members from ESIP (Earth Science Information Partners) Data Stewardship Committee and Preservation Cluster, data managers from NOAA and NASA data centers, to refine language in the matrix for consistency and to extend the scope of datasets that the matrix will be suitable for.

**PUBLICATIONS**

- Peng, G., J.L. Privette, E.J. Kearns, N.A. Ritchey, and S. Ansari, 2014: A unified framework for measuring stewardship practices applied to digital environmental datasets. Submitted to Data Science Journal.

**PRESENTATIONS**

- Peng, G. and J. L. Privette, 2014: Stewardship maturity matrix – a unified framework for assessing data quality and usability practices applied to individual digital environmental data products. 2014 ESIP (Federation of Earth Science Information Partners) summer meeting, 7 – 11 July 2014, Copper Mountain, CO, USA.
- Peng, G. and J. L. Privette, 2014: A stewardship maturity matrix for assessing the state of environmental data quality and usability. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS 2014 annual meeting, February 2- 6, 2014, Atlanta, GA, USA.
- Peng, G. and J. L. Privette, 2013: Toward a unified scientific data stewardship framework. On August 7, 2013 to NCDC Deputy Director along with CDR program and RSAD division management.
- Peng, G., 2013: A straw man idea on the scope of long-term scientific stewardship CDRs. On March 1, 2013 for the NCDC Metadata Working Group and on March 7, 2013 to NCDC CDR Program management.

**OTHER**

- A member of the NOAA Metadata and Dataset Identifier Working Groups - participated in their monthly meetings and reviewed the NOAA Data Citation Procedure Directive v0.4.
- A member of ESIP preservation and Documentation Clusters – participated in their monthly meetings and reviewed the Attribute Convention for Data Discovery (ACDD) 1.3 version.
- Chaired a session of the ESIP Summer 2014 meeting, entitled "Identifying and Assessing Best Practices in Data Quality"

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 1 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 0 |
| # of graduate students supported by a CICS task | N/A |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**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-12_NCICS-OP |
| **NOAA Sponsor** | Brian Nelson |
| **NOAA Office** | NESDIS/NCDC/RSAD |
| **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.

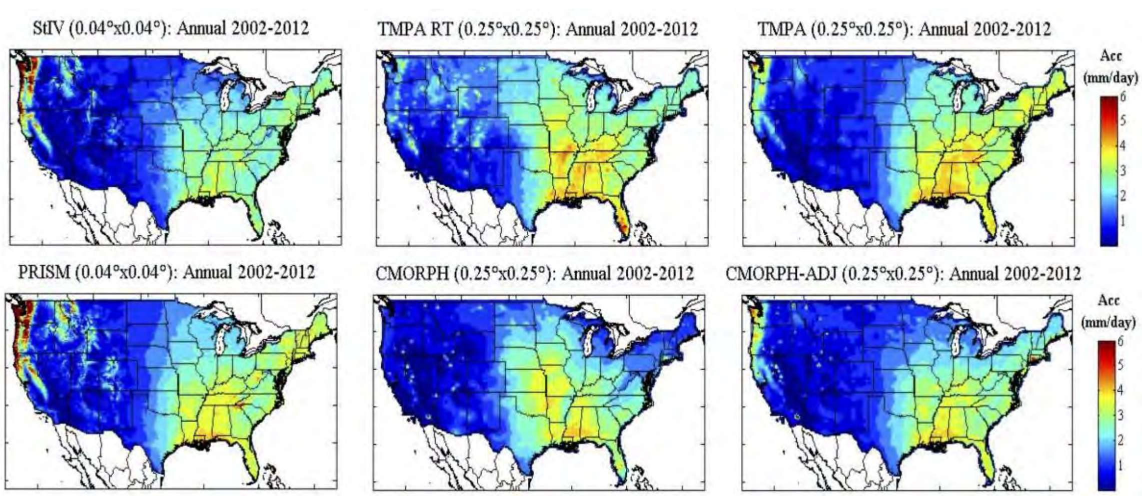



*Figure 1. From top left to bottom right. Annual precipitation for the period 2002-2012 derived from Stage IV, TMPA-RT (Real Time), TMPA, PRISM, CMORPH, and CMORPH-ADJ (Adjusted).*

*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*).

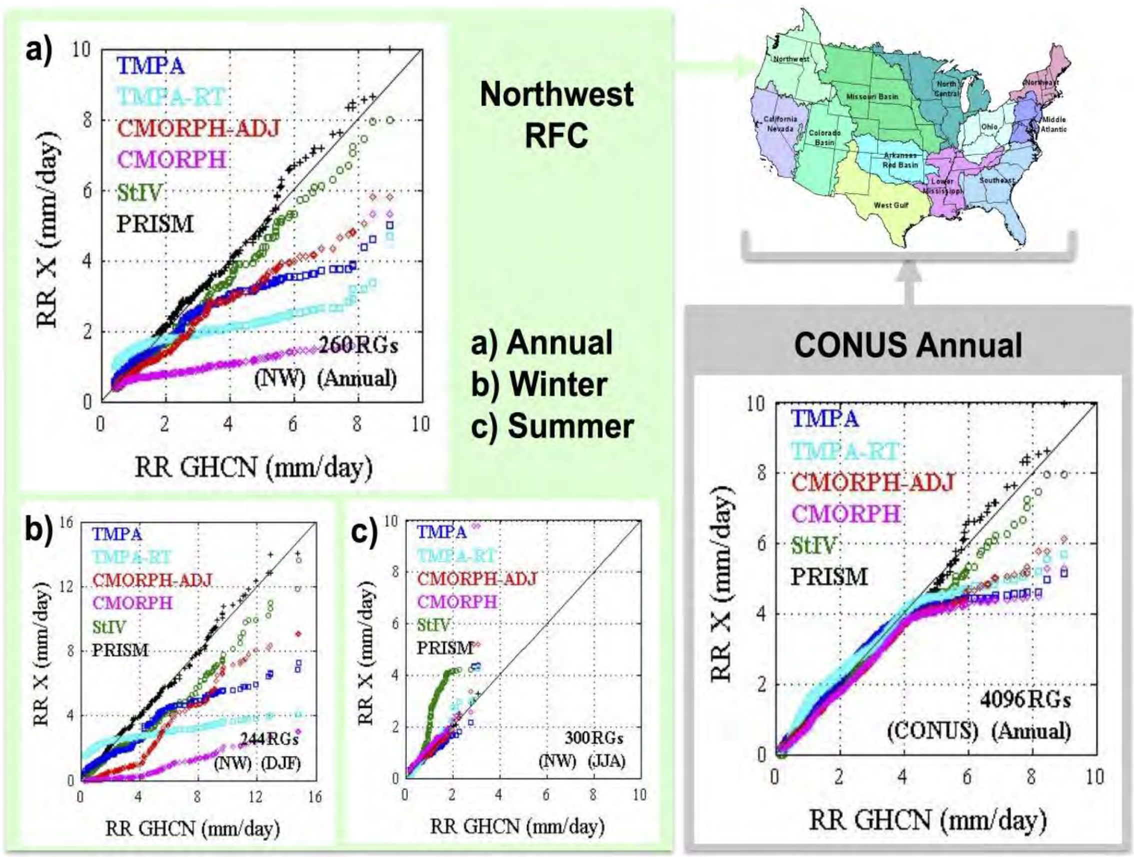



*Figure 2. Comparison (Quantile-Quantile plot) of TMPA, TMPA-RT, CMORPH-ADJ, CMORPH, St-IV, and PRISM with surface observations from GHCN-daily for the annual precipitation over CONUS. While a good agreement is found for PRISM (expected because incorporate surface observation including GHCN) and TMPA 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
- 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.
- Prat, O.P., and B.R. Nelson, 2014. Characteristics of annual, seasonal, and diurnal precipitation in the Southeastern United States derived from long-term remotely sensed data. *Atmos. Res.*, in press, http://dx.doi.org/10.1016/j.atmosres.2013.07.022

**DELIVERABLES**

- Complete assessment of the differences between all the QPE products for the period 2002-2012 at the annual, seasonal, and daily scale;
- Metrics quantifying each dataset ability to capture precipitation patterns and extreme precipitation events;
- Manuscript summarizing the results of this comparison effort; and
- Software (SPEC) tailored for comparison of precipitation datasets with differing formats, spatial and temporal resolution.

**PRESENTATIONS**

- Prat, O.P., B.R. Nelson, S. Stevens, and D.-J. Seo, 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. *8th European Conference on Radar in Meteorology and Hydrology (ERAD 2014)*, 1-5 September 2014, Garmisch-Partenkirchen, Germany.

- Prat, O.P., 2014. Overview of satellite quantitative precipitation estimates. *NCDC-NODC-NGDC-CICS-AFCCC Internal Seminar,* July 8 2014, Asheville, NC, USA.
- Prat, O.P., 2014. Toward the development of Climate Data Records (CDR) for precipitation: Evaluation and applications of radar, satellite, and ground based QPE product. *CICS-MD Seminar,* April 11 2014, College Park, MD, USA.
- Prat, O.P., B.R. Nelson, and L. Vasquez, 2014. Characterization of CONUS rainfall using a multi-sensor approach: Evaluation of radar-based, satellite-based, and ground-based QPE products. *International Weather Radar and Hydrology symposium*, 7-9 April 2014, Washington, DC, USA.
- Nelson, B.R, S.E. Stevens, O.P Prat, C. Langston, K. Ortega, J. Zhang, Y. Qi, K. Howard, and T. Smith, 2014. The National Mosaic and Multi-sensor Quantitative Precipitation Estimate (NMQ/Q2) Reanalysis Effort. *International Weather Radar and Hydrology symposium*, 7-9 April 2014, Washington, DC, USA.
- Prat, O.P., and B.R. Nelson, 2014. Toward the development of an evaluation framework of Climate Data Records for precipitation: A characterization of CONUS rainfall using a suite of satellite, radar, and rain gauge QPE products. *94th annual meeting of the American Meteorological Society,* 2-6 February, 2014, Atlanta, GA, USA.
- Prat, O.P., and B.R. Nelson, 2013. Characterization of precipitation features over CONUS derived from satellite, radar, and rain gauge datasets (2002-2012). *2013 AGU fall meeting*, 9-13 December, 2013, San Francisco, CA, USA.
- Nelson, B.R., S.E. Stevens, and O.P. Prat, 2013. NEXRAD: An overview and NCDC/NSSL/CICS Reanalysis effort. *Climate Data and Applications Workshop – A Focus on Precipitation*, 3-4 December, 2013, Asheville, NC, USA.
- Cifelli, R., S. Goodman, R. Ferraro, N.-Y. Wang, P. Xie, R. Joyce, B. Nelson, O.P. Prat, P. Groisman, Y. Xie, S. Albers, D. Birkenhaeuer, K. Mahoney, and S. Rudlosky, 2013. NOAA activities in support of the NASA GPM GV program. *6th international workshop for GPM ground validation,* 5-7 November 2013, Rome, Italy.
- Prat, O.P., and B.R. Nelson, 2013. Characterization of precipitation features over CONUS using quantitative precipitation estimates derived from TRMM satellite and Stage IV data for the period 2002-2012. *11th International Precipitation Conference*. 1-3 July, 2013, Ede-Wageningen, Netherlands.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | |
| # of products or techniques transitioned from research to ops without NOAA guidance | |
| # of peer reviewed papers | 4 |
| # of non-peered reviewed papers | |
| # of invited presentations | 8+2 |
| # of graduate students supported by a CICS task | |
| # of graduate students formally advised | |
| # of undergraduate students mentored during the year | |

**PERFORMANCE METRICS EXPLANATION**

During the last year, the project group participated in the PERSIANN-CDR adjustment to comply with CDR requirements (1). This development concerned the transition from research to operations (1). One journal article on the precipitation characteristics in the Southeastern United States using long-term remotely sensed data has been published (1). We coauthored one journal article describing the PERSIANN-CDR algorithm (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). Eight presentations have been made or co-authored on the project (8). Those results were also presented at two invited seminars (2).

**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-13_NCICS-OP |
| **NOAA Sponsor** | Brian Nelson |
| **NOAA Office** | NESDIS/NCDC/RSAD |
| **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).

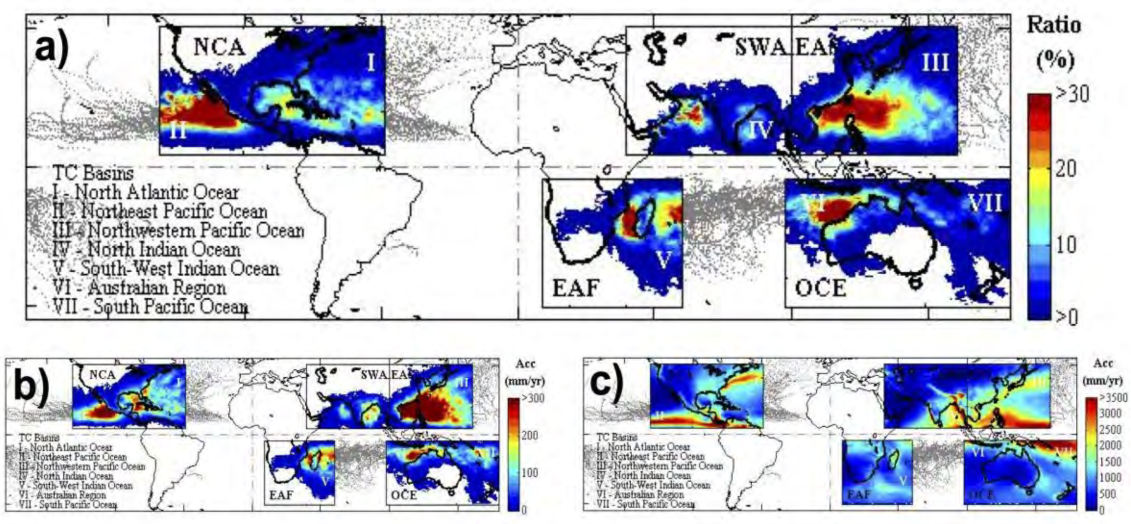



*Figure 1. Tropical cyclone (TC) contribution (a), tropical cyclone rainfall (b), and total rainfall (c) for North and Central America (NCA), East Asia (EAS), South and West Asia (SWA),*

*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.

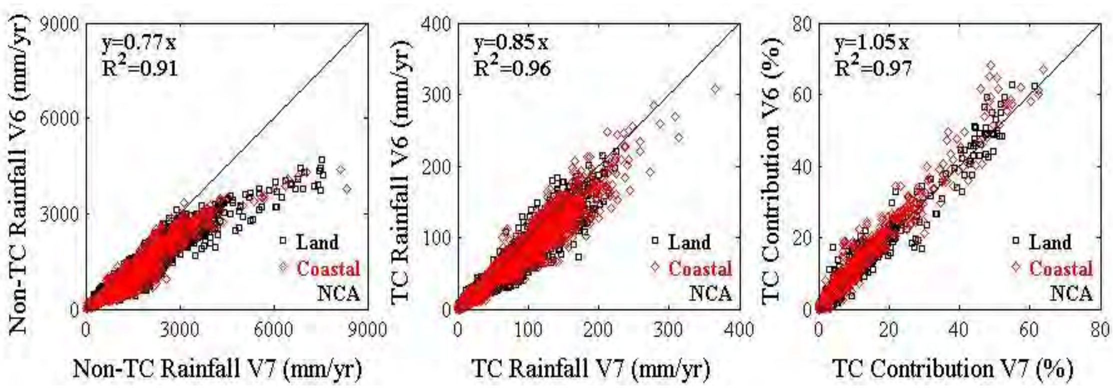



*Figure 2. Comparison between TMPA 3B42V7 (version 7) and TMPA 3B42V6 (version 6) for the North and Central America (NCA) domain.*

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.
- Prat, O.P., and B.R. Nelson, 2013. Mapping the world's tropical cyclone rainfall contribution overland using the TRMM Multi-satellite precipitation analysis. *Water Resources Research*, 49, 7236–7254, http://onlinelibrary.wiley.com/doi/10.1002/wrcr.20527/abstract

**DELIVERABLES**

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

**PRESENTATIONS**

- Prat, O.P., 2014. Overview of satellite quantitative precipitation estimates. *NCDC-NODC-NGDC-CICS-AFCCC Internal Seminar,* July 8 2014, Asheville, NC, USA.
- Prat, O.P., 2014. Toward the development of Climate Data Records (CDR) for precipitation: Evaluation and applications of radar, satellite, and ground based QPE product. *CICS-MD Seminar,* April 11 2014, College Park, MD, USA.
- Ferraro, R., R. Cifelli, C. Kondragunta, N.-Y. Wang, P. Xie, R. Joyce, Y. Zhang, D. Kitzmiller, R. Kuligowski, J. Gourley, P. Groisman, B. Nelson, O.P. Prat, K. Mahoney, S. Rudlosky, Y. Xie, S. Albers, and D. Birkenheuer, 2013. NOAA Contributions to and Utilization of GPM-era Data and Products, 2013 GPM Applications Workshop, 12-13 November, 2013, College Park, MD, USA.

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | |
| # of products or techniques transitioned from research to ops following NOAA guidance | |
| # of new or improved products developed without NOAA guidance | |
| # of products or techniques transitioned from research to ops without NOAA guidance | |
| # of peer reviewed papers | 2 |
| # of non-peered reviewed papers | |
| # of invited presentations | 1+2 |
| # of graduate students supported by a CICS task | |
| # of graduate students formally advised | |
| # of undergraduate students mentored during the year | |

**PERFORMANCE METRICS EXPLANATION**

One journal article on the contribution of tropical cyclone rainfall for basins around the world was published (1), and one manuscript on the link between tropical cyclones and extreme rainfall is still under preparation (1). Some of the results described above were included in a collaborative poster presentation describing NOAA's applications in connection with the Global Precipitation Mission (GPM) (1). Additionally those results were presented partially at two invited seminars (2).

**Dual-Pol signature of microphysical processes in warm rain**

| | |
|---|---|
| **Task Leader** | Olivier Prat |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 opposite, 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…) as well as the full physic 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 ($Z_H$, $Z_{DR}$, $K_{DP}$) increase toward the ground as mass from smaller drops (d<1 mm) is shifted to larger sizes. Finally, the full physics configuration display a decrease in $Z_H$ and $Z_{DR}$ while $K_{DP}$ exhibit 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*).

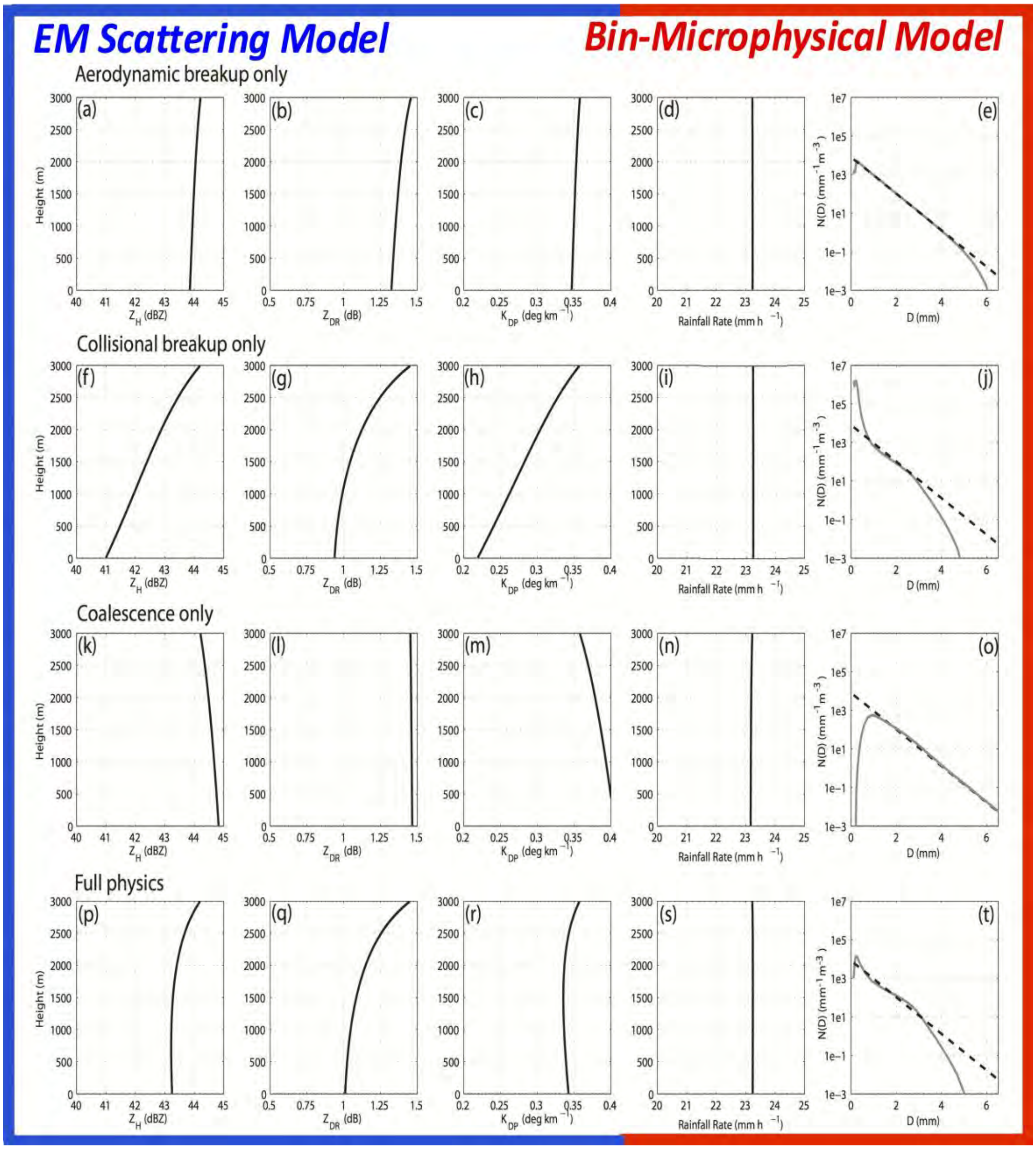



*Figure 1. Vertical profiles of the polarimetric variables ($Z_H$: first column; $Z_{DR}$: second column: $K_{DP}$: third column) for selected microphysical processes: aerodynamic breakup (a-c), collisional breakup (f-h), coalescence (k-m), and full physics (p-r). The profiles are established after 60 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 processes display 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 environment (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, suggest that real time radar rainfall field observations could help improving microphysical parameterization of drop-drop interactions via inverse problem modelling techniques (5).

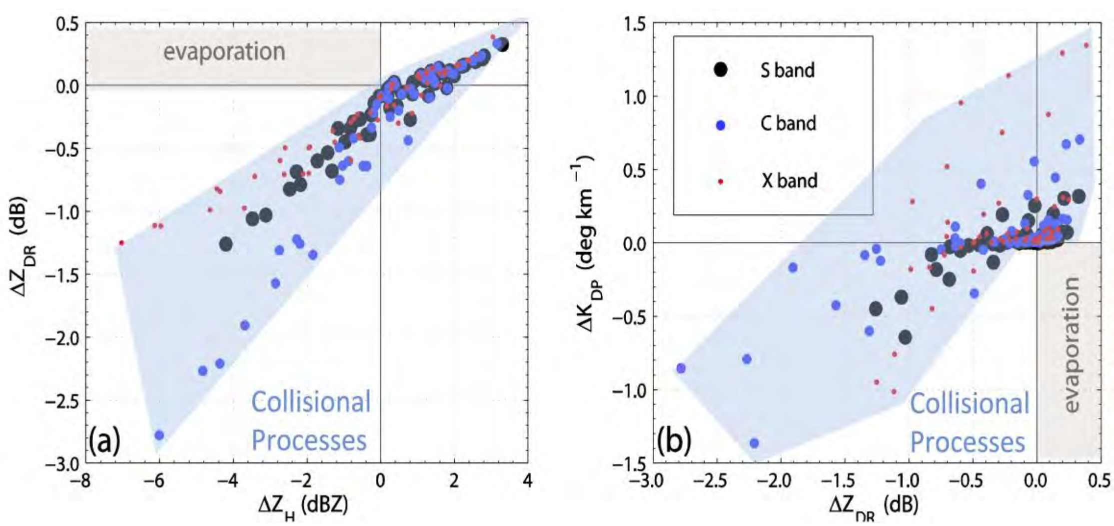



*Figure 2. Change in the polarimetric variables in the spaces ($Z_H$, $Z_{DR}$) and ($Z_{DR}$, $K_{DP}$) over the 3-km rainshaft for a variety of initial DSDs. Calculations are performed for S, C, and X bands. The quadrant marked "evaporation" indicates the region expected for evaporation.*

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**

- Implement and test additional parameterizations for the microphysical column model.

- Perform a sensitivity analysis using synthetic and real rainfall events covering a wide range of situations.

**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 conferences presentations were delivered. The continuation of this work is pending the availability of external funding and proposal to be submitted.

**PRESENTATIONS**

- Kumjian, M.R., and O.P. Prat, 2014. The impact of raindrop collisional processes on the polarimetric radar variables. *ERAD 2014: 8th European Conference on Radar in Meteorology and Hydrology*, September 1-5 2014, Garmisch-Partenkirchen, Germany.
- Prat, O.P., and M.R. Kumjian, 2014. Transient behavior of polarimetric signatures of warm rain microphysical processes. Abstract submitted to the *International Weather Radar and Hydrology symposium*, 7-9 April 2014, Washington, DC, USA.
- Kumjian, M.R., and O.P. Prat, 2013. The impact of raindrop collisional processes on the polarimetric radar variables. *36th AMS conference on radar meteorology*, 17-19 September 2013, Breckenridge, CO, USA.
- Prat, O.P., and M.R. Kumjian, 2013. Polarimetric signatures of microphysical processes in warm rain. *11th International Precipitation Conference*, 1-3 July 2013, Ede-Wageningen, Netherlands.

**PERFORMANCE METRICS**

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

**PERFORMANCE METRICS EXPLANATION**

One journal article on the signature of raindrop collisional processes on the polarimetric radar variables was published (1). Four conference presentations have been made on the topic (4).

| **Reanalyzing Tropical Cyclones Imagery with Citizen Scientists** | |
|---|---|
| **Task Leader** | Carl Schreck and Scott Stevens |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 is a web-based interface through which citizen scientists have already produced more than 300,000 classifications of tropical cyclone intensity and structure. Preliminary research has shown that these classifications 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. The human eye best recognizes patterns in storm imagery, so the project is 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**

During Year 2 of Cyclone Center, classifications from volunteers continued to be collected, and the site has now obtained nearly 300,000 analyses from more than 5,000 scientists. In addition, the site underwent a major overhaul, and the way in which storms were selected and questions asked changed considerably.

Preliminary analysis has been performed, comparing output from Cyclone Center with that from both the best track data for cyclone intensity and objective techniques including the Advanced Dvorak Technique (ADT). *Figure 1* shows an example for two storms, Typhoons Ivan (1997) and Yvette (1992). The Cyclone Center estimates reproduce the major features of each storm's lifecycle, including the weakening on day 9 of Yvette (bottom). They also avoid a known issue of ADT, which limits the intensification of a storm until the eye is clearly visible (around days 5–6 for both storms).

The panels on the right in *Fig. 1* show another unique advantage of the Cyclone Center estimates. Since at least 10 citizen scientists analyze each image, we can analyze the uncertainty in those estimates. In this case, we have used a Monte Carlo technique to stitch together randomly selected estimates for each time step.

The project group presented this initial research at the annual meetings of both the American Geophysical Union and the American Meteorological Society. In addition, a manuscript has been accepted for publication in the *Bulletin of the American Meteorological Society (BAMS)*.

CICS-NC intern, Brady Blackburn, is a recent graduate of Asheville High School with an interest in pursuing a degree in environmental science. During FY13, CICS-NC helped Mr. Blackburn explore that interest by contributing to tropical cyclone research through Cyclone Center. He examined the classifications provided by Cyclone Center's volunteer users, and he compared them with the actual satellite images. In particular, Mr. Blackburn sought to understand why a volunteer might mistakenly classify a storm as having an eye when it does not. His work will help us develop an objective method for evaluating the classifications, which will improve our future analysis.

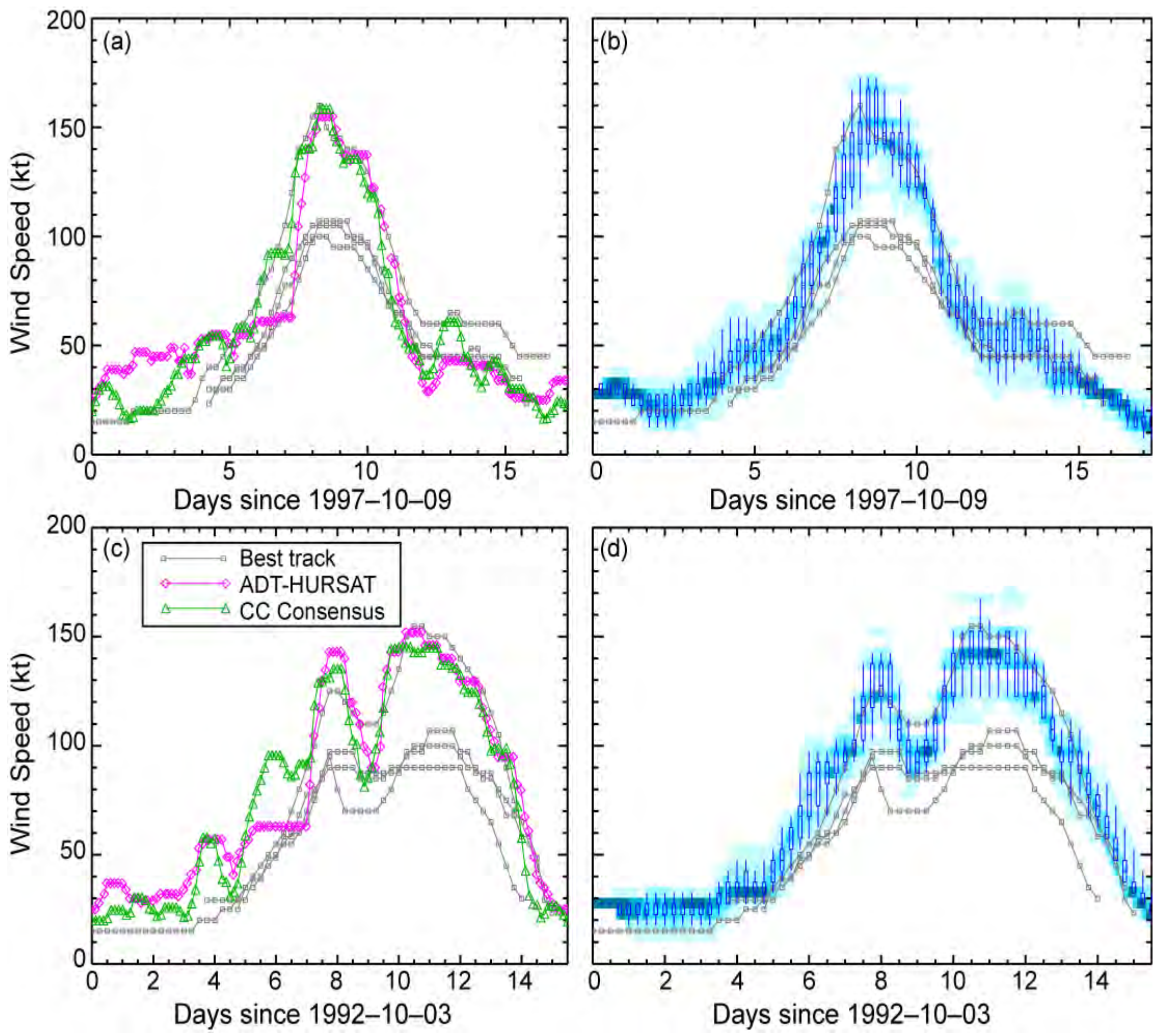



*Figure 1. Time series of intensities from (a,b) Typhoon Ivan (1997) and (c,d) Typhoon Yvette (1992). a,c) Comparisons between best tracks, ADT-HURSAT, and Cyclone Center (CC Consensus). b,d) Spread in the Cyclone Center estimates.*

**PLANNED WORK**

- Continue promoting this project through a variety of media outlets, particularly during the 2014 Atlantic Hurricane Season
- Publish the initial results in the *Bulletin of the American Meteorological Society (BAMS)*
- Develop method for applying the full Dvorak analysis to the data collected, including the "Data T-Number"

**PRESENTATIONS**

***Invited***

- Hennon, C.C., K.R. Knapp, C.J. Schreck, S.E. Stevens, and J.P. Kossin, 2013: Cyclone Center: Using crowdsourcing to determine tropical cyclone intensity. *AGU Fall Meeting,* 9-13 December 2013, San Francisco, CA.

***Other***

- Thorne, P.W., C.C. Hennon, K.R. Knapp, C.J. Schreck III, S.E. Stevens, P.A. Hennon, J.P. Kossin, M.C. Kruk, J. Rennie, and L.E. Stevens, 2014: Cyclonecenter: Crowdsourcing insights into historical tropical cyclone intensities. *26th Conference on Climate Variability and Change,* 2-6 February 2014, Atlanta, GA.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | N/A |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 1 |

**Satellite Data Support for Hydrolic and Water Resource Planning and Management**

| | |
|---|---|
| **Task Leader** | Soroosh Sorooshian |
| **Task Code** | NC-CDR-        -UCI |
| **NOAA Sponsor** | NESDIS/NCDC |
| **NOAA Office** | |
| **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:** A new daily precipitation climate data set was developed. The PERSIANN Precipitation Climate Data Record (PERSIANN-CDR) is a precipitation dataset with product resolution at daily $0.25^{0}$ lat-long scale. The product covers from $60^{o}$S to $60^{o}$N and 0° to 360° longitude from 1983 to near current time.

**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 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*.

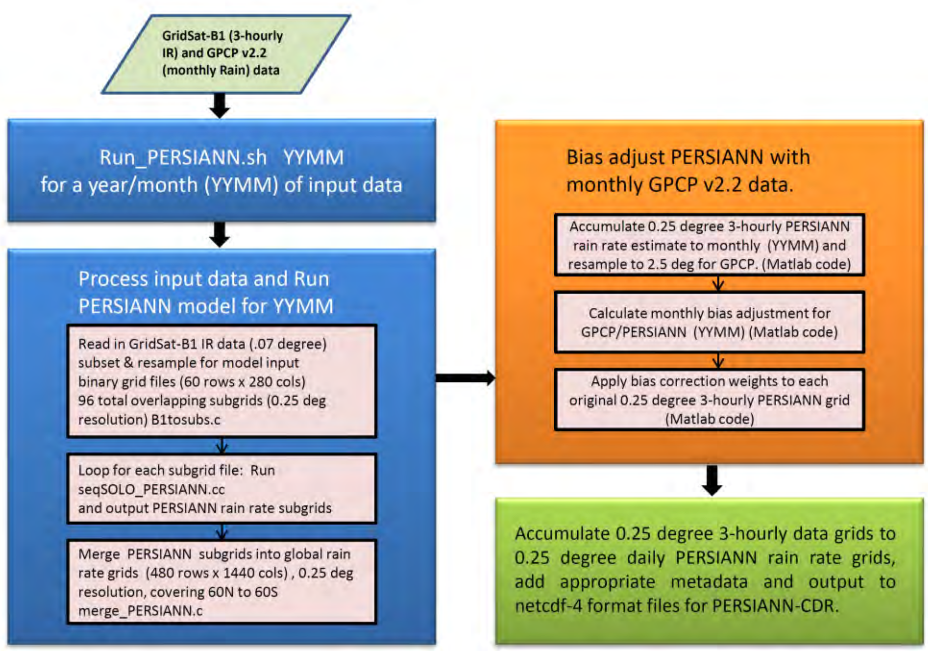



*Figure 1. The PERSIANN-CDR flowchart*

**ACCOMPLISHMENTS**

*Figure 2* shows comparison of PERSIANN-CDR precipitation data with Stage IV radar data at the 0.25° spatial scale during Hurricane Katrina. As shown, PERSIANN-CDR shows similar precipitation patterns to the radar data. Moreover, in regions where radars are blocked by mountains or where particular radar sites are down (e.g., the Lake Charles radar site in Southwest Louisiana during Katrina), the spatial coverage provided by PERSIANN-CDR is very valuable and captures a wide view of the precipitation and hurricane landfall.

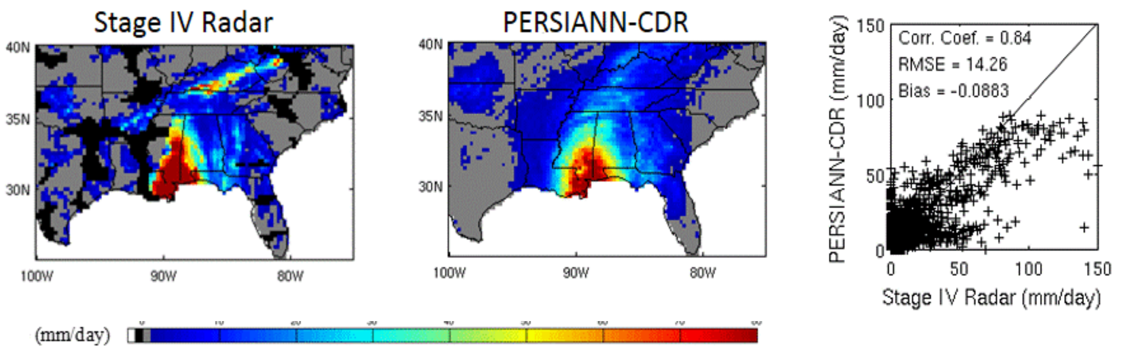



***Figure 2. Daily-accumulated rainfall (mm/day) map over land during Hurricane Katrina on 29 August 2005 from PERSIANN-CDR and Stage IV Radar. Black and gray pixels show radar blockages and zero precipitation.***

The automated algorithm and the software system have been developed. *Figure 3* presents the top 5% heavy rainfall (mm/day) patterns from PERSIANN-CDR 0.25° for the period of 1997-2012. PERSIANN-CDR shows larger rainfall for extreme precipitation events over the Intertropical Convergence Zone (ITCZ). With the 0.25° rainfall data at daily scale from PERSIANN-CDR, the intensity, duration, and spatial coverage of historical extreme events can be investigated.

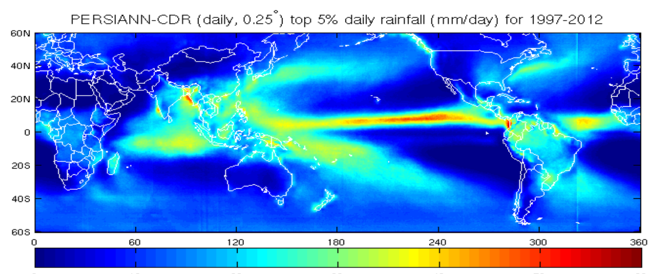



***Figure 3. Top 5% heavy rainfall (mm/day) maps from PERSIANN-CDR 0.25° for the period of 1997-2012.***

PERSIANN-CDR daily precipitation data is made available and updated regularly when GridSat-B1 IRWIN data and GPCP monthly precipitation data are both available. An update of PERSIANN-CDR in 2014 using the recent update of GridSat-B1 is completed.

Statistical analysis of the daily precipitation variability and trends is performed. *Figure 4* shows the wet-day counts (rainfall >= 10 mm) of 0.25° daily precipitation total higher than 10 mm/day over CONUS for the time period from 1983 to 2011. The results were compared with the NOAA Climate Prediction Center (CPC) gridded gauge data. The scatter plot of the results between CPC and PERSIANN-CDR data products is also plotted on the right-hand-side of *Figure 4*. As shown, PERSIANN-CDR depicts a significant correlation coefficient (0.93) and a relatively very low bias (~ -4%) when compared to the CPC gridded data.

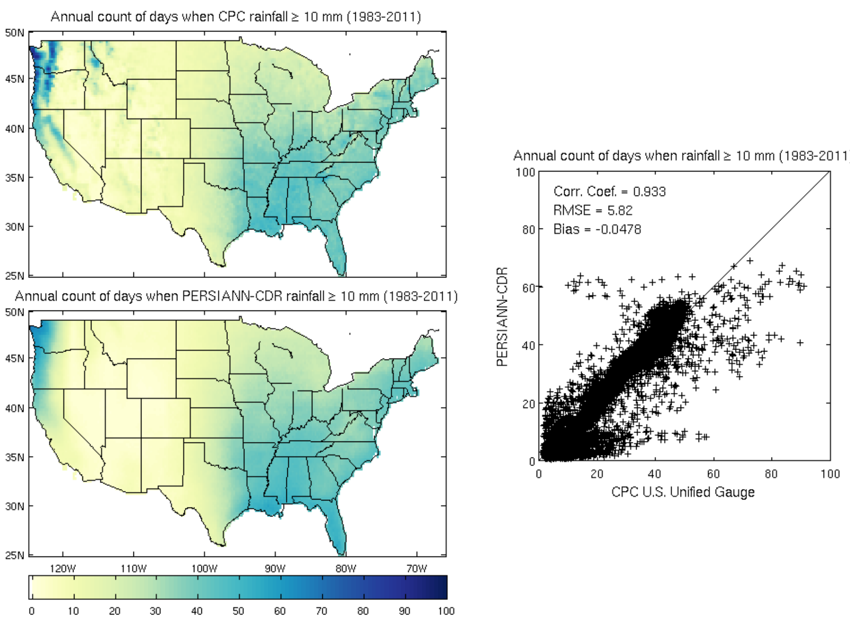



*Figure 4. Average annual number of rainy days (rain rate >= 10 mm/day) over the U.S. for 1983-2011 from CPC gridded gauge data (top) and PERSIANN-CDR (bottom) daily precipitation data products. The scatter plots and the calculated statistics are shown on the right.*

**DELIVERABLES**

- PERSIANN-CDR software and data product for a new daily precipitation analysis at 0.25-degree resolution
- Documentation for software and data product

**PUBLICATIONS**


- Nasrollahi, N., K. Hsu, and S. Sorooshian, 2013, Reducing False Alarm in Satellite Precipitation Products, *Journal of Hydrometeorology*, **14**(4). doi:10.1175/JHM-D-12-0172.1.
- Sellers, S., P. Nguyen, W. Chu, X. Gao, K. Hsu, and S. Sorooshian, 2013: Computational Earth Science: Big Data Transformed into Insight. *EOS*, **94**(32), 277-278. *doi: 10.1002/2013EO320001*
- Zahraei, A., K. Hsu, S. Sorooshian, J.J. Gourley, Y. Hong, and A. Behrangi. 2013: Short-term Quantitative Precipitation Forecasting Using An Object-based Approach. *Journal of Hydrology*. **483**, 1-15.
- 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**

- Ashouri H., K. Hsu, S. Sorooshian, J. Lee, M. G. Bosilovich, and J. Y. Yu, 2014: Evaluation of the Reanalyses Products in Detecting Extreme Precipitation Trends over United States, American Meteorological Society (AMS) 94th Annual Meeting, 28th Conference on Hydrology, February 1-6, 2014, Atlanta, GA.
- 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; Dec 15-19, 2014; 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**

| | |
|---|---|
| # 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 | 5 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 0 |
| # of graduate students supported by a CICS task | 2 |
| # of graduate students formally advised | 2 |
| # 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** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **Contribution to CICS Themes (%)** | Theme 1: 70%; Theme 2: 30%; Theme 3: 0%. |
| **Main CICS Research Topic** | Data Fusion and Algorithm Development |
| **Contribution to NOAA Goals (%)** | Goal 1: 10%; Goal 2: 60%; Goal 3: 0%; Goal 4: 30%; Goal 5: 0% |

**Highlight**: This project has generated four years of a high-resolution gridded precipitation product for the entire continental United States at CICS-NC, with an additional seven years being produced at the National Severe Storms Laboratory /CIMMS in Norman, OK. The project group continues to work closely with these partners toward quality assurance and the transfer of this very large dataset.

**BACKGROUND**

This report summarizes Year 4 of the ongoing NEXRAD reanalysis project. A joint project among partners in Asheville, NC, and Norman, OK, aims to apply the National Mosaic and Multisensor Quantitative Precipitation Estimate (NMQ/Q2) algorithms to the entire archive of NEXRAD data (1997-2011), producing a suite of gridded precipitation products at a far finer temporal frequency (five-minute) and spatial scale (0.01° / 1km) than is presently available.

The data are pulled from the NCDC archive and processed on the CICS-NC computing cluster using two stages of software provided by NSSL. The end result is a wide variety of severe weather products, three-dimensional radar reflectivity, and quantitative precipitation estimates at high-resolution.

**ACCOMPLISHMENTS**

The process has been adapted from NSSL's experimental real-time system to run in an archive mode, with processing taking place in parallel across several hundred processors simultaneously, each running a different instance of the software. Since the process takes place in stages – one for single radar processing, one for merging, one for hydrological analysis, etc. – scripts have been developed at CICS-NC to largely automate the process, with each process communicating with the others and initiating new jobs to be submitted.

The result so far is six years of completed processing at CICS-NC, with an additional five years being completed by the dedicated team in Norman, OK. This represents the majority of the 15-year record being used as input for this dataset. *Figure 1* shows a sample image of daily precipitation over the continental United States for a day in 2011. Similar figures can be generated quickly from the dataset for any desired time period for a wide variety of variables including precipitation estimates, hail size, precipitation type, and cloud top height.

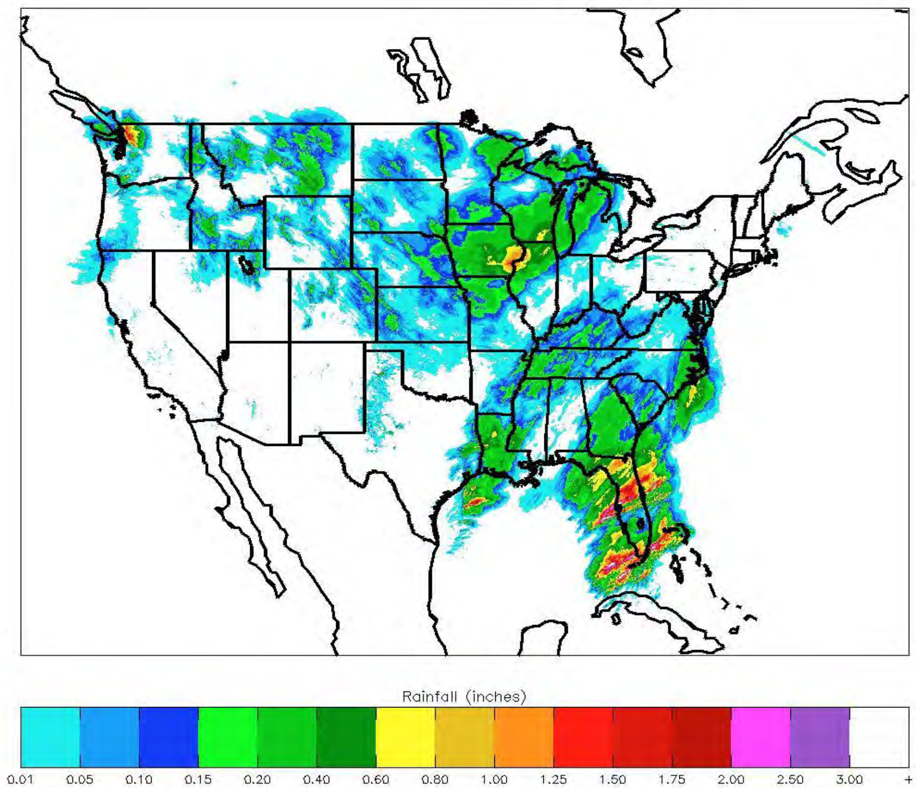



*Figure 1.* Daily precipitation for 2011 Jan 18 for the continental United States. Custom time periods can be easily aggregated and mapped in a similar fashion.

**PLANNED WORK**

- Complete first-round processing of the remaining years of data
- Work with NSSL to assess the quality of the product
- Coordinate transfer of this very large dataset between partners in North Carolina and Oklahoma

**DELIVERABLES**

- Gridded precipitation dataset for continental United States for years 2011, 2009, 2005-2007, and 2003 at CICS-NC, with additional years completed at NSSL

**PRESENTATIONS**

- Stevens, S.E., B.R. Nelson, C.L. Langston, and K.L. Ortega, 2014: Toward a climate-quality high-resolution precipitation dataset: An early look at the National Mosaic and Multisensor Quantitative Precipitation Estimate (NMQ/Q2). *28th Conference on Hydrology*, 2-6 Feburary 2014, Atlanta, GA.

**OTHER**

- Joined several other CICS scientists in helping with "Wave Day" an activity at a local middle school to help students understand the properties of waves.
- Met with local high school student and aspiring meteorologist to give her information on the career and the education that it requires, as well as a look at our day to day jobs here at CICS-NC.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 1 |

**PERFORMANCE METRICS EXPLANATION**

This year, presentations were given at both the American Meteorological Society's Annual Meeting in Atlanta, GA, and at the NCDC/CICS Dataset Discovery Day focusing on severe weather datasets. In addition, CICS-NC scientist Scott Stevens is providing mentorship to an intern with the National Climate Assessment, who will be focusing on radar-derived precipitation for her senior project.

**Satellite Product Evaluation and Near Real Time Monitoring**

| | |
|---|---|
| **Task Leader** | Lou Vasquez |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**: This project applies the Satellite Product Evaluation Center (SPEC) tool to the Surface Fluxes and Analysis (SurFA) project used to generate a Near Real-Time Monitoring (NRTM) website. Ingest operations were supported with modifications to manifest creation in support of multiple archive site common manifest generation.

**BACKGROUND**

Satellite Product Evaluation Center (SPEC) software performs subset, analysis, and comparison of multiple datasets to determine aberrant behavior or disparate results between datasets. This project outputs results of analysis in HTML and software parse-able XML for potential further processing.

The Surface Fluxes and Analysis (SurFA) project implements SPEC software to analyze and compare multiple surface winds sources in a near real-time fashion, providing static HTML, email, and downloadable daily output or results noting alerts where operator thresholds are crossed. This output is available for use and further software analysis. The SurFA Near Real-Time Monitoring (NRTM) project converts SurFA SPEC implementation output into a web based, GIS, user-interactive display, for convenient access to near real-time results.

The Remote Sensing and Applications Division (RSAD) Ingest system allow automated provision of data to NCDC from a variety of national sources, processing them prior to, and in preparation, of archive. Manifests of files are created describing its contents to track incoming data along with the data itself for integrity and future access to data after archive.

**ACCOMPLISHMENTS**

Satellite Product Evaluation Center (SPEC) software was modified for Near Real-Time Monitoring (NRTM) project, extending output formats to allow web services to more easily parse and display analysis output. A prototype webpage was created at request of NCDC project lead for the SPEC project with the intent, upon approval, of releasing, sharing versions, documentation, and relevant information with the public. Code was written and integrated for multiple CF compliant Network Common Data Form (NetCDF) adapters (IOSP). Adapters were integrated into the SPEC subset framework to enable processing of specific QPE datasets in a standardized manner. They included programmatically accessible (API) tools to extract subset and dataset oriented information directly from data files for expedience as well as testing/validation purposes. The project was separated into multiple branches for concurrent development in different environments (NCDC,NCSU) for multiple purposes (operations,testing/research). The project was also ported to major upgrades of Java, and separately NetCDF toolkit (UITools), with testing and operational output comparison made prior to release.

SURFA (Surface Fluxes and Analysis) daily SPEC runs were coordinated with user feature modifications and bug requests driving changes to the core software project and upgrades to operational code. A repository was created for deployed scripts to track and manage changes to operational and development/testing deployments.

Tests were performed of NMQ/Q2 reanalysis on NOAA NSSL/ESRL and provided a high performance computing system to evaluate additional or alternate resources for processing. The test required rewriting run scripts and working with system administrators to ensure the best use of machines while not impacting other cluster users. Current CICS-NC systems were found to be the best available approach for processing given unique requirements of software and the ability to manipulate equipment to meet these needs.

This project group worked with an NCDC intern converting a mock up SurFA near real-time monitoring (NRTM) web design into initial operational site. The site, seen in *Figure 1*, transforms information from SurFA SPEC project for interactive web display. Development of the site continued until it was prepared for release, adding features to integrate GIS site status with requested date, provide condensed site history display, and other items for page clarity and consistency. Tools were prototyped for data pull to web access using near real-time data. NoSQL database (Mongo) was tested to quickly load daily data and display.

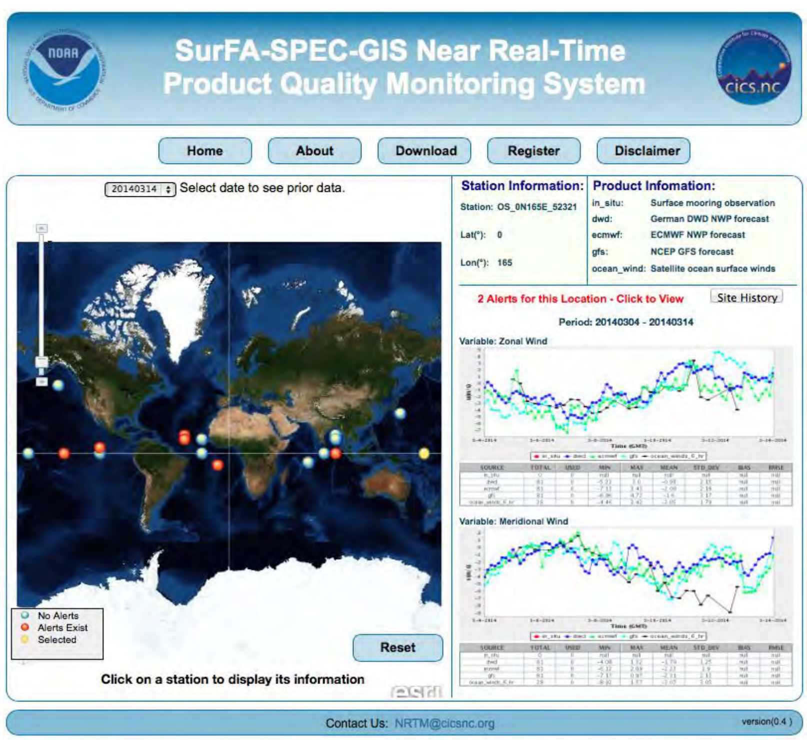



*Figure 1: SurFA NRTM operational website showing SPEC results for March 14$^{th}$ of 2014. The left map shows user interactive GIS map of sites color coded to alert state. The right side displays site information, alert details, time series plots, and statistical results.*

Training was provided to an NCDC intern in various tools for initial SurFA NRTM website development. The tools included a variety of web-oriented programming languages (DHTML, jQery, JavaScript, PHP), development environments (IDE, editors, git, linux), as well as best practices and related modules required for site.

The Remote Sensing and Applications Division (RSAD) Ingest system manifest creation tool was modified into a common formatting for multiple archival systems. As recommendations for a single manifest were not approved by both parties, the system was modified to fit both requirements by including a complete set of information in original and transforming via XML schema XSL into more stringent requirement set. Various additional modifications to the manifest creation tool were made to meet conditions discovered during ingest operation.

Regular assistance was provided debugging ingest system issues, recreating FTP server failure scenarios, data inconsistencies due to drive array failure, and other items not caused by Ingest system but significantly impacting its operations. Participation also provided in design process as new components are brought into consideration such as load balancing replacement and implementation of iRODS to manage data movement.

The SPEC tool was evaluated for comparison of precipitation measurements across multiple datasets. SPEC NetCDF adapters (IOSP) were created for multiple precipitation datasets (PRISM, TRMM, TMPA-RT, QPE) and IOSPs were validated against 3rd party tools. Initial runs were completed producing total rainfall estimates, average rainfall, and statistics relating requested results to available data with some discrepancies discovered. Additional tools were added to IOSP for low level comparison and direct analysis of data to better understand discrepancies.

Visual representations were created for Q2/QPE comparisons using the SPEC tool and its enhancements for rainfall estimates. Q-Q plots were used to display variations in the dataset types for scientific comparison and further evaluation and usefulness of the SPEC tool in this approach. Additionally, relief graphs displaying CVRMSD for the contiguous US were generated to display the regional variation between TRMM and TRMMRT datasets.

**PLANNED WORK**

- Continue implementing SPEC for precipitation estimation evaluation to better understand discrepancies and compare additional datasets.
- Expand precipitation estimation to include additional statistics.
- Respond to user requests on release of SurFA NRTM site.

**DELIVERABLES**

- Released SurFA NRTM website.
- SurFA NRTM website enhancements for users.
- New release of Ingest Manifest creator meeting CLASS common ingests requirements.
- Evaluation and enhancement of SPEC tool for QPE dataset comparisons.

- Tools to create poster session ready visual representations of QPE analysis using SPEC, in the form of Q-Q plots and relief graphs.

**OTHER**

- Participated in NCDC Configuration Management (CM) Initiative producing configuration documents for branch.
- Received "Certificate of Appreciation" for work on CM initiative.
- Assisted QA lead for CDR in creation of recommendations whitepaper.
- Took part in planning and initial phase of NCDC ingest system management transition.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 1 |

**PERFORMANCE METRICS EXPLANATION**

This year, the SurFA NRTM website project was developed and released (1). During deveopment of site, NCDC undergraduate was mentored (1) in all required web tools for initial operation. The Ingest Manifest tool was improved (1) to meet common ingest requirements for multiple archive sites.

# Assessment Activities

Assessment efforts support interagency activities for global, national, and regional assessments of climate change.

**Background**

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 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. The agency also plans to invest in core competencies including modeling, data management, visualization, communication, web management, and other expertise.

Support of NOAA- and NCDC-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 NCDC 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 Chair of TSU for the National Climate Assessment 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 NCDC 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)."

**ACCOMPLISHMENTS**

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 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** | |
| **NOAA Sponsor** | David Easterling |
| **NOAA Office** | |
| **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 and author contributions supported the completion of the Third National Climate Assessment.

**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**

There were several rounds of revisions of the Third National Climate Assessment in response to several rounds of reviews. These include public comments, two reviews by a National Research Council panel, and two rounds of government review. As one of the lead authors of the climate science sections, Kunkel responded to many of the comments on those sections, with text and graphics revisions and composing responses to these comments. There were also comments on the climate science portions of the other chapters, many of which were addressed by Kunkel. The other members of the science team provided substantial support to this effort by updating analyses and graphics, and producing metadata on the graphics.

One major effort was the updating of a number of the graphics in response to the availability of a new statistically downscaled data set (1/8 degree-CONUS Daily Downscaled Climate Projections) produced for the U.S. Geological Survey by Katharine Hayhoe and colleagues. This new data set has statistical properties that better reproduce the climatology of daily observations. Updated maps were produced for several of the regional chapters, and some of the sectoral chapters. Another important update was of a graphic showing the range of model-simulated future projections for high and low scenarios (*Fig. 1*). This update required an analysis of CMIP3 and CMIP5 model simulations and the production of a more-easily understood graphic.

Metadata for a number of the key climate science figures produced by the TSU were compiled and input by the science team to the web system that makes these data available via the report website and the USGCRP's Global Change Information System. The science team also worked to make the data used to generate more than two dozen figures in the assessment available online, via the CIS-NC website (http://www.cicsnc.org/about/tsu/nca3-data). In addition, several individual requests for NCA data were fulfilled, providing data, figures, and other NCA-related content to the Centers for Disease Control (CDC), the NOAA Climate Program Office (CPO), and others.

Substantial analysis of the CMIP5 model simulations was conducted. This will be summarized in an upcoming report.

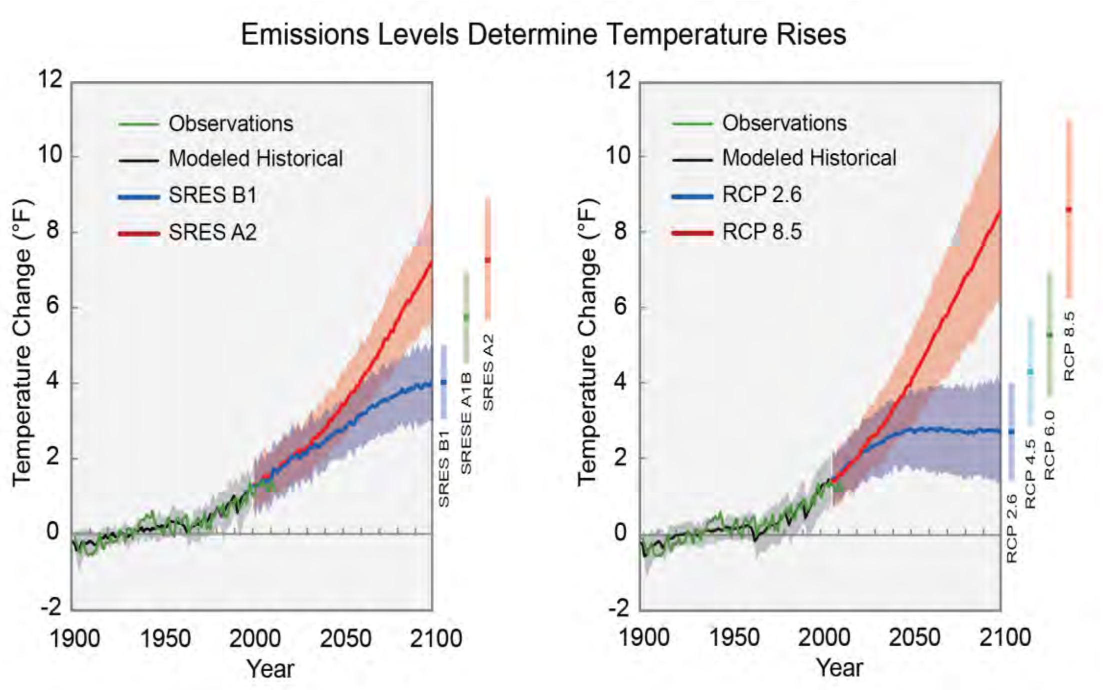


*Figure 1: Comparison of climate model simulations of historical and future global temperature changes for high (SRES A2 and RCP 8.5) and low (SRES B1 and RCP 2.6) emissions scenarios. Left graph shows climate model simulations from the Coupled-Model Intercomparison Project Phase 3 (CMIP3) and right graph shows simulations from CMIP Phase 5. Shading indicates the 5 to 95-percentile range.*

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

**PLANNED WORK**

- Publish a report comparing CMIP3 and CMIP5 climate simulations for the NCA regions
- Lead author on climate change and health report
- Complete papers on analysis of historical observations, including the probability distribution of monthly temperature, time of observation effects on extreme precipitation trends, day of the week signals in extreme precipitation, and the effect of the changeover to MMTS on extreme temperature trends

**PUBLICATIONS**


- Peterson, T.C., T.R. Karl, J.P. Kossin, K.E. Kunkel, J.H. Lawrimore, J.R. McMahon, R.S. Vose and X. Yin, 2014: Changes in weather and climate extremes: State of knowledge relevant to air and water quality in the United States. *Journal of the Air & Waste Management Association*, 64,184-197, DOI:10.1080/10962247.2013.851044.
- Lawrimore, J., T.R. Karl, M. Squires, D.A. Robinson, and K.E. Kunkel, 2013: Trends and variability in severe snowstorms east of the Rocky Mountains. J. Hydromet., submitted.
- Janssen, E., D.J. Wuebbles, K.E. Kunkel, S.C. Olsen, and A. Goodman, 2013: Observed and modeled trends and projections of extreme precipitation over the contiguous United States. *Earth's Future*, accepted.
- Vose, R.S., S. Applequist, M.A. Bourassa, S.C. Pryor, R.J. Barthelmie, B. Blanton, P.D. Bromirski, H.E. Brooks, A.T. DeGaetano, R.M. Dole, D.R. Easterling, R.E. Jensen, T.R. Karl, R.W. Katz, K. Klink, M.C. Kruk, K.E. Kunkel, M.C. MacCracken, T.C. Peterson, K.Shein, B.R. Thomas, J.E. Walsh, X.L. Wang, M.F. Wehner, D.J. Wuebbles, and R.S. Young, 2012: Monitoring and understanding changes in Extremes: Extratropical storms, winds, and waves. *Bull. Amer. Meteor. Soc.*, accepted.
- Wuebbles, D.W., G. Meehl, K. Hayhoe, T. R. Karl, K. Kunkel, B. Santer, M. Wehner, B. Colle, E. M. Fischer, R. Fu, A. Goodman, E. Janssen, H. Lee, W. Li, L. N. Long, S. Olsen, A. Seth, J. Sheffield, and L. Sun, 2013: CMIP5 climate model analyses: Climate extremes in the United States. *Bull. Amer. Meteor. Soc*., accepted
- Peterson, T.C., R.J. Heim, Jr., R. Hirsch, D.P. Kaiser, H. Brooks, N.S. Diffenbaugh, R.M. Dole, J.P. Giovannettone, K. Guiguis, T.R. Karl, R.W. Katz, K.E. Kunkel, D. Lettenmaier, G.J. McCabe, C.J. Paciorek, K. Ryberg, S. Schubert, V.B.S. Silva, B.C. Stewart, A.V. Vecchia, G. Villarini, R.S. Vose, J. Walsh, D. Wolock, K. Wolter, C.A. Woodhouse, M. Wehner, and D. Wuebbles, 2013: Monitoring and understanding changes in heat

waves, cold waves, floods and droughts in the United States: State of knowledge. *Bull. Amer. Meteor. Soc.*, **94**, 821-834.

- Kunkel, K.E., T.R. Karl, H. Brooks, J. Kossin, J. Lawrimore, D. Arndt, L. Bosart, D. Changnon, S.L. Cutter, N. Doesken, K. Emanuel, P.Ya. Groisman, R.W. Katz, T. Knutson, J. O'Brien, C. J. Paciorek, T. Peterson, K. Redmond, D. Robinson, J. Trapp, R. Vose, S. Weaver, M. Wehner, K. Wolter, D. Wuebbles, 2013: Monitoring and understanding changes in extreme storms: state of knowledge. *Bull. Amer. Meteor. Soc.*, **94**, 499-514, doi: http://dx.doi.org/10.1175/BAMS-D-12-00066.1.

**DELIVERABLES**

- Scientific support for the entire NCA report, resulting in the production of the NCA website, PDF versions of the full report, PDF and print versions of the "Highlights" version of the report, and print and PDF versions of the "Overview" of the report as well as several other derivative products
- Publication of papers summarizing the extremes workshops
- Updated graphics for NCA report
- Compiled metadata for key science chapter graphics
- Fulfillment of 15 unique requests for data, figures, and other related NCA content
- Worked to provide data sets for more than two dozen NCA figures online, via the CICS-NC website

**PRESENTATIONS**

- Stevens, L.E., and K.E. Kunkel, 2014: Climate Change in the Carolinas, invited talk, Carolinas Climate Resilience Conference, Charlotte, NC (29 April).
- Kunkel, K.E., 2014: Extreme Precipitation Trend Estimation in Conterminous United States (CONUS), poster paper, Donald R. Johnson Symposium, Annual Meeting of the American Meteorological Society, Atlanta, GA (6 February).
- Kunkel, K.E., 2014: Observed Trends in Extreme Precipitation: Illinois and Beyond, invited talk, Stanley A. Changnon Symposium, Annual Meeting of the American Meteorological Society, Atlanta, GA (4 February).
- Kunkel, K.E., 2014: Historical Trends and Future Projections of Extreme Climate Conditions for the U.S. National Climate Assessment, Annual Meeting of the American Meteorological Society, Atlanta, GA (4 February).
- Kunkel, K.E., 2014: What are the Innovations in Science and Scenarios for this and Future Assessments, invited talk, National Council for Science and Engineering 14th National Conference, Washington, DC (28 January).
- Kunkel, K.E., 2013: Observed Trends in Extreme Precipitation in the U.S., invited talk, 2013 Fall Meeting of the American Geophysical Union, San Francisco, CA (13 December).
- Kunkel, K.E., 2013: U.S. Regional Extreme Climate Conditions in CMIP5 Simulations, invited talk, 2013 Fall Meeting of the American Geophysical Union, San Francisco, CA (12 December).
- Kunkel, K.E., 2013: National Climate Assessment Climate Modeling and Downscaling, invited talk, Scoping Workshop for the National Climate Assessment (NCA) Special Report on Climate Change and Health, Washington, DC (21 November).

- Kunkel, K.E., 2013: U.S. Climate Scenarios, invited talk, Second Nature webinar on "Understanding Climate Impacts: Using Tools and Resources to Prepare Your Campus for a Changing Climate" (20 November).
- Kunkel, K.E., 2013: Extreme Precipitation Events: Data Issues and Meteorological Causes, invited talk, U.S. CLIVAR Workshop: Analyses, Dynamics, and Modeling of Large Scale Meteorological Patterns Associated with Extreme Temperature and Precipitation Events, Berkeley, CA (20 August).
- Seyller, E., K.E. Kunkel, and L.E. Stevens, 2013: Regional Climate Trends and Scenarios for the United States, GreenGov Workshop on Climate Science and Adaptation Planning, Washington, D.C. (2 August).
- Kunkel, K.E., 2013: National Climate Assessment: Potential CDR Program Contributions, invited talk, NOAA Climate Data Record Annual Meeting, Asheville, NC (30 July).
- Kunkel, K.E., 2013: Climate Extremes Research: Recent Findings and New Directions, invited talk, Snowmass 2013 Integrated Climate Change Impacts Session, Energy Modeling Forum, Snowmass, CO (24 July).
- Kunkel, K.E., 2013: An Assessment of Extreme Weather and Climate Events, invited talk, Summer Meeting of the Federation of Earth System Information Providers, Raleigh, NC (11 July).
- Kunkel, K.E., 2013: Extreme Weather and Climate Events, invited talk, Tokio Marine's Eighth Summit on Global Warming and Climate Change , Atlanta, GA (28 June).
- Kunkel, K.E., 2013: Observed Trends and Future Projections of Drought, invited talk, Advisory Committee on Water Information, webinar (27 June).
- Kunkel, K.E., 2013: Observed Trends and Future Projections of Extremes, invited talk, $35^{th}$ MIT Global Change Forum, Cambridge, MA (5 June).
- Kunkel, K.E., 2013: Climate Change and Extreme Weather and Climate Events, invited talk, Executive Forum for Business and Climate, Asheville, NC (4 June).
- Kunkel, K.E., 2013: Observed Trends and Future Projections of Extremes, invited talk, Advisory Committee on Water Information, webinar (30 May).
- Kunkel, K.E., 2013: Analysis of Historical and Future Snow Conditions for the National Climate Assessment, Western Snow Conference, Jackson, Wyoming (16 April).

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 7 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | |
| # of products or techniques transitioned from research to ops without NOAA guidance | |
| # of peer reviewed papers | 6 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 16 |
| # 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**

This year, we made major contributions to the revision and completion of the Third National Climate Assessment report. Three journal papers were published and 3 more were accepted. Numerous invited talks were given.

**Trends in Extra-tropical Cyclone Occurrence**

| | |
|---|---|
| **Task Leader** | Kenneth Kunkel |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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.

**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. Future changes in extreme weather in mid- to high-latitudes will likely involve changes in the frequency, intensity, and tracks of ETCs.

A number of recent studies focused on the Northern Hemisphere have documented a significant poleward shift of the storm track in both the Pacific and Atlantic Ocean basins, a decrease in ETC frequency in mid-latitudes, and a corresponding increase in ETC activity at higher latitudes for the latter half of the 20$^{th}$ 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-20$^{th}$ century as used in previous studies, back to the late 19$^{th}$ Century. We have used this new 20$^{th}$ Century Reanalysis (20CR) data set to extend the analysis of ETC occurrence in the Northern Hemisphere to the period 1871-2007.

**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 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. This project analyzed the variability of cyclone tracks and computed the average variability over consecutive 5-year periods. Two of the periods are illustrated in *Figs. 1* and *2*. In the early part of the reanalysis period, variability is quite high over the North Pacific and much of the high latitude area, indicating greater uncertainty. These coincide with areas of low data availability. By contrast, variability is quite low, indicating lower uncertainty, over most land areas and the North Atlantic. By the middle of the 20$^{th}$ Century (e.g. *Fig. 2*), data availability has increased in most areas. In the North Pacific and high latitudes, variability of ETC tracks has decreased by about a factor of three, indicating substantially lower uncertainties.

The analysis results were interpreted to mean that the ETC counts over the North Pacific are probably reliable back to the 1920s or so and back to the 1930s for high latitude locations except for the Arctic Ocean, but before those points in time the uncertainties are large enough to call into question the reality of the analyzed temporal variations. For mid-latitude land areas and the North Atlantic, estimates of ETC activity can probably be considered reliable back to the 1890s.

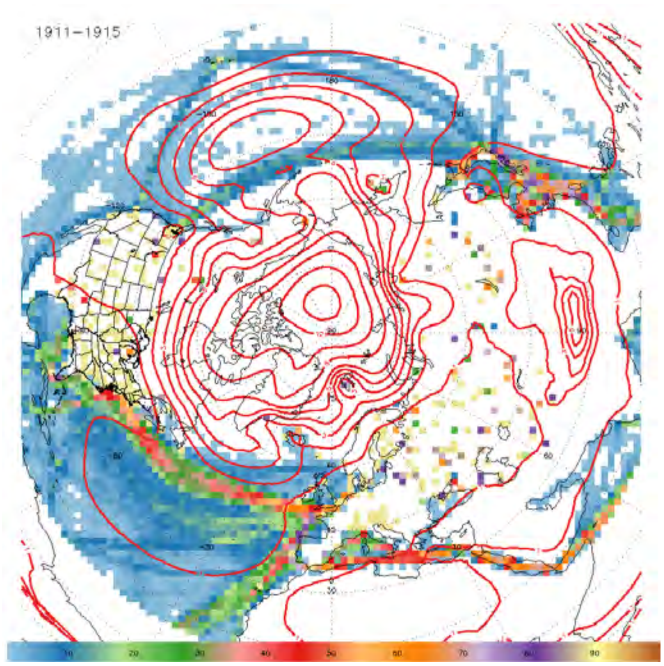



*Figure 1: Variability in cyclone track location (contours) for the period 1911-1915. Color shading shows the percentage of days with at least one pressure observation in the grid box.*

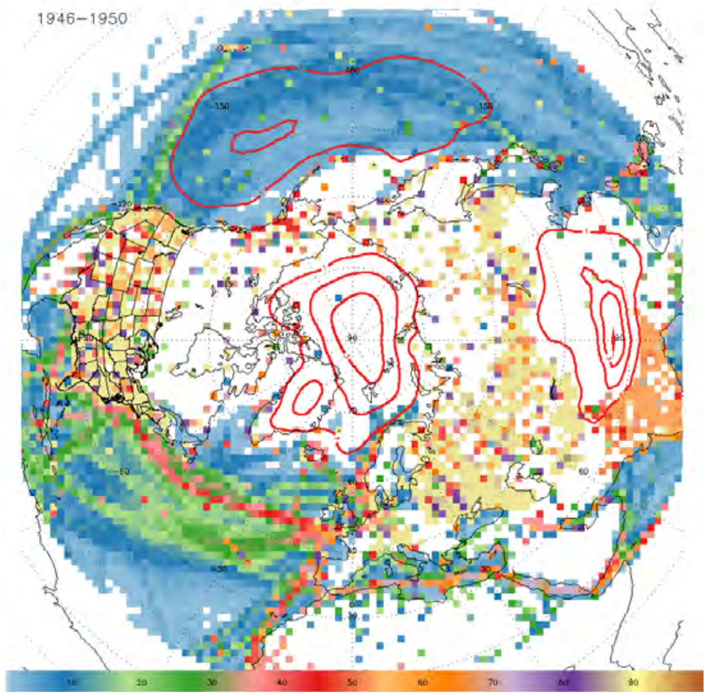



*Figure 2: Variability in cyclone track location (contours) for the period 1946-1950. Color shading shows the percentage of days with at least one pressure observation in the grid box. Compared to 1911-1915 (Fig. 1), variability is much reduced in the North Pacific and high latitudes*

Two journal articles and a chapter of the Third National Climate Assessment summarized our scientific assessment of historical and future changes in storm track and intensity.

A web site is being developed that will show the results of this project. Specifically, it will provide maps of individual ETC tracks and climatologies for various periods.

**PLANNED WORK**

- Update the analysis to include a newly-released version of the 20$^{th}$ Century reanalysis
- Complete and submit a paper on reliable periods of ETC activity
- Complete web site providing maps of ETC tracks

**PUBLICATIONS**


- Vose, R.S., S. Applequist, M.A. Bourassa, S.C. Pryor, R.J. Barthelmie, B. Blanton, P.D. Bromirski, H.E. Brooks, A.T. DeGaetano, R.M. Dole, D.R. Easterling, R.E. Jensen, T.R. Karl, R.W. Katz, K. Klink, M.C. Kruk, K.E. Kunkel, M.C. MacCracken, T.C. Peterson, K.Shein, B.R. Thomas, J.E. Walsh, X.L. Wang, M.F. Wehner, D.J. Wuebbles, and R.S. Young, 2014: Monitoring and understanding changes in Extremes: Extratropical storms, winds, and waves. *Bull. Amer. Meteor. Soc.*, **95**, 377-386.
- Wuebbles, D.W., G. Meehl, K. Hayhoe, T. R. Karl, K. Kunkel, B. Santer, M. Wehner, B. Colle, E. M. Fischer, R. Fu, A. Goodman, E. Janssen, H. Lee, W. Li, L. N. Long, S. Olsen,

A. Seth, J. Sheffield, and L. Sun, 2014: CMIP5 climate model analyses: Climate extremes in the United States. *Bull. Amer. Meteor. Soc*., 95, 571-583.

- Walsh, J., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, D. Anderson, S. Doney, R. Feely, P. Hennon, V. Kharin, T. Knutson, F. Landerer, T. Lenton, J. Kennedy, and R. Somerville, 2014: Ch. 2: Our Changing Climate. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.

**DELIVERABLES**

- Completion of uncertainty analysis

**PRESENTATIONS**

- Kunkel, K.E., 2013: Extreme Precipitation Events: Data Issues and Meteorological Causes, invited talk, U.S. CLIVAR Workshop: Analyses, Dynamics, and Modeling of Large Scale Meteorological Patterns Associated with Extreme Temperature and Precipitation Events, Berkeley, CA (20 August).
- Kunkel, K.E., 2014: The Third National Climate Assessment, invited seminar, Ouranos Consortium on Regional Climatology and Adaptation to Climate Change, Montreal, Canada (11 June).

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 0 |
| # of invited presentations | 2 |
| # 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**

Two papers on extremes included work on historical trends and future projections of ETCs. A talk on the role of ETCs in extreme precipitation was given.

**National Climate Assessment Technical Support Unit Program Support Activities**

| | |
|---|---|
| **Task Leader** | Paula Ann Hennon |
| **Task Code** | NC-NCA-03-NCICS-PH |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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% |

**Highlight**: Implementing new production processes and maintaining a supportive workforce are ongoing priorities. Coordinating TSU/USGCRP activities and delivering the Third National Climate Assessment report and website were primary accomplishments of the TSU in 2014.

**BACKGROUND**

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the ongoing National Climate Assessment 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**

2014 was a milestone year for the TSU, as four years of work culminated in the release of the Third National Climate Assessment (NCA3) on May 6, 2014. The multi-disciplinary TSU team played crucial roles in the development, production, and distribution of the report. Since the release of the report, the team has begun translating lessons learned from the NCA3 process into helping developing tools and processes for the sustained assessment. The TSU is already putting those processes and tools into action as it begins work on the forthcoming USGCRP assessment of the impacts of climate change on human health. Team members also contributed to a workshop on evaluating NCA3, planning for NCA4, and expanding support for UGSGCRP.

Individual task reports detail the contribution of the various TSU teams to NCA3. A few highlights include:

The editorial team was responsible for translating the scientific text and assessment information contributed by the authors into a non-scientific, public facing document, readable by the Congress and the general public. They worked closely with chapter authors, the NCA Development Advisory Committee members, and Ex Officio members from Federal agencies, to finalize the content of the report. They also played a major role in the development of the "Highlights" version of the report, as well as several other derivative materials, and provided editorial support for the website version of the report.

The web development team designed and implemented the widely acclaimed NCA3 website, and, working with the data team, ensured robust traceability of sources and enhanced connection to other climate and environmental information across the Government and elsewhere, through participation in the development of the Global Change Information System. This web-focused activity of the NCA serves as a key component of the ongoing, sustainable process.

The Graphical Design Team produced the PDF versions of the report as well as print version of "Highlights" and several other derivative products. They also assembled broadcast-ready digital assets that were made available via the report website.

During the development of the report, the TSU coordinated and facilitated several meetings of the National Climate Assessment and Development Advisory Committee, the Federal advisory committee for the NCA, as well as a series of author team meetings to facilitate writing the report and engagement and outreach meeting to coordinate the rollout.

**PLANNED WORK**

- Strategic planning for the NCA TSU's sustained process
- Planning support for the USGCRP climate and health assessment
- Continue to manage the overall team, their activities and milestones, and provide general management oversight of the report completion process

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 17 |
| # 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 |

**National Climate Assessment Technical Support Unit Software Engineer**

| | |
|---|---|
| **Task Leader** | Andrew Buddenberg |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**

A comprehensive suite of analyses was developed to process the U.S. Geological Survey's new statistically downscaled CMIP3 dataset. Successive upgrades of the suite to better take advantage of cluster computing resources reduced the complete runtime of all analyses from several hours to approximately five minutes. The inclusion of an automated unit-testing framework greatly increased the detection rate and control of configuration errors (see below). Beyond their use in the NCA, these results were made available to the Centers for Disease Control for use in their research.

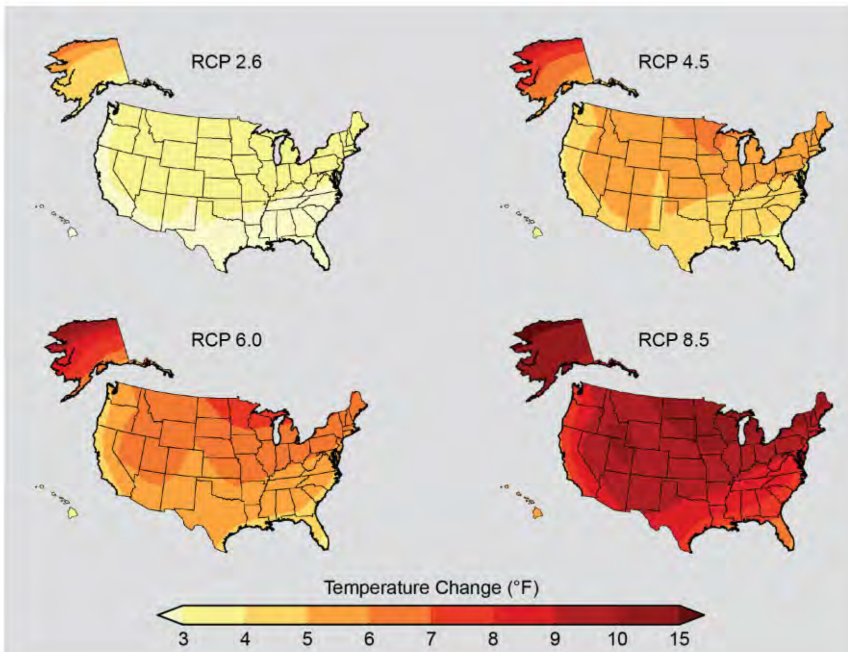
```
=============================== test session starts ===============================
platform linux2 -- Python 2.7.3 -- pytest-2.4.2 -- /usr/local/uvcdat/1.2.0rc1/bi
n/python
collected 4 items

test_suite.py:9: test_config_model_consistency PASSED
test_suite.py:22: test_config_files_for_scenario PASSED
test_suite.py:36: test_config_vars PASSED
test_suite.py:45: test_all_files_exist PASSED

=============================== 4 passed in 0.13 seconds ===============================
```

These cluster computing techniques were further employed in a separate but similar set of analyses of a 1/8 degree gridded observational dataset by Ed Maurer out of Santa Clara University. Incorporating lessons learned from the statistically downscaled CMIP3 analyses, this package was written in a more modular fashion; enabling the use of the unit-testing framework to detect data processing errors. Computations were similarly performant: ~100,000 grid points * 60 years processed in a matter of minutes.

Using these and other datasets in collaboration with Kenneth Kunkel (lead senior scientist), Laura Stevens (support scientist), and Jessicca Griffin (graphic designer), several figures and tables for the National Climate Assessment were produced with examples below:




**Projected Temperature Change by 2071-2099 (CMIP5 models):**
*The largest uncertainty in projecting climate change beyond the next few decades is the level of heat-trapping gas emissions. The most recent model projections (CMIP5) take into account a wider range of options with regard to human behavior, including a lower scenario than has been considered before (RCP 2.6). This scenario assumes rapid reductions in emissions-more than 70% cuts from current levels by 2050 and further large decreases by 2100 -and the corresponding smaller amount of warming. On the higher end, the scenarios include one that assumes continued increases in emissions (RCP 8.5) and the corresponding greater amount of warming. Also shown are temperature changes for the intermediate scenarios RCP 4.5 (which is most similar to B1) and RCP 6.0 (which is most similar to A1B; see the Climate Science Appendix). Projections show change in average temperature in the later part of this century (2071-2099) relative to the late part of last century (1970-1999). (Figure source: NOAA NCDC / CICS-NC).*

| | Consequences: Challenges and Opportunities | |
|---|---|---|
| Region | Cooling | Heating |
| **Physical Impacts - High Likelihood** | **Hotter and longer summers**<br>Number of Additional Extreme Hot Days (> 95°F) and % Increase in Cooling Degree Days per Year in 2041-2070 above 1971-2000 Level | **Warmer winters**<br>Number of Fewer Extreme Cold Days (< 10°F) and % Decrease in Heating Degree Days per Year in 2041-2070 below 1971-2000 Level |
| **Northeast** | +10 days, +77% | -12 days, -17% |
| **Southeast** | +23 days, +43% | -2 days, -19% |
| **Midwest** | +14 days, +64% | -14 days, -15% |
| **Great Plains** | +22 days, +37% | -4 days, -18% |
| **Southwest** | +20 days, +44% | -3 days, -20% |
| **Northwest** | +5 days, +89% | -7 days, -15% |
| **Alaska** | Not studied | Not studied |
| **Pacific Islands** | Not studied | Not studied |

**Changing Energy Use for Heating and Cooling Will Vary by Region:**
*Hotter and longer summers will increase the amount of electricity necessary to run air conditioning, especially in the Southeast and Southwest. Warmer winters will decrease the amount of natural gas required to heat buildings, especially in the Northeast, Midwest, and Northwest. This information table is adapted from multi-model means from 8 NARCCAP regional climate simulations for the higher emissions scenario (A2) considered in this report and is weighted by population. (Source: adapted from Regional Climate Trends and Scenarios reports)*

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.

To facilitate the automated transfer of NCA metadata to the SDS, several software products have been developed:

- 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 to groups of undergraduate interns as well as basic techniques of scientific computing.

**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 NCA publication.
- GCIS SDS client software for packaged for public release, including documentation and test suite.
- Various figures and analyses used in the National Climate Assessment with comprehensive supporting metadata.

**PRESENTATIONS**

- Stevens, L.E. and A. Buddenberg, 2013: Climate Modeling for the National Climate Assessment, UNC Asheville, Asheville, NC (11 September).

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 7 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 2 |
| # 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 | 5 |

**PERFORMANCE METRICS EXPLANATION**

This year, we created two data analysis packages, approximately twenty figures for the National Climate Assessment, one Drupal module, one client software package for GCIS SDS, one metadata problem discovery and resolution tool, and one hack for Endnote (7). TSU transitioned one database schema and one version control tool from research to operations. An invited presentation was given to students at UNC-A (1) and five undergraduate interns (5) were mentored.

**Information Quality Act Compliance and Metadata Collection for the Third National Climate Assessment**

| | |
|---|---|
| **Task Leader** | Sarah Champion |
| **Task Code** | |
| **NOAA Sponsor** | David Easterling |
| **NOAA Office** | |
| **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**: TSU built a sustainable process and technical infrastructures to collect, curate, and display the metadata of the National Climate Assessment. The effort satisfies compliance with the Information Quality Act and includes 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. TSU has completed approximately 75% of the collection.

**BACKGROUND**

This report summarizes the work of the ongoing NOAA data sources project entitled "Information Quality Act Compliance and Metadata Collection for the Third National Climate Assessment." The Technical Support Unit (TSU) Data Team has built a sustainable process to collect, curate, and display all associated metadata for the National Climate Assessment, and future Assessments. This effort is in direct response to a Federal requirement for the Assessment to meet guidelines in the Information Quality Act and a Highly Influential Scientific Assessment, requiring traceability (transparency), and reproducibility of all data. The sustainable process includes a collection point and repository of metadata inputs, ongoing documentation of the collected information and status within the overall process, connection to a structured data server with integration to the U.S. Global Change Research Program (USGCRP) future Global Change Information System (GCIS) (development is ongoing), and a metadata viewer, integrated with the web design/display of the full Report.

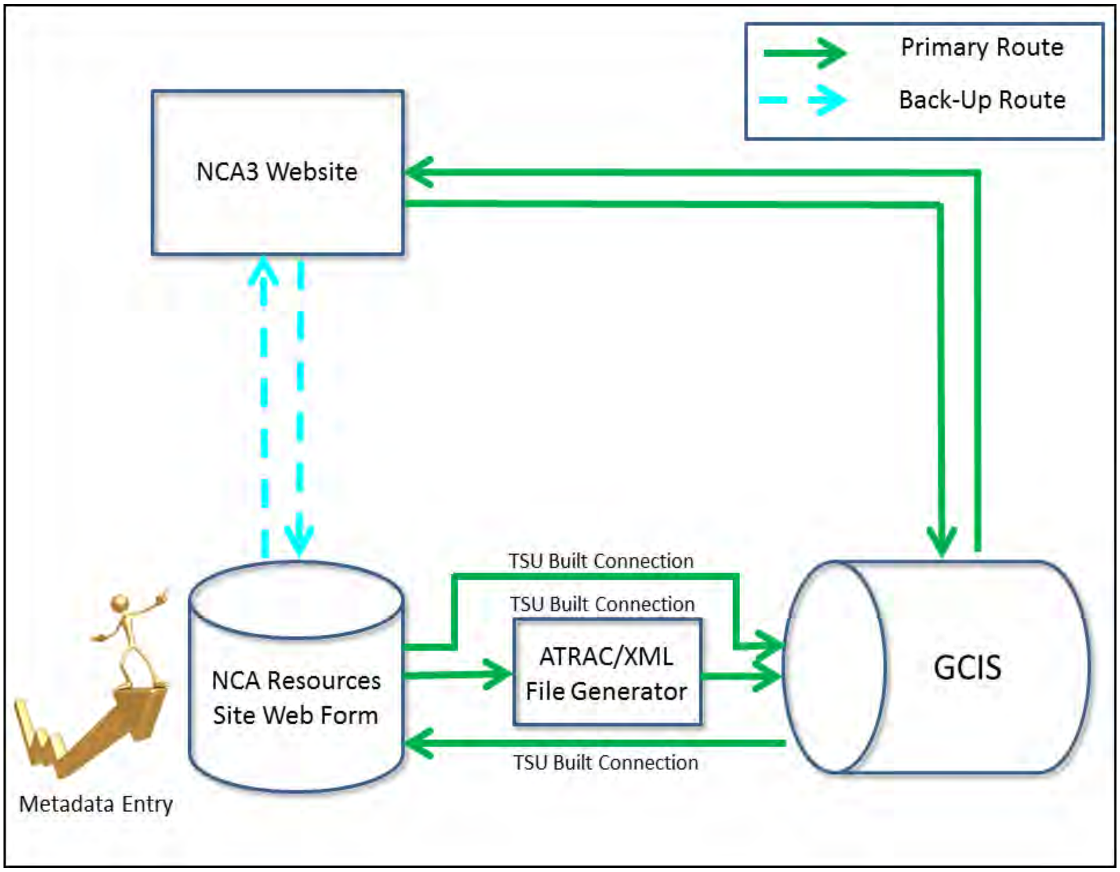



*Figure 1: The TSU Data Team workflow and sustainable metadata collection process. The process is initiated, as indicated in the lower left of the figure, with the "metadata entry" into the "web form." The content contained in this web form is pulled into the GCIS/Structured Data Server, either directly, or after requiring filtering through an XML Metadata File generator. The workflow also depicts a back-up solution to collect, store, and display collected information, should the connection to the GCIS ever be terminated. This technical infrastructure has been successfully built and implemented, using a series of software development collaborations, internally with the TSU and through collaboration with USGCRP GCIS Developers.*

**ACCOMPLISHMENTS**

The process and level of detail are a first-time success in the history of the National Climate Assessment project. The web form, connections between the web form, GCIS, and the Metadata Viewer on the National Climate Assessment website (including the website itself), have been completely built and designed internally and are fully functioning. All components have been designed, built, and executed. The infrastructure was recently tested during development to satisfy a high-level request for metadata pertaining to a potential "show-stopper" comment during the Report Draft review period. Demonstration and delivery of this particular metadata satisfied the interested parties and the concern was eliminated. Additionally, the level of detail of metadata input and collection has successfully traced challenging contributions, such as analysis and methods with modified model output data. To date, we have collected approximately 75% of the Report metadata.

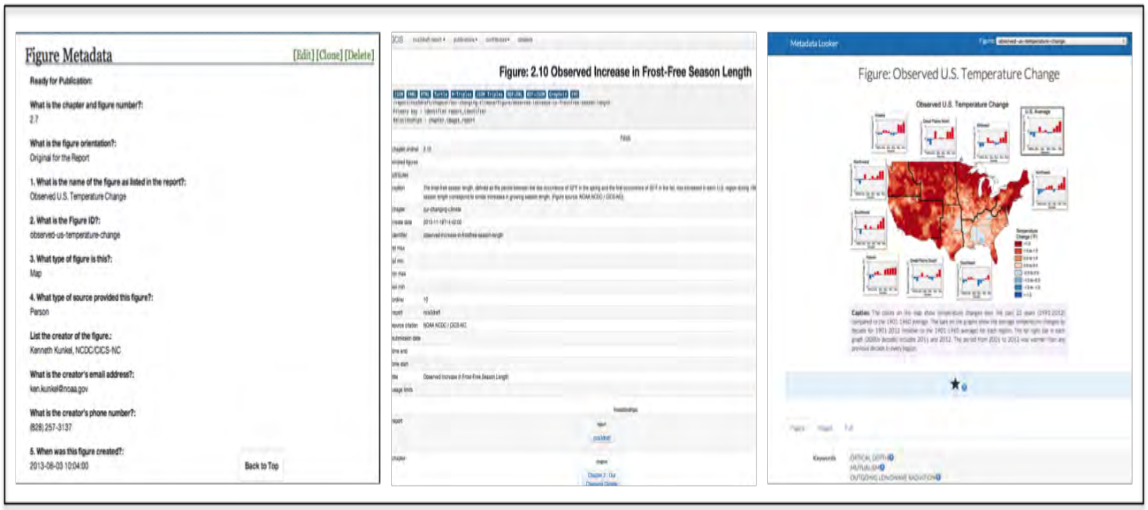



*Figure 2: Examples of the three main components of the metadata collection process. The first panel depicts a portion of collected input for a graphic within the Report. The middle panel shows the same input from the left panel as it is stored and organized within the GCIS/Structured Data Server. The far right panel depicts the metadata viewer on the Report website, with selected input displayed for a typical user. This is not all-inclusive of the complete functionality of all three components, but is meant to demonstrate how the information is processed throughout the collection process.*

All project deliverables (documentation and software) and milestones have been accomplished as planned. Currently, the software system is being tested and preparations are under way for the Test Readiness Review (TRR).

**PLANNED WORK**

- Continue collaborative efforts with GCRP in populating the GCIS with Report metadata, data, and contributors
- Continue metadata documentation efforts for all 300 Report graphics, references, and data (approximate)

**DELIVERABLES**

- Fully documented metadata for the entire National Climate Assessment
- End-to-end collection, documentation, and curation process and infrastructure for metadata for the Sustained Assessment

**PRESENTATIONS**

- Timles, C., Champion, S., and Aulenbach, S. 2014: *The Federation of Earth Science Information Partners Winter Meeting, Washington, D.C., ESIP*

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 developed a process to collect metadata in accordance with Federal Requirements (1), and two additional supporting components to support a sustainable and seamless process (2). The progress of these components and process were invited as part of a presentation at the Winter ESIP meeting in Washington D.C.

**Development of Geospatial Visualizations, Online resources, and Decision Support Tools for the National Climate Assessment**

| | |
|---|---|
| **Task Leader** | Jim Fox |
| **Task Code** | NC-NCA- -UNCA |
| **NOAA Sponsor** | |
| **NOAA Office** | CPO |
| **Contribution to CICS Themes (%)** | Theme 1: 100%; Theme 2: 0%; Theme 3: 0% |
| **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:** Staff from UNC Asheville's NEMAC created maps and products for the National Climate Assessment; co-developed digital resource environments and interactive and static graphics for users of the Climate Assessment and Indicators team; and researched and presented a decision framework for use by the Climate Assessment. These new products support the overall advancement and progression of the National Climate Assessment program.

**BACKGROUND**

The University of North Carolina Asheville's (UNCA's) National Environmental Modeling and Analysis Center (NEMAC) has assisted CICS-NC and the NOAA Assessments Technical Support Unit (TSU) through the provision of expertise, staff time, and technical resources.

NEMAC specializes in using science communication and delivery to develop decision-making tools for local and regional planners, decision makers, and the public. NEMAC staff members have expertise in visualization, geographic information systems (GIS), programming, multimedia, marketing, community engagement, outreach, meeting facilitation, and environmental science. Located in Asheville, site of NOAA's National Climatic Data Center and NOAA's Cooperative Institute for Climate and Satellites–North Carolina, NEMAC is uniquely situated to address the needs of the TSU through the provision of expertise, staff time, and technical resources.

NEMAC provided its expertise and resources to address the following task areas:

- Geographic Information Systems/Climate Projections Resource Development
- Development of Regional and State-based Web Services
- Co-Development of Online Environment for National Climate Assessment/Global Change Information System
- Development of Watershed Based GIS products
- Decision Support

**ACCOMPLISHMENTS**

*Geographic Information Systems/Climate Projections Resource Development*

NEMAC continues to provide assistance in developing and maintaining a 'library' of GIS maps and shapefiles from model output associated with CMIP5 and other resources. The development of the GIS viewer, in coordination with CICS-NC/TSU, will serve non-technical and scientific audiences of the National Climate Assessment and Global Change community. These visualization tools will help achieve accessibility and interpretation of complex scientific data in a way that facilitates decision-making, conveys scientific uncertainty where appropriate, and allows full transparency and traceability of the underlying data.

- CMIP5 and updated CMIP3 data were processed for a new set of climate maps to better compare CMIP5 and CMIP3 (Figure 1). Three sets of maps were produced:
  - o CMIP3 (A2, A1B, B1) and CMIP5 (RCP 8.5, RCP 6.0, RCP 4.5, RCP 2.6) scenario comparison maps for each time period (2021-2050, 2041-2070, 2071-2099) – precipitation and temperature
  - o CMIP3 (A2) and CMIP5 (RCP 8.5) seasonal (winter, spring, summer, fall) comparison maps for the 2041-2070 time period – precipitation and temperature
  - o CMIP5 CLIMDEX variable maps for 8 temperature variables and 5 precipitation variables.
- Research and development tasks on the GIS Viewer have included work towards a unified code base to serve National Climate Assessment products using PostGIS and other web services.
- All the CMIP and CLIMDEX maps are included in the draft NOAA Technical Report NESDIS 144.
- Three scales of the CMIP and CLIMDEX data have been processed and mapped, including CONUS, Alaska, and Hawaii.
- All maps delivered in high-resolution jpeg and Adobe Illustrator format and all GIS datasets used to generate each map were packaged together into Esri map packages.
- An automation script was developed to generate state-specific maps from tabular climate data and packaged GIS data.

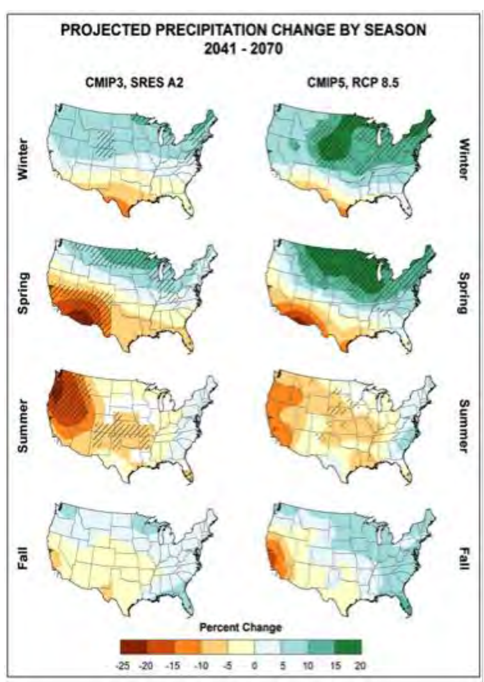



*Figure 2. Final CMIP5 seasonal precipitation data comparison between the CMIP5 RCP and CMIP3 SRES datasets.*

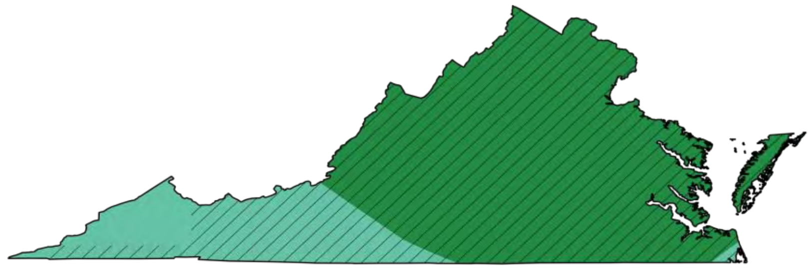


*Figure 2. Example state-specific map automatically generated for the winter season at the 2070-2099 time period.*

*Development of Regional and State-based Web Services*

The NOAA TSU aims to provide NCA-based materials for stakeholders such as State Climatologists, RCCs, and RISAs to disseminate to their stakeholders. NEMAC assisted with the reference implementation of a web application showcasing relevant material from the NCA (or other NOAA climate assessments, like the scenarios, etc.).

- Jim Fox interacted with a variety of partners towards this effort, including the South Atlantic, Gulf Coast, and Appalachian Landscape Conservation Cooperatives, the Southern Appalachian Man and Biosphere program, and RISAs in the Carolinas, Colorado, and Arizona.
- NEMAC continued to work with Broward County (Ft. Lauderdale), Florida's Natural Resources Planning and Management Division on applications of the National Climate Assessment at local levels. Efforts have focused on vulnerability to sea-level rise, storm surge and other flooding, and salt-water intrusion issues. While a joint NEMAC/Broward County NOAA SARP proposal was unsuccessful, Broward County funded NEMAC to integrate the findings from the NCA into local 3D visualizations and storytelling.
- NEMAC worked with the Southeast Sustainability Directors Network to launch the Partnerships for Resilience and Empowering Planning (PREP) program in developing an online Community Resilience Handbook for communities across the Southeast.

*Co-Development of Online Environment for National Climate Assessment/Global Change Information System*

NEMAC assisted with the following tasks: 1) Co-development of Drupal interface to implement an ensemble of websites, to access a wide array of information, and to design and implement key features, initially focusing on the website for the Third National Climate Assessment; 2) co-development of web sites and services for climate indicators; 3) maintenance of collaborative environments for authors, the science community, and federal staff, as needed; and 4) assist with identifying personnel who can lead and scope the needs for the user experience design process. The goal is to bring the design a curated "museum-like" feel and for it to be accessible and provide easy access to the NCA source material.

- NEMAC worked with the *HabitatSeven* team to create several interactive graphics applications for the NCA report web site.
- NEMAC worked with Melissa Kenney and Ainsley Lloyd from GCRP on the Indicators graphics effort, including gathering original Indicator author source data and re-designing the original graphic to have a consistent look and feel. Six indicators were redesigned with the plan to complete approximately 30 graphics for a pilot project.

- In response to a request from Tom Peterson, NEMAC developed an author collaboration web site using Drupal for authors of the Climate Extremes report. It allows report authors to share documents and images with each other during the writing of the report.
- In collaboration with Jessica Blunden, NEMAC modified the State of the Climate author portal to create chapter workspace for State of the Climate sections and add and manage users for each section.
- Assisted Stephanie Herring in modifying the Climate Extremes Editor Portal 2014 to create chapter workspace for Climate Extremes report sections and add and manage users for each section.

*Development of Watershed Based GIS Products*
NEMAC assisted with the development of a suite of snow climatology products at the watershed scale that will link to the NCA. These products will include relevant hydrologic tools and allow the water resources community to take full advantage of NCA climate products and models relevant to key water themes.

*Decision Support*
NEMAC continued to provide decision support assistance to NCA communities to help in the application and communication of data. NEMAC worked with NOAA, CICS-NC, the NCA Network of partners (NCANET), as well as internal NCA employees and technical teams, NCA ambassadors, and other key stakeholders of NOAA and NCA information. Methods of engagement and interaction include leading and participating in workshops on data and user needs and facilitating the development of indicators for scenario planning as needed.

- Jim Fox participated and presented at two Data Discovery Days: the Frost and Freeze workshop in March 2013, which led to two follow-up meetings with attendees in April 2013, and the Precipitation workshop in December 2013 that led to six meetings with other users and participants.
- Jim Fox participated in an Outreach workshop in Washington D.C, February 17$^{th}$-19$^{th}$, 2014, and worked with a Decisions sub-group on the May 2014 NCA rollout.
- NEMAC had discussions with Dr. Jessica Whitehead, NC Sea Grant's Coastal Communities Hazards Adaptation Specialist, about applying NEMAC's decision support tools and facilitation efforts to various projects and programs led by their organization.
- Jim Fox participated in an outreach workshop Asheville, NC, at the new "Collider" space in Asheville in July 2014.
- Jim Fox worked with the Water Resources Theme Team chaired by NOAA's Nancy Beller-Simms to determine their data needs for decision support, and followed up with a series of webinars. Through this dialog, conceptual models of their data needs were generated and key data sets were added to the Climate Explorer in the US Climate Resilience Toolkit.
- Jim ran a webinar in January 2015 for the USGCRP leadership on the "Getting Started" steps in the U.S. Climate Resilience Toolkit and on how communities and companies can use key assets from the NCA in this decision process. Jim ran a similar webinar for the NWS in April 2015 on a similar topic.

- Jim continues to work with David Herring at NOAA's Climate Program Office, Paula Hennon and Ken Kunkel at CICS-NC, Fabien Laurier and Fred Lipschultz at USGCRP, and others on the integration of NCA with other NOAA and USGCRP products related to decision making.
- NEMAC has formed a partnership with *HabitSeven* to find ways to better synergize products supporting the NCA and Climate Resilience Toolkit.

**PLANNED WORK**

Development work will continue on this project's overarching tasks, with coordination of work on the Climate Resilience Toolkit, Climate.gov, and the NCA under a new CICS cooperative agreement project.

**PUBLICATIONS**


- Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, J. Rennells, A. DeGaetano, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 1. Climate of the Northeast U.S., *NOAA Technical Report NESDIS* 142-1, 79 pp.
- Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, C.E. Konrad II, C.M. Fuhrman, B.D. Keim, M.C. Kruk, A. Billet, H. Needham, M. Schafer, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 2. Climate of the Southeast U.S., *NOAA Technical Report NESDIS* 142-2, 94 pp.
- Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, S.D. Hilberg, M.S. Timlin, L. Stoecker, N.E. Westcott, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 3. Climate of the Midwest U.S., *NOAA Technical Report NESDIS* 142-3, 95 pp.
- Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, M.C. Kruk, D.P. Thomas, M. Shulski, N. Umphlett, K. Hubbard, K. Robbins, L. Romolo, A. Akyuz, T. Pathak, T. Bergantino, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 4. Climate of the U.S. Great Plains, *NOAA Technical Report NESDIS* 142-4, 82 pp.
- Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K.T. Redmond, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 5. Climate of the Southwest U.S., *NOAA Technical Report NESDIS* 142-5, 79 pp.
- Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K.T. Redmond, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 6. Climate of the Northwest U.S., *NOAA Technical Report NESDIS* 142-6, 75 pp.
- Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 9. Climate of the Contiguous United States, *NOAA Technical Report NESDIS 142-9*, 77 pp.
- Liqiang, S.; Kunkel, K.E.; Stevens, L.E.; Buddenberg, A.; Dobson, J.G.; and Easterling, D.E., 2015. Regional Climate Conditions in CMIP3 and CMIP5 for the United States:

Differences, Similarities and Implications for the U.S. National Climate Assessment. *NOAA Technical Report NESDIS 144*, 109 pp. (forthcoming).

**PRESENTATIONS**

- NEMAC's Greg Dobson and Jim Fox co-organized and co-chaired a 94th AMS Annual Meeting session, "Identifying the Needs and Opportunities of Small and Medium-Sized Communities for Data, Information, and Integrated Tools for Enhanced Decision Support-Part I: Users" in Atlanta, Georgia, in February 2014. A second session, co-organized and co-chaired by Riverside Technology, focused on Providers.
- Dobson, J.G. and J.F. Fox. *Providing Meaningful and Actionable Decision Tools to Local and Regional Stakeholders across the Southeastern U.S.* The 94th American Meteorological Society's Annual Meeting, 9th Symposium on Policy and Socioeconomic Research. February 2nd-6th, 2014, Atlanta, Georgia.
- Fox, J.F. and J.G. Dobson. *Framing the Climate Issue for Small and Medium-Sized Communities across the Southeastern U.S.* The 94th American Meteorological Society's Annual Meeting, 9th Symposium on Policy and Socioeconomic Research. February 2nd- 6th, 2014, Atlanta, Georgia.
- Fox, J.F. and J.G. Dobson. *Framing the Climate Issue for Small and Medium-Sized Communities across the Southeastern U.S.* The 94th American Meteorological Society's Annual Meeting, 9th Symposium on Policy and Socioeconomic Research. February 2nd- 6th, 2014, Atlanta, Georgia.
- Kunkel, K.E, L.E. Stevens, and J.G. Dobson. *Uncertainties in Model Simulations of the Regional U.S. Climate* (Poster). The International Conference on Regional Climate – CORDEX 2103. November 4th- 7th, 2013, Brussels, Belgium.
- Dobson, J.G. and M.F. Squires, *Local Applications of the Regional Snowfall Indices and GIS Snowstorm Database* (Poster). The 71st Annual Eastern Snow Conference. June 3rd-5th, 2014, Boone, North Carolina.
- Jim Fox made a presentation to the Southeast Natural Resource Leaders Group (SENRLG) on December 9th, 2014 in Atlanta, GA, integrating local information with NCA findings.

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 7 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 1 |
| # of peer reviewed papers | 7 |
| # of invited presentations | 5 |
| # of undergraduate students mentored during the year | 3 |

**PERFORMANCE METRICS EXPLANATION**

The following products and projects have been improved or developed during this year: a) CMIP5 mapped products; b) CMIP3 mapped products; c) CMIP5 CLIMDEX products; d) research of PostGIS options for GIS Viewer; e) interactive graphics for the NCA report website; f) re-designed graphics for Indicators pilot project; and g) the Climate Extremes portal. The Climate Extremes portal has transitioned from research and development phase to operational phase.

| **National Climate Assessment Technical Support Unit Graphical Services** | |
|---|---|
| **Task Leader** | Jessicca Griffin |
| **Task Code** | |
| **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**: CICS staff provided editorial, graphics, and production support for the National Climate Assessment, making significant contributions to the release of the NCA in May 2014.

**BACKGROUND**

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

**ACCOMPLISHMENTS**

Graphic design support services were provided for the development of the National Climate Assessment report. Tasks included basic image editing as well as more extensive editing and new creations to improve readability and ensure accuracy. Production services included preparing graphics for various pre-release drafts, as well as the final PDFs and printed materials released to the public in May 2014. With tight deadlines and short turnaround times, delivery of that report also required successful integration of the functions of multiple staff members within the TSU and effective coordination between the TSU staff and the USGCRP office in Washington, D.C. The final report was delivered on May 6, 2014.

July 2014 - Awarded NOAA’s National Climatic Data Center Special Service Award for providing excellent support of the development of the White House-released 3rd National Climate Assessment.

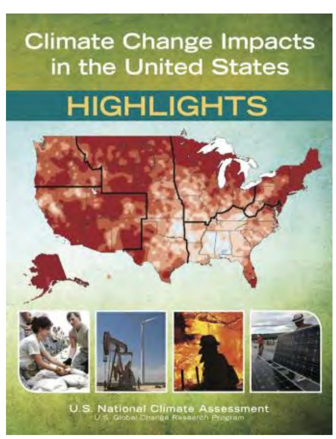



*Figure 3. Highlights of the 3rd National Climate Assessment released on May 6, 2014.*

**PLANNED WORK**

- 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.
- Explaining Extreme Events (Summer 2015)
- BAMS State of the Climate (Fall 2015)
- Health Assessment Report (Spring 2016)

**DELIVERABLES**

- Third NCA Full report PDF
- Third NCA Highlights document, print and PDF formats
- Third NCA Overview document, print and PDF formats
- Third NCA supplemental products
    - Brochure
    - 8 Regional factsheets
    - Media package

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 15 |
| # 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**

This past year, we delivered the Third NCA report and a variety of derivative materials.

| **Web Development for National Climate Assessment** | |
|---|---|
| **Task Leader** | Angel Li |
| **Task Code** | |
| **NOAA Sponsor** | |
| **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**: Designed and implemented a new web site for CICS-NC. Concluded a performance evaluation of the NCA Comment and Review system. Completed web development support for Dataset Discovery Days and the Executive Forum on Business and Climate websites.

**BACKGROUND**

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

**ACCOMPLISHMENTS**

- NCDC newsletter modeled after the CICS-NC newsletter
- Load testing of Review and Comment System for NCA
- Optimization of Review and Comment System
- Working on the 3$^{rd}$ National Climate Asssessment: Setting up development servers, styling and design of the NCA3 website, inputing content, re-formatting images, hosting server configuration and management
- Support for the National Climate Assessment meeting web site
- Maintained and edited CICS-NC website
- Produced HTML newsletter for CICS-NC

**PLANNED WORK**

- Re-design the NCICS/CICS-NC web site
- Continued support of the NCA website(s)
- Continue support of the Metadata Survey
- Continue support of the Metadata Looker
- Continue support of old and new USGCRP web sites
- Contributed to CICS-NC outreach efforts

**DELIVERABLES**

The following products were delivered:

- NCA website
- NCDC newsletter

- CICS-NC newsletter
- NCA data portal on CICS-NC website

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 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 | 0 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

| | |
|---|---|
| **National Climate Assessment Editorial Services** | |
| **Task Leader** | Tom Maycock |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 editorial, production, and project management support for the NCA, contributing to multiple drafts and the final approved document. Facilitated delivery to layout and website production and contributed to the development of the shorter *"Highlights"* summary of the NCA and several other derivative products. Reviewed and edited final PDF, web, and print content resulting in the delivery of the assessment on May 6, 2014. Providing ongoing support, including updating errata.

**BACKGROUND**

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the ongoing National Climate Assessment 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**

**NCA Full Report:** Editorial Services provided editorial, production, and project management support for the development of several drafts of the full version of the NCA, as well as the final version of the report, which was approved in March 2014 and released in May 2014. Tom Maycock worked closely with authors, the TSU editorial and graphics teams, and United States Global Change Research Program (USGCRP) coordinating staff to develop and refine changes made in response to the initial public/National Research Council (NRC) review, a subsequent agency/NRC review, and a final government review. The editorial focus was on ensuring that the document would be readable for a general audience while maintaining the strictest standards for scientific accuracy. In addition to editorial work, Tom Maycock helped coordinate and conduct webinars/teleconferences with lead authors and provided technical production and project management support to the the TSU group. Through March and April, the editorial team provided final Word documents to the graphics and web teams for production, and then reviewed and edited draft PDF layouts as well as the web version of the report. This work culminated in the successful release of the Third National Climate Assessment on May 6, 2014.

**NCA Highlights:** Tom Maycock worked closely with fellow members of editorial team and the graphics team to select content from the 1,200+ page full report for inclusion in the 150-page *"Highlights"* version. Editors worked with authors to refine content selections and language and provided “traceability” information, allowing reviews to ensure that Highlights content was entirely derivative from the full report. TSU also worked to update the *“Highlights”* drafts as needed as final edits were made to full report and as a result of the final government review process. The editorial staff reviewed and provided edits during the production process for the PDF, print, and web versions of the *“Highlights”* document, as well as several other products derived from *“Highlights”*, leading up to the release of the NCA on May 6, 2014.

**NCA References Database:** A significant portion of time was devoted to curating the EndNote database of more than 3,600 references used in the NCA. Tom Maycock worked to identify and correct errors and improve consistency throughout the year. A major task was re-linking all references for all chapters in the NCA. NCA editorial staff also developed a solution for linking and maintaining references for the derivative *Highlights* document. Tom Maycock also assisted TSU/CICS-NC software engineer with the task of connecting the EndNote database to the Global Change Information System (GCIS) data server.

**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.

Tom Maycock contributed to revisions to two figures in the National Climate Assessment and Development Advisory Committee (NCADAC) special report “Preparing the Nation for Change: Building a Sustained National Climate Assessment” and provided editorial support for the development of two-page summaries of the nine-part “Regional Climate Trends and Scenarios” report (NOAA Technical Report NESDIS 142). The summaries are available at: http://scenarios.globalchange.gov/.

**PLANNED WORK**

- Continuing to manage identification and correction of errata as needed
- Contribute to development of additional web content, including web versions of the two climate science appendices, which are currently only available in PDF form.

**DELIVERABLES**

The following products were delivered:

- Full NCA report PDF
- NCA Highlights document, in print and PDF formats
- NCA Overview document, in print and PDF formats
- NCA website
- Updates to references and corrections of minor errata

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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**

Primary work was editorial and coordination efforts to produce the NCA3 report.

| **National Climate Assessment Science Support: Analysis of Observational and Modeled Climate Data** | |
|---|---|
| **Task Leader** | Laura Stevens |
| **Task Code** | |
| **NOAA Sponsor** | David Easterling |
| **NOAA Office** | |
| **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 several observational and model datasets has been performed, and 23 figures produced for the Third National Climate Assessment report, along with the compilation of associated metadata.

**BACKGROUND**

Primary science and technical support is being provided to NOAA and the NOAA Technical Support Unit (TSU) of the National Climate Assessment (NCA). This includes the processing and analysis of observational and modeled climate data, production of graphics for the latest NCA report, and research on Assessment-relevant topics.

**ACCOMPLISHMENTS**

Analyses of several observational and model data sets were carried out in order to produce figures for the Third National Climate Assessment (NCA3). A total of 23 figures were produced for the NCA3 report in collaboration with Dr. Kenneth Kunkel (lead senior scientist), Andrew Buddenberg (software engineer), and Jessicca Griffin (graphic designer).

Three datasets were used for analysis of the historical climate: Global Historical Climate Network – Monthly (GHCN-M), Global Historical Climate Network – Daily (GHCN-D), and Climate Division Database version 2 (CDDv2). These data were used to create time series and bar graphs in order to analyze regional trends in temperature and precipitation, including metrics of extremes (e.g. days with very heavy precipitation). All figures were updated to include the years 2012 and 2013. An example is given in Figure 1.

The primary model data used were the 1/8 degree-CONUS Daily Downscaled Climate Projections. Several figures were updated to use this new statistically downscaled data set, derived from CMIP3 projections (see "National Climate Assessment Scientific Support Activities"). These figures show future climate simulations, based on two emissions scenarios, for multiple temperature and precipitation-based metrics, such as the length of the frost-free season, and the number of consecutive dry days. Such climate projections are of interest to a wide-range of communities and decision makers, and are included in several sectoral chapters of the NCA3 report (e.g., Agriculture, Energy Supply and Use, Rural Communities), as well as several regional chapters. An example is given in Figure 2.

Alongside the creation of figures for the NCA3 report, associated metadata for these and additional graphics produced by the TSU were compiled and input to the NCA web system.

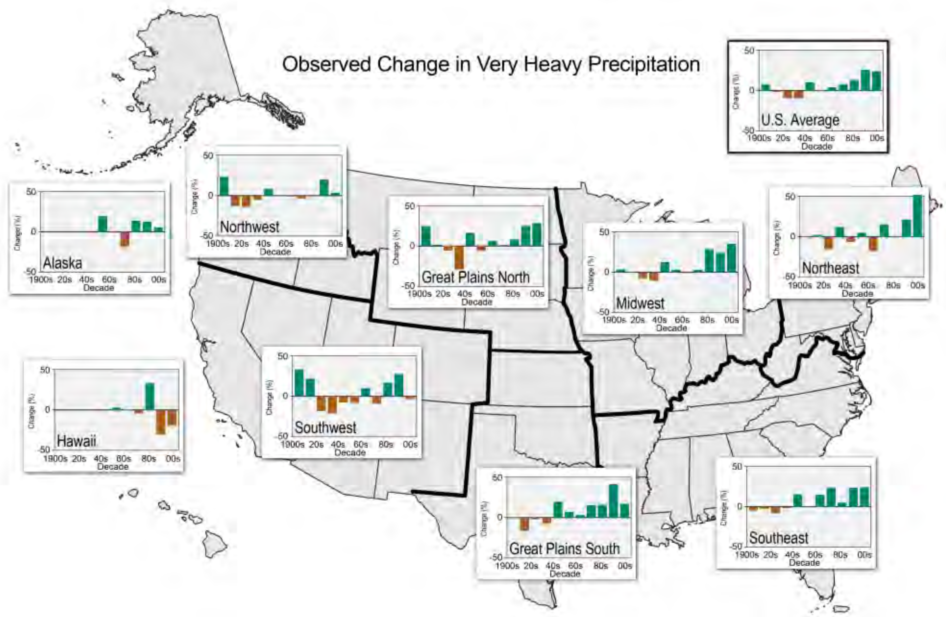



*Figure 1: Percent changes in the annual amount of precipitation falling in very heavy events, defined as the heaviest 1% of all daily events from 1901 to 2012 for each region. The far right bar is for 2001-2012. In recent decades there have been increases nationally, with the largest increases in the Northeast, Great Plains, Midwest, and Southeast. Changes are compared to the 1901-1960 average for all regions except Alaska and Hawai'i, which are relative to the 1951-1980 average.*

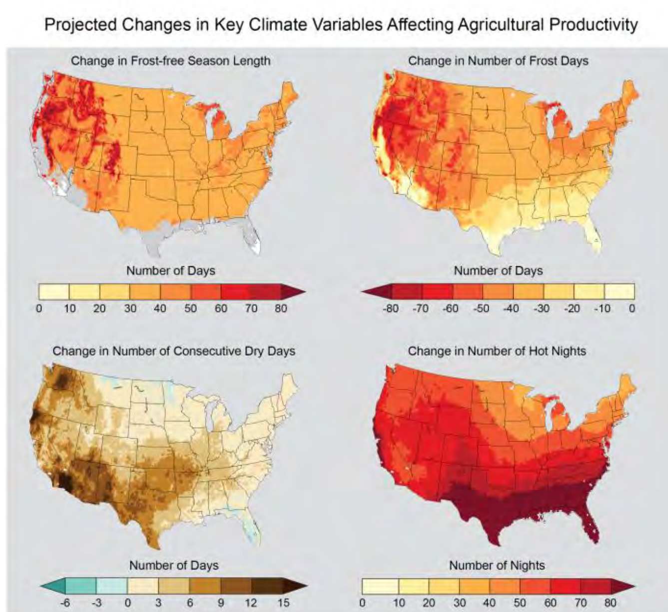



*Figure 2. Many climate variables affect agriculture. The maps above show projected changes in key climate variables affecting agricultural productivity for the end of the century (2070-2099) compared to 1971-2000. On the frost-free map, white areas experienced no freezes*

*during the reference period (1971-2000), and gray areas experienced more than 10 frost-free years during the same period. In the lower left graph, consecutive dry days are defined as days with less than 0.01 inches of precipitation. In the lower right graph, hot nights are defined as nights with a minimum temperature higher than 98% of minimum temperatures between 1971 and 2000.*

In addition to the production of figures, scientific assistance was given to the TSU graphics team in selecting appropriate photographs to aid in illustrating key components of the NCA3 report.

Another task was to produce summaries for the nine-part "Regional Climate Trends and Scenarios" report (NOAA Technical Report NESDIS 142). Information from the full report was synthesized into two-page documents with the assistance of the TSU lead scientist, editorial team, and graphic designer. The summaries are hosted on http://scenarios.globalchange.gov/.

**PLANNED WORK**

- Continuation of metadata compilation for figures in the NCA3 report;
- Data analysis and creation of figures for a supplemental report to the NOAA Technical Report NESDIS 142 series, comparing CMIP3 and CMIP5 temperature and precipitation simulations for the NCA regions;
- Additional data analysis on Assessment-relevant topics, e.g. co-author of a paper assessing temporal changes in the probability distribution of U.S. monthly temperatures.
- Worked to provide data sets for more than two dozen NCA figures online, via the CICS-NC website.

**PUBLICATIONS**


- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: The Northeast U.S.*, NOAA Technical Report NESDIS 142-1 Summary, 2 pp.
- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: The Southeast U.S.*, NOAA Technical Report NESDIS 142-2 Summary, 2 pp.
- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: The Midwest U.S.*, NOAA Technical Report NESDIS 142-3 Summary, 2 pp.
- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: The U.S. Great Plains*, NOAA Technical Report NESDIS 142-4 Summary, 2 pp.
- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: The Southwest U.S.*, NOAA Technical Report NESDIS 142-5 Summary, 2 pp.
- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: The Northwest U.S.*, NOAA Technical Report NESDIS 142-6 Summary, 2 pp.
- Stevens, L.E. and B. Stewart (2013), *Regional Climate Trends and Scenarios: Alaska*, NOAA Technical Report NESDIS 142-7 Summary, 2 pp.
- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: Hawai'i and Pacific Islands*, NOAA Technical Report NESDIS 142-8 Summary, 2 pp.

- Stevens, L.E. (2013), *Regional Climate Trends and Scenarios: Contiguous United States*, NOAA Technical Report NESDIS 142-9 Summary, 2 pp.

**DELIVERABLES**

- Scientific support for the entire NCA report, resulting in the production of the NCA website, PDF versions of the full report, PDF and print versions of the "Highlights" version of the report, and print and PDF versions of the "Overview" of the report as well as several other derivative products
- New and updated graphics for the NCA3 report
- Compilation and logging of metadata for many NCA3 graphics
- Selection of photographs for the NCA3 report
- Two-page summaries produced for the NOAA Technical Report NESDIS 142 series

**PRESENTATIONS**

- Stevens, L.E., 2014: Climate Change Impacts in the United States, French Broad Mensa Meeting, Asheville, NC (13 September).
- Stevens, L.E, 2014: Climate Change Impacts in the United States, North Carolina Arboretum, Asheville, NC (31 July).
- Stevens, L.E., and R. Taylor, 2014: Climate Change Impacts in the United States, NOAA's National Climatic Data Center (presentation for the Black Mountain Presbyterian Church Friends of Creation group), Asheville, NC (6 June).
- Stevens, L.E., and K.E. Kunkel, 2014: Climate Change in the Carolinas, Carolinas Climate Resilience Conference, Charlotte, NC (29 April).
- Stevens, L.E., 2014: National Climate Assessment: An Overview, Presentation for the Montreat Presbyterian Earth Care Team at NOAA's National Climatic Data Center, Asheville, NC (21 March).
- Stevens, L.E., 2014: National Climate Assessment Panel Discussion, 94th Annual Meeting of the American Meteorological Society, Atlanta, GA (2 February).
- Stevens, L.E. and A. Buddenberg, 2013: Climate Modeling for the National Climate Assessment, UNC Asheville, Asheville, NC (11 September).
- Seyller, E., K.E. Kunkel, and L.E. Stevens, 2013: Regional Climate Trends and Scenarios for the United States, GreenGov Workshop on Climate Science and Adaptation Planning, Washington, D.C. (2 August).

**OTHER**

- North Carolina State University "Pride of the Wolfpack Award." This award was received as a nominee for the 2013 Awards of Excellence, in recognition of outstanding overall job performance for the North Carolina State University Office of Research and Innovation;
- Participated in "Wave Day," an outreach event at Asheville Middle School;
- Participated in a local radio interview discussing findings from the Third National Climate Assessment report.

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 7 |
| # 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 | 9 |
| # of invited presentations | 8 |
| # of graduate students supported by a CICS task | N/A |
| # of graduate students formally advised | N/A |
| # of undergraduate students mentored during the year | N/A |

**PERFORMANCE METRICS EXPLANATION**

The majority of work was carried out on the Third National Climate Assessment report, as well as finalizing the NOAA Technical Report NESDIS 142 series. Additional research is being conducted on Assessment-relevant topics, including one paper currently in preparation (see "Planned Work" section). Seven NCA-related invited talks were given.

| **Science Editor/Publication Support for the National Climate Assessment Technical Support Unit** | |
|---|---|
| **Task Leader** | Brooke Stewart |
| **Task Code** | NC-NCA-11-NCICS-BS |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **Contribution to CICS Themes (%)** | Theme 1: %; Theme 2: %; Theme 3: 100% |
| **Main CICS Research Topic** | National Climate Assessments |
| **Contribution to NOAA Goals (%)** | Goal 1: 100%; Goal 2: %; Goal 3: %; Goal 4: %; Goal 5: % |

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

**BACKGROUND**

NOAA's Assessment Technical Support Unit (TSU) continues to provide critical input and support to the ongoing National Climate Assessment 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**

Overall leadership and coordination of the Technical Support Unit's (TSU) editorial, graphics, and production efforts for the draft National Climate Assessment (NCA) report resulted in the successful and timely incorporation of input from a variety of sources (staff and management at USGCRP and TSU, authors, scientists, and federal advisory committee members) to finalize production and revisions of more than 300 figures for the assessment report. Source and copyright information was collected for report figures, as well as preliminary information to aid in the collection of metadata.

- Extensive editing was performed to help ensure scientific accuracy and consistency throughout the report. Work with a large team of editors, authors, and staff to respond to comments received from the public, an expert review panel, and government agencies, led to the finalization of full-report chapters. This work required extensive organization, collaboration, and multiple iterations on every change made in each of more than 30 chapters.
- Worked with editors, authors, and federal advisory committee members to revise and produce the NCA Highlights report, a brief document that provides highlights from across the full NCA report.

- Coordinated final production and distribution of full NCA report and Highlights report (along with editors, graphic designers, and USGCRP staff) to ensure timely delivery of both products
- Worked with web team to develop interactive graphics for the NCA website, and edited the final content on the report website.
- Helped develop graphics for "Preparing the Nation for Change: Building a Sustained National Climate Assessment Process", a federal advisory committee report, published in September 2013.
- Assisted with the production of summaries for the nine-part "Regional Climate Trends and Scenarios" report (NOAA Technical Report NESDIS 142). The summaries are hosted on http://scenarios.globalchange.gov/.
- Assisted with development of an algorithm that identifies contiguous high pressure blocking events using the 20th Century Reanalysis data.

**PLANNED WORK**

- Further development of blocking high algorithm
- Develop algorithm to identify blocking high pressure systems that persist for more than 5 days
- Calculate climatologies and various statistics for blocking high pressure systems using 20th Century Reanalysis data
- Re-run same algorithms and create climatologies for blocking high-pressure systems using other reanalysis datasets, such as NCEP/NCAR Reanalysis.
- Publish results of blocking high studies with Senior Scientist Ken Kunkel

**PUBLICATIONS**

- Stevens, L.E. and B. Stewart (2013), Regional Climate Trends and Scenarios: Alaska, NOAA Technical Report NESDIS 142-7 Summary, 2 pp.

**DELIVERABLES**

- Full NCA report PDF
- NCA Highlights document, in print and PDF formats
- NCA Overview document, in print and PDF formats
- NCA website

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 1 |
| # of invited presentations | 0 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**PERFORMANCE METRICS EXPLANATION**

Primary work was editorial leadership and coordination to produce the NCA3 report.

**National Climate Assessment Scientific Support Activities**

| | |
|---|---|
| **Task Leader** | Liqiang Sun |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 Technical Support Unit (TSU) at CICS-NC develops state-of-art scientific products that support the development of the NCA Reports. The primary effort 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**

Scientific analyses of CMIP5 model data are performed on annual, seasonal, monthly, and daily temporal scales, for the scenarios RCP8.5, RCP6.0, RCP4.5, RCP2.6, historical runs, and historical runs with natural forcing only. These analyses are based on 1) all the models and ensembles available, and 2) a common set of models and ensembles. The analyses are used to produce robust and reliable climate information at regional scales for the United States, including, annual, seasonal, and monthly temperature and precipitation for historical and possible future conditions with uncertainty estimate.

The analyses of climate extremes using CLIMDEX data are also carried out to support the NCA activities. The extremes include warm (cold) spell duration, consecutive dry (wet) days, maximum 1 (5) day precipitation, precipitation above 99$^{th}$ percentile, minimum $T_{max}$ and $T_{min}$, and maximum $T_{max}$, growing season length, number of nights above 20$^{o}$C, and number of nights below 0$^{o}$C.

Comparison between CMIP3 and CMIP5 simulations is in process. We assess the ability of two sets of models to simulate the historical climate conditions over the United States, and document their projections for NCA regions.

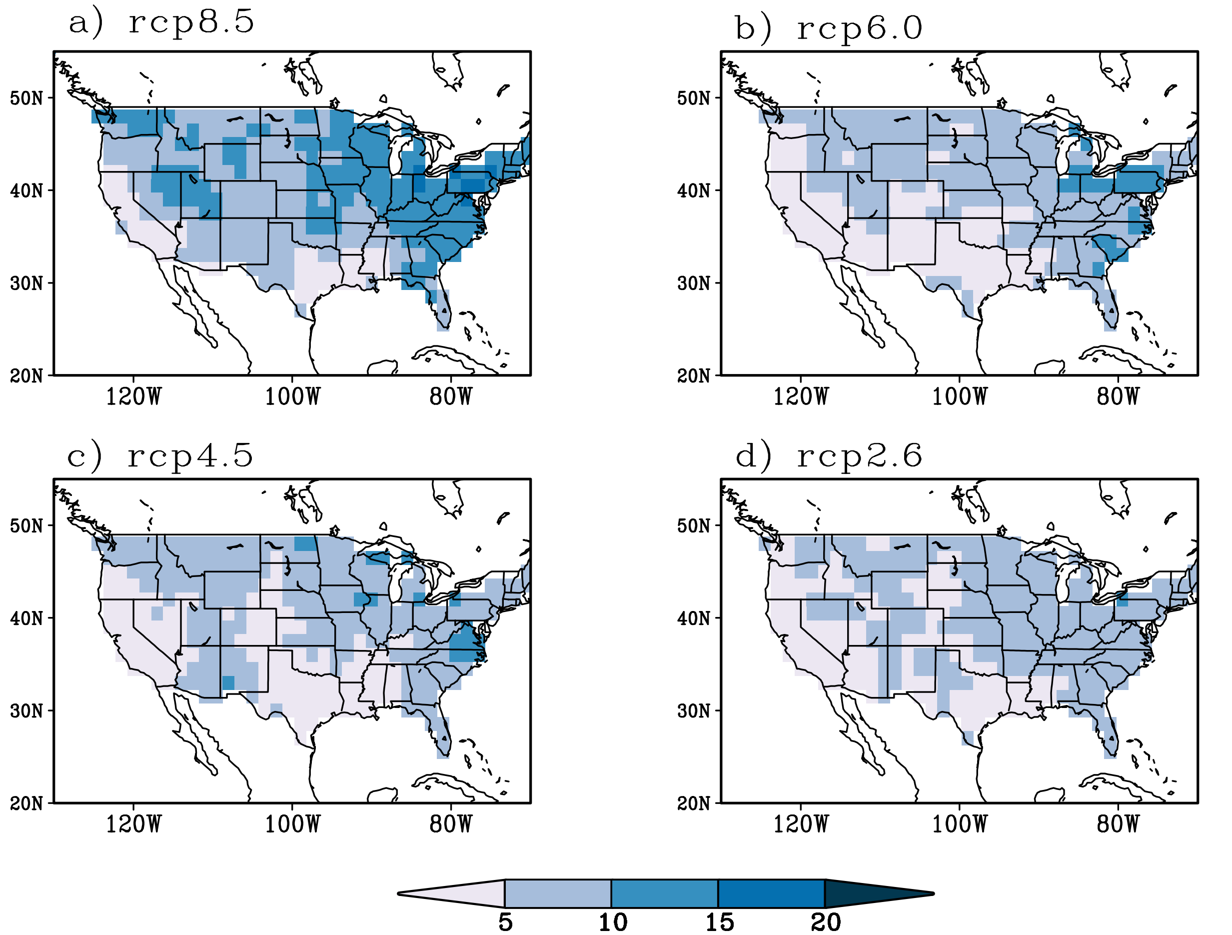



*Figure 1. Simulated difference of maximum consecutive 5-day precipitation (%) for future time period of 2046-2075, with respect to the reference period of 1971-2000. These are CMIP5 multi-model multi-ensemble means for emissions scenarios of RCP8.5, RCP6.0, RCP4.5 and RCP2.6.*

**PLANNED WORK**

- Continue ongoing comparison between CMIP5 and CMIP3 model simulations
- Continue research on mesoscale convection systems in changing climate
- Data analysis to meet the specific needs of the assessment.

**PUBLICATIONS**


- Li, H., M. Kanamitsu, S-Y Hong, K. Yoshimura, D. Cayan, V. Misra, and L. Sun, 2014: Projected climate change scenario over California by a regional ocean-atmosphere Coupled Model system. *Climatic Change*, doi:10.1007/s10584-013-1025-8.
- Wuebbles, D., G. Meehl, K. Hayhoe, T. R. Karl, K. Kunkle, B. Santer, M. Wehner, B. Colle, E. Fischer, R. Fu, A. Goodman, E. Janssen, H. Lee, W. Li, L. Long, S. Olsen, S.

Rauscher, A. Seth, J. Sheffield, L. Sun, 2014: CMIP5 climate model analyses: Climateextremes in the United States. *Bull. Amer. Meteor. Soc*., doi: 10.1175/BAMS-D-12-00172.1
- Dehaan, L., M. Kanamitsu, F. D. Sales, and L. Sun, 2014: Seasonal prediction downscalingover North America using regional models: Added values. *Theor. Appl. Climatol.*, **118**, DOI 10.1007/s00704-014-1278-9.

**DELIVERABLES**
- Comparison of CMIP5 and CMIP3 simulations for NOAA technical report
- Scientific support for the entire NCA report, resulting in the production of the NCA website, PDF versions of the full report, PDF and print versions of the "Highlights" version of the report, and print and PDF versions of the "Overview" of the report as well as several other derivative products
- Submit a regional model paper for publication

**PRESENTATIONS**
- Sun, L. 2014: Seasonal climate prediction: Lessons learned from the past, Seminar at Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing China (17 September 2014)
- Sun, L., 2014: Regional climate modeling: Status and outstanding issues, Seminar at Meteorological Research Institute of Jilin Province, Changchun, China (15 September 2014)
- Sun, L., 2014: Multi-model ensemble seasonal climate forecasts for Northeast Brazil, invited talk via Skype, 16th Semi-Arid Northeast Brazil Climate Outlook Forum, Fortaleza, Brazil (17 January, 2014)
- Sun, L., 2013: climate-crop modeling: a climatological perspective, 4th Annual AgMIP Global Workshop, New York (29 October, 2013)
- Sun, L., 2013: lead panel discussions on "identify, evaluate and develop improved climate-prediction metrics for applications-based use, U.S. CLIVAR 2013 Summit, Annapolis, MD (10 July, 2013)

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 7 |
| # 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 | N/A |
| # 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 regions, using observations, CMIP3 and CMIP5 model simulations, and downscaled data.

# Surface Observing Networks

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

**Background**

The National Climatic Data Center (NCDC) along with NOAA partner institutions leads 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 NCDC in partnership with NOAA's Atmospheric Turbulence and Diffusion Division.

NCDC 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 NCDC 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.

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

| | |
|---|---|
| **Task Leader**: | Jesse E. Bell |
| **Task Code**: | |
| **NOAA Sponsor:** | |
| **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 US. Each station, along with traditional measurements of surface air temperature, precipitation, infrared ground surface temperature, wind speed, and solar radiation, now also transmits relative humidity, soil temperature, and soil moisture measurements every hour. The data is maintained and stored at NOAA's National Climatic Data Center, while installation and maintenance is performed by NOAA's Atmospheric Turbulence and Diffusion Division (ATDD). In order to improve the ability of the network, multiple projects were started to analyze soil moisture variability and change. 1). An analysis of the 2012 drought using soil moisture observations from 2011-2013. 2). Spatial representativeness of USCRN soil observations using a dense temporary network.

**ACCOMPLISHMENTS**

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

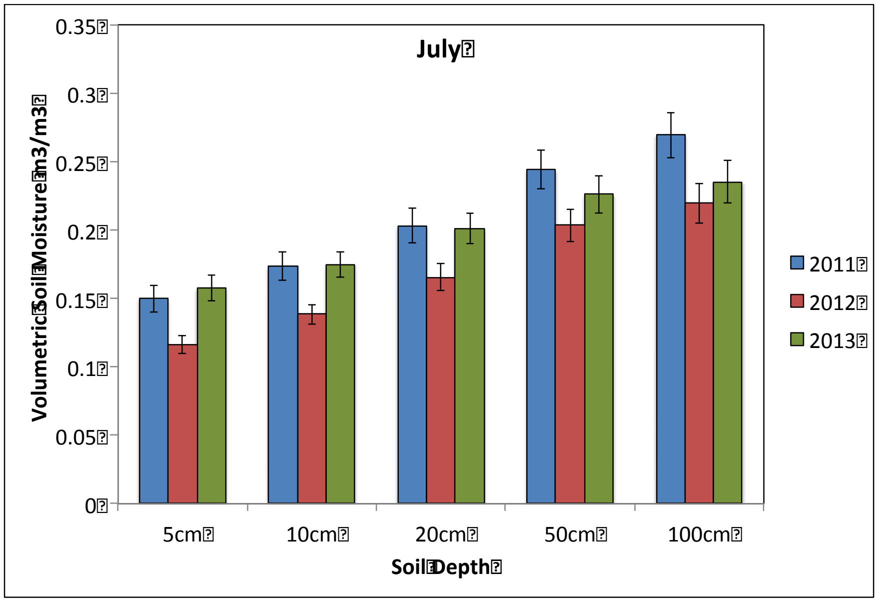



*Figure 1. National soil moisture signal for each soil depth of the USCRN soil observations during July of 2011 -2013. The top three levels experienced recovery from the 2012 drought, but the bottom two levels never fully rebounded.*

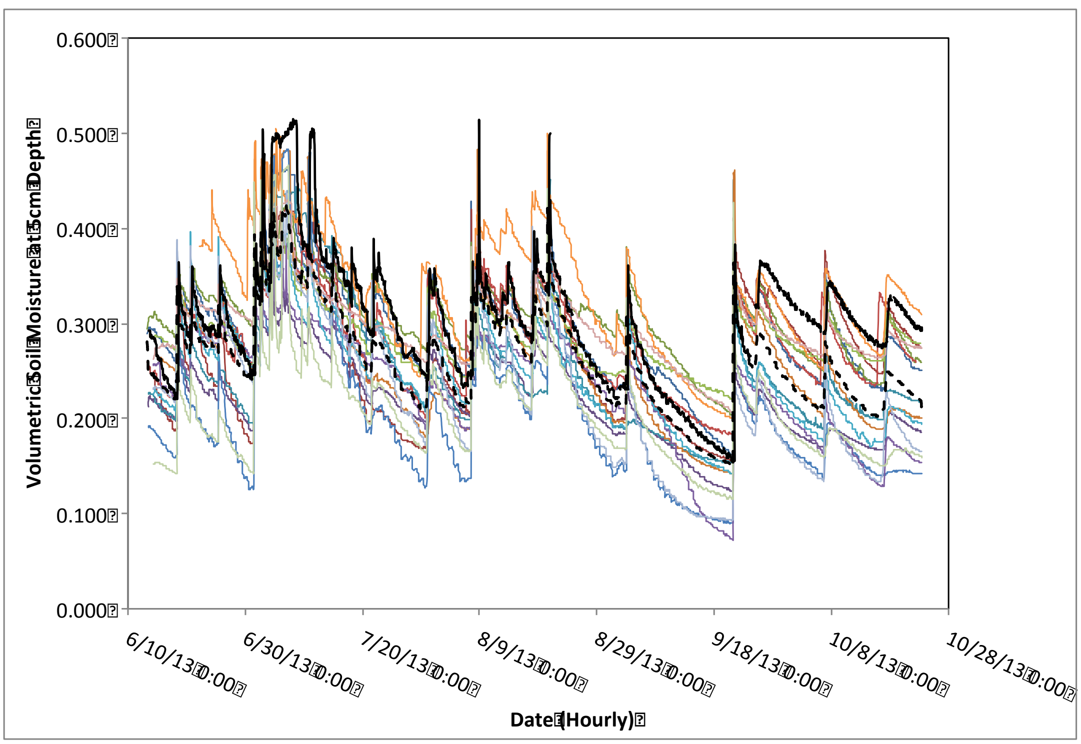



*Figure 2. Results of the spatial representativeness study at Crossville, TN. The solid black line represents the USCRN soil moisture observations and the colored lines represent each station in the temporary network. The dashed black line represents the average of the temporary network.*

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.

Other accomplishments include:

- Quality control analysis of soil observations for improved measurements
- Regular evaluation of exclusion list to remove faulty measurements from the record and coordination with ATDD for maintenance
- Evaluation and streamlining of the quality control methodology
- Continued evaluation of data for quality control purposes
- Two publications dealing with USCRN and soil observations
- Developed collaboration with multiple groups to develop research activities (including USDA-ARS and NASA).
- Spatial representativeness project at Millbrook, NY and Crossville, TN.
- Machine learning algorithm generating a modeled historical soil moisture record
- Assisted in developing a research paper on Air-freezing Index.

**Planned Work**

- Continue to perform soil observation quality assurance.
- Complete manuscript of USCRN observations for drought monitoring.
- Complete analysis and manuscript for soil moisture spatial representativeness.
- Continue to work on additional research manuscripts with USCRN data.
- Continue external collaborations and present work.

**PUBLICATIONS**


- Bilotta R., J.E. Bell, E. Shepherd, & A. Arguez. 2014. Calculation and evaluation of an air-freezing index for the 1981-2010 climate normal period in the coterminous United States. Journal of Applied Meteorology and Climatology. http://dx.doi.org/10.1175/JAMC-D-14-0119.1
- Palecki, M.A., & J.E. Bell. 2013. U. S. Climate Reference Network: soil moisture variability and uncertainty. Vadose Zone Journal. doi:10.2136/v2j2012.0158
- Bell, J.E. M.A. Palecki, C.B. Baker, W. Collins, J.H.Lawrimore, R.D. Leeper, M.E. Hall, J. Kochendorfer, T.P. Meyers, T. Wilson, & H.J. Diamond. 2013. US Climate Reference

Network soil moisture and temperature observations. Journal of Hydrometeorology, 14, 977-988

- Yan, L., Y. Luo, R.A. Sherry, J.E. Bell X. Zhou, & J. Xia. 2013. Rain use efficiency as affected by climate warming and biofuel harvest: results from a 12-year field experiment. GCB Bioenergy. doi: 10.1111/gcbb.12081
- Bell, J.E. & J.L. Matthews. Evaluation of air and soil temperatures for determining the onset of the growing season. Revisions
- Bell, J.E., S. Embler, T. Wilson, & M.A. Palecki. Evaluation of the 2012 drought with a newly established nation-wide soil monitoring network. In review

**PRESENTATIONS**

- Bell, J.E., M. Cosh, and M. Hall. Validating USCRN Soil Observations with a Dense Temporary Soil Monitoring Network. 21st Conference on Applied Climatology, Westminster, CO. June 2014
- Bell, J.E. (Poster Presentation) Evaluation of the change in soil conditions with the newly established national soil network. AMS 94th Annual Meeting, Atlanta, GA. February 2014.
- Bell, J.E., M. Cosh, and M. Hall. (Invited Poster Presentation) Validating USCRN Soil Observations with a Dense Temporary Network. AGU Annual Meeting, San Francisco, CA. December 2013
- Bell, J.E. Preparation of NOAA's USCRN for NASA's SMAP Mission. Pasadena, CA. November 2013.

**OTHER**

- SMAP cal/val effort to understand spatial representativeness of sparse data networks was completed for Crossville, TN and Millbrook, NY. The project brought together USDA, ATDD, CICS-NC, CREST, and NOAA.
- SMAP cal/val Team Member
- Co-supervised Jennifer Meyer (UNC-Asheville Mathematics) for the summer of 2013.
- Manuscript Referee: Ecological Applications, Ecohydrology, International Journal of Remote Sensing, Ecology, Journal of Applied Meteorology and Climatology, Vadose Zone Journal
- Pending Review: Validating the spatial representativeness of in situ soil observations with a dense temporary network. PI: J.E. Bell Co-PIs: M. Cosh, E. Saikawa. NSF Hydrological Science: submitted December 5, 2013

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 3 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

Research Dealing with the Impacts of Climate on Health

| | |
|---|---|
| **Task Leader**: | Jesse E. Bell |
| **Task Code**: | |
| **NOAA Sponsor:** | |
| **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 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 increase in the future. Understanding the potential health risks associated with climate change is important for preparing for the future. The Centers for Disease Control and Prevention (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 US 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.

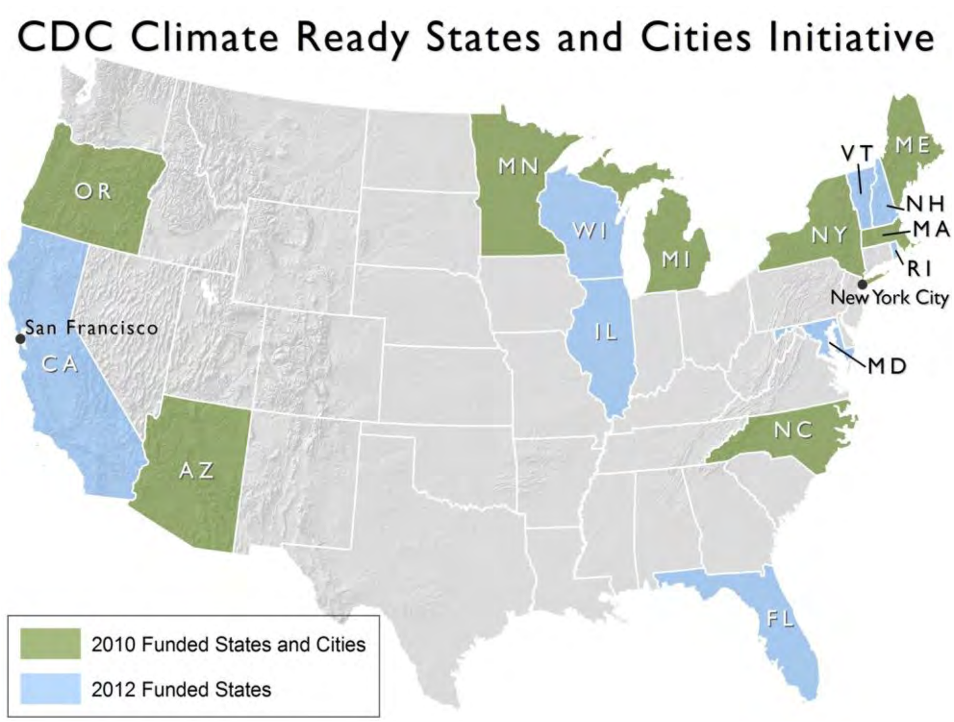



*Figure 1. List of states and cities being funded by CDC's Climate-Ready States and Cities Initiative.*

**ACCOMPLISHMENTS**

In order to develop projects dealing with climate and health, Jesse E. Bell became a Guest Researcher in the Climate and Health Program (located in CDC's National Center for Environmental Health (NCEH)). His role is to serve as a conduit between NOAA's National Climatic Data Center and CDC's NCEH to assist CDC researchers in accessing climate data and better understanding ways of applying these data. Through this interaction, 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 NCA climate change projections and National Integrated Drought Information System (NIDIS) drought data for the National Environmental Health Tracking Network. Dr. Bell was also able to obtain an Adjunct Professor Position in the Rollins School of Public Health at Emory University and has started mentoring Masters of Public Health students that are interested in working on topics dealing with climate and health.

Other accomplishments include:

- Climate Science Position position CDC
- Adjunct Assistant Professor Emory University Rollins School of Public Health
- CDC's Climate and Health Program Science Team Member
- CDC BRACE Team Member: Provide technical guidance to the states and cities in the Climate Ready Initiative
- CDC Drought Response Workgroup Member
- Developed collaboration with CDC Mycotics Group
- Developed collaboration with CDC Waterborne Group
- CDC paid for my travel to two meeting
- Developed multiple research projects with folks for researchers at CDC (traffic accidents, heat waves, valley fever)
- Chapter lead and author of the NCA Interim Report on Climate and Health

**PLANNED WORK**

- Continue collaboration with CDC Climate and Health Program: the Nation's only investment in climate change preparedness for the public health sector.
- Find new partners at CDC
- Lead Author for the NCA Interim Report on Climate and Health
- Continue to work on climate and health research
- Further develop collaboration between NOAA and CDC

**PRESENTATIONS**

- Bell, J.E. Recent coordination between NOAA and CDC for improved access of climate data for public health. Climate Prediction Applications Science Workshop, Fairfax, VA, May 2014.
- Bell, J.E. Climate Data Sources. CDC Annual Grantee Meeting for Climate-Ready States and Cities Initiative, Atlanta, GA May 2014.

**OTHER**

- Panelist for AWMA Annual Meeting section titled: "Building Engagement Efforts to Connect NASA and NOAA's Climate and Environmental Data and Satellite Measurements to Decision-Makers" on June 2014.
- Panelist for Public Forum to Inform the Interagency Special Report on the Impacts of Climate Change on Human Health in the United States on March 2014.
- Co-Mentor for Four MPH Graduate Students at Emory University Rollins School of Public Health
- Pending Review: Development and ingestion of a soil moisture index product for the CDC National Environmental Public Health Tracking Network. PI: J.E. Bell Co-Is: B. Zavodsky, J. Case, W. Crosson, J. Srikishen NASA Earth Science Applications: Health and Air Quality: Submitted April 24, 2014

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 4 |
| # 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- -ORAU |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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**

A new site was installed in Alaska about 70 miles north of Glennallen. The site is near the intersection of the Denali and Richardson Highways (Paxson) at a small landing strip. This station is solar powered, supplemented by a methanol fuel cell during the winter months. This brought the total of Alaska USCRN sites to 13 in 2013. Four of these stations are remotely powered. Improvements to the design of the methanol fuel cell enclosure were made at three of these sites to improve performance during the extreme cold conditions of the Alaska winter. Annual maintenance was performed at all existing Alaska stations.

A design change was made to the precipitation gauge inlet heater at the site at Barrow, AK. This site experiences long periods of extreme cold that caused frost buildup in the gauge inlet. The design change has allowed the inlet to stay frost free in these conditions.

A site survey trip was completed to identify potential sites for future installs. Four locations were selected and work has begun to get site licenses in place. These sites will most likely be installed in FY2015 and beyond. The locations selected are near Fort Yukon, Denali National Park, Yakutat, and Bethel.

Three installations were completed near Deadhorse, Ivotuk, and Nowitna in summer 2014 bringing total Alaska USCRN sites to 16 in 2014. All three of these sites are powered remotely. Deadhorse and Nowitna have solar and methanol fuel systems, like the existing remote powered sites. The site at 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.*

*Figure 2. Maintenance at King Salmon (Katmai National Park) Alaska CRN Site*

**PLANNED WORK**

Installation and maintenance of new and existing Alaska CRN sites will continue under the new CICS cooperative agreement.

**PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 2 |
| # 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 |

**Investigating the Hydrological Iimpacts of Tropical Cyclones over the Carolinas from Observational and Modeling Based Perspectives.**

| | |
|---|---|
| **Task Leader** | Ronald Leeper and Olivier Prat |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | NESDIS/NOAA/NCDC |
| **Contribution to CICS Themes (%)** | Theme 1: 5%; Theme 2: 40%; Theme 3: 55% |
| **Main CICS Research Topic** | Surface Observing Network and Earth System Monitoring from Satellites |
| **Contribution to NOAA Goals (%)** | Goal 1: 60%; Goal 2: 40%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0% |

**Highlight**: Four Tropical cyclones (Floyd 1999, Isabel 2003, Frances 2004, and Irene 2011) that impacted the Carolinas were simulated using the Weather Research and Forecasting model (WRF) for an ensemble of microphysical parameterizations. Modeling results were compared against surface and remotely sensed observations to assess the model's ability to capture such extreme events and their impacts on local communities.

## BACKGROUND

The Carolinas are often frequented by Tropical Cyclones (TCs) that bring intense precipitation and damaging winds. The societal risks TCs pose are not limited to coastal areas (direct hit storms), impacting interior communities following landfall (e.g. Frances 1999 and Isabel 2003). Assessing societal risks of TCs is challenging given the limited nature of observing systems. This is particularly true over the complex terrain that exists in the Western Carolinas (Appalachian). Sharp contrasts in precipitation intensity over short spatial and temporal scales are difficult to resolve with near-ground (radar; beam-blockage and Z-R relationships) and space-based (satellite; timing and resolution constraints) observing systems. Advancements in numerical methods (e.g. higher resolution and domain following) for TCs provide an opportunity to explore these challenges and improve societal risk assessments by bridging observational gaps.

## ACCOMPLISHMENTS

Seven member ensembles for the selected TCs (Floyd 1999, Isabel 2003, Frances 2004, and Irene 2011) were initialized with commonly used microphysical schemes (ETA, Lin, Morrison, Thompson, WSM3, WSM5, and WSM6) for a total of 28 distinct simulations. Model performance was evaluated against IBTrACS TC center (*figure 1*), wind speed and minimum pressure. Overall, model performance was sensitive to the selection of microphysics and storm track. For instance, variance among ensemble member tracks was much lower for Irene 2011 (less curvature over flat coastal plain) than the more complex track (greater curvature over mountainous terrain) of TC Frances 2004.

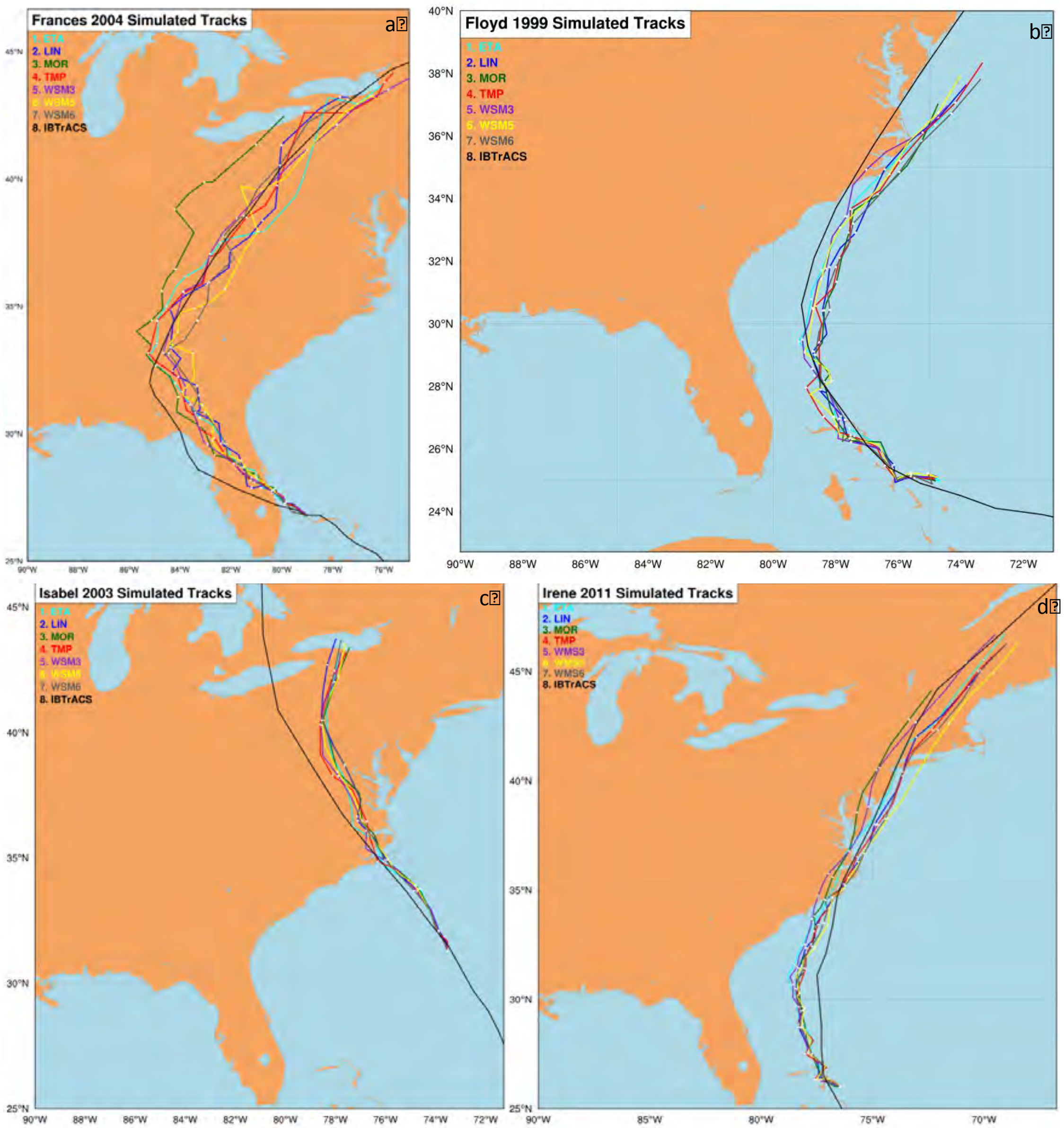



*Figure 1. Observed (black) IBTrACS and ensemble member (light blue) ETA, (blue) LIN, (green) Morrison, (red) Thompson, (purple) WSM3, (yellow) WSM5, and (gray) WSM6 TC tracks for (a) Frances 2004, (b) Floyd 1999, (c) Isabel 2003, and (d) Irene 2011.*

To explore the use of simulated precipitation fields, modeled and satellite precipitation intensity and location of maxima were compared against available surface observations. The WRF model was in good agreement with station observations and in some locations (particularly over complex terrain) outperformed satellite-based measurements (*figure 2*).

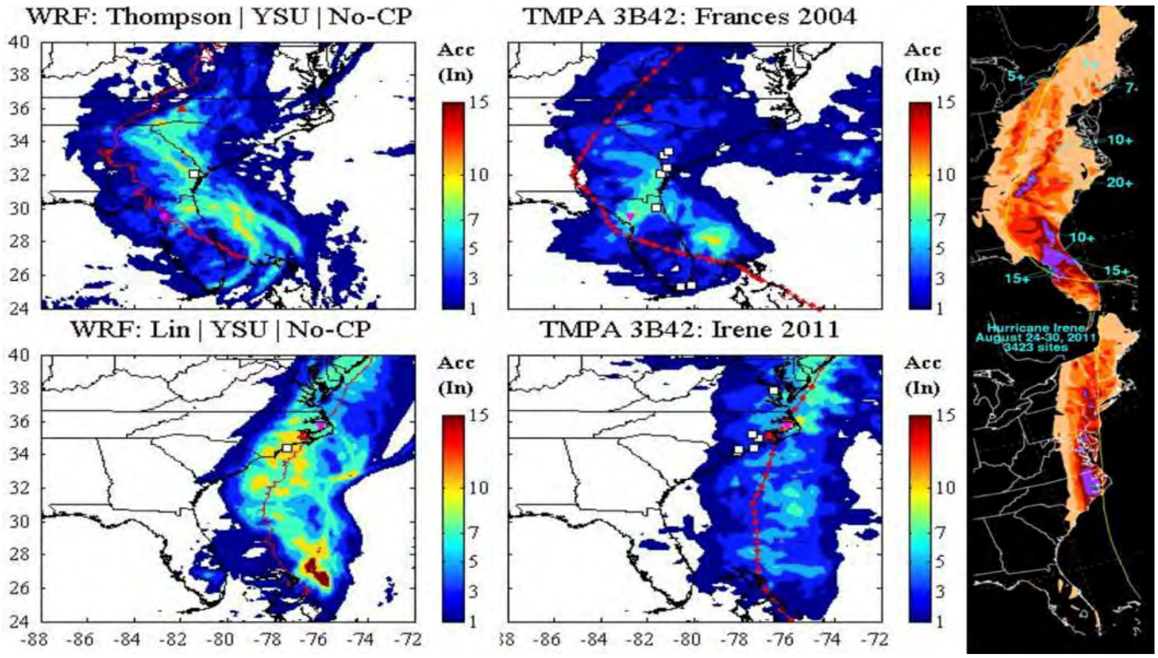



*Figure 2: Modeled (WRF; left), remotely sensed (TMPA 3B42; middle), and station observed (right) rainfall accumulation for hurricane Frances (2004; top) and hurricane Irene (2011; bottom). Locations of the ground based (red triangle), remotely sensed (pink triangle), and modeled (white squares) precipitation maxima.*

**PLANNED WORK**

- Complete model and satellite precipitation comparisons with surface measurements (GHCN-D, CRN). Extend the model/satellite comparison to other datasets (TMPA 3B42RT, CMORPH, CMORPH-Corrected, PERSIANN, PERSIANN-CDR)
- Include radar based estimates of precipitation (Stage IV) for the four TCs

**DELIVERABLES**

- A manuscript describing the challenges and usefulness of numerical methods to investigate TC based hydrological events.

**PRESENTATIONS**

- Leeper, R.D., O.P. Prat, and B.O. Blanton. Evaluating the Sensitivity of the Weather Research and Forecasting (WRF) Model for Tropical Cyclones Impacting the Carolinas. Abstract submitted to the *Carolinas Climate Resilience Conference*. 28-29 April 2014, Charlotte, NC.
- Prat, O.P., R.D. Leeper, and B.O. Blanton. Comparison of Weather Research and Forecasting (WRF) Model-Simulated Tropical Cyclones and Multi-Sensor Precipitation Estimates Over the Carolinas. Abstract submitted to the *Carolinas Climate Resilience Conference*. 28-29 April 2014.

**OTHER**

- This project is conducted in collaboration with Brian O. Blanton (Renaissance Computing Institute) for high performance computing and storm surge modeling.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 |

**PERFORMANCE METRICS EXPLANATION**

The evaluation of the WRF model performance with respect to TC track evolution and precipitation fields will be presented at a conference in Charlotte (April 2014).

**Development and verification of US Climate Reference Network (USCRN) Quality Assurance Methods**

| | |
|---|---|
| **Task Leader** | Ronald Leeper |
| **Task Code** | NC-SON-NCICS-RL |
| **NOAA Sponsor** | |
| **NOAA Office** | NESDIS/NOAA/NCDC |
| **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**: A field campaign was initiated this year with NOAA's Air Resources Laboratory (ARL) precipitation testbed in Marshall, CO. The field study focused on gauge evaporation over the summer of 2013, which showed USCRN gauges were prone to evaporative losses. However, preliminary results indicate that evaporative losses had little impact on total precipitation. In addition, a website was developed to both improve the dissemination of USCRN climate-quality data and serve as a spatial check for manual quality control (QC). A manuscript describing the new precipitation algorithm for the USCRN network was drafted and is currently being reviewed by the USCRN Project Science Manager.

## BACKGROUND

The US Climate Reference Network (USCRN) monitors the US climate from over 124 well representative (obstacle free) locations across the US, 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

The previously developed QA algorithm for precipitation was fined tuned as it was recoded into Java (USCRN production language) and deployed within a testing environment prior to production. From the testing environment, the new precipitation algorithm was evaluated in more detail (precipitation event scales) for a selection of 42 stations. Overall, the new precipitation algorithm reported more precipitation inline with earlier network-wide comparisons across all seasons and months. However, algorithms were more dissimilar over the winter season (*figure 1*). Additional analysis revealed that the auxiliary disdrometer, used as an indicator of wetness, had slower response times to hydrological activity, during windy, snowy conditions. The complete analysis (network-wide and station subset studies) and a description of the algorithm have been submitted for peer-review to the Journal of Amospheric and Oceanic Technology.

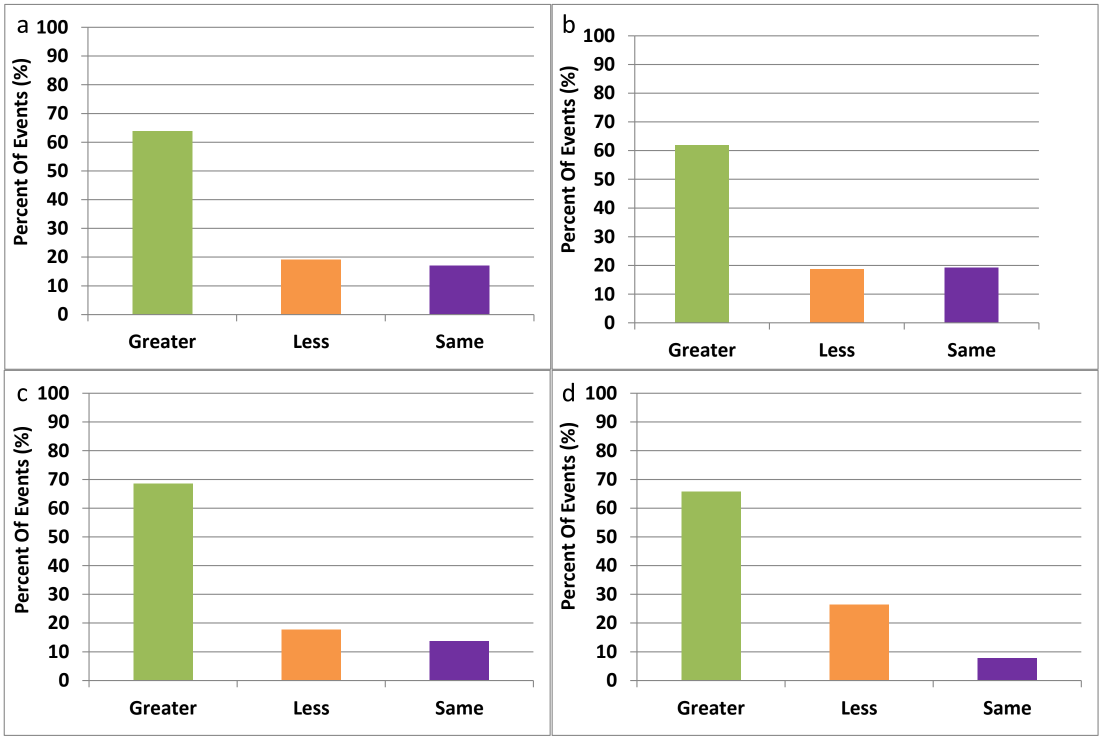



*Figure 1. Percentage of precipitation events wAvgQA had (green) greater, (orange) less, and (purple) the same accumulations as currentQA for (a) all cases, and (b) warm (Avg. temperature > 5 C), (c) near-freezing (Avg. temperature < 5 & > -5 C), and (d) frozen (Avg. temperature <= -5 C) temperature conditions.*

A gauge evaporation field campaign was initiated at NOAA's ARL testbed over the summer of 2013. The purpose of this campaign was to quantify potential evaporative losses from USCRN gauges and determine what impact these losses may have on precipitation measurements. Over the study period (May to October), there were numerous precipitation events that culminated into one of Colorado's wettest years on record, including the record-breaking precipitation event in early September. Results indicate that USCRN precipitation gauges were prone to evaporative losses, likely due to the lack of a gauge funnel, but had little impact on total precipitation (*figure 2*). The minimum impact of gauge evaporation on QA results may have resulted from the above normal precipitation pattern that existed across much of the Eastern half of the US.

In an effort to enhance access to USCRN data, an interactive website was deployed to disseminate USCRN climate-quality data and promote the network's research activities (*figure 3a*). Using geographic information system technology, USCRN data is visually provided in an easy to comprehend content. Beyond disseminating climate data, the website has a dual purpose as a tool for manual QA inspection (spatial consistency check). In addition, a web mapping Application Programming Interface (API) was developed to depict the location of USCRN stations and provide users tools to identify and select stations of interest interactively with embedded links to station data (*figure 3b*).

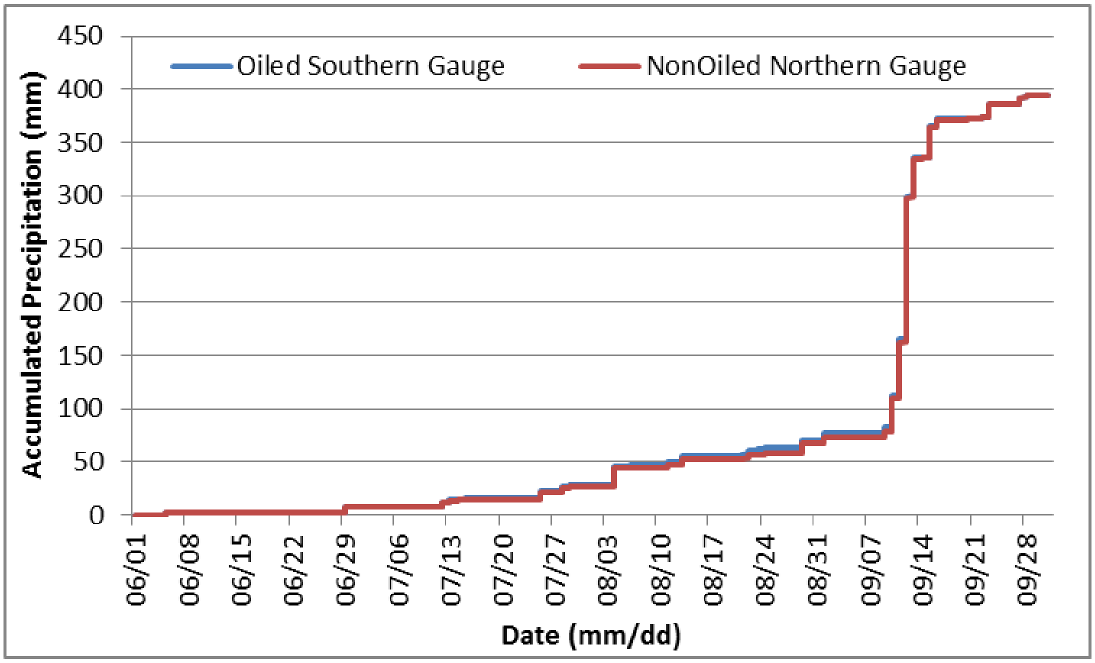



*Figure 2. Accumulated precipitation from the (blue) oiled-southern gauge and (red) non-oiled northern gauge at Marshall, CO ARL Precipitation Testbed from June to October of 2013.*

**PLANNED WORK**

- Revise and submit manuscript describing the precipitation algorithm
- Complete analysis of gauge evaporation field campaign
- Transition data visualization and mapping API to USCRN website

**DELIVERABLES**

- A new QA algorithm to process redundant measures of precipitation.
- A dataset that can be used to evaluate the sensitivity of future precipitation QA methods to gauge evaporation.
- A manuscript documenting the potential evaporative losses from gauges and its impacts on USCRN measures of precipitation
- Enhance methods of communication and user interaction of USCRN climate-quality datasets

**PRESENTATIONS**

- Leeper, R. D. U.S. Climate Reference Network Gauge Evaporation and Impacts on Precipitation Observations. National Climatic Data Center. Asheville, NC. March 2013

**OTHER**

- NOAA's ARL precipitation testbed experiments were conducted in collaboration with John Kochendorfer of the Atmospheric Turbulent Diffusion Division (ATDD)

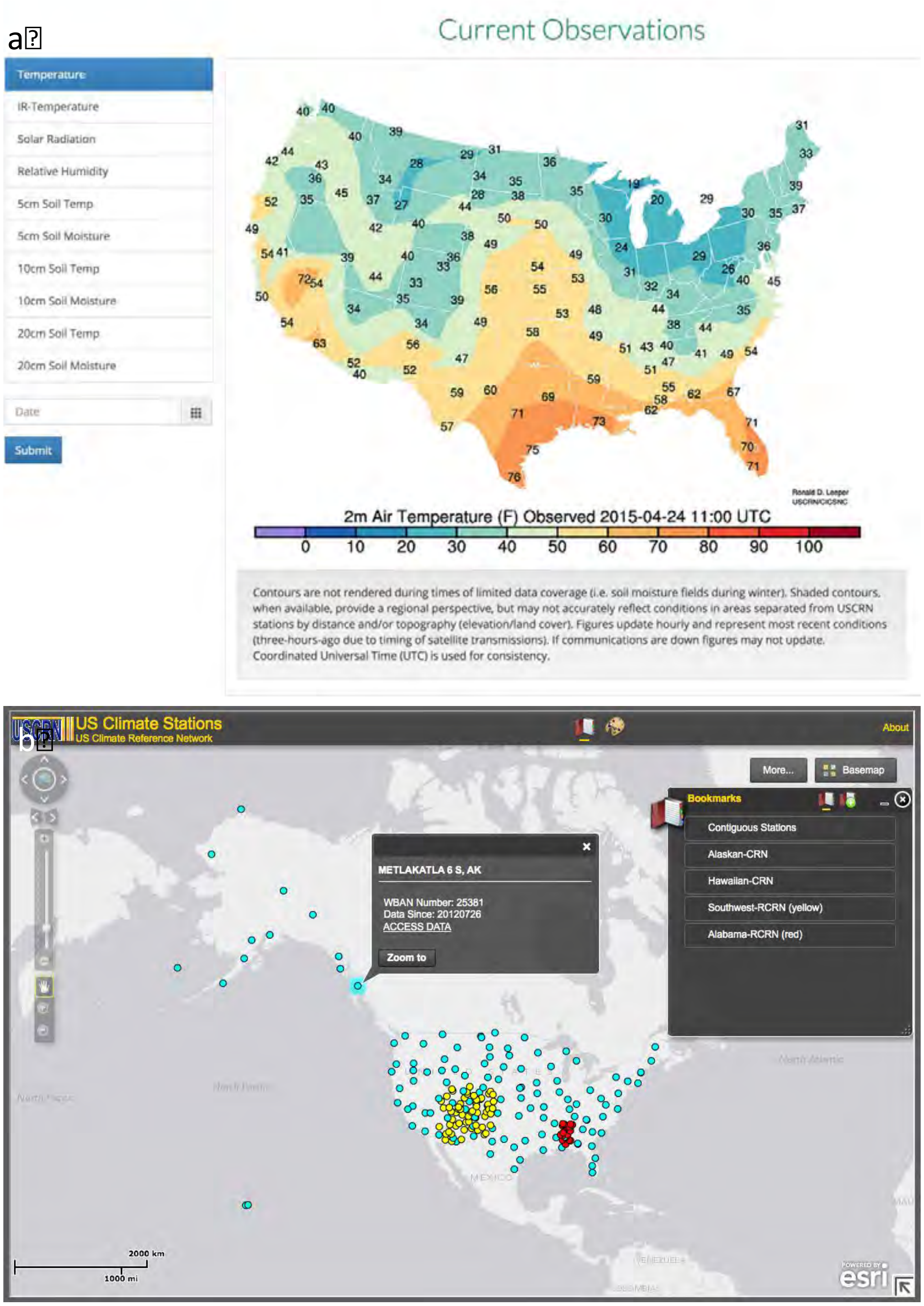



*Figure 3. Snapshots of CRNSpatial (a) main page showing two-meter air temperature from USCRN stations, and (b) web mapping API depicting station popup information.*

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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**

Previously designed QA algorithm for precipitation was slightly modified during recoding. In addition, development of spatial graphics for USCRN climate-quality data and web mapping API were developed within the cooperative institute environment. The sole presentation was given via NCDC's internal seminar series on the role of gauge evaporation on USCRN measures of precipitation.

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

| | |
|---|---|
| **Task Leader** | Ronald Leeper and Jared Rennie |
| **Task Code** | NC-SON-NCICS-RL |
| **NOAA Sponsor** | |
| **NOAA Office** | NESDIS/NOAA/NCDC |
| **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 describing network differences between USCRN and COOP networks was completed and submitted for internal review. Pending reviewer responses to revised manuscript, the document will be submitted for publication in a peer-reviewed journal.

**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 comparisons were reanalyzed to better account for shifts in local observation time as a result of daylight saving adjustments, which had little impact on comparison results. Additional analysis was carried out investigating the synchronization of USCRN and COOP maintenance logs to shifts in network biases, which revealed human observers partially explained some of the inter-station variability in network differences. Regardless of the temperature biases noted in study, anomalous national temperature trends for COOP and USCRN were within 0.1 °C (*figure 1*), indicating the importance of homogenization routines applied to COOP station data. The manuscript describing the network comparison has been submitted for peer-review in the Journal of Amospheric and Oceanic Technology.

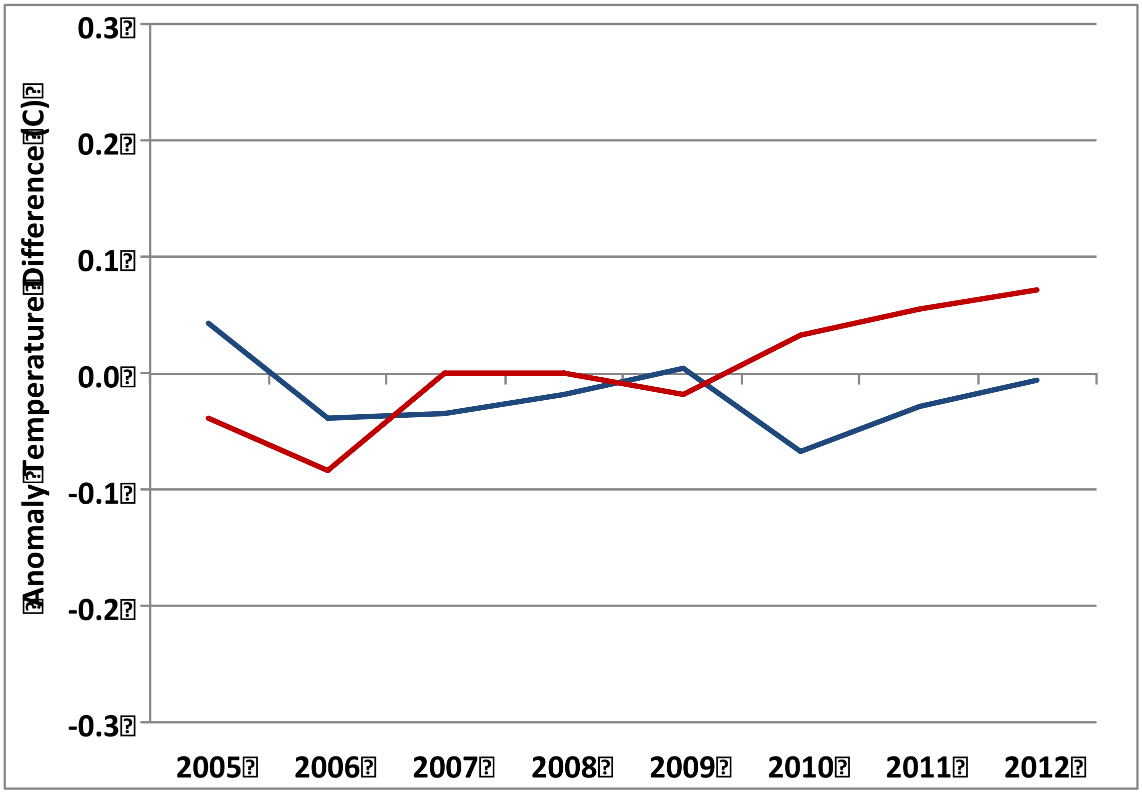



*Figure 1. Annual USCRN and USHCNv2.5 maximum (red) and minimum (blue) anomalous National temperature differences*

**PLANNED WORK**

- Submit manuscript externally for publication

**DELIVERABLES**

- A manuscript describing differences between two networks that will be used in future climate studies.

**PRESENTATIONS**

- Leeper, R. D. First and last day of frost: A USCRN perspective. Cooperative Institute for Climate and Satellites North Carolina (CICS-NC) Workshop. March 2013.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 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 identification and correction of suspicious COOP observations, mainly precipitation, has resulted in an improvement in the COOP daily record. A presentation was given at the Frost and Freeze workshop hosted by CICS-NC to illustrate how data collection routines can alter the timing of the first and last day of frost.

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

| | |
|---|---|
| **Task Leader** | Jared Rennie |
| **Task Code** | NC-SON-07-NCICS-JR |
| **NOAA Sponsor** | Jay Lawrimore |
| **NOAA Office** | NESDIS/NCDC/GCAD/IAB |
| **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 publically available through beta releases and work is underway to transition from research to operations. This product will lay the groundwork for the next iteration of GHCN-M, which will include updates to quality assurance and bias correction.

**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. More can be done to improve practices to ensure full openness, transparency, and availability of data and the details associated with each processing step.

To address these concerns, scientists from both CICS-NC and NCDC established the International Surface Temperature Initiative (ISTI) in 2010. Since its inception, the initiative has worked to create a single, comprehensive global Databank of surface temperature observations in a consistent and traceable manner. The Databank is version controlled, and has data provenance flags appended to every single value, in order to remain open and transparent. There are multiple stages of the Databank, including the original paper record (Stage Zero), keyed data in its native format (Stage One and Two), and a merged dataset with duplicate source data reconciled (Stage Three). All data, along with its underlying code, is available to the public free of charge.

**ACCOMPLISHMENTS**
Multiple sources of data on numerous timescales have been submitted to NCDC and are currently hosted on the Databank FTP site. Currently the Databank comprises of 33 daily and 25 monthly sources, collected and converted to a common format (known as Stage Two). In order to have a more robust record of monthly data, daily sources are converted to monthly averages, following standards set by the World Meteorological Organization (WMO). Out of the 58 total sources, 23 of them have regular updates (i.e. daily, monthly, quarterly, etc.). These sources have been updated to include data up to December 2013.

An algorithm has been in development to merge these Stage Two sources together to create a consolidate dataset of monthly global temperature (known as Stage Three). The algorithm attempts to identify and remove duplicate stations, merge identical stations to produce a longer station record (see Figure 1), add stations considered unique, and withhold records where it is unclear whether to merge the record or create a new unique record. Using a probabilistic approach, the algorithm attempts to mimic the decisions a hand analyst would make, consisting of metadata matching and data equivalence criteria. Using user-defined thresholds, a candidate station works through these tests and its fate is to merge with an existing station, become unique in its own right, or be withheld for future research.

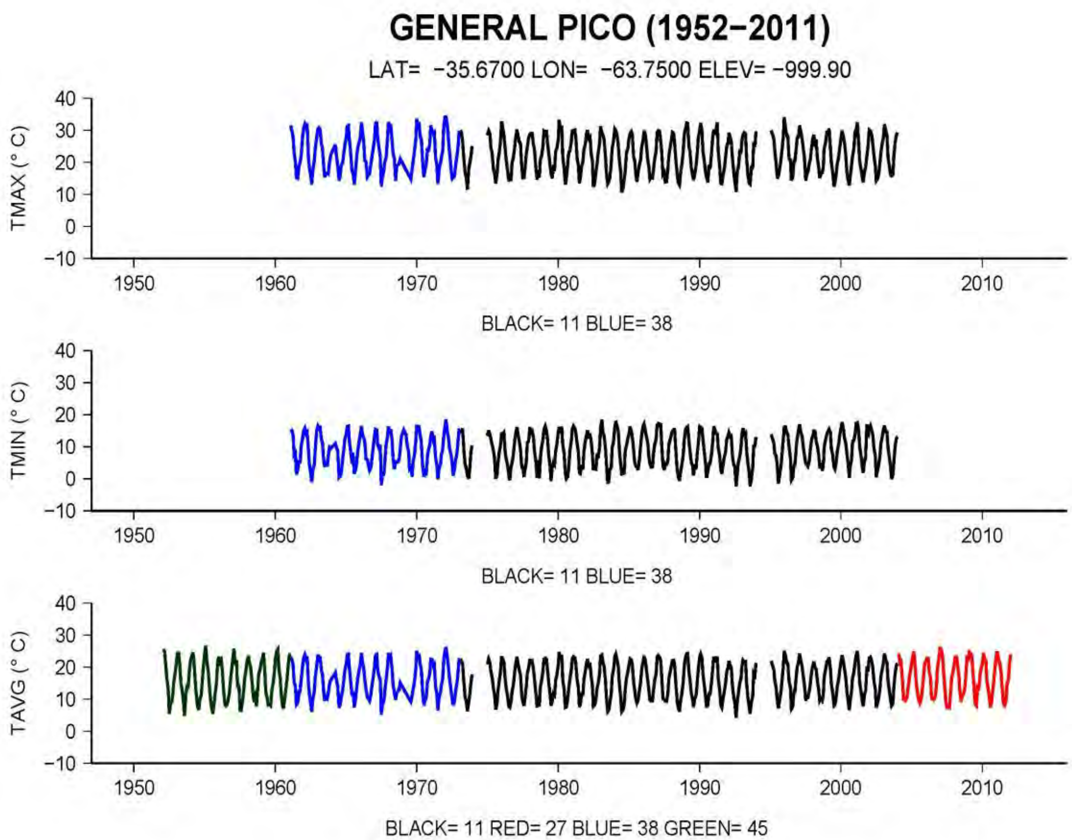



*Figure 1. Station series of TMAX, TMIN, and TAVG for General Pico, Argentina. Four data sources consist of the final merged product (Stage Three) including data from Argentina's*

*National Institute of Agriculture (source 11, black), Monthly Climatic Data for the World (source 27, red), NOAA's National Climatic Data Center (source 38, blue), and UK Met Office's CRUTEM4 (source 45, green).*

Throughout the algorithm development, multiple beta versions of the Stage Three Databank have been released to the public. For every beta, there exists a recommended product, endorsed by ISTI, along with multiple variants in order to characterize the uncertainty of the algorithm. In June of 2013, a fourth beta release was made publicly available. This update included code improvements, a format change to the Stage Three data, and the inclusion of an additional format in netCDF. Having the Databank in netCDF format was a request made from earlier betas, and developed to be compliant with the Climate and Forecast (CF) Metadata Conventions, version 1.6. The current recommended version of the merged product contains over 32,000 stations, over four times as many stations as GHCN-M version 3. A histogram of station count by record length compared to GHCN-M version 3 is shown in Figure 2. There are not only many more stations in the recommended merge, but also more stations with long series (100+ years).

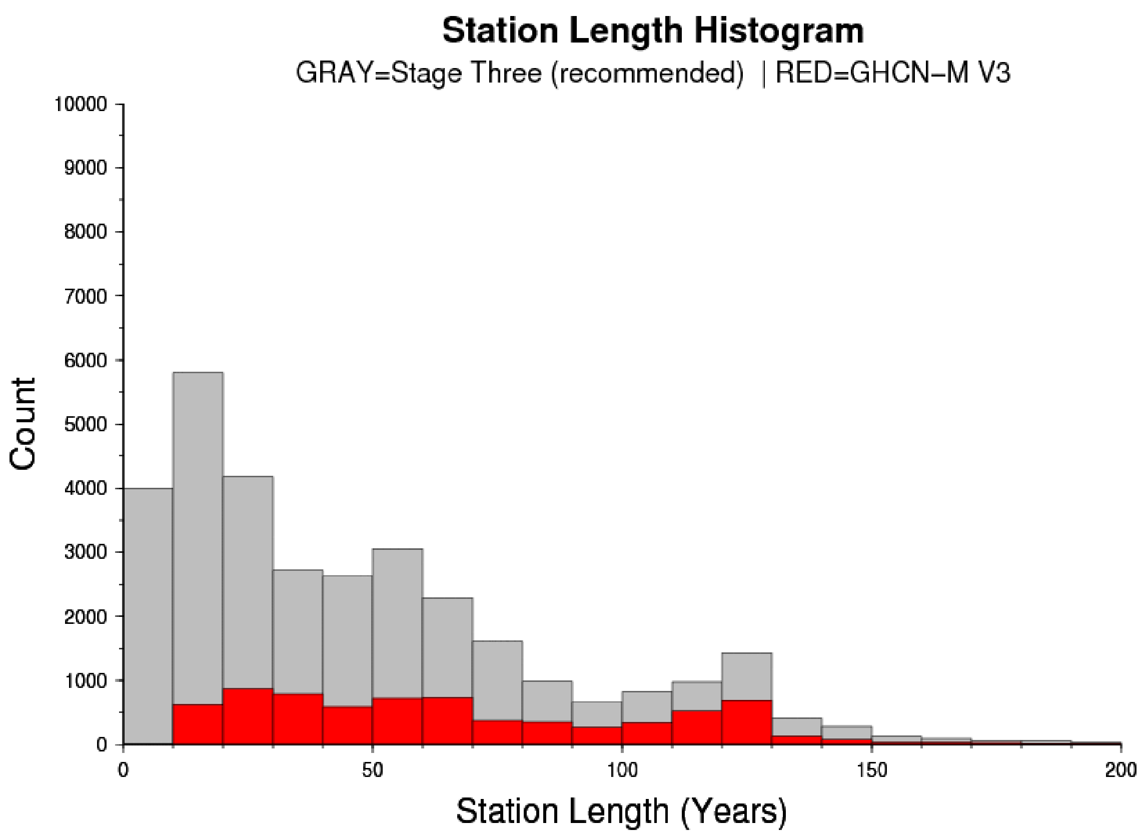



*Figure 2. Histogram of station count by record length for the recommended version of the merge product (gray), compared to the operational version of GHCN-M (red).*

The dataset has been well documented including the development of data flow diagrams describing its entire process (see *Figure 3*). The product underwent an Operational Readiness Review in May 2014, where members of the NCDC Executive Council reviewed and approved the databank for an official release. In addition, a landmark paper describing the methods has been written and submitted to Geoscience Data Journal. The paper has since been accepted, and was published the day the dataset became operational, June 30th, 2014.

The recommended product will serve as the basis for GHCN-M version 4. A development environment has been set up and tests have already been applied to the Databank, including a statistical test for variance. Work is also underway to provide monthly updates, quality control, and bias corrections using NCDC's pairwise homogeneity algorithm. The final output, known currently as alpha 1 (GHCN-M v4.a.1) has been running each night and will be tested against current operational versions (GHCN-M v3.2.2).

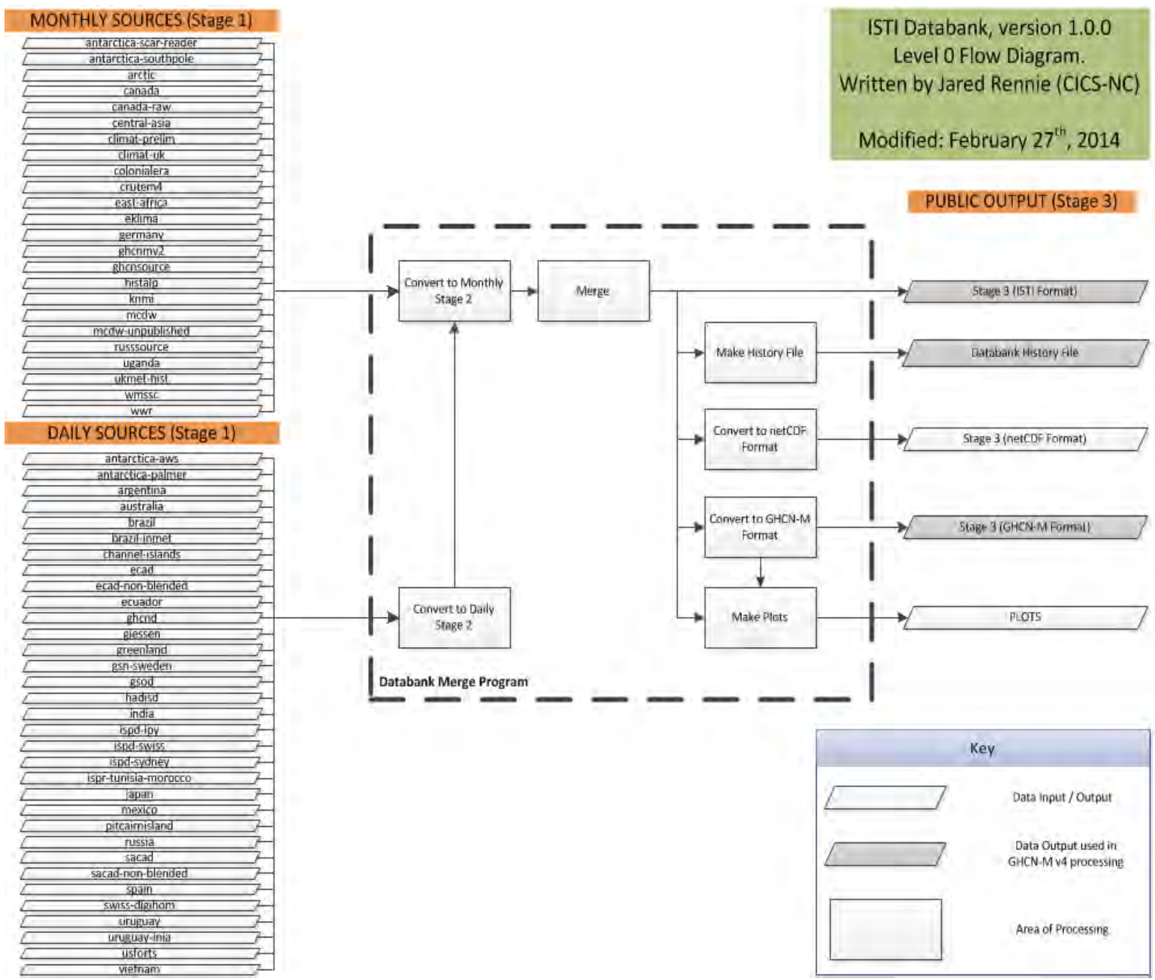



*Figure 3. Level 0 Data Flow Diagram of the entire Databank process for version 1.*

**PLANNED WORK**

- Engage with public on feedback regarding Version 1 of the Databank.
- Provide updates as needed, including addition of monthly data, as well as action items from user suggestions.

- Continue development of GHCN-M Version 4, Alpha 1, including updating quality control and bias correction algorithms used in GHCN-M version 3 to account for an increase in the number of stations.
- Establish end-to-end process for GHCN-M version 4.0.0, including adhering to standards provided by the Capability Maturity Model Integration (CMMI) model.

**PUBLICATIONS**

- Rennie, J.J. and coauthors (2014), The International Surface Temperature Initiative's Global Land Surface Databank: Monthly Temperature Data Version 1 Release Description and methods. *Geoscience Data Journal,* **1,** 75-102, doi:10.1002/gdj3.8.

**DELIVERABLES**

- Fourth beta release of Stage Three Databank.
- Automated algorithm to merge sources together to one consolidated dataset.
- Documentation for merging algorithm and software system.
- Public release of Databank Version 1.
- Alpha versions of GHCN-M version 4.

**PRESENTATIONS**

- Rennie, J.J. (2013) An Open and Transparent Databank of Global Land Surface Temperature, AGU Fall Meeting, San Francisco, CA, 12 Dec 2013

**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**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 2 |
| # 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 | 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 | 1 |

**PERFORMANCE METRICS EXPLANATION**

This year, we have worked on improving our Stage Three Databank Product, and have successfully completed the transition from research to operations (a version 1 release). In addition, we have developed an alpha version of GHCN-M version 4 for internal use. One journal paper has been written, submitted, and accepted by Geoscience Data Journal. A poster, summarizing the Databank, was given at the AGU fall meeting in December 2013. A CICS-NC Intern, Andrew Rodgers, has assisted with Databank activities from March to September of 2013.

# Workforce Development

Workforce development is long-term investment in NOAA's future workforce. NCDC 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 NCDC 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. William hopes to explore his interests in carbon dioxide, emissions scenarios, and ocean acidification
- Kelly Gassert is persuing a second bachelor's degree in Atmospheric Sciences at the University of North Carolina-Asheville. 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 is currently involved in another internship through CICS-NC, where she will be developing a project in support of the next National Climate Assessment. Under the guidance of Dr. Paula Hennon, Scott Stevens, Andrew Buddenberg, and

others, she will analyze radar data, gain knowledge in Python, and continue a more detailed study of climate science.

- Tiffany Maupin is currently a Junior at the University of North Carolina-Asheville. She will be graduating in May 2015 with a major in Weather Forecasting and a minor in Mathematics. As an undergraduate CICS-NC intern, Tiffany is working closely with the Technical Support Unit and the National Climate Assessment and is 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 is an Atmospheric Sciences major from the University of North Carolina-Asheville, with a concentration in Climatology and minor in mathematics. As an undergraduate CICS-NC intern, he is gaining 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. In particular, Mr. Taylor worked with NCA lead science writer Susan Hassol and copy editor Tom Maycock on the NCA3 *Highlights* Document. Moving forward, Mr. Taylor will contribute 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 is participating in an ongoing 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 |
| **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 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**

It was found a decrease in surface temperature anomalies and trends when data gaps from NOAA Temp/MLOST and HadCRUT4 are taking into account. This 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*)

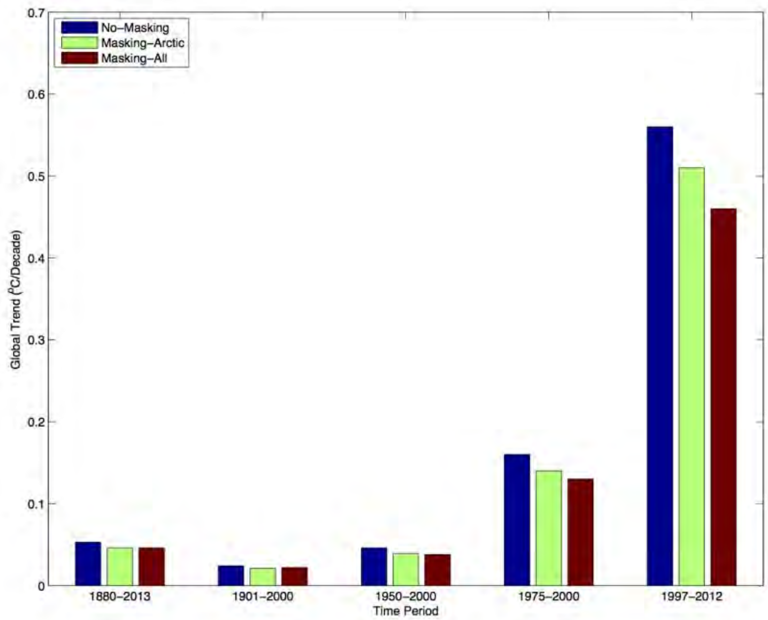



*Figure 1. Surface temperature anomalies trends (° C /Decade) from CM3 model (period 1880-2012) for full coverage (blue), taking into account all gaps (red) and taking into account only Arctic region gaps (green), for different periods of time.*

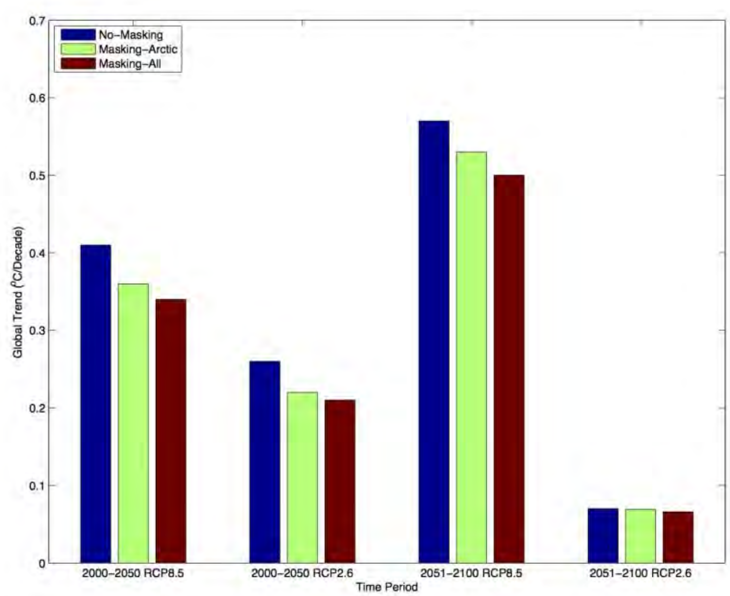



*Figure 2. Surface temperature anomalies trends (° C /Decade) from CM3 model (period 2000-2100) for full coverage (blue), taking into account all gaps (red) and taking into account only Arctic region gaps (green), for different periods of time and RCPs.*

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.

**PLANNED WORK**

- Some small changes in the periods of time (up till 2013 instead of 2000) and few edits are in process in order to submit an article for publication.

**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**

| | |
|---|---|
| # 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 |
| **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 to address 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 pretends 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 the last decades and 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, 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 Antarctic 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, using as a mask the monthly GHCN-M V3 stations network. These monthly inputs are already generated. The number of original stations is reduced due to the grid size of ERA Interim (0.75$^{o}$) (*Figure 2.)*

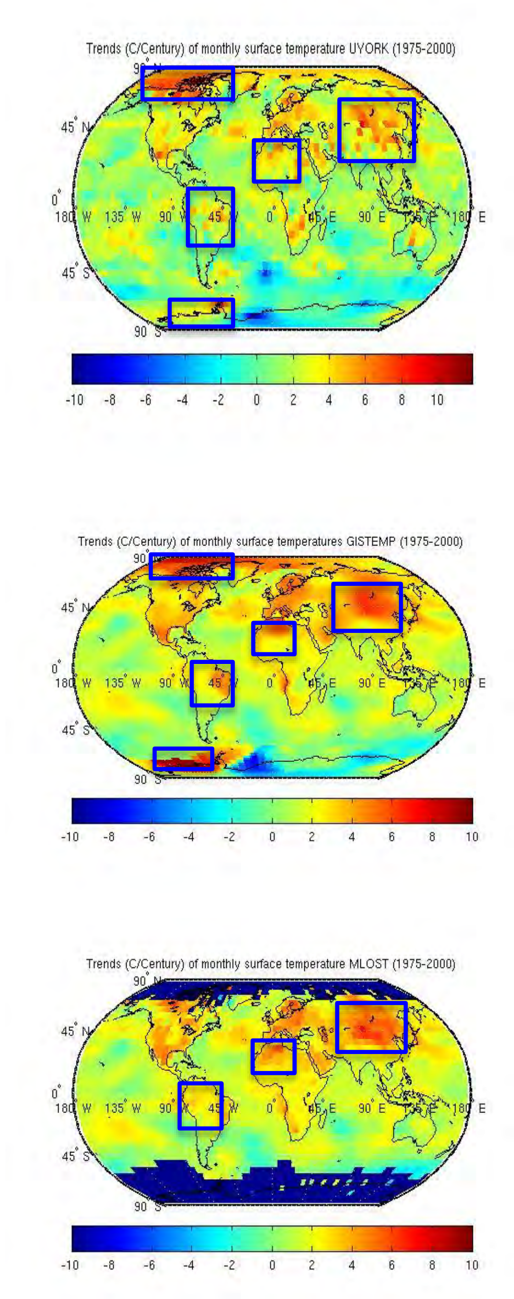



*Figure 1*. Trends ($^{o}$C /Century) of monthly surface temperature from University of York, GISTEMP and NOAATemp/MLOST datasets, for the period 1975-2000. Boxes show differences.

During the last weeks, we've been discussing about the use of CM3 model for the historical analysis. Boying Huang (NOAA/NCEI) is evaluating the use of ERA Interim as an input for NOAA Temp/MLOST evaluation since the method takes into account sea surface temperature and ice in addition of surface temperature observations.

The next step is to apply the different methods using the ERA Interim inputs and then compared the interpolated fields with ERA Interim fields (benchmark) in order to estimate errors.

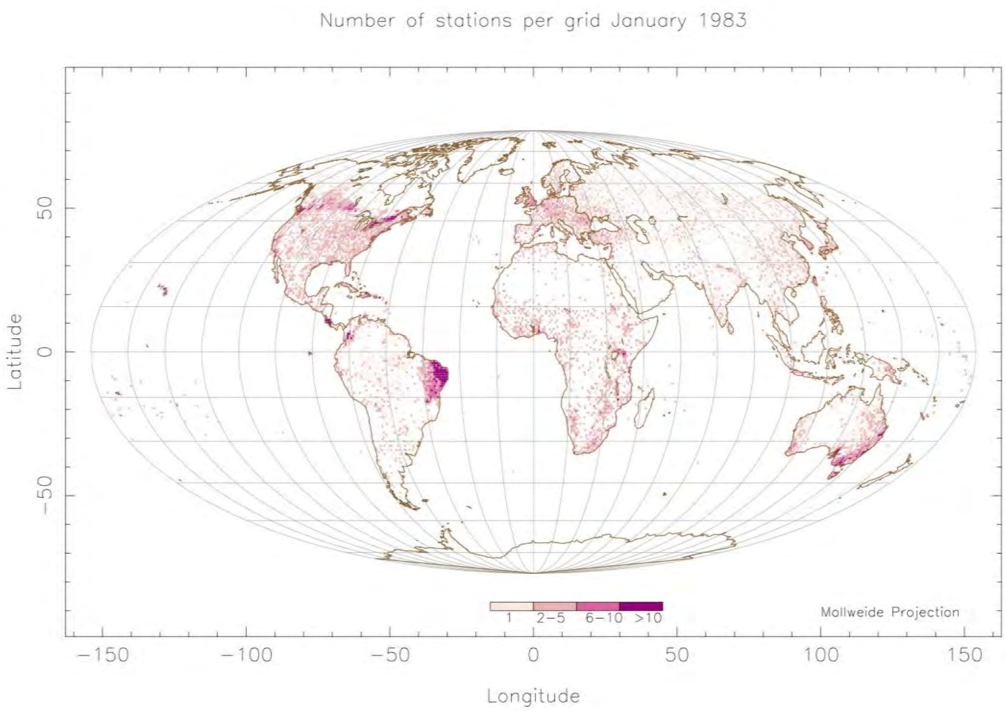



*Figure 2. Number of stations per ERA Interim grid for january 1983. The final number of inputs are 45% of the original number of GHCNV3 stations.*

**PLANNED WORK**

- Apply the interpolation methods using ERA Interim inputs to estimate monthly surface temperatures for the period 1979-2014
- Estimate errors using ERA Interim as a dataset benchmark
- Prepare a journal article based on results

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 about the methods evaluation.

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

| | |
|---|---|
| **Task Leader** | Elsa Nickl |
| **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 into account topography is applied to estimate monthly land surface temperatures for US and compare 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. An adjustable-scale ellipse with different orientations and sizes are used for estimating orographic scales (resolution of topography at which the relationship with precipitation is optimal). This ellipse allows capturing better the topographic patterns associated to precipitation (e.g. 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 to consider 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 correlations values remains moderate and high when analyzing climatologies, specific months, specific days, and lower station densities.

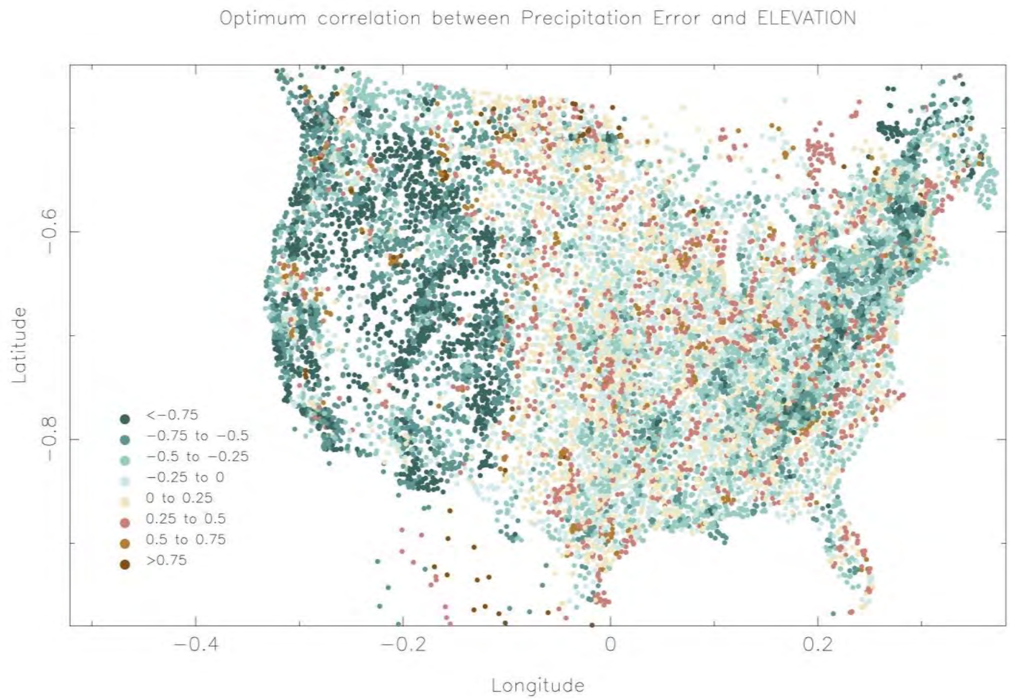
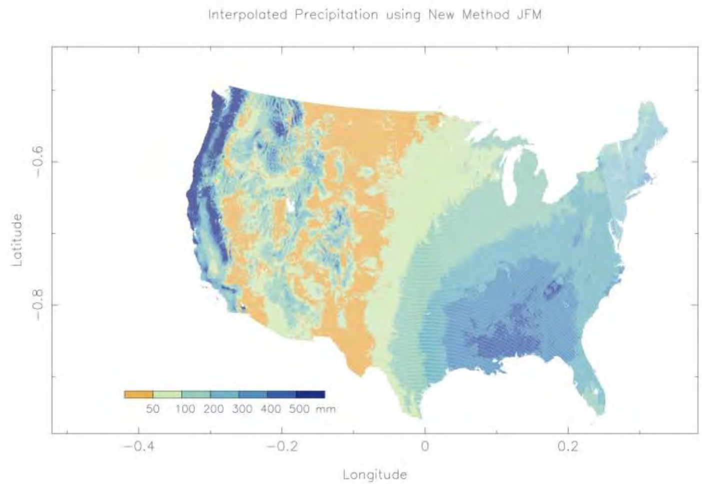



*Figure 1. Optimum correlations (best correlation selected at each point from eight orographic scales) between precipitation errors and elevation.*

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 with NOAA/NCEI maps, with most differences in mountainous regions (Figure 2). When testing for lower stations density (200 stations) and daily (lots of zero value precipitation) there is a problem of sensitivity of parameters when applying the MLR causing extreme low and high values.

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



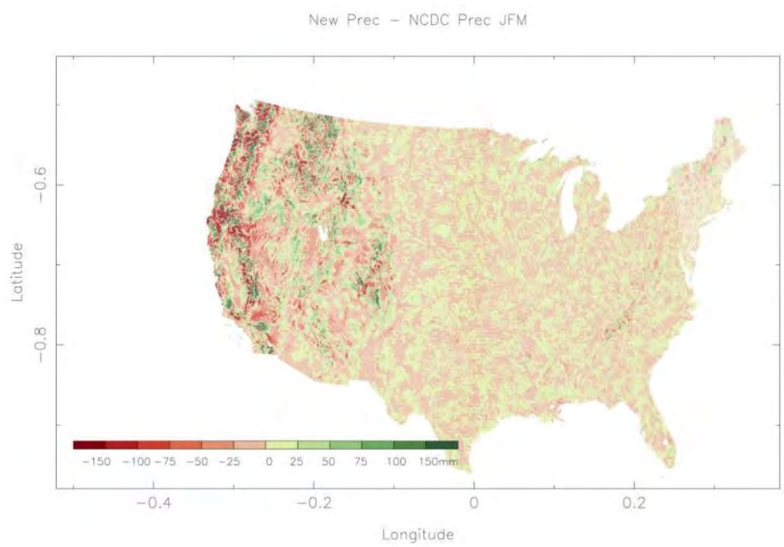




*Figure 2. Estimated precipitation for JFM climatology (1981-2010) using new interpolator and differences between new estimates and NOAA/NCEI*

**PLANNED WORK**

- Finish the cross-validation analysis for climatologies, specific months and days and high/low density station
- Prepare an article about the results found
- Evaluate possibility of writing and article with Olivier Prat (CICS) 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**

| | |
|---|---|
| # 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- -NCICS-SS |
| **NOAA Sponsor** | NESDIS/NCDC |
| **NOAA Office** | |
| **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 NRA). 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 surface temperature observed 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 are metrics 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 and bias schemes etc. 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 U.S. 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 U.S. vs. the eastern U.S. This is most likely due to the heterogeneous topography and land surface types in the western U.S. vs. the more homogenous land surface types and topography in the Easter. U.S. 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.

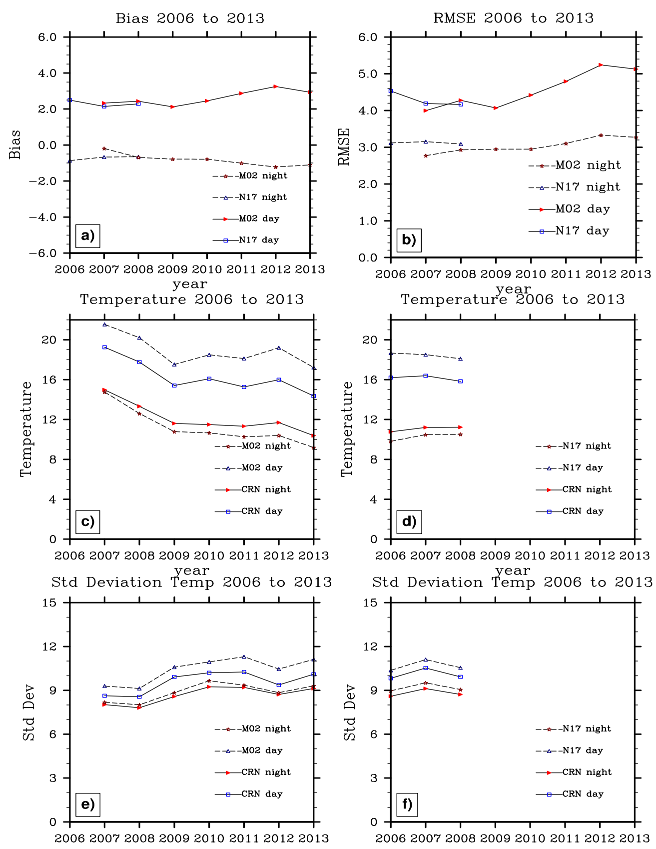



*Figure 1. Annual bias and RMSE (both day and night) of HIRS M02 and N17 satellites surface temperatures. Each year represents the average bias and RMSE of the stations. Bias is*

*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.

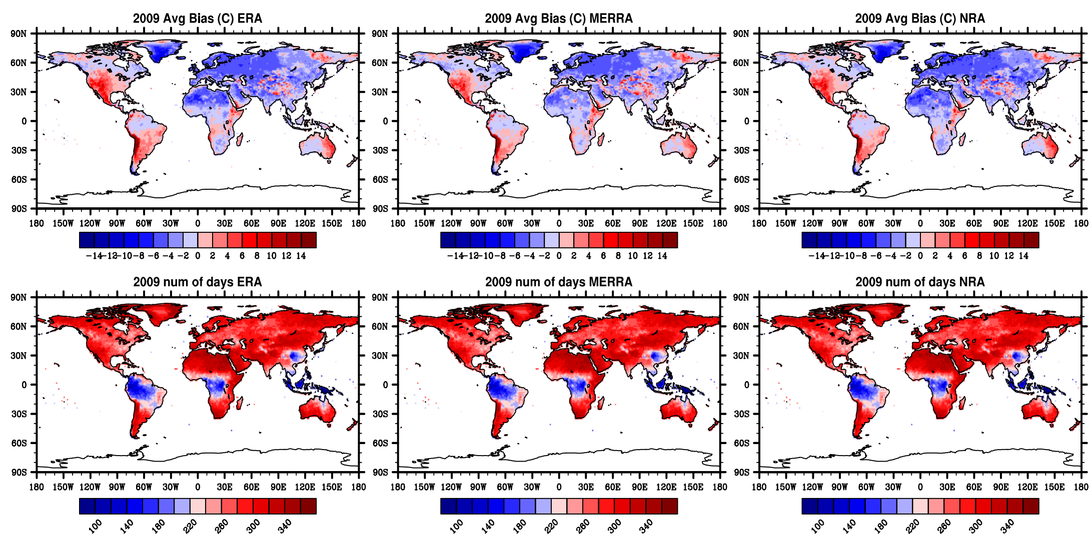



*Figure 2. 2009 average bias of HIRS surface temperatures collocated to ERA-interim, MERRA, and NRA land surface datasets. Included is the number of collocations for 2009 of HIRS surface temperatures to each dataset.*

**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.

**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**

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|---|---|
| # 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 |

# Consortium Projects

The CICS Consortium includes a wide range of research universities, non-profit organizations, and community groups. Its role is to augment the capabilities of CICS and to extend its ability to conduct innovative and original collaborative research with NOAA. The CICS Consortium provides NOAA with an extraordinary opportunity to engage the extra-federal scientific and user communities on research, development, and outreach issues. It is a remarkably broad and flexible mechanism that enables NOAA to benefit from the collective wisdom and capability of its members.

Consortium projects have involved such projects as quantifying the ecological effects of sea level rise in North Carolina, the development and distribution of high-resolution gridded Standardized Precipitation Index (SPI); enhancing the data visualization capabilities of NOAA's Climate Services Portal; and studying the spatio-temporal patterns of precipitation and winds in flood prediction.

**Improving Prediction of Heavy Precipitation Events in the Eastern US**

| | |
|---|---|
| **Task Leader** | Gary Lackmann |
| **Task Code** | NC-CON- - NCSU-GL |
| **NOAA Sponsor** | Allen White |
| **NOAA Office** | NOAA/ESRL/PSD |
| **Contribution to CICS Themes (%)** | Theme 1: 0%; Theme 2: 0%; Theme 3: 100%. |
| **Main CICS Research Topic** | Climate Research, Data Assimilation, and Modeling |
| **Contribution to NOAA Goals (%)** | Goal 1: 0%; Goal 2: 100%; Goal 3: 0%; Goal 4: 0%; Goal 5: 0% |

**Highlight**: We have utilized the NOAA GEFS Reforecast database to develop a model-error climatology for heavy precipitation in the eastern US. Comparison of reanalysis and reforecast data, for event-relative composites stratified by precipitation character and synoptic weather setting, is providing insight in to model error sources during heavy precipitation.

**BACKGROUND**

The goal of this project is to utilize the GEFS Reforecast dataset (Hamill et al. 2004, 2006ab, 2013) in order to develop a quantitative precipitation forecast (QPF) error climatology for heavy eastern US precipitation events. Having a stable model configuration provides a valuable opportunity to identify error sources, ultimately leading to correction or mitigation of the errors. Basic requirements for such an undertaking are (i) computation of a skill metric with which to categorize forecasts based on quality, and (ii) a classification system to allow stratification of the case sample by character of precipitation (e.g., convective versus stratiform) and synoptic pattern (e.g., strongly versus weakly forced). In order to narrow the scope of the project, we have focused our most intensive analysis efforts on highly convective, strongly forced events at 5-day lead-time.

**ACCOMPLISHMENTS**

During the first year, the project group ran Python scripts on the NOAA/ESRL server to compute equitable threat score (ETS) and mean absolute error (MAE) for days 1, 3, and 5 QPF forecasts relative to the NOAA/Climate Prediction Center's Daily U.S. Unified Precipitation Dataset (Chen et al. 2008). An overall summary of the Reforecast performance was the subject of our initial publication based on this award, Baxter et al. (2014).

Working from this forecast error database, a team of undergraduate research assistants worked with graduate student Jennifer Tate, and Drs. Baxter and Lackmann to categorize the events based on synoptic setting, atmospheric stability, forecast lead-time, and intensity of observed precipitation. The resulting classification offers a unique dataset with which to explore the causes of model forecast error.

Next, event-relative composites were generated for a sample of the cases, both for the North American Regional Reanalysis (NARR), and for the Reforecast. This required interpolation of the two datasets to a common grid, and identification of the event centroid for each case. An automated routine was developed for this purpose, to identify the maximum location of a heavily filtered precipitation analysis or forecast.

Comparisons of forecast and observation are underway. The Reforecast tends to locate the zone of heavy precipitation too far to the north and east (*Fig. 1*) relative to observations. Both the observed and Reforecast composites indicate a synoptic pattern featuring a lifting upper-level trough with strong southerly moisture transport from the Gulf of Mexico into the SE US (not shown).

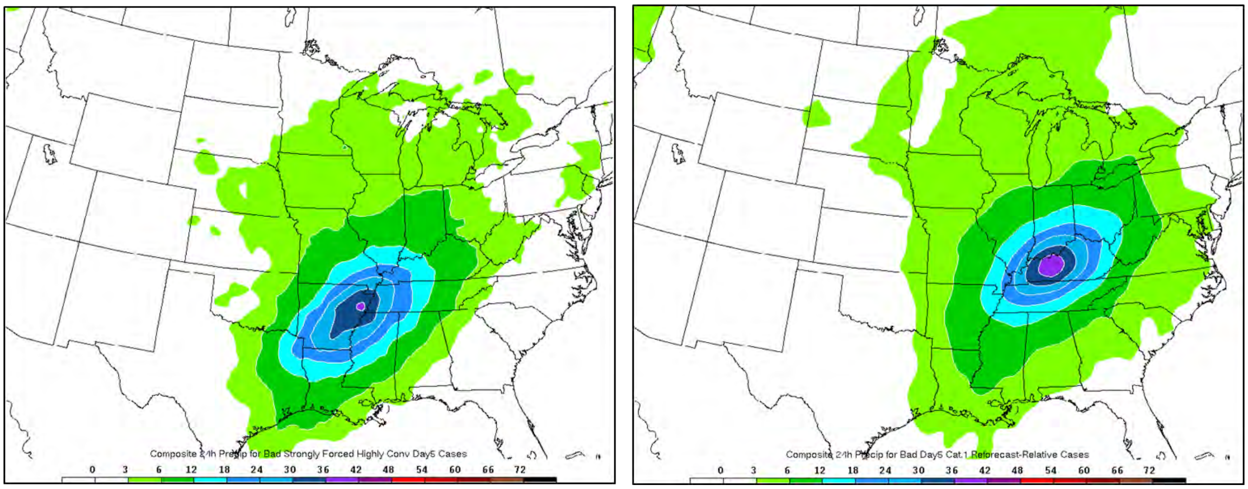


*Figure 1. Comparison of observed (a) and Reforecast (b) 24-h total precipitation for day 5 QPF in strongly forced, highly convective events.*

Further comparison of the strength of moisture transport (*Fig. 2*) and instability (*Fig. 3*), reveal that the lower-tropospheric moisture feed from the Gulf of Mexico was too weak in the model forecast, and in part as a result of this, the amount of instability was too small in these cases. The spatial offset in the precipitation maximum is consistent with this in that a propagating region of organized convection would be less likely in the forecast, and this could possibly explain the northward bias in the Reforecast.

The negative bias in the strength of lower-tropospheric moisture transport could be related to the topographic/radiative potential vorticity generation mechanism documented by Lackmann (2013) for the extreme flooding event in early May 2010.

It is difficult to pinpoint the cause of these model errors using composites, because the dominant error source comprising the composites varies from case-to-case, blurring the error-source signal. Therefore, individual case-study analyses, conducted using support from a different funding source, are currently underway and will be continued beyond the funding period. A code to compute the correlation between any individual event and the composite was utilized to quantify the degree of similarity, enabling us to select representative events for more detailed analysis.

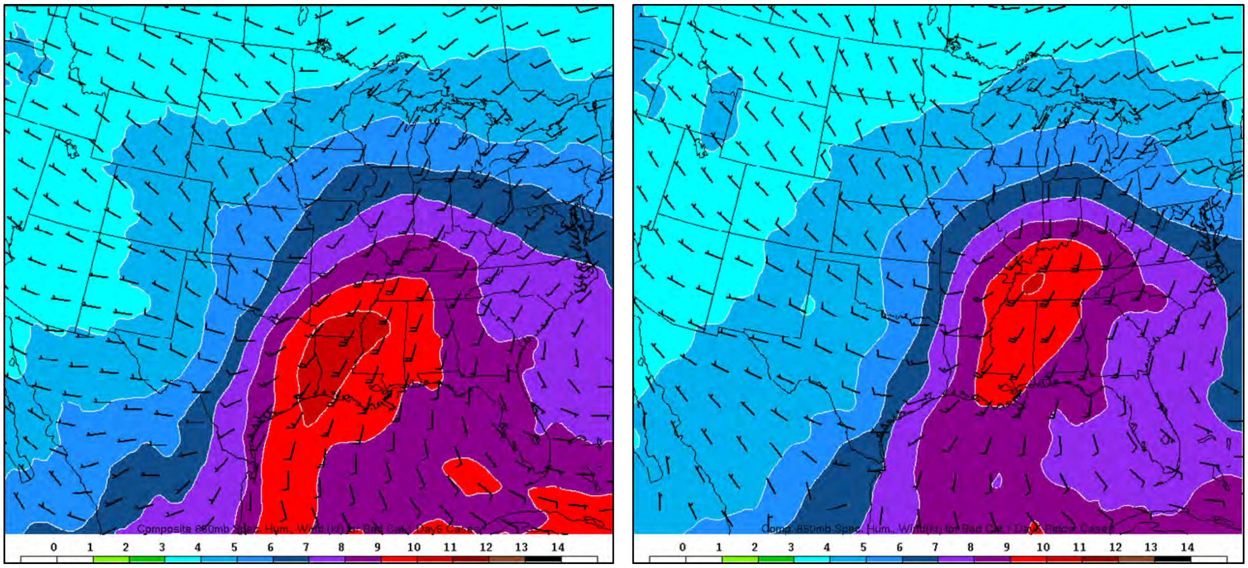


*Figure 2. Comparison of observed (a) and Reforecast (b) 850-hPa wind and specific humidity for day 5 QPF in strongly forced, highly convective events.*

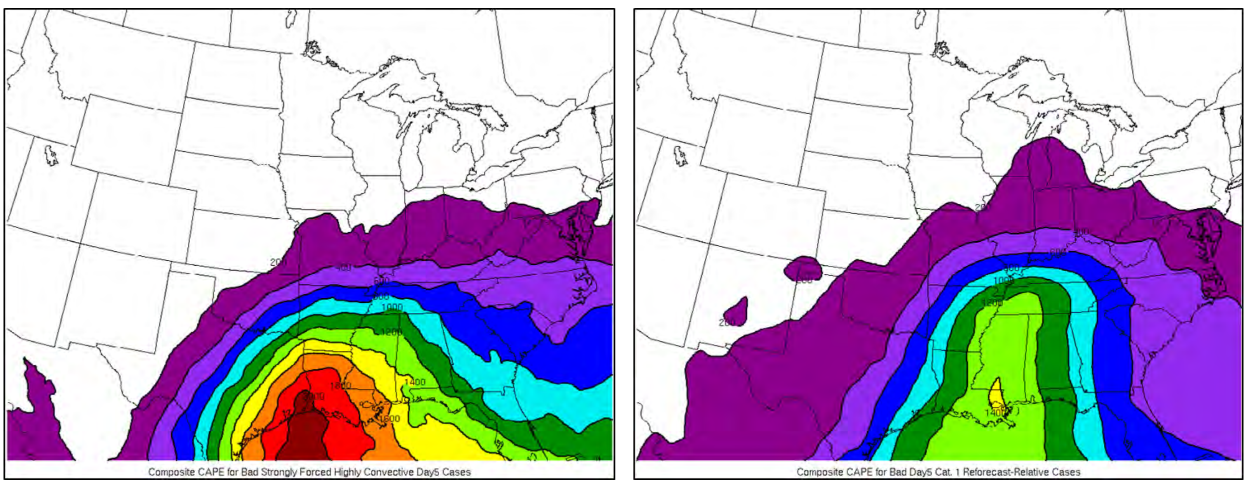


*Figure 3. Comparison of observed (a) and Reforecast (b) surface-based convective available potential energy (CAPE) for day 5 QPF in strongly forced, highly convective events.*

**PLANNED WORK**

- Integrate the event-relative composite results with ongoing case-study simulation results to pinpoint more specifically the sources of moisture transport and instability errors.
- Develop potential-vorticity based composite analyses in order to better link errors in standard meteorological fields to physical processes and atmospheric dynamics.

**PUBLICATIONS**

- Baxter, M. A., G. M. Lackmann, K. M. Mahoney, T. E. Workoff, and T. M. Hamill, 2014: Verification of quantitative precipitation reforecasts over the Southeast United States. *Wea. Forecasting, 1199–1207*.

**DELIVERABLES (completed)**

- Model QPF-error climatology, stratified by amount, synoptic setting, precipitation character, and forecast lead time;
- Event-relative composites of basic meteorological fields to facilitate comparison of Reforecast and reanalysis; and
- A selection of candidate case-study dates that represent specific classes of skill-dropout events for detailed model simulation and analysis.

**PRESENTATIONS**

- Jennifer Tate, 19 September 2014: "Improving Heavy Precipitation Forecasting in the Southeast U.S." NC State Graduate Seminar.
- Baxter, M. A., G. M. Lackmann, J. E. Tate, K. Mahoney, T. E. Workoff, and T. M. Hamill: Predictability of precipitation in the Southeast United States, Part I: Verification and categorization. AMS 27th Conference on Weather Analysis and Forecasting/23rd Conference on Numerical Weather Prediction. 13.A2
- Tate, J. E., M. A. Baxter, and G. M. Lackmann: Predictability of precipitation in the Southeast United States, Part II: Composites and case studies. AMS 27th Conference on Weather Analysis and Forecasting/23rd Conference on Numerical Weather Prediction. 13.A3

**OTHER**

- Graduate student Jennifer Tate participated in the Weather Prediction Center Winter Weather Experiment during January, 2015. She also provided forecasting support for the NASA IPHEX field program during June 2014; this project was QPF-related, affiliated with the NOAA Hydrometeorological Testbed Southeast (HMT-SE).

**REFERENCES**


- Chen, M., W. Shi, P. Xie, V. B. S. Silva, V. E. Kousky, R. W. Higgins, and J. E. Janowiak, 2008: Assessing objective techniques for gauge-based analyses of global daily precipitation. J. Geophys. Res., 113, D04110, doi:10.1029/2007JD009132.
- Hamill, T. M., J. S. Whitaker, and X. Wei, 2004: Ensemble reforecasting: improving medium-range forecast skill using retrospective forecasts. *Mon. Wea. Rev.*, **132,** 1434–1447.
- Hamill, T. M., J. S. Whitaker, and S. L. Mullen, 2006a: Reforecasts: an important dataset for improving weather predictions. *Bull. Amer. Meteor. Soc.*, **87,** 33–46.
- Hamill, T. M., and J. S. Whitaker, 2006b: Probabilistic quantitative precipitation forecasts based on reforecast analogs: theory and application. *Mon. Wea. Rev.*, **134,** 3209–3229.
- Hamill, T. M., and co-authors, 2013: NOAA's second-generation global medium-range ensemble reforecast data set. *Bull. Amer. Meteor. Soc.*, **94,** 1553–1565.
- Lackmann, G. M., 2013: The South-Central US flood of May 2010: Present and future. *J. Climate,* **26**, 4688–4709.

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 2 |
| # 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 | 1 |
| # of graduate students formally advised | 1 |
| # of undergraduate students mentored during the year | 3 |

**PERFORMANCE METRICS EXPLANATION**

The GEFS Reforecast error climatology represents a powerful and unique database with which to identify and diagnose numerical forecast model deficiencies. There was some NOAA guidance in this from Tom Hamill, but it was largely developed independently. The event-relative composites, of forecast and analysis, also represent a unique and highly useful product developed independently.

The Baxter et al. (2014) article is based on this work, though lead author Dr. Baxter had his own source of support during this work.  Graduate student Jennifer Tate was supported by this project, and during the spring of 2014, three undergraduate research assistants worked on the event classifications described above.

**Programming and Applications Development for NOAA's Climate Services Portal (NCSP)**

| | |
|---|---|
| **Task Leader** | Jim Fox |
| **Task Code** | NC-CON- -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 enhancement and launch of the Multigraph website, the development of the Climate Explorer application, and the design and development of the U.S. Climate Resilience Toolkit. 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 Global Climate Dashboard, the new Climate Conditions section, the Data section, and other sections of the Portal. This work addressed NCSP's immediate needs in the following three task areas: a) enhancement of current data visualization capabilities (Multi-Graph, etc); b) enhancement of current online mapping (GIS-based) applications; and c) Past Weather Widget replacement and related activities.

**ACCOMPLISHMENTS**

*Enhancement of current data visualization capabilities:*

***Multigraph*** is a software library, developed at NEMAC, which supports the creation of interactive data graphs in web pages and web-based applications. It has been in use for several years on NCDC's web site and on climate.gov.

- Several maintenance updates were made to the core Multigraph codebase to support features needed for the Global Climate Dashboard and the Climate Explorer; these adjustments allow applications to have more control over the display of graph axes, and labels along the axes.
- The Multigraph software library was completed and was deployed to the Global Climate Dashboard and the Climate Explorer.
- In order to fully document the Multigraph framework, a public website (www.multigraph.org) was developed and launched in May 2014 with the help of NEMAC intern Henry Henderson (Figure 1). This website includes information about

using Multigraph, the source code, how to report bugs, and information about the developers.

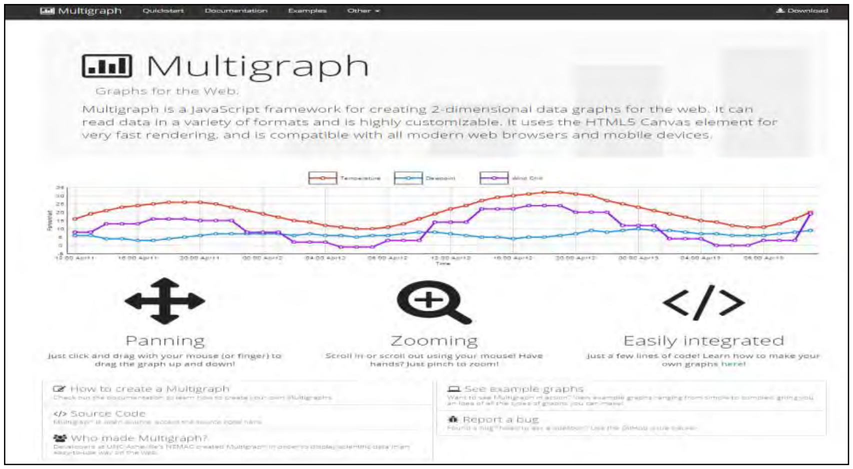


*Figure 1. Screenshot of multigraph.org*

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 key to understanding climate change trends. The current Dashboard application was written by NEMAC in 2011 and has been deployed on the home page of climate.gov since October of that year.

- A new version of the Dashboard was deployed to climate.gov in October 2013 to work around a bug in Internet Explorer; this version allows the Dashboard to work correctly in IE in spite of the bug.
- Another new version of the Dashboard, and the Drupal module that contains it, was deployed in February 2014 (*Figure 2*), to allow the data sets displayed in the Dashboard to be moderated and edited by site editors as Drupal content types.

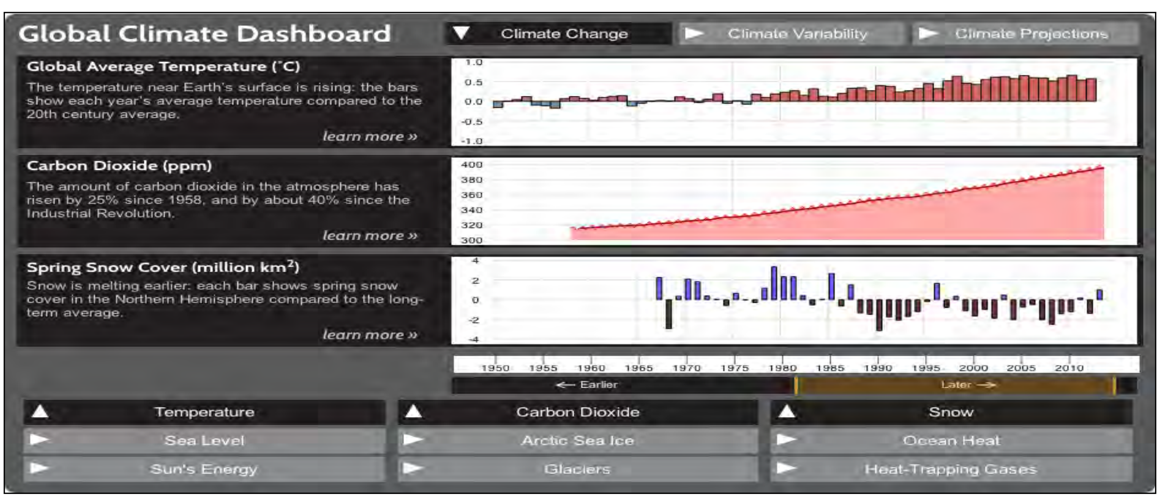


*Figure 2. Screenshot of Global Climate Dashboard*

*Enhancement of current on-line mapping (GIS-based) applications:*

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. This application replaced the current "Past Weather Widget" of climate.gov, which allows users to call up a text display of past weather conditions at any location in the United States (see below). 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.

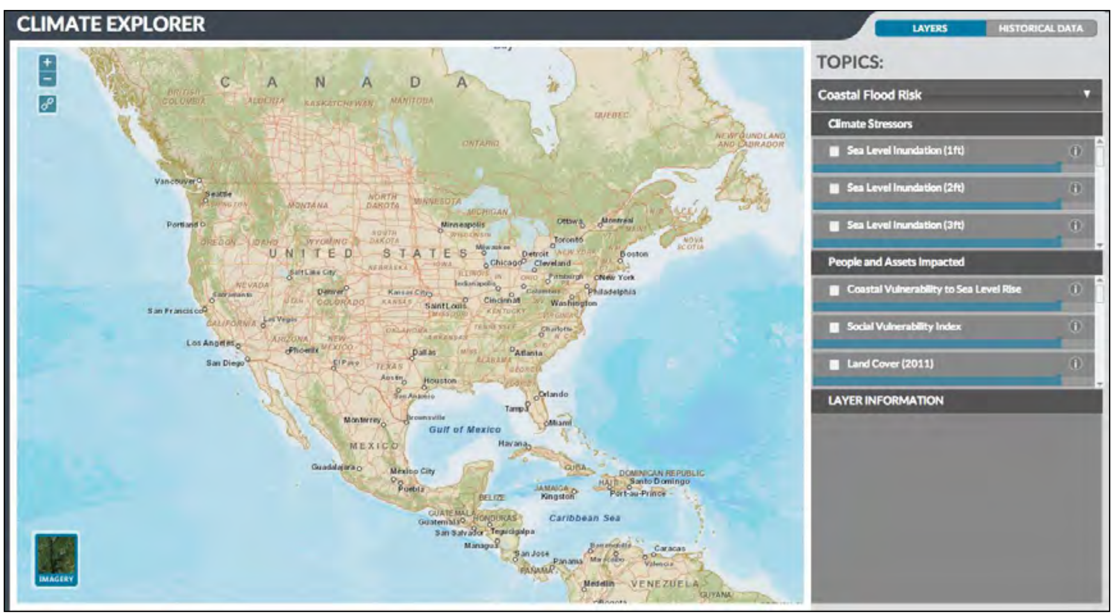


*Figure 3. Screenshot of Climate Explorer*

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.
- The CRT (Figure 4) was in planning and development stages during this time period. This included project management, site design, systems programming and web development, and content generation and editorial support tasks.
- This work and development were in preparation for the full website launch in November, 2014.

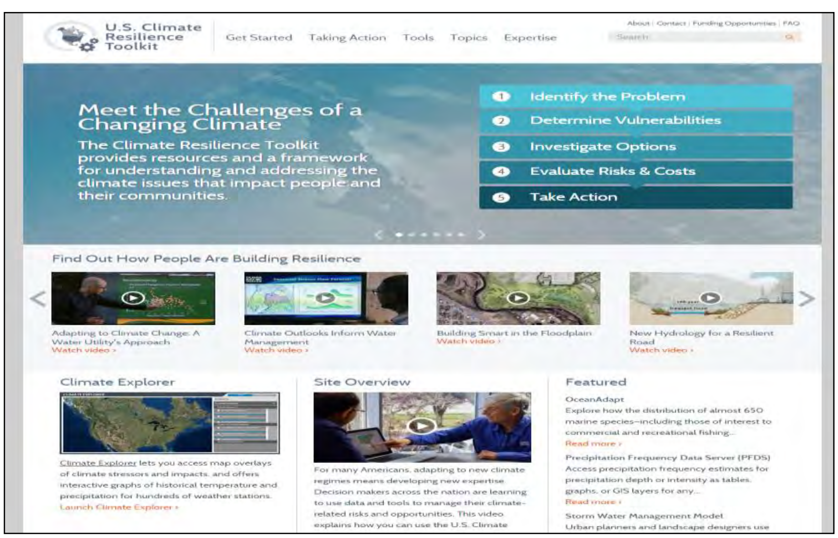


*Figure 4. Screenshot of U.S. Climate Resilience Toolkit*

The “***Past Weather Widget***” is a web application that will allow users to call up a short graphical summary of the climate of a given location. While somewhat similar in concept to the Climate Explorer application, it is intended to be used as a small “widget” that takes up a much smaller region of the screen and for displaying information from only one location at a time.

***Data Snapshots****:* This is project started in September 2013, creating an application that will provide a common interface for viewing map-based “snapshots” of several key data sets from the period 2000 to present. NEMAC began developing a *Drupal* module that allows users to move between different data sets and time points by adjusting sliders on the page.

- In order to allow work on the U.S Climate Resilience Toolkit and Climate Explorer applications (see above), work on the Climate Widget and Data Snapshots was suspended, but will be continued under a new CICS cooperative agreement project.

***Other:***

***ClimateCast*** is a series of climate videos published as completed in the online News & Features section of NOAA’s Climate.gov web portal. Each video is three to five minutes long and features NOAA scientists and staff offering insight and interpretation to climate-driven weather events and other features of the climate system. The videos complement on-screen shots of scientists with dynamic visualizations produced expressly for video by NOAA staff and scientists, contractors to NOAA working on the NOAA Climate.gov web portal, and other collaborators. Videos are filmed at the NEMAC Engagement Site in Asheville, NC, utilizing projectors, computers, and a visualization wall located at the site.

To date, the following episodes have been filmed at the RENCI Engagement Site and were completed and uploaded to the NOAA Climate.gov web portal:

- March: Out Like a Lion | Posted April 18, 2013
- Local Is Not Global: Pockets of Cold in a Warming Planet | Posted April 19, 2013
- Local Is Everything: Climate Divisions Tell Your Story | Posted May 20, 2013
- To Escape Drought, Slow and Steady Wins the Race | Posted May 20, 2013

**PLANNED WORK**

- Work will continue on the Climate Explorer, Climate Resilience Toolkit and other interactive tools under a new CICS cooperative agreement project.

**PERFORMANCE METRICS**

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|---|---|
| # 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 | 1 |
| # of peer reviewed papers | 0 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 0 |
| # of graduate students supported by a CICS task | 2 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 5 |

**PERFORMANCE METRICS EXPLANATION**

During this reporting period, a new website was planned, designed and prototyped called the U.S Climate Resilience Toolkit and the Climate Explorer application was upgraded (2). A new website for the Multigraph software library was built and launched (1).

**LINKS TO RESEARCH PAGES**

- Multigraph: www.multigraph.org
- U.S Climate Resilience Toolkit: www.toolkit.climate.gov
- Climate Explorer: http://toolkit.climate.gov/climate-explorer

**Spatio-Temporal Patterns of Precipitation and Winds in California**

| | |
|---|---|
| **Task Leader** | Dr. Sandra Yuter |
| **Task Code** | NC-CON- -NCSU-SY |
| **NOAA Sponsor** | NWS/ESRL |
| **NOAA Office** | |
| **Contribution to CICS Themes (%)** | Theme 1:100%; Theme 2: 0%; Theme 3: 0% |
| **Main CICS Research Topic** | Land and Hydrology |
| **Contribution to NOAA Goals (%)** | Goal 1: 100%; Goal 2: 100% |

**Highlight**: Precipitation frequency as a function of altitude in northern California does not correspond to the standard idealized relationship. It is widely variable with respect to both basin and storm type.

**BACKGROUND**

Atmospheric rivers (ARs) are narrow corridors of enhanced water vapor transport within extratropical cyclones. When they arrive in California, ARs contribute significantly to the water supply and flood generation in the State. Although focused research during the last few years has yielded quantitative linkages between ARs and both regional water supply and extreme precipitation events, questions remain regarding the modification and redistribution of water vapor and precipitation in ARs by California's coastal mountains and Sierra Nevada. Previous work indicates that all recent flooding events on the US west coast were associated with an AR but not all ARs yielded flooding. Several factors can potentially turn an AR event into a flooding event. There is limited understanding of the relative roles of atmospheric stability, barrier jets, and small-scale ridges along the windward slope on watershed precipitation totals.

A key piece missing on the role of ARs in flooding events is knowledge of the detailed spatial distribution of precipitation over the windward slopes of the Sierra Nevada for each AR event and for groupings of AR events with similar environmental variables. The proposed work will utilize operational radar data from six National Weather Service WSR-88D radars (KBHX, KBBX, KRGX, KDAX, KMUX and KHNK) to construct a radar echo precipitation climatology of AR events for a 10 year period. Long-term radar echo climatology is needed since existing rain gauges provide only incomplete information on precipitation in this region, particularly over rugged mountainous terrain.

**ACCOMPLISHMENTS**

The project group completed National Weather Service WSR-88D radar data processing for all 64 atmospheric river storms during the period from 2005-2010 for which archived radar data are available for at least KBBX and KDAX. A methodology was developed to "stitch" together precipitation frequency maps from the multiple radars to obtain regional maps.

Upper air soundings were analyzed from two California sites to characterize the range of environments of AR events; 439 soundings from KDAK (Oakland, CA; soundings every 12 hours during AR events from Oct 1997 – Apr. 2011) and 68 soundings from KLHM (Lincoln, CA; soundings ~4-6 hours during events from Dec. 2010 – Mar 2011). Typical AR storms, (between the 25$^{th}$ and 75$^{th}$ percentiles) are stable, have cross-barrier wind speeds of 0 to 7 m/s, and freezing level heights between 2.5 and 4 km. Higher freezing levels > 4 km are associated with higher stability and higher cross-barrier wind speeds.

Previous studies have developed an idealized precipitation model for the Sierra Nevada hydrologic region that produces a doubling of precipitation from 0 to 1 km MSL and constant precipitation above 1 km MSL. The accuracy of this model was tested by comparing the normalized hours of precipitation (P) from the storm type composites (below) relative to a 1 km reference level in the Sierra Nevada region. The idealized model was then compared to the change of relative precipitation with elevation in the other hydrologic regions to test the model's transportability (*Fig. 1*). It was determined that the idealized model consistently under predicts relative precipitation frequency in the lowest 1 km, while precipitation frequency above 1 km altitude is widely variable with respect to both basin and storm type.

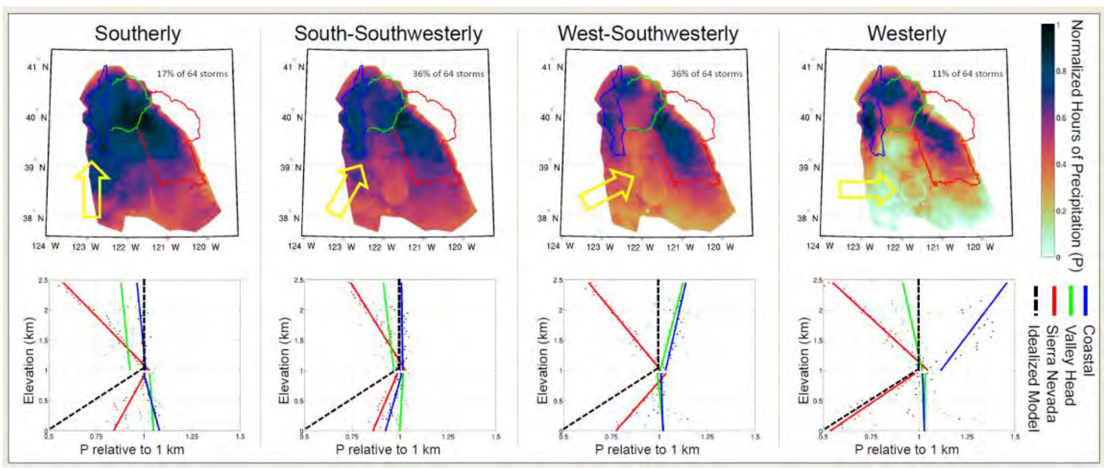


*Fig. 1. Top row: Multi-radar composites of precipitation frequency for periods with different wind directions at Bodega Bay (yellow arrow). Bottom row: Precipitation frequency normalized to value at 1 km altitude above sea level. Different colors correspond to different basins (blue=coastal, green=valley, red=Sierra Nevada, black=standard idealized model).*

**-- All work was completed and this is final report for this task/project. ---**

**PLANNED WORK (post project)**

- Finish writing up results for second publication

**PUBLICATIONS**

- Kingsmill, D. E., P. J. Neiman, B. J. Moore. M. Hughes, S. E. Yuter and F. M. Ralph, 2013: Kinematic and thermodynamic structures of Sierra barrier jets and overrunning atmospheric rivers during a land-falling winter storm in northern California. *Mon. Wea. Rev., 141, 2015-2036*.

**PRESENTATIONS**

- Corbin, N., and S. Yuter, 2013: A six-year climatology of precipitation within major storms in northern California. Poster presentation at NC State Summer Undergraduate Research Symposium, 31 July 2013.
- Corbin, N., S. Yuter, and A. Hall, 2014: A six-year climatology of precipitation within major storms in northern California. Poster presentation at NC State College of Sciences Access Day, 6 Feb 2014

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 1 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 2 |

# Other CICS PI Projects

| | |
|---|---|
| **Water Sustainability and Climate Change: a Cross-Regional Perspective** | |
| **Task Leader** | Kenneth Kunkel |
| **Task Code** | |
| **NOAA Sponsor** | |
| **NOAA Office** | |
| **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 reproduce observed temperature trends for the southeast and southwest U.S. for the period 1981-2010. Trends in the number of extreme monthly temperatures are simulated well for most regions, but not for the northwest.

**BACKGROUND**

Water resource availability varies across the Sunbelt of the United States with a sharp East-West transition at 105° W. Arid regions west of the 105th Meridian produce less runoff. On the other hand, humid regions in the east produce greater than 40 cm of mean annual runoff. Consequently, reservoirs in the west are over-year systems holding multiple years of inflows, whereas reservoirs in the east are within-year storage systems with the need to refill the system in the beginning of spring. Accordingly, water policies also differ substantially with western states pursuing “prior appropriation” and the eastern states following “riparian rights” for allocation. These contrasting strategies also impact freshwater biodiversity with the ratio of non-native to native fish species being nearly 6 times higher in the West compared to the East. In spite of these cross-regional differences, both regions face two common stressors: (a) uncertainty in available water arising from global climate change and (b) increased human demand due to population growth and consumption. Consequently, there is an ever-increasing need for an integrated assessment of fresh water sustainability under these two stressors over the planning horizon (10-30 years). The main objective of this study is to understand and quantify the potential impacts of near-term climate change and population growth on freshwater sustainability - defined here as integrating daily to annual flows required to minimize human vulnerability and maximize ecosystem needs (including native biodiversity) for freshwater - by explicitly incorporating the feedbacks from human-environmental systems on water supply and demand. Using retro-analyses involving CMIP5 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 objectives for this period were to (1) extend our analysis of mean temperature and precipitation trends in the CMIP5 hindcast simulations to 2010; and (2) perform an initial 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. The total number of ensemble members for these thirteen models was 75. Several types of analyses were performed on these model simulations:

1. Temperature and precipitation trends were calculated for the period 1981-2010 for the contiguous U.S. as a whole and for two of the regions of study in this project: the southeast and the southwest. The trends were calculated for the year as a whole and the seasons of summer and winter. The trends and the mean values of temperature and precipitation were compared with observations.
2. 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 $>+1.5\sigma$ ($\sigma$ 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 U.S., i.e. the Southeast, Southwest, Northeast, Northwest, the Great Plains, and the Midwest (these regions are defined in the Third National Climate Assessment; Melillo et al. 2014). For each region, the total numbers of grid point values above and below $1.5\sigma$ (POS and NEG indices respectively) are summed up for each of the 30 years for observations and the models

All models simulate upward trends in temperature for 1981-2010. For the southeast U.S., the magnitude of the multi-model mean trends is almost exactly equal to observations. For the southwest U.S., the magnitude of the observed trend (0.18°C/decade) is somewhat smaller than the multi-model mean trend (0.28°C/decade), but the range of individual model trends straddles the observed value. Precipitation trends in the southeast are small and not statistically significant both for observations and for all model simulations. For the southwest, observed precipitation trends are more negative than all but one model, although trends for most models and observations are not statistically significant.

Analysis of the extreme temperature index indicates that the number of positive and negative temperature trends from the model simulations agree well qualitatively with observations for the SE (Fig. 1), SW (Fig. 1), NE, and MW regions. The GP region shows the model simulations agreeing with observations for the winter season, but not as well with the other three seasons. The NW regions show that the model simulations do not simulate well with observations for the extreme temperature index.

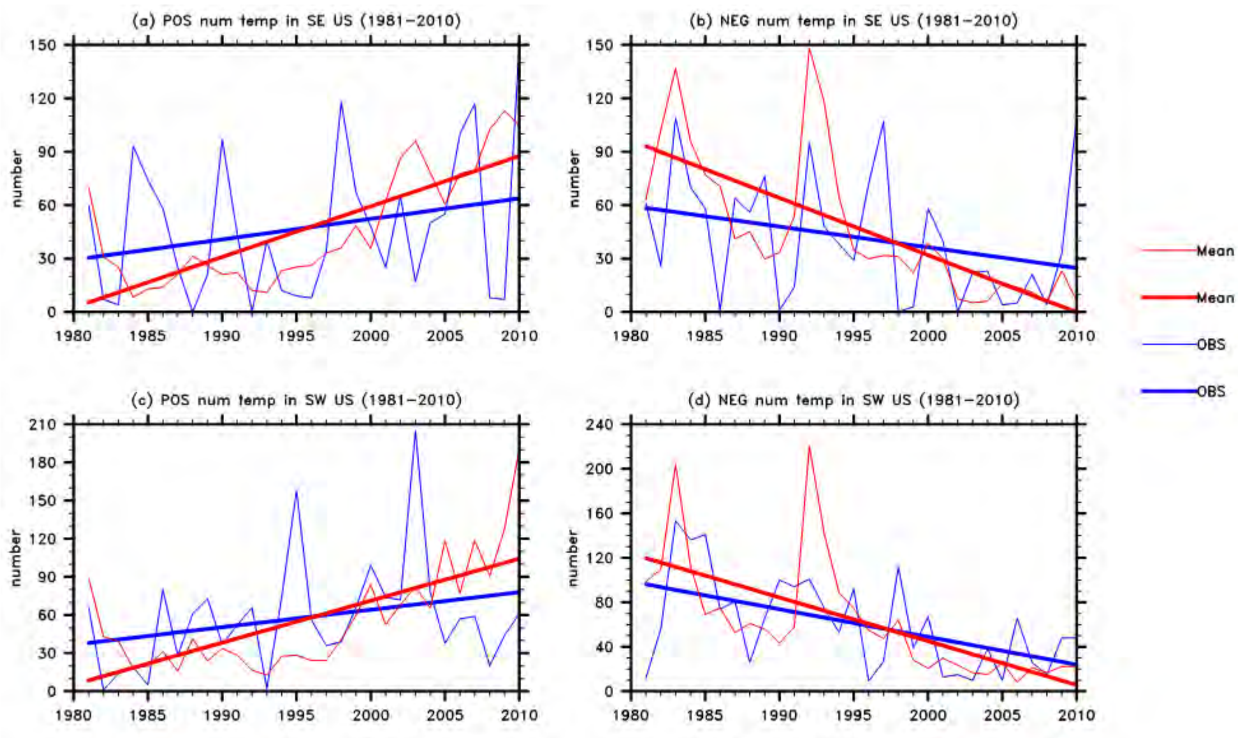


*Figure 1. Comparison of CMIP5 multi-model mean (red) trends in the number of months with extreme temperatures for 1981-2010 with observations (blue) for the Southeast (top) and Southwest (bottom) regions for extreme warm months (left) and extreme cold months (right). Extreme months are defined as exceeding 1.5 standardized anomalies (POS) or less than -1.5 standardized anomalies (NEG). There is good agreement between model and observed trends for these regions.*

**PLANNED WORK**

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

**PRESENTATIONS**

- Arumugam, S., K.E. Kunkel, and T. Sinha, 2014: Water Sustainability under Near-term Climate Change: A Cross-Regional Analysis Incorporating Socio-Ecological Feedbacks and Adaptations, annual investigator meeting for NSF Watershed Science and Climate Program, Washington, DC (30 January).

**PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | |
| # of products or techniques transitioned from research to ops without NOAA guidance | |
| # of peer reviewed papers | 0 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 1 |
| # 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**

A paper reviewing progress was given at an NSF program meeting.

# Appendix 1: Performance Metrics for CICS-NC

**TOTAL CICS-NC PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 128 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 12 |
| # of new or improved products developed without NOAA guidance | 14 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 2 |
| # of peer reviewed papers | 40 |
| # of non-peered reviewed papers | 12 |
| # of invited presentations | 85 |
| # of graduate students supported by a CICS task | 7 |
| # of graduate students formally advised | 8 |
| # of undergraduate students mentored during the year | 22 |

**ADMIN: TOTAL PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 77 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 0 |
| # of new or improved products developed without NOAA guidance | 6 |
| # 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 |

**CLEO: TOTAL PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 12 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 0 |
| # of undergraduate students mentored during the year | 0 |

**CDR: TOTAL PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 15 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 7 |
| # of new or improved products developed without NOAA guidance | 1 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 1 |
| # of peer reviewed papers | 21 |
| # of non-peered reviewed papers | 2 |
| # of invited presentations | 30 |
| # of graduate students supported by a CICS task | 2 |
| # of graduate students formally advised | 2 |
| # of undergraduate students mentored during the year | 6 |

**SON: TOTAL PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 6 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 2 |
| # 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 | 4 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 10 |
| # of graduate students supported by a CICS task | 0 |
| # of graduate students formally advised | 4 |
| # of undergraduate students mentored during the year | 1 |

**ASSESSMENTS: TOTAL PERFORMANCE METRICS**

| | |
|---|---|
| # of new or improved products developed following NOAA guidance | 28 |
| # of products or techniques transitioned from research to ops following NOAA guidance | 3 |
| # of new or improved products developed without NOAA guidance | 3 |
| # of products or techniques transitioned from research to ops without NOAA guidance | |
| # of peer reviewed papers | 12 |
| # of non-peered reviewed papers | 10 |
| # of invited presentations | 32 |
| # of graduate students supported by a CICS task | 1 |
| # of graduate students formally advised | 1 |
| # of undergraduate students mentored during the year | 5 |

**Consortium and Other PI: TOTAL PERFORMANCE METRICS**

| | |
|---|---|
| # 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 | 2 |
| # of products or techniques transitioned from research to ops without NOAA guidance | 1 |
| # of peer reviewed papers | 2 |
| # of non-peered reviewed papers | 0 |
| # of invited presentations | 1 |
| # of graduate students supported by a CICS task | 4 |
| # of graduate students formally advised | 1 |
| # of undergraduate students mentored during the year | 10 |

# Appendix 2: CICS-NC PUBLICATIONS

**CICS-NC Publications: 2009–2015**


**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

**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 Atmopsheric 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

**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

**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*, **In press**, doi:10.1175/JTECH-D-14-00185.1.

**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.**, Z. Liu, J. Cheng, and H. Hu, 2015: On the stability of the Atlantic meridional overturning circulation during the last deglaciation. *Climate Dynamics*, **44,** 1257-1275, doi:10.1007/s00382-014-2153-1. Available online at: http://dx.doi.org/10.1007/s00382-014-2153-1

**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 datasets (2002–2012). *Hydrology and Earth System Sciences*, **11,** 11489-11531, doi:10.5194/hessd-11-11489-2014. Available online at: http://www.hydrol-earth-syst-sci-discuss.net/11/11489/2014/

**Schreck, C. J.**, 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

**2014**

Allen, T. R., 2014: Advances in Remote Sensing of Coastal Wetlands: LiDAR, SAR, and Object-Oriented Case Studies from North Carolina. *Remote Sensing and Modeling*, C. W. Finkl, and C. Makowski, Eds., Springer International Publishing, 405-428. Available online at: http://dx.doi.org/10.1007/978-3-319-06326-3_17

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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, 2014: 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

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Janssen, E., D. J. Wuebbles, **K. E. Kunkel**, S. C. Olsen, and A. Goodman, 2014: Observational- and model-based trends and projections of extreme precipitation over the contiguous United States. *Earth's Future*, **2,** 2013EF000185, doi:10.1002/2013EF000185. Available online at: http://dx.doi.org/10.1002/2013EF000185

Kruk, M. C., **C. J. Schreck**, 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

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# Appendix 3: CICS-NC PRESENTATIONS

**2014-2015**

- Jesse **Bell**, “NOAA Climate Data for Public Health”, invited presentation, Air & Waste Management Association (AWMA) Annual Meeting in Long Beach, CA. Bell served as a panelist and gave a presentation on NCDC data being used at the Centers for Disease Control and Prevention (CDC). July 2014
- **Bell, J.E.,** M. Cosh, and M. Hall. Validating USCRN Soil Observations with a Dense Temporary Soil Monitoring Network. 21st Conference on Applied Climatology, Westminster, CO. June 2014
- **Bell, J.E.** Recent coordination between NOAA and CDC for improved access of climate data for public health. Climate Prediction Applications Science Workshop, Fairfax, VA, May 2014.
- **Bell, J.E.** Climate Data Sources. CDC Annual Grantee Meeting for Climate-Ready States and Cities Initiative, Atlanta, GA May 2014.
- **Bell, J.E.** (Poster Presentation) Evaluation of the change in soil conditions with the newly established national soil network. AMS 94th Annual Meeting, Atlanta, GA. February 2014.
- **Biard, J.C., Copley**, L.B., Saunders, D. and Privette, J., 2014: Easy Access to the VIIRS Science Raw Data Record, *STAR JPSS Annual Science Team Meeting,* College Park, MD (13 May).
- **Biard, J.C.,** 2014: The VIIRS Climate Raw Data Record, *STAR JPSS Annual Science Team Meeting,* College Park, MD (14 May). (Poster)
- Timles, C., **Champion, S**., and Aulenbach, S. 2014: *The Federation of Earth Science Information Partners Winter Meeting, Washington, D.C., ESIP*
- **Copley, L.,** 2014: Graph Databases Conceptual Overview. Presentation to NCDC Metadata Working Group, 7 March 2014.
- 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.
- **Dissen, J**., Houston, T., Margolin, J. (2014). Climate Change & Variability – Data Sources, Accessibility, and Use. Georgia Environmental Conference. Jekyll Island, GA.
- **Jim Fox** made a presentation to the Southeast Natural Resource Leaders Group (SENRLG) on December 9th, 2014 in Atlanta, GA, integrating local information with NCA findings.
- NEMAC’s Greg Dobson and **Jim Fox** co-organized and co-chaired a 94th AMS Annual Meeting session, “Identifying the Needs and Opportunities of Small and Medium-Sized Communities for Data, Information, and Integrated Tools for Enhanced Decision Support-Part I: Users” in Atlanta, Georgia, in February 2014. A second session, co-organized and co-chaired by Riverside Technology, focused on Providers.
- Dobson, J.G. and **J.F. Fox**. *Providing Meaningful and Actionable Decision Tools to Local and Regional Stakeholders across the Southeastern U.S.* The 94th American

Meteorological Society's Annual Meeting, 9th Symposium on Policy and Socioeconomic Research. February 2nd-6th, 2014, Atlanta, Georgia.

- **Fox, J.F**. and J.G. Dobson. *Framing the Climate Issue for Small and Medium-Sized Communities across the Southeastern U.S.* The 94th American Meteorological Society's Annual Meeting, 9th Symposium on Policy and Socioeconomic Research. February 2nd- 6th, 2014, Atlanta, Georgia.
- **Fox, J.F.** and J.G. Dobson. *Framing the Climate Issue for Small and Medium-Sized Communities across the Southeastern U.S.* The 94th American Meteorological Society's Annual Meeting, 9th Symposium on Policy and Socioeconomic Research. February 2nd- 6th, 2014, Atlanta, Georgia.
- Thorne, P.W**., C.C. Hennon**, K.R. Knapp, **C.J. Schreck III, S.E. Stevens**, **P.A. Hennon**, J.P. Kossin, M.C. Kruk, **J. Rennie, and L.E. Stevens**, 2014: Cyclonecenter: Crowdsourcing insights into historical tropical cyclone intensities. *26th Conference on Climate Variability and Change,* 2-6 February 2014, Atlanta, GA.
- **Anand Inamdar**, 28th Hydrology Conference, American Meteorological Society 94th Annual Meeting, Atlanta. Feb 3 2014.
- Ken **Kunkel**, **"**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**, "Climate Projections-Southern U.S.", invited talk, Innovation in Water Treatment and Conservation webinar, Southern Legislative Conference, July 17, 2014.
- Ken **Kunkel**, "Climate Impacts in the United States: An Overview from the National Climate Assessment", invited presentation, Climate Impacts and Resilience Workshop, Business Environmental Leadership Council, Washington, DC, July 16, 2014. Type of group: business leaders. CICS-NC
- **Kunkel, K.E.,** 2014: The Third National Climate Assessment, invited seminar, Ouranos Consortium on Regional Climatology and Adaptation to Climate Change, Montreal, Canada (11 June).
- **Kunkel, K.E.,** 2014: Extreme Precipitation Trend Estimation in Conterminous United States (CONUS), poster paper, Donald R. Johnson Symposium, Annual Meeting of the American Meteorological Society, Atlanta, GA (6 February).
- **Kunkel, K.E**., 2014: Observed Trends in Extreme Precipitation: Illinois and Beyond, invited talk, Stanley A. Changnon Symposium, Annual Meeting of the American Meteorological Society, Atlanta, GA (4 February).
- **Kunkel, K.E**., 2014: Historical Trends and Future Projections of Extreme Climate Conditions for the U.S. National Climate Assessment, Annual Meeting of the American Meteorological Society, Atlanta, GA (4 February).
- **Kunkel, K.E.,** 2014: What are the Innovations in Science and Scenarios for this and Future Assessments, invited talk, National Council for Science and Engineering 14th National Conference, Washington, DC (28 January).
- Arumugam, S., **K.E. Kunkel**, and T. Sinha, 2014: Water Sustainability under Near-term Climate Change: A Cross-Regional Analysis Incorporating Socio-Ecological Feedbacks and Adaptations, annual investigator meeting for NSF Watershed Science and Climate Program, Washington, DC (30 January).

- Baxter, M. A., **G. M. Lackmann**, J. E. Tate, K. Mahoney, T. E. Workoff, and T. M. Hamill: Predictability of precipitation in the Southeast United States, Part I: Verification and categorization. AMS 27th Conference on Weather Analysis and Forecasting/23rd Conference on Numerical Weather Prediction. 13.A2
- Tate, J. E., M. A. Baxter, and **G. M. Lackmann**: Predictability of precipitation in the Southeast United States, Part II: Composites and case studies. AMS 27th Conference on Weather Analysis and Forecasting/23rd Conference on Numerical Weather Prediction. 13.A3
- Chante' Vines, **Leeper, R.D.**, and Michael Palecki. Evaluating the 2012 U.S. Drought using Modeled and In Situ Climate Datasets. *2014 NOAA OEd Student Science and Education Symposium*, Silver Springs, MD, (29th July, 2014).
- **Leeper, R.D., O.P. Prat**, and B.O. Blanton. Evaluating the Sensitivity of the Weather Research and Forecasting (WRF) Model for Tropical Cyclones Impacting the Carolinas. Abstract submitted to the *Carolinas Climate Resilience Conference*. 28-29 April 2014, Charlotte, NC.
- **Matthews, J.L.** and Lei Shi, 2014: Validation of satellite-derived temperature and humidity profiles, *SIAM Conference on Uncertainty Quantification*, Savannah, GA (31 Mar).
- **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
- 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.
- **Peng, G.** and J. L. Privette, 2014: Stewardship maturity matrix – a unified framework for assessing data quality and usability practices applied to individual digital environmental data products. 2014 ESIP (Federation of Earth Science Information Partners) summer meeting, 7 – 11 July 2014, Copper Mountain, CO, USA.
- **Peng, G**. and J. L. Privette, 2014: A stewardship maturity matrix for assessing the state of environmental data quality and usability. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS 2014 annual meeting, February 2- 6, 2014, Atlanta, GA, USA.
- **Peng, G**., L. D. Cecil, and B. Cramer, 2014: An End-to-End Framework for Probabilistic Uncertainty Characterization of Climate Satellite Data and Products. 10th Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS 2014 annual meeting, February 2- 6, 2014, Atlanta, GA, USA.

- **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
- **Prat, O.P**., B.R. Nelson, S. Stevens, and D.-J. Seo, 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. *8th European Conference on Radar in Meteorology and Hydrology (ERAD 2014)*, 1-5 September 2014, Garmisch-Partenkirchen, Germany.
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- **Prat, O.P.,** and M.R. Kumjian, 2014. Transient behavior of polarimetric signatures of warm rain microphysical processes. Abstract submitted to the *International Weather Radar and Hydrology symposium*, 7-9 April 2014, Washington, DC, USA.
- **Prat, O.P.,** and B.R. Nelson, 2014. Toward the development of an evaluation framework of Climate Data Records for precipitation: A characterization of CONUS rainfall using a suite of satellite, radar, and rain gauge QPE products. *94th annual meeting of the American Meteorological Society,* 2-6 February 2014, Atlanta, GA, USA.
- Jared **Rennie**, Asheville Middle School: Presentations to 6th and 7th graders at Asheville Middle School on weather, climate, and what we do at CICS-NC / NCDC. November 2014
- Jared **Rennie**, 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 ~1,000 students in middle school. October 2014 https://www.youtube.com/watch?v=vrWiCx7U0kw
- 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.

- 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; Dec 15-19, 2014; San Francisco, California, USA.
- Ashouri H., K. Hsu, **S. Sorooshian**, J. Lee, M. G. Bosilovich, and J. Y. Yu, 2014: Evaluation of the Reanalyses Products in Detecting Extreme Precipitation Trends over United States, American Meteorological Society (AMS) 94th Annual Meeting, 28th Conference on Hydrology, February 1-6, 2014, Atlanta, GA.
- Dobson, J.G. and **M.F. Squires**, *Local Applications of the Regional Snowfall Indices and GIS Snowstorm Database* (Poster). The 71st Annual Eastern Snow Conference. June 3rd-5th, 2014, Boone, North Carolina.
- **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.
- Laura **Stevens**, "Climate Change Impacts in the United States" to Environmental Biology students at AB Tech, Asheville, NC, March 10, 2015
- Laura **Stevens**, "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 AB Tech Environmental Biology students at NCDC, Asheville, NC, Nov 3, 2014
- Laura **Stevens**, "Climate Change Impacts in the United States" to French Broad Mensa, Asheville, NC, September 13, 2014
- Laura **Stevens**, "Climate Change Impacts in the United States" as part of the North Carolina Arboretum seminar series at the NC Arboretum, Asheville, NC, July 31, 2014.
- Laura **Stevens**, "Climate Change Impacts in the United States" - 20 minute radio interview with Jess Messer on WPEK-AM, Asheville NC (July 29,2014)
- **Stevens, L.E.,** and **R. Taylor,** 2014: Climate Change Impacts in the United States, NOAA's National Climatic Data Center (presentation for the Black Mountain Presbyterian Church Friends of Creation group), Asheville, NC (6 June).
- **Stevens, L.E.,** and **K.E. Kunkel**, 2014: Climate Change in the Carolinas, Carolinas Climate Resilience Conference, Charlotte, NC (29 April).
- **Stevens, L.E.,** 2014: National Climate Assessment Panel Discussion, 94th Annual Meeting of the American Meteorological Society, Atlanta, GA (2 February).
- Nelson, B.R**, S.E. Stevens, O.P Prat**, C. Langston, K. Ortega, J. Zhang, Y. Qi, K. Howard, and T. Smith, 2014. The National Mosaic and Multi-sensor Quantitative Precipitation Estimate (NMQ/Q2) Reanalysis Effort. *International Weather Radar and Hydrology symposium*, 7-9 April 2014, Washington, DC, USA.
- **Stevens, S.E**., B.R. Nelson, C.L. Langston, and K.L. Ortega, 2014: Toward a climate-quality high-resolution precipitation dataset: An early look at the National Mosaic and Multisensor Quantitative Precipitation Estimate (NMQ/Q2). *28th Conference on*

*Hydrology*, 2-6 Feburary 2014, Atlanta, GA.

- Robert **Taylor**, “Climate Change Impacts in the United States” to Environmental Biology students at AB Tech, Asheville, NC, **March 16, 2015**
- **Sun, L.** 2014: Seasonal climate prediction: Lessons learned from the past, Seminar at Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing China (17 September 2014)
- **Sun, L.,** 2014: Regional climate modeling: Status and outstanding issues, Seminar at Meteorological Research Institute of Jilin Province, Changchun, China (15 September 2014)
- **Sun, L.,** 2014: Multi-model ensemble seasonal climate forecasts for Northeast Brazil, invited talk via Skype, 16th Semi-Arid Northeast Brazil Climate Outlook Forum, Fortaleza, Brazil (17 January, 2014)
- **Jennifer Tate**, 19 September 2014: "Improving Heavy Precipitation Forecasting in the Southeast U.S." NC State Graduate Seminar.
- Corbin, N., **S. Yuter**, and A. Hall, 2014: A six-year climatology of precipitation within major storms in northern California. Poster presentation at NC State College of Sciences Access Day, 6 Feb 2014