NCICS Highlights



Inspire. Advance. Engage.

2015–2016 Institute Highlights

Formally approved as an inter-institutional research institute by the University of North Carolina General Administration in January 2011, the North Carolina Institute for Climate Studies (NCICS) is a unique center of excellence showcasing a partnership between universities, the private sector, non-profit organizations, community groups, and the federal government.

NCICS' primary activity continues to be the operation of the NOAA Cooperative Institute for Climate and Satellites-North Carolina (CICS-NC), facilitated by its co-location with our primary NOAA sponsor, the National Centers for Environmental Information (NCEI), in the Veach-Baley Federal Complex in Asheville.

Other extramural support continues to expand, however, with new federal NSF, DoD SERDP, and NASA projects awarded in 2015–2016, as well as several smaller private industry project awards.

NCICS' main objectives are to

- promote discovery of new knowledge about global, regional, and local climate variability and its impacts, and
- provide information that is critical for determining trends and validating climate forecasts at all of these spatial scales.

Current Institute Personnel

As of May 2016: Thirty-one full-time faculty and staff plus one part-time temporary staff. Faculty appointments include two North Carolina State University Research Professors and one Research Assistant Professor, as well as four adjunct research faculty appointments (2 NCSU, 1 Emory, 1 NCAT).

Institute Vision

- Inspire cutting-edge research and collaboration
- Advance understanding of the current and future state of the climate
- *Engage* with business, academia, government, and the public to enhance decision making

Task Streams

NCICS/CICS–NC efforts are organized in eight task/activity streams:

Administration

Administrative and information technology support for Institute activities

Access and Services Development

Supporting improvements to access mechanisms for NCEI's data and product holdings

Assessments

Supporting interagency activities for global, national, and regional assessments of climate change

Reference Environmental Data Records and Data Stewardship

Providing quality satellite and in situ climate observing datasets to document the Earth's climate

Climate Literacy, Outreach, Engagement, and Communications

Improving public knowledge and understanding of climate change, its impacts, and options for adaptation and mitigation

Surface Observing Networks

Sustaining and improving the quality of in situ observations and observing networks

Workforce Development

Preparing the next generation of climate scientists, engineers, and technicians

Consortium and Other Projects

Augmenting institute capabilities through CICS consortium member partnerships and other collaborative endeavors

Selected Highlights By Task Stream

Key staff names for each project listed in brackets.

Administration

- IT staff continue to refine and improve the Institute's high-performance computing infrastructure. Virtualization capabilities have been transitioned to a new implementation (*oVirt 3.6*), which allows for better stability and reliability while reducing the management demands.
- The Institute moved to using Google apps for email, which also provides access to Hangouts, Calendar, and other Google services while improving integration with NOAA and NCSU, who also use Google apps.
- Improvements to tape vaulting allows our 500-slot tape library to manage 1200 tapes.

Access and Services Development

• CICS-NC is providing technical and scientific support to make data from NCEI available via several cloud-based services as part of NOAA's Big Data Project. The team successfully transferred the entire Level 2 Next Generation

Weather Radar (NEXRAD) archive from NOAA's NCEI to the Amazon Web Services platform, where the data was made available to the public on October 27, 2015.

The AWS platform provides users with seamless, single-API access to both historical and real-time NEXRAD data (https://aws.amazon.com/noaa-big-data/nexrad/).

NEXRAD data is also being transferred to Microsoft Azure, and plans for other data transfers are in process. [Brannock, S. Stevens, Wilkins]

- The "Agile" software development team established last year in Asheville continues to support the existing Ingest Archive System at the Asheville NCEI location. [Copley, Vasquez]
- In collaboration with NCEI staff in Boulder, CO, installed a proof-of-concept instance of the Common Ingest system used in Boulder on CICS-NC hardware in Asheville. This system is being evaluated for potential implementation in operations at the Asheville location. [Copley, Vasquez]
- Monitoring of the Local Data Manager (LDM) service was recommended following significant undetected failures of upstream data providers for National Weather Service (NWS) data. A monitoring solution was created which connects to the live LDM application event stream, tracks state to deduce processing metadata, and reports that through the existing IAS monitoring system.

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Assessments

• The Technical Support Unit provided extensive scientific, editorial, graphics, metadata, software, web design, and project management support for the U.S. Global Change Research Program (USGCRP) report on the impacts of climate change on human health.

Working closely with colleagues at USGCRP, the Environmental Protection Agency, and other agencies, the team facilitated on-time delivery of multiple review drafts and the final report and website, which were released on April 4, 2016. The report is available online at health2016.globalchange.gov. [Multiple]

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Climate and Health Assessment

copyright permissions for the USGCRP Climate and Health Assessment. Full documentation of original metadata for the NOAA NESDIS Technical Report 144: "Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment." [Champion]

GlobalChange.gov

- Refined approximately 500 figures for NOAA's State Summaries for the National Climate Assessment and designed the layout to house the summaries. Collaborated with fellow members of the NCEI visual communications team to produce figures, PDFs, and supporting communication materials for the USGCRP Climate and Health Assessment. [Griffin]
- Publication of NOAA Technical Report TR-144 "Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment," comparing CMIP3 and CMIP5 simulations in support of the National Climate Assessment. [Multiple]
- Scientific support, project management, science writing and editing, graphic design support, web design, and metadata collection for the forthcoming NOAA State Summaries for the National Climate Assessment project. The outcome will be reports (approximately 4 pages and up to 12 figures each) for all fifty states, providing an overview of notable climate information, observed trends, and projected changes in temperature, precipitation, and selected climate extremes. [Multiple]
- Working with the USGCRP on the development of processes, timelines, and author guidance for the forthcoming Climate Science Special Report. Attended first author meeting in Washington, DC, in April 2016. [Stewart]
- Produced CMIP5 data with resolution of 5 km over the United States for analyses of climate change in each of the 50 states in the United States. Variables are surface temperature, precipitation, maximum and minimum daily temperature, maximum 1-day precipitation, and growing season length for four scenarios and historical simulations. [Sun]



- Developed and deployed an approach to create ensemble average extra-tropical cyclone (ETC) tracks from the 20th Century Reanalysis. This dataset contains tracking information for weather systems outside of the tropics (i.e. Nor'easters, Alberta Clippers, etc.) in much the same way hurricanes are tracked. An interactive website has been set up to showcase and provide access to the dataset. [Leeper]
- In anticipation of the Fourth National Climate Assessment, the TSU is working with the LOCA (Localized Climate Analogs) dataset—a new statistically-downscaled daily data set based on CMIP5 simulations at 1/16-degree spatial resolution for the conterminous United States. This dataset is relatively large (11 TB) and requires an HPC (High Performance Computing) cluster to deliver results in a timely fashion. Computer programs to process these data were developed, and an initial set of 23 derived climate variables were calculated. The processing framework can seamlessly scale to any number of CPUs and runs modular, arbitrary functions against the data to accommodate unforeseen requirements. [Multiple]
- Metadata for the figures used in the USGCRP Climate and Health Assessment were transmitted to the U.S. Global Change Research Program's Global Change Information Service (GCIS) on schedule. Improvements to software

during this process resulted in gcis-pyclient 1.1 being released to the public. Development of our next-generation, real-time climate science metadata collection system is nearly complete. [Multiple]

- Using massively parallel MPI compute cluster, developed value-added pressure dataset from 20th Century reanalysis data in support of Extra Tropical Cyclones/ Blocking Highs research. [Buddenberg]
- Temperature scaled by global temperature with different warming thresholds was carried out for the 50 states and 8 NCA regions in the United States using CMIP5 data.

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• Provided continuing support for the USGCRP website and related tools, including a new web tool for soliciting and managing author nominations and other public contributions. A new version of an author collaboration website is also under development, with an expected release in May 2016. [Sides, Li]

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Reference Environmental Data Records and Data Stewardship

- Work continues on a joint project with the NOAA National Severe Storms Laboratory (NSSL)/Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) in Norman, OK, to apply the National Mosaic and Multi-
- sensor Quantitative Precipitation Estimate (NMQ/Q2) algorithms to the entire archive of NEXRAD data (1997–2011). This reanalysis produced a suite of gridded precipitation products at a far finer temporal frequency (five-minute) and spatial scale (0.01°/1 km) than was previously available.
- In addition to providing this data via cloud providers as part of the "Big Data" effort described earlier in this report, efforts are underway to introduce the completed dataset into the NCEI archive. The dataset is also



being used in some applied science. The sub-hourly rain rates are being used in a study to investigate fatal traffic accidents and are being integrated into the SERDP project. [S. Stevens]

- Generated obs4MIPs datasets from the entire period of record for three different Climate Data Records (CDRs): the HIRS Outgoing Long-wave Radiation CDR, the Optimum Interpolation Sea Surface Temperature (OISST) CDR, and the Sea Ice Concentration CDR. Based on the success of this project, six other CDR's have been proposed for conversion to obs4MIPs. [Biard]
- Calibration of the visible channel for the full GOES series of satellites has been processed separately and delivered for the Global Geostationary Surface Albedo project.
 [Matthews, Inamdar]
- Extensive support for the transition of the ISCCP satellite cloud data set to NCEI and contributions to the next generation H-series ISCCP cloud data satellite products. [Inamdar]
- Planning and implementation of large-scale (~300 TB) GOES satellite imagery reprocessing. [Matthews]
- Spatial-temporal data fusion of land surface albedo products in collaboration with NC State University Statistics Department. [Matthews]
- Assessment of stewardship maturity of NOAA/NSIDC sea ice concentration climate data record (CDR) and Global Historical Climatology Network–Monthly (GHCN-M) version 3, utilizing the data stewardship maturity matrix described in Peng et al. (2015). [Peng]

- Launched an improved version of website for monitoring and prediction of the Madden–Julian Oscillation and other tropical variability: http://monitor.cicsnc.org/mjo/. The website serves ~300 unique users each month. [Schreck]
- Development of a Climate Data Record for the High-Resolution Infrared Radiation Sounder (HIRS) satellite atmospheric temperature and humidity profile. Recent work includes the use of neural networks to produce global profiles and development of a two-tiered bias correction methodology. [Matthews]
- Cutting-edge research on the scientific stewardship of individual digital environmental data products. Leading, coordinating, and participating in NCEI and across-agency DSMM (data stewardship maturity matrix) use-case studies and development of tools for integrating DSMM results for enhanced data discovery and decision-making support. Results include multiple seminar and conference presentations and two published papers, with a third paper in development. The paper published in D-Lib Magazine introduces



the roles of data, scientific, and technology stewards and describes the responsibilities of these stewards and other major stakeholders in effectively ensuring and improving data quality and usability. [Peng]

- Calibration for the GOES series for the extended period of 2010–2015 has been completed. Results from the new approach compared favorably with the ISCCP and previous calibration. A journal paper on the calibration of the visible channel of the ISCCP (International Satellite Cloud Climatology Project) B1U data has been published. [Inamdar]
- Working with the Principal Investigator for the High resolution Infrared Radiation Sounder (HIRS) Outgoing Long-wave Radiation (OLR) Monthly CDR to refactor the production software in preparation for continual production operations within NCEI. [Biard]
- Merged radar quantitative precipitation estimates (QPEs) from the high-resolution NEXRAD reanalysis over CONUS with rain-gauge observations (GHCN-D, HADS, CRN). Performed bias-adjustment of the



radar-only product at the daily and hourly scale for the period 2002–2011. Currently implementing and testing techniques for optimally merging the rain gauge datasets and the radar-only estimates. [Prat]



Daily bias-adjusted NMQ: Annual 2002-2011



Climate Literacy, Outreach, Engagement, and Communications

- Worked with the NCEI Data Information Services, Communications, and Outreach (DISCO) team to develop a sector prioritization activity for the following NCEI calendar years, mapping work efforts to sector prioritizations.
- Leading NCEI in the development of a robust customer and engagement solution to improve customer information and engagement, understand customer requirements for environmental information, and develop strategic and targeted engagement discussions. [Dissen]

PRIORTIZED SECTORS	ACTIVITY	REGION	TIMING	
Energy	Energy Resilience Workshop Workshop Utility Analytics Summit* NOAA Energy Team Industry sector engagement continues (Jenny <u>Dissen</u>)	 National / South National 	 January 2016 April 2016 FY 2016 - 201 	
Agriculture / Forestry / Fishing / Hunting	USDA, High Plains Regional Climate Center (HPRCC) and NOAA Regional Climate Services Meetings (Doug <u>Kluck</u>) Ongoing APGA collaboration (Tami Houston)	 Western Eastern National 	 March 2016 March 2016 Ongoing 	
Transportation /	NC Department of Transportation Summer Workshop (Committee on Waste Management and Resource Efficiency) Developing engagement options for FY17	National	 July 2016 Focus for 201 	
Government / Interagency	NWS Climate Services Meeting Ongoing Tribal Engagement Department of Energy Partnership for Resilience New opportunity with US EDA (in discussion)	National	 May 2016 FY 2017 Ongoing Ongoing 	
Healthcare	Partnership established with NIH / NIEHS Working with NCA Climate and Health Team Regional Meeting on Climate and Dengue Forecasting Developing engagement options for FY17	 State/National National International 	 Ongoing Ongoing January 2016 	
Insurance	 NOAA's Strategic reinsurance industry engagement project (Adam Smith) 	National	 Ongoing 	
Finance	 New - developing engagement options for FY 2017 	• TBD	 FY 2017 	

- CICS-NC staff participated in more than a dozen local and regional climate literacy outreach events, including several NC Science Festival activities and a variety of summer science camps, K-12 STEM programs, Career Day activities, and presentations to adult continuing education groups. [Multiple]
- Worked with NCEI to develop and host an executive forum discussion on "Moving from Environmental Data to Resilience" on January 14, 2016, in New Orleans, Louisiana. The meeting was held in conjunction with the annual meeting of the American Meteorological Society.



• Continuing support of the local Western North Carolina community in the development of STEM capabilities, including working with the Asheville–Buncombe Sustainable Community Initiative in the development of the Collider, a downtown Asheville climate innovation and business center that works to advance climate and environmental literacy and supports the development of climate services business in our county. The Collider's office/co-working space officially opened in early 2016. We also serve on the Board of the Asheville Museum of Science. [Dissen, Brown]



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- Developed/updated Institute communications materials, including a new institute brochure and an issue of our Trends newsletter. The Institute website is currently being redesigned, with a launch expected in summer 2016. The new site will align with NCSU branding guidance and will provide a more cohesive presentation of the Institute's capabilities, activities, and outcomes. [Maycock, Griffin, Li]
- Provided editorial and writing support to the NCEI communications and outreach branch. [Maycock]
- Uncertainty quantification for billion-dollar disaster events. [Matthews]
- Progress on developing the Partnership for Resilience (PfR), an NC State University consortium, including assembling an Advisory Board, drafting the consortium charter and bylaws, and developing a business model and financial plan. The mission of the PfR is to empower society to consider environmental variability in decision-making processes to address increasingly challenging social, environmental, and economic consequences. [Hennon]

Business & Industry will ...

- · Share challenges and experiences with climate risks
- · Propose projects for working group activities

Benefits:

- Access to a network of other businesses sensitive to climate •
- Opportunities to learn about best practices for adaptation
- Learn about capabilities available in other sectors
- · Have their challenges drive research and development agenda

Partner Organizations will ...

- Share community-specific experiences with climate risks
- Propose projects for working group activities

Benefits:

- · Access to a network of other businesses sensitive to climate
- Opportunities to learn about best practices for adaptation
- Learn about capabilities available in other sectors
- Have their challenges drive research and development agenda •
- - Highlighted case-studies and tools Organized and relevant information for climate

Better understanding of stakeholder needs Access to audience for products and services Better transition from research to applications

Partnership for Resilience

Student Career Growth Improved understanding of adaptation problen Participation in cross-sector projects

Business support for collaborative projects

A network of experts and potential clients

Exposure to best practices and case studies

- Academia will ...
- Share relevant research experiences
- Provide educational resources

Benefits:

- Greater exposure to adaptation problems
- Greater exposure to federal resources and activities
- Opportunities for student career growth
- Opportunities to participate in projects with compensation

- Government will ...
- Share up to date information on resources and plans
- Identify tools and projects ready for transition to the private sector
- · Resource selected projects, as appropriate with in-kind expertise
- Share use-inspired science

Benefits:

- · Greater exposure of activities and accomplishments
- · Sustained access to a broad community to respond to potential plans

Surface Observing Networks

- Used USCRN soil climate observations to evaluate the national changes in soil moisture for improved drought monitoring. [Bell]
- A new precipitation algorithm for the U.S. Climate Reference Network (USCRN) was deployed this year, wrapping up a multiyear effort to improve the network's capacity to monitor precipitation at a 5-minute frequency. Currently working with the National Ecological Observatory Network (NEON) to setup an operational version of this algorithm for their precipitation system. [Leeper]



- Development continues on the next version of NOAA's global temperature product, known as the Global Historical Climatology Network–Monthly (GHCN-M) dataset. This new version includes nearly four times as many stations as well as updated quality control and bias-correction procedures. In October of 2015, GHCN-M version 4 was released as a public beta. Work is underway to finalize the operational structure, provide documentation on the product, and produce a journal article that will be published along with the official data release. [Rennie]
- Developed a sub-monthly tool for monitoring impacts of temperature extremes in the United States. Using observations in near-real time, station data is aggregated on different levels, including individual states, regions defined by the National Climate Assessment, and the contiguous United States. Data is updated on a daily basis to analyze current temperatures against the period of record. [Rennie]
- Under a multi-year IPA agreement with the Centers for Disease Control and Prevention (CDC), working with a variety of CDC groups on projects related to climate and health and utilizing NCEI data (e.g., valley fever, *Vibrio vulnificus*, heat wave indices, and mental health). [Bell]
- 4day NCA Region Ranks Ending On 2015 09 22
- Analyzed changes to USCRN precipitation patterns over the 2012 drought and compared USCRN soil conditions to a commonly used reanalysis model—the North American Regional Reanalysis. These two studies highlighted the severity of the 2012 drought and the model's capacity to simulate the evolution of hydrological extremes. In addition, the development of a soil product for the USCRN that can monitor both sides of hydrological extremes (droughts and floods) is currently underway. [Leeper]



Workforce Development

• Evaluation of new spatial interpolator based on topography, using cross-validation. Compared seasonal precipitation obtained using the new method with results from traditional interpolation methods. [Nickl]





- Collocated and analyzed 2006–2013 HIRS surface temperature to NOAA U.S. Climate Reference Network (USCRN) station data. Constructed a best-fit equation to bias correct the HIRS surface temperatures improving the overall bias and RMSE for 2006 to 2013. [Stegall]
- Jesse Bell holds an adjunct faculty appointment with Emory University's Rollins School of Public Health. In that role, he mentored MPH student interns investigating the relationship of climate to human health issues. [Bell, students]



- Carl Schreck holds an adjunct faculty appointment with NC A&T University and serves as PhD co-advisor for Hilawe Semunegus (NCEI). [Schreck]
- Jared Rennie supervised two local high school students, Jason Yu and Sean Feirstein, who provided summer intern research support for the Snowfall Extremes project gathering, plotting, mapping and verifying snowfall data at the county level. [Rennie, students]
- Andrew Buddenberg oversaw the software engineering support efforts of local high school intern, Isaac Pohl-Zaretsky, including an extensive reprocessing of climate model projections using the LOCA (localized constructed analogs) downscaling technique. [Buddenberg, student]
- Carl Schreck advised a NASA DEVELOP student intern team, Derek Podowitz (TAMU) and Kelly Dobeck (UNCA), on their project focused on the relationship of long-wave radiation data to U.S. temperatures for energy industry users. [Schreck]
- Sarah Champion and Brooke Stewart-Garrod are engaged in NCSU doctoral studies in Atmospheric Sciences, with Champion focusing on extreme precipitation and Stewart-Garrod investigating atmospheric blocking highs. [Champion, Stewart-Garrod]
- Four UNCA students completed NCICS internships and projects including:
 - > an examination of economic impacts of climate change (potential losses resulting from sea level rise) and the development of an inundation impact model for New Hanover County (William Clark);
 - > a study of the spatial correlation among NOAA's Global Historical Climatology Network-Daily (GHCN-D) gauge precipitation data and Stage IV gridded radar data in order to evaluate the sufficiency of in situ network coverage (Kelly Gassert);
 - > an investigation of climate modeling applications, the impacts of climate change on human health and the health impact of heat waves (Tiffany Maupin); and
 - > research on the intersection between climate science and policy as well as support of National Climate Assessment outreach and engagement activities (Bobby Taylor).

Other NCICS Projects

- Under a collaborative NSF project, 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. 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. [Kunkel, Stegall]
- Carl Schreck, PI for a NASA-funded project, was sole author on a paper entitled "Kelvin Waves on Tropical Cyclogenesis" published in *Monthly Weather Review* that describes the effect of Kelvin waves on tropical cyclone activity around the globe. [Schreck]
- CICS-NC provided research support to Riskpulse, Inc. for their development of WindRisk, a statistical model to forecast German wind power. The predictors in this model are the leading EOFs for a variety of atmospheric variables, including NCEI's daily outgoing longwave radiation (OLR) CDR. OLR proved to be a valuable predictor in week 2 and beyond. [Schreck]
- New DoD Strategic Environmental Research and Development Program (SERDP) award received with Ken Kunkel as lead PI; this is a \$2.8 million (\$1.53 million to NCSU), five-year project supporting incorporation of effects of climate change into rainfall design values. [Kunkel, Multiple]



- New collaborative NSF award received with Ken Kunkel as co-PI; this is a 5-year multi-institutional collaborative project (lead institution, Arizona State University) studying urban resilience to climate-driven extreme events. [Kunkel]
- NASA award received with Carl Schreck as lead PI; this is a 3-year collaborative project with NC A&T University to investigate multi-scale interactions between the MJO, equatorial waves, and the diurnal cycle over the Mari-time Continent. [Schreck]
- Notification received of pending NASA award with Ge Peng as co-PI; this is a 3-year multi-institutional collaborative project (lead, NASA Goddard) to develop climate indicators to track the seasonal evolution of the Arctic sea ice cover. [Peng]

Individual Highlights

Jesse Bell

Surface Observing Networks

- Working with a variety of groups at the Centers for Disease Control and Prevention on projects related to climate and health and utilizing NCEI data (e.g., valley fever, *Vibrio vulnificus*, heat wave indices, and mental health).
- Working on a number of projects with U.S. Department of Agriculture (USDA) to extend the historical soil moisture record for the United States. Using a soil moisture model that can learn the response of soil moisture to precipitation events, when both measurements are available, and then extend the record to historical periods that have only precipitation measurements.



- Working on understanding the spatial representativeness of a point-based measurement to the surrounding area for improved validation/calibration with satellite measurements. Installation of temporary dense soil monitoring networks at two locations improved understanding of how soil moisture varies within a small area. This work will directly benefit the NASA's Soil Moisture Active Passive (SMAP) satellite mission.
- Used USCRN soil climate observations to evaluate the national changes in soil moisture for improved drought monitoring.



Figure 3. Solid lines indicate the average percent change in summer (JJA) soil moisture from the three-year average (2011–2013). Each line represents the 5cm (red line, diamond), 10cm (blue line, square), 20cm (green line, triangle), 50cm (orange line, cross), and 100cm depths (purple line, circle). Dashed black line indicates the average percent change in total precipitation for each hydrological year from the three-year average (2011–2013).

Jim Biard

Reference Environmental Data Records

- Generated obs4MIPs datasets from the entire period of record for three different CDRs: the HIRS Outgoing Long-wave Radiation CDR, the Optimum Interpolation Sea Surface Temperature (OISST) CDR, and the Sea Ice Concentration CDR. Based on the success of this project, six other CDR's have been proposed for conversion to obs4MIPs.
- The Optimum Interpolation Sea Surface Temperature (OISST) product was selected as a pilot case for investigating the feasibility of refactoring scientific software to meet CDR program requirements while keeping costs manageable. Accomplishments to date include development of a robust and configurable replacement for the refactored control scripts, development of an application to update the format of one of the current production software outputs, and assistance in performing an analysis of differences between the current production outputs and the refactored software outputs.
- Ported the Climate & Forecast Metadata Conventions compliance checker application to an NCEI server where it is available for use by NCEI personnel.
- Assisted in porting the Normalized Difference Vegetation Index (NDVI) CDR to the United States Geological Survey (USGS) EarthExplorer data system. This involved converting the CDR files from netCDF format to GeoTIFF format. Worked with USGS to get a colormap obtained from the NDVI CDR Principal Investigator team applied to thumbnails and browse images for the NDVI measurements.
- Working with the Principal Investigator for the High resolution Infrared Radiation Sounder (HIRS) Outgoing Long-wave Radiation (OLR) Monthly CDR to refactor the production software in preparation for continual production operations within NCEI.
- Built and deployed a web page that provides a detailed view of the scientific units understood by the Unidata UDUNITS software package.

Jonathan Brannock, Scott Stevens, Scott Wilkins

Data Stewardship / Access and Services Development, Information Technology

Support for NOAA Big Data Project

CICS-NC is providing technical and scientific support to help make data from NCEI available via several cloud-based services as part of NOAA's Big Data Project. This project established a partnership between NOAA, Amazon Web Services, Google Cloud Platform, IBM, Microsoft, and the not-for-profit Open Cloud Consortium. The goals include providing the public and private sectors with unprecedented access to environmental data and positioning data in close proximity to cloud-based high-performance computing resources, which will expand opportunities for both research and economic development.

As part of this initiative, the entire Level 2 Next Generation Weather Radar (NEXRAD) archive from NOAA's NCEI is being transferred to both the Amazon Web Services and Microsoft Azure platforms.

On October 27, 2015, Amazon Web Services became the first of the Big Data partners to make NEXRAD data available publicly via their website. The AWS platform provides users with seamless, single-API access to both historical and real-time NEXRAD data.



Figure 1. NEXRAD data is now available via Amazon Web Services.

2015-2016

Current Infrastructure

- High speed networking
 - > 802.11 AC WIFI
 - › Video Communications
 - > 10 Gigabit Ethernet
- High-performance computing
 - > 45 Nodes
 - > 528 Cores / 3.2TB RAM
- Virtual Machine Platform
 - > 6 Hosts, 72 Cores, 640GB RAM
 - Over 30 virtualized systems
- Data services
 - > Over 1.2 PB on disk
 - > Over 2.25 PB on Tape
 - > 8 Gigabit Fiber Channel

Other Recent Accomplishments



- Continuing management of system security, OS and application updates, and infrastructure upgrades
- Provided enhanced videoconferencing capabilities in support of the transition to the new, multi-location NCEI organization
- Rolled out a new scheduling tool (OpenLava) for managing high-performance computing cluster jobs
- IT staff continue to refine and improve the Institute's high-performance computing infrastructure. Virtualization capabilities have been transitioned to a new implementation (*oVirt 3.6*), which allows for better stability and reliability while reducing the management demands.
- The Institute moved to using Google apps for email, which also provides access to Hangouts, Calendar, and other Google services while improving integration with NOAA and NCSU, who also use Google apps.
- Improvements to tape vaulting allows our 500-slot tape library to manage 1200 tapes.

Andrew Buddenberg

Climate Assessments

• Metadata for the figures used in the USGCRP Climate and Health Assessment were transmitted to the U.S. Global Change Research Program's Global Change Information Service (GCIS) on schedule. Improvements to software during this process resulted in gcis-py-client 1.1 being released to the public. Development of our next-generation, real-time climate science metadata collection system is nearly complete (figure below).

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	U.S. Global Chang 1800 G Street, NW Washington, D.C.	te Research Program I, Suite 9100 20006 USA	Tel: +1 202 223 6262 Fax: +1 202 223 3365 Privacy Policy					

- In anticipation of the Fourth National Climate Assessment, a processing framework for the LOCA (Localized Climate Analogs) dataset was developed. This dataset is relatively large (11 TB) and requires an HPC (High Performance Computing) cluster to deliver results in a timely fashion. The eponymous processing framework can seamlessly scale to any number of CPUs and runs modular, arbitrary functions against the data to accommodate unforeseen requirements.
- Using massively parallel MPI compute cluster, developed value-added pressure dataset from 20th Century reanalysis data in support of Extra Tropical Cyclones/Blocking Highs research.



Sarah Champion

Climate Assessments

- Successful collection of all metadata and copyright permissions for the Impacts of Climate Change on Human Health in the United States: A Scientific Assessment:
 - > first success of its kind
 - > proof of concept of end-to-end metadata collection process executed by participating report authors, guided by TSU
 - > 62 figures with 110 individual images in total, and 7 data sets
- Full documentation of original metadata for the NOAA NESDIS Technical Report Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment
 - > 78 figures, each with as many as 8 individual images, and 4 data sets
- Ongoing coordination of first-ever U.S. State Climate Summary project, detailing climate change projections for each state
 - > Co-authoring content
 - Coordinating graphics development (as many as 12 graphics per state)
 - Co-coordinating review between Regional Climate Center Directors and State Climatolgists
 - Co-coordinating formal NOAA-level review



Figure 1. Sample draft layout of the NOAA State Climate Summary report for New Mexico.

Linda Copley and Lou Vasquez

Access and Services Development

- A software development team developed to employ Agile Scrum principles continues to support the existing Ingest Archive System used at the Asheville NCEI location.
- Supported Operations with numerous enhancements and corrections to the Ingest Archive System. Extended system to include file ingest using http, and archive using secure FTP protocols.
- In collaboration with NCEI in Boulder, CO, we installed a proof-of-concept instance of the Common Ingest system used in Boulder on CICS-NC hardware in Asheville. This proof-of-concept is being evaluated for potential

implementation in operations at the Asheville location. The architecture allows for ready addition and modification of software components (figure below). Enhancements required for use at the Asheville location have been identified, following analysis and load-testing. Planning is underway to implement the new ingest architecture in the production environment, initially for one data set.

• Monitoring of the Local Data Manager (LDM) service was recommended following significant undetected failures of upstream data providers for National Weather Service



(NWS) data. A monitoring solution was created which connects to the live LDM application event stream, tracks state to deduce processing metadata, and reports that through the existing IAS monitoring system.



Jenny Dissen and Theresa Stone

Climate Literacy, Outreach, and Engagement (Jenny Dissen)

- Jenny Dissen partnered with Phil Hanser of the Brattle Group to present at the National Association of Regulatory Utility Commissioners (NARUC) Summer Meeting in July 2015 to understand requirements for environmental information, particularly related to their upcoming survey state plans for climate change resiliency and the potential impacts to the energy industry.
- Otis Brown and Jenny Dissen currently serve on the Executive Advisory Council (EAC) for the Utility Analytics Institute, a membership-based group for energy industry professionals that discusses strategic analytics issues and promote leading practices of innovation to transform the energy business. Otis Brown, Ken Kunkel, and Jenny Dissen presented at the Fall 2015 EAC meeting on climate risks and impacts at Southern Company Headquarters and attended the Utility Analytics Summit (New Orleans, October 2015) to further build collaborations with industry partners on uses and applications of environmental data.
- Leading NCEI in the development of a robust customer and engagement solution to improve customer information and engagement, understand customer requirements for environmental information, and develop strategic and targeted engagement discussions.
- Worked with the NCEI Data Information Services, Communications, and Outreach team to develop a sector prioritization activity for the following NCEI calendar years, mapping work efforts to sector prioritizations.
- Contributed to the planning and hosting of the 2015 Climate Data Record Program's 2015 Annual PI meeting, in Asheville, NC. The meeting focused on sharing the latest information from NOAA's CDR Program, best practices, and new processes, and included a featured discussion on collaboration with other U.S. Government and international agency program leads.

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

• Worked with NCEI to develop and host an executive forum discussion on "Moving from Environmental Data to Resilience" on January 14, 2016, in New Orleans, Louisiana. The meeting was held in conjunction with the annual meeting of the American Meteorological Society.



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

• CICS-NC also supports Asheville Buncombe Sustainable Community Initiatives (ABSCI), which successfully launched The Collider, a consortium of public-private partners focused on climate adaptation and resiliency of communities and businesses in Asheville, North Carolina.

The Collider project includes a collaborative work and event space in downtown Asheville. The Collider's office/co-working space officially opened in early 2016.

Outreach Activities Coordination (Theresa Stone)





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

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



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



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



Jessicca Griffin

Climate Assessments

- Refined approximately 500 figures for NOAA's State Summaries for the National Climate Assessment and designed the layout to house the summaries.
- Collaborated with fellow members of the NCEI visual communications team to design and produce the PDF versions of the U.S. Global Change Research Program assessment of the impacts of climate change on human health.
- Also created or refined approximately two dozen figures for the US-GCRP climate and health assessment, working with author teams to develop new infographics, improve communication and clarity of scientific figures, and establish a consistent look and style for figures across the report.



Example scientific figure and infographic from the USGCRP Climate and Health Assessment.

Climate Literacy, Engagement, Outreach, and Communications

- Provided graphics support for a variety of NCEI communications projects, including work on figures and layout design for the "State of the Climate" and "Explaining Extreme Events" reports published annually in the *Bulletin of the American Meteorological Society*.
- Developed and polished Institute communications materials, including a new brochure.

sure Pathway Diagram

Each topical chapter includes an exposure pathway digar (see Figure 1). These compatial digaram litturtes a key example by which climate charge affects health within the and of interest of that chapter. These diagrams are not meant to be comprehensive representations of all the factors that affect numma health. Rather they summarize the key connections between climate drives and health in the context of other factors that positively or negative in themeon health cutomes.

uence health outcomes. e exposure pathway diagram in Chapter 1: Introduction: war Change and Naman Health is a high-level overw of the main routes by which dimate change affects this, unmuniting the linkaged scattering the the following opters. Because the exposure pathway diagrams m/y on majes from a specific health toojc area, a diagram is not used in Ougher 9: Populations of Concern a, at that they denoting according to the law high horizont. For other include reasests highlight: Temperature-Before and Death and Times, 24 And Death ymacst, there here a binases, and Water-Marked Times. It reases the highlight to the second term of the other second term of the highlight to the second term of the other second term of the highlight to the second term of the highlight term of the second call of the highlight term of the other second term of the other second term of the second term of the second term of the highlight term of the other second term other second term of the other second term of the other second term of the highlight term of the other second term other second term of the other second term of the second term of the highlight term of the other second terms are applied with modeling allows and the drag present an integrate modeling second term of the highlight terms terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the highlight terms of the other second terms of the terms of term



⁴⁻IMPACTS OF EXTREME EVENTS ON HUMAN HEALTH

Introduction

about in ground of the Ontering States i and a wave optimised optimised—in items of both lives lost and economic gass—from observed changes in the frequency, internally unation of central waterme events (Figure 1). Climate do projections show that there will be continuing increases is occurrence and severity of some extreme events by the e fibe century, while for other extremes the lists to clima change are more uncertain (Table 1). (See also Ch. 1: Intrition)

Four categories of atoreme events with important health impacts in the United States are addessed in the chapters 12 flooding mainted to entireme precipitation, hurintanse, and on some thread states. The health impact of atoreme heat enterme to dura discussed in Chapter 2: Temperature Pelader integrate and states and lines. The health impact of a durates integrate addition to adverse health outcome. The air capability for additional to adverse threads boost and air in Chapter and additional to adverse health outcome. The air capability to adverse head to addite the are discussed in Chapters 2: Marganian additional to adverse heads boost and air in Chapters 1: Air Quadi impacts. Monogin mental health effects are noted briefly becaused of the adverse heads have a strength of the chapters 1- developed and hurter are come and the chapters 1- developed advection of While it is include that enteress can have health impacts us a dash or injury during a weet fift or anning, downing during floaded, health impacts can allo occur before or after an enteress evera a studioda any be invalued in studies contained a studies of the studies of the studies contained cancer. Health risks may also using offer the contained cancer, the studies that any also the studies as a result of damage to property, distribution event too place, and contained algoridation, and other factors. Listence events informatives and place intervents, social and exerct too place, there into a studies of the studies of the studies of the studies environment in a given to action, but these lasses of the studies or composition in a given to action, but these lasses inducing in the studies of the studies.

pramic interactions between extreme events, their physical spacts, and population vulnerability and response can make diricult to quantitatively masure all the health impacts at may be associated with an externe event type, particary those that are diricultud over longer periods of the efficiency to integrate the same periods of the efficiency to integrate the unan health outcomes into climate makes, and thus projections of future health hurdens as to externe event used relimer through each outcome to be enterne event used relimer through each out and burdens as to enterne event used relimer through each out and burdens as to enterne event used relimer through each out and burdens as to enterne event used relimer through each out and burdens and the effect of the effect of the effect of the effect of the event of the effect of the



Pages from the Climate and Health Assessment.

Paula Hennon

Climate Assessments

• Program Management support for the development, implementation, and execution of current year operating plans and budget implementation timetables for the National Climate Assessment Technical Support Unit and the U.S. Global Research Program activities, web services, and technical report production infrastructure.

Other NCICS Projects

• As founding Director of the Partnership for Resilience (PfR), an NC State University consortium, assembled an Advisory Board and convened preliminary Advisory Board meetings, drafted the consortium charter and bylaws, and developed a business model and financial plan. The mission of the PfR is to empower society to consider environmental variability in decision-making processes to address increasingly challenging social, environmental and economic consequences. The PfR's government, business, academia, and non-profit partners will work together to develop innovative approaches to the societal stress and opportunities from environmental change based on the latest science, private-sector expertise and best practices.

Business & Industry will ...

- · Share challenges and experiences with climate risks
- · Propose projects for working group activities

Benefits:

- · Access to a network of other businesses sensitive to climate
- Opportunities to learn about best practices for adaptation
- · Learn about capabilities available in other sectors
- Have their challenges drive research and development agenda

Partner Organizations will ...

- Share community-specific experiences with climate risks
- · Propose projects for working group activities

Benefits:

- · Access to a network of other businesses sensitive to climate
- · Opportunities to learn about best practices for adaptation
- Learn about capabilities available in other sectors
- · Have their challenges drive research and development agenda
- Business support for collaborative projects
 A network of experts and potential clients
 Exposure to best practices and case studies
- Well developed best practices
- Highlighted case-studies and tools

Partnership for Resilience

- ♦ Student Career Grow
- Improved understanding of adapta
- Participation in cross-sector projects
 Exposure to federal resources

Academia will ...

- · Share relevant research experiences
- Provide educational resources

Benefits:

- Greater exposure to adaptation problems
- Greater exposure to federal resources and activities
- Opportunities for student career growth
- · Opportunities to participate in projects with compensation

- ♦ Better understanding of stakeholder needs
- ♦ Access to audience for products and services
- ♦ Better transition from research to applications

Government will ...

- Share up to date information on resources and plans
- Identify tools and projects ready for transition to the private sector
- Resource selected projects, as appropriate with in-kind expertise
- Share use-inspired science

Benefits:

- · Greater exposure of activities and accomplishments
- · Sustained access to a broad community to respond to potential plans

Anand Inamdar

Reference Environmental Data Records

- Calibration for the Geostationary Operational Environmental Satellite (GOES) series for the extended period of 2010–2015 (Figure 1) has been completed. Results compared favorably with the ISCCP and previous calibration and a paper has been published on the calibration of the visible channel of the ISCCP (International Satellite Cloud Climatology Project) B1U data.
- Calibration of the visible channel for the full GOES series of satellites has been processed separately and delivered for the Global Geostationary Surface Albedo project (PI is Jessica Matthews);
- Extensive support for the transition of the ISCCP project to NCEI. The latest version of the ISCCP processing code, Build 5, was delivered and implemented in September 2015, and has undergone several modifications and upgrades over the past year. Major contributions included:



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

- Development of software packages for the automated Quality Control (QC) of the ISCCP B1 and AVHRR Global Area Coverage (GAC) data, which are core inputs in the generation of the next generation H-series ISCCP cloud products;
- Visual inspection of the ISCCP B1 and AVHRR GAC imagery for the full base period (1983–2009) has been completed;
- Delivery of fully documented code to perform calibration of ISCCP B1 data to the ISCCP team for inclusion in the H-series production catalogue;
- Scientific analysis of the ISCCP H-series products from Build 5 runs commenced recently.

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



IGM : GM = 64.47 GMn = 5.50 GMx = 99.50 LM = 56.89 LMn = 5.50 LMx = 94.80 WM = 67.64 WMn = 8.30 WMx = 99.50 M : TM = 55.62 TMn = 5.50 TMx = 95.30 NPM = 62.82 NPMn = 10.10 NPMn = 90.60 SPM = 83.00 SPMn = 22.10 SPMx = 91.9



2 : CM = 64.72 GMn = 6.50 GMz = 99.50 LM = 56.28 LMn = 6.50 LMz = 93.50 WM = 68.51 WMn = 11.50 WMz = 99.50



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CMIP5

Kenneth Kunkel

Climate Assessments

- Publication of NOAA Technical Report TR-144 "Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment," comparing CMIP3 and CMIP5 simulations, in support of the National Climate Assessment.
- Lead PI on an awarded Strategic Environmental Research and Development Program (SERDP) grant. This is a \$2.8 million (\$1.53 million to NCSU), five-year project supporting incorporation of effects of climate change into rainfall design values. Work this year included identifying and evaluating trends for extreme precipitation events for selected combinations of average recurrence interval and duration.
- Drafts of 50 states for the NOAA State Summary project have been completed. Twenty-six have been sent out for the formal NOAA anonymous external review process. Express interest exists already in these summaries.
- In support of the upcoming Climate Science Special Report and the Fourth National Climate Assessment, the Localized Constructed Analogs (LOCA) data set was obtained. This is a new statistically-downscaled daily data set based on CMIP5 simulations at 1/16th-degree spatial resolution for the conterminous United States. Computer programs to process these data were developed and an initial set of 23 derived climate variables were calculated.
- Results of Northern Hemisphere analysis of snow trends are generally consistent with simple hypotheses for the likely effects of global warming. In particular, seasonal maximum snow depth has been decreasing in most areas where sufficient data are available to evaluate trends.
 - Global analysis of extreme precipitation trends, finding strong upward trends in middle to high latitudes of the Northern Hemisphere; inadequate data availability elsewhere to make general conclusions.



Simulated Decadal Mean Change in Annual Temperature: Contiguous U.S. Model Distributions for CMIP3 and CMIP5

CMIP3



Figure 1. Figure from the NOAA NESDIS Technical Report TR-144.



Ronnie Leeper

Surface Observing Networks

- The new precipitation algorithm for the U.S. Climate Reference Network (USCRN) was deployed this year, wrapping up a multi-year effort to improve the network's capacity to monitor precipitation at a 5-minute frequency. Currently working with the National Ecological Observatory Network (NEON) to set up an operational version of this algorithm for their precipitation system.
- In a collaborative effort with Scott Stevens of CICS-NC, a preliminary comparison of USCRN precipitation intensities with the Q2 radar analysis has revealed step changes in radar-based precipitation associated with changes in the Z–R relationship. While this was expected at the higher intensity range (moderate to intensity precipitation) to better handle instances of hail, the changeover from stratiform to convective precipitation was also evident.
- Analyzed changes to USCRN precipitation patterns over the 2012 drought and compared USCRN soil conditions to a commonly used reanalysis model: the North American Regional Reanalysis. These two studies highlighted the severity of the 2012 drought and the model's capacity to simulate the evolution of hydrological extremes. In addition, the development of a soil product for the USCRN that can monitor both sides of hydrological extremes (droughts and floods) is currently underway.

Climate Assessments

• Developed and deployed an approach to create ensemble average

proach to create ensemble average extra-tropical cyclone (ETC) tracks from the 20th Century Reanalysis. This dataset contains tracking information for weather systems outside of the tropics (i.e., Nor'easters, Alberta Clippers, etc.) in much the same way hurricanes are tracked. The track data dates back to the 1870's and allows further investigations into ETC track

patterns (i.e., poleward progress of mid-latitude weather systems, changes in track densities with interannual oscillations, etc.). An interactive website has been set up to allow users to access the dataset (see figure 2): https://etcsrv.cicsnc.org/ETCv8/.

• As a follow-up to the ETC project, an ongoing analysis utilizing this dataset is investigating changes in track density anomalies with Madden Julian Oscillation (MJO) phases. This is a multi-institutional collaboration with folks from CICS-NC (Carl Schreck), Colorado State University, and the University of Tasmania. Preliminary results reveal Nor'easter type tracks have a more positive anomaly (are more frequent) during MJO phases 7–8, which seems to correlate well with significant Northeast snow events based on NCEI's Regional Snowfall Index (RSI) scores.



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



Figure 2. A snapshot of the ETC-viewer showing ensemble ETC tracks for March 1993 colored by track intensity (member mean peak pressure gradient). A popup of the March-93 super storm (highlighted in green) reveals additional track attributes in the top-right when tracks are clicked-on.

Angel Li

Climate Assessments

- Web development support for globalchange.gov, including implementation of an extensive list of requested enhancements.
- Design and programming of the website for the U.S. Global Change Research Program's Climate and Health Assessment. The website is now available at http://health2016.globalchange.gov/. This site is fully responsive, i.e., the site adjusts to the current screen width, be it on a phone, a tablet, or a desktop display. Metadata has been collected for every figure in the report and is easily viewable on the website.



• In preparation for the completion of the U.S. State Climate Summary project, a new site was designed and implemented in Drupal. The development site includes a prototype of the home page, a clickable map of the 50 states, and fact sheets rendered as HTML pages. The project team will be dealing with over 1000 figures later this year.

Climate Literacy, Outreach, Engagement, and Communications

- Continuing work on monitor.cicsnc.org, which provides access to a variety of exploratory tools for accessing and viewing climate and weather data.
- Development of a new version of the Institute website is now underway, with completion expected in summer 2016. The site will follow NCSU branding guidelines while highlighting the expertise and activities of NCICS and CICS-NC.
- Developed HTML version of the Fall 2015 issue of the CICS-NC newsletter for distribution to stakeholders via email.

Jessica Matthews

Reference Environmental Data Records

• Spatial-temporal data fusion of land surface albedo products (collaboration with NC State University Statistics Department)



Figure 1: A pilot study of spatial-temporal data fusion for white-sky land surface albedo over a 50km x 50km region in Colorado. (a) 16 day (Jan 9-24, 2003) 500-m product from MODIS, (b) Daily (Jan 9, 2003) 2-km product from GSA, (c) Fused daily (Jan 9, 2003), 500-m product.

- Development of a Climate Data Record for the High-Resolution Infrared Radiation Sounder (HIRS) satellite atmospheric temperature and humidity profile. Recent work includes the use of neural networks to produce global profiles and development of a two-tiered bias correction methodology (Figure 2).
- Planning and implementation of large-scale (~300 TB) GOES imagery reprocess.

Climate Literacy, Outreach, Engagement, and Communications

• Uncertainty quantification for billion-dollar disaster events (see Figure 3).



Figure 2: The mean bias error (MBE) of HIRS retrievals compared to 2011-2012 radiosonde observations for global and latitude bands (HIRS values minus radiosonde values) for (a) temperature ($^{\circ}C$) and (b) specific humidity (g/kg).



Figure 3: Histogram presenting the results of a Monte Carlo simulation and confidence interval estimates for Hurricane Ike loss estimates.

• Mathematical support for analysis of web-based citizen science characterization of tropical cyclone imagery (<u>CycloneCenter.org</u>). An expectation-maximization algorithm was used to provide probabilities of a particular image's "type" (*e.g.*, curved band, eye, shear, *etc.*) based on multiple classifications of a single image. The algorithm can characterize classifiers with varying levels of expertise. Analysis suggests that about 200 classifications are needed to quantify an individual's precision, and each image needs about 10 classifications to determine image type.

Tom Maycock

Climate Literacy, Outreach, Engagement, and Communications

- Directed Institute communication efforts. Accomplishments include producing the third edition of the CICS-NC newsletter *Trends*, 13 press releases and web stories highlighting Institute publications and other news, managing social media posts, and overseeing development of the Institute's annual reports. Worked with Jessicca Griffin and other staff members to develop a new brochure and adopt stronger NC State University branding for communications materials.
- Provided editorial support to the NCEI communications and outreach branch, including drafting several web stories, coordinating communications effort for joint CICS-NC/NCEI activities, and copyediting several chapters of the "Explaining Extreme Events" supplement to the *Bulletin of the American Meteorological Society*.
- Currently working with other Institute staff to finalize a new version of the Institute's website. The new site will adopt standard NC State University web templates and will harmonize the NCICS and CICS-NC web presences.



Fall 2015 issue of the CICS-NC newsletter.

Climate Assessments

• Served as the Technical Support Unit's project coordinator and editorial lead for the U.S. Global Change Research Program report on the impacts of climate change on human health. Worked with key stakeholders at USGCRP and the U.S. Environmental Protection Agency to coordinate efforts of the various TSU teams and to manage processes, deliverables, and timelines. The TSU provided editorial support services through multiple rounds

of writing and review to ensure that the content was accessible to a broad audience. The editorial team also contributed to the development and revision of scientific figures and infographics and managed final delivery of the website content, report PDFs, and a variety of supporting materials.

The final report was released on April 4, 2016 and is available online at http://health2016.globalchange.gov. The official rollout event was held by the White House and featured presentations by White House Science Advisor John Holdren, EPA Administrator Gina McCarthy, and U.S. Surgeon General Vivek Murthy as well as panel discussions by report authors and other public health officials.

• Also provided editorial and communications input for the State Summaries project.



The USGCRP Climate and Health Assessment website.

Elsa Nickl

Workforce Development

- Estimation of topographic variables at high resolution (1 km) for the contiguous U.S. using Global 30 Arc-Second DEM (GTOPO 30). The variables are: elevation, latitudinal and longitudinal components of slope, and exposure to orography. This information is being used by Olivier Prat and other researchers in a project using high-resolution reanalysis (NEXRAD). Results were presented at the Fall Meeting of the American Geophysical Union.
- Evaluation of a new spatial interpolator based on topography, using cross-validation. Compared seasonal precipitation obtained using the new method with estimations from Cressman's traditional interpolator, the National Centers for Environmental Information (NCEI/NOAA), and the Parameter-elevation Regressions on Independent Slope Model (PRISM).



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

Ge Peng

Reference Environmental Data Records

• Evaluation of the accuracy of the NOAA NCEI High Resolution Infrared Radiation Sounder (HIRS) near-surface air temperatures in the Arctic using 1-year, quality-controlled data collected during the Surface Heat Budget of the Arctic Ocean (SHEBA) project (October 1997 – September 1998). Lead author on a paper published in the AMS *Journal of Atmospheric and Oceanic Technology*.

> Figure 1: Scatter diagram of co-located HIRS and SHEBA 2-m air temperature (T2m). The color code is for overcast (red: SHEBA cloud fractions \geq 85%), clear-sky (green: SHEBA cloud fractions \leq 10%), and cloudy (blue: 10% < SHEBA cloud fractions < 85%). The cross-correlation coefficient between these two time series is denoted in the plot by "r". The linear regression is in the plot along with the percentage of variance explained by the linear regression.



 Cutting-edge research on the scientific stewardship of individual digital environmental data products. Leading, coordinating, and participating in NCEI and across-agency DSMM (data stewardship maturity matrix) use-case studies and development of tools for integrating DSMM results for enhanced data discovery and decision-making support.

Results include multiple seminar and conference presentations and two published papers, with a third paper in development. A paper published in *D-Lib Magazine* introduces the roles of data, scientific, and technology stewards and describes the responsibilities of these stewards and other major stakeholders in effectively ensuring and improving data quality and usability.

Data Stewardship Maturity Ratings Global Historical Climatology Network-Monthly Version 3							
Preservability	\star	\star	\star	\star	$\stackrel{\frown}{\sim}$		
Accessibility	\star	\star	$\stackrel{\frown}{\sim}$	$\stackrel{\wedge}{\sim}$	$\stackrel{\frown}{\sim}$		
Usability	\star	\star	\star	$\stackrel{\wedge}{\sim}$	$\stackrel{\frown}{\sim}$		
Production Sustainability	\star	\star	\star	\star	\star		
Data Quality Assurance	\star	\star	\star	\star	$\stackrel{\frown}{\sim}$		
Data Quality Control/Monitoring	\star	\star	\star	$\stackrel{\wedge}{\sim}$	$\stackrel{\frown}{\simeq}$		
Data Quality Assessment 🛛 🖈 🛧 🛧 🕁							
Transparency/Traceability $\star \star \star$							
Data Integrity 🗙 ★ 🛧 📩							
Assessment Date: 09/04/2015 SMM Version: NCDC-CICS-SMM_0001 Rev. 1 12/09/2014							
Dark solid filled stars – completely satisfied Light solid filled stars – partially satisfied Non-filled stars – not satisfied							

Figure 2: Diagram of data stewardship maturity ratings for GHCN-M, version 3 as of 09/04/2015 in nine key components.

Olivier Prat

Reference Environmental Data Records

• Merged radar quantitative precipitation estimates (QPEs) from the high-resolution NEXRAD reanalysis over CONUS with rain-gauge observations (GHCN-D, HADS, CRN). Performed bias-adjustment of the radar-only product at the daily and hourly scale for the period 2002–2011. Currently implementing and testing techniques for optimally merging the rain gauge datasets and the radar-only estimates (inverse distance weighting, kriging, and variants).







• Work is progressing on the evaluation of using quantitative precipitation estimates (QPEs) derived from satellite observations to derive long-term global precipitation characteristics at fine spatial and temporal resolution. This is part of a broader effort to develop Reference Environmental Data Records (REDRs) for precipitation. Three papers have been published in the past year.



• Lead author of a manuscript published in *Hydrology and Earth System Sciences* (HESS) on the evaluation of multi-sensor precipitation estimates over CONUS.

Jared Rennie

Surface Observing Networks

- Developing the next version of NOAA's global temperature product, known as the Global Historical Climatology Network–Monthly (GHCN-M) dataset. This update includes nearly four times as many stations as well as updated quality control and bias-correction procedures. In October of 2015, GHCN-M version 4 was released as a public beta (known as v4.b.1). Work is underway to finalize the operational structure, provide documentation on the product, and produce a journal article that will be published along with the official data release.
- Developed a sub-monthly tool for monitoring impacts of temperature extremes in the United States. Using observations in near real time, station data is aggregated on different levels, including individual states, regions defined by the National Climate As-

2014 Annual Average Temperature 5 Degree Gridboxes



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

sessment, and the contiguous United States. Data is updated on a daily basis to analyze current temperatures against the period of record. Results are archived and are published on a public website for collaborative feedback (http://monitor.cicsnc.org/sub/).

A journal article describing the overall process is currently underway. Work is also underway at Clemson University to build a daily homogenization algorithm. Once published, their process will be incorporated here to provide a more robust analysis.

This data has already been used in numerous projects, including an analysis of heat waves done by the Society of Actuaries, along with a comparison of these values to teleconnections, including the Madden Julian Oscillation (MJO) and El Nino Southern Oscillation (ENSO).

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



4day NCA Region Ranks Ending On 2015 09 22

Figure 2: Map of regional 4-day temperature rankings produced by the CICS-NC sub-monthly product. The regions are based on those used in the Third National Climate Assessment.



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



Jennifer Runkle

Climate Assessments

• USGCRP Climate and Health Report: Provided editorial and project support for all aspects of TSU support for this report. As chapter coordinator and contributing author of the Extreme Events chapter, developed content for the chapter and coordinated responses to approximately 150 comments from the public, the NRC, and Federal agencies.



Figure 1: Estimated fatalities and billion dollar losses from extreme weather events. From the public comment draft of the USGCRP Climate and Health Assessment.

• Coauthor for the NOAA State Summaries project. Successfully completed 24 state summaries, with the majority in preparation for review or already sent out for Regional Climate Center/State Climatologist review.

Climate Literacy, Outreach, Engagement, and Communications

• Along with Jim Fox at the National Environmental Modeling and Analysis Center at the University of North Carolina Asheville (NEMAC), gave a talk on the Climate and Health Report and its connection with The Third National Climate Assessment to the Asheville Science Tavern.

Reference Environmental Data Records

 With the support of NEMAC, the Centers for Disease Control and Prevention's Climate and Health Program, and the Medical University of South Carolina, successfully submitted a NOAA Climate Program Office SARP proposal to address Coastal Hospital Resilience. The results of this study will inform coastal hospitals of how climate and weather data can be used to determine gaps in their preparedness plans and develop evidence-based climate-ready strategies to mitigate coastal flooding vulnerability.

Carl Schreck

Reference Environmental Data Records

 Launched an improved version of website for monitoring and prediction of the Madden–Julian Oscillation and other tropical variability: http://monitor.cicsnc.org/mjo/. The website serves ~300 unique users each month.

Other Projects

• Lone author of a paper published in *Monthly Weather Review* describing the effect of Kelvin waves on tropical cyclone activity around the globe (NASA funded). Figure 2 shows vertical composites of Lagrangian zonal wind for eastern Pacific storms that formed 3.00–3.75 days after a Kelvin wave's peak convection. The equatorial westerlies in Kelvin waves (red contours) are tilted westward with height. Before intersecting the Kelvin wave (*Fig. 1a*), the easterly wave (vertical dashed line) has only shallow westerlies (red shading). These deepen somewhat as they are



Figure 1: Left: Schematic of the interaction between Kelvin waves, the Madden–Julian Oscillation (MJO), and easterly waves during tropical cyclogenesis. The shading indicates zonal wind at 850 hPa with easterlies in blue and westerlies in red. The contours identify the rainfall associated with each feature. Right: Example time–longitude Hovmöller from http://monitor.cicsnc.org/ mjo/ of the outgoing longwave radiation (OLR) climate data record (CDR). The circle highlights a particularly strong Kelvin wave that preceded the formation of tropical depression Nine and tropical storm Ida in the Atlantic.

reinforced by the Kelvin wave's low-level westerlies (*Fig. 1b*). As the Kelvin wave passes, these westerlies deepen due to the Kelvin wave's tilt. Tropical cyclogenesis happens when these westerlies extend up to 400 hPa (*Fig. 1c*), which would support a deep cyclonic circulation.

• Provided research support to Riskpulse, Inc. for their development of WindRisk, a statistical model to forecast German wind power. The predictors in this model are the leading EOFs for a variety of atmospheric variables, including NCEI's daily outgoing longwave radiation (OLR) CDR. These EOFs were calculated using both raw daily data and time-averaged data to leverage intraseasonal-to-interannual climate variability. OLR proved to be a valuable predictor in week 2 and beyond. A sample forecast is shown in Figure 3.









Figure 2: Vertical cross-section composites for eastern Pacific tropical cyclones forming 3.00–3.75 days after Kelvin wave passage. Semi-Lagrangian zonal winds are shaded and Kelvin-filtered zonal winds are contoured.

April Sides

Climate Assessments

- Climate and Health Assessment website: Contributed requirements documentation with personas and scenarios, wireframe design, Drupal web development, and final refinements and delivery of the website. The report and website were launched on April 4, 2016: https://health2016.globalchange.gov/
- GlobalChange.gov web support: Continuing support of the U.S. Global Change Research Program (USGCRP) website, using the continuous integration workflow established by the hosting company.
- Metadata Survey integration: Integrated a newly developed metadata survey into existing author workspace sites to make metadata collection more user-friendly.
- USGCRP Public Contribution website (photo below): Contributed Drupal web development for the site used by the USGCRP to solicit nominations, technical inputs, etc. from the public.
- With Angel Li, obtained an NCSU Invention Disclosure for the Global Change Information System Metadata Looker.
- Developed the Drupal elements of a new version of the assessment author collaboration website tools. The new tool will be launched in May 2016. It will be used to support the forthcoming USGCRP Climate Science Special Report, the Fourth National Climate Assessment, and other reports.
- Provided project management functions for the TSU web team.

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User login Username or e-mail * Password * Create new account Request new password Log in	Welcome to the You have accessed the United site provides an interface for u Please login into the system or if If there are no projects for public Please click on the 'Help'' tab ab You must log in or create an Public Projects Availab • Local, State, Tribal, and Regional • Advisory Committee for the Sus	USGCRP Public Co d States Global Change Resear isers to provide input on USGCRF f you do not have an account, pleas c contribution available at this time ove for additional information abo n account to proceed. le for Public Contribution Collaboration tained National Climate Assessment	Ch Program (USGCRP ² -related activities. se click on Create New Account ut how to create an acco	ystem) Public Contribution System. This count (left). t link may not be shown. unt and login.
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U.S. Global Change Research Program 1800 G Street, NW, Suite 9100 Washington, D.C. 20006 USA	Tel: +1 202 223 6262 Fax: +1 202 223 3065	This website is operated by th Global Change Research Prog	ne University Corporation for A gram (USGCRP). Privacy Policy	tmospheric Research in support of the U.S.

Steve Stegall

Climate Assessments, Workforce Development

- Collocated High-Resolution Infrared Radiation Sounder (HIRS) surface temperatures to the ERA-Interim global LSAT 0.5° × 0.5° latitude/longitude and 24 times daily (hourly output) for the years 1980–2009. Includes the satellites M02, N17, N16,...,N06. Collocation is done at ≤ 50 km and hourly.
- Analyzed HIRS surface temperatures collocated to three global LSAT data sets.



Surface Observing Networks, Workforce Development

• Collocated and analyzed HIRS surface temperature to NOAA U.S. Climate Reference Network (USCRN) station data from 2006–2013. Constructed a best-fit equation to bias correct the HIRS surface temperatures as explained in figure 2. This correction improves the overall bias and RMSE for 2006 to 2013.



Figure 2. Scatterplot of the 2011 M02 bias (HIRS surface temperature minus USCRN surface temperature) vs. the HIRS surface temperatures for 2011. The black line is the best fit and the equation is: 0.1252202*x - 1.200186 in which x is the HIRS surface temperature. This equation is for HIRS temperatures at or above -15°C. For HIRS temperatures below -15°C, a bias correction is done which is represented by the black line at -3.078488. The units of bias and temperature are °C.

Laura Stevens

Climate Assessments

- Co-author on NOAA Technical Report TR-144 "Regional Surface Climate Conditions in CMIP3 and CMIP5 for the United States: Differences, Similarities, and Implications for the U.S. National Climate Assessment," comparing CMIP3 and CMIP5 simulations, in support of the National Climate Assessment.
- Served as co-coordinator for first-ever U.S. State Climate Summary project, detailing climate change projections for each state. Additionally, co-authored content, developed figures, and assisted with editing and review processes.
- Processed the Localized Constructed Analogs (LOCA) data set in support of the upcoming Climate Science Special Report and the Fourth National Climate Assessment. This is a new statistically-downscaled daily data set based on CMIP5 simulations at 1/16th-degree spatial resolution for the conterminous United States. An initial set of 23 derived climate variables have been calculated with additional variables in progress.





Figure 8a from NOAA NESDIS TR144. Projected change in seasonal mean temperature (°F) for the contiguous United States, for 2041–2070 with respect to the reference period of 1971–2000. These are multi-model means using CMIP3 SRES A2 (left column), and CMIP5 RCP8.5 (right column). Color with hatching (category 3) indicates that more than 50% of the models show a statistically significant change, and more than 67% agree on the sign of the change.

Scott Stevens

Reference Environmental Data Records

- Initiated work on a project to move the quality control of Hydrometerological Automated Data System (HADS) data from research to operations. CICS-NC work focuses on streamlining and automating existing algorithms so that they can be run autonomously and in an archive mode on archived data. Accomplishments include development of a decoder to read incoming HADS data in Standard Hydrometeorological Exchange Format (SHEF) and replicating existing metadata checks. The metadata checks have been streamlined and rewritten to run on a variety of machines.
- Work continues on a joint project with the NOAA National Severe Storms Laboratory (NSSL)/Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) in Norman, OK, to apply the National Mosaic and Multisensor Quantitative Precipitation Estimate (NMQ/Q2) algorithms to the entire archive of NEXRAD data (1997–2011). This reanalysis produced a suite of gridded precipitation products at a far finer temporal frequency (five-minute) and spatial scale (0.01°/1 km) than was previously available.

In addition to providing the data via cloud providers as part of the "Big Data" effort described earlier in this report, efforts are underway to introduce the completed dataset into the NCEI archive. A process is being finalized which will attempt to fill in the few remaining gaps in the record. The dataset is already being used in some applied science, including the use of hourly rain rates to study fatal traffic accidents, in the SERDP heavy precipitation project.



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

Brooke Stewart

Climate Assessments

- Assisted with development of a geopotential height-based algorithm that identifies contiguous high pressure blocking events using all 56 ensemble members of the 20th Century Reanalysis (20CR) data. The algorithm has also been adapted for use with the NCEP NCAR Reanalysis.
- Editorial support for the NOAA State Summaries project and the USGCRP Climate and Health assessment.
- Worked with senior staff at the U.S. Global Change Research Program (USGCRP) in the planning phases of the Climate Science Special Report (CSSR). Working with USGCRP staff, led the development of the timeline for the CSSR as well as the Fourth National Climate Assessment and developed the initial guidelines to authors for page limits and graphic limits for their individual sections. Also assisted USGCRP with the development of content for the first author meeting, which was held in Washington, DC, in April 2016



Figure 1: Frequency of blocking events by decade, ensemble mean for the first 25 ensemble members of the 20CR dataset.

Climate Assessments

- Identification and tracking of extra-tropical cyclones (ETC) in the CMIP5 simulations were carried out. Analysis of Northern Hemisphere ETCs in the CMIP5 models is focused on the future climate change of ETC frequency, intensity and duration.
- A 6-hourly dataset of geopotential height on pressure levels was created using CMIP5 temperature, surface pressure, and topography data. This dataset covers the time period from 1950 to 2100, and is used for identification and tracking of blocking anticyclones.
- Produced CMIP5 data with resolution of 5 km over the United States for analyses of climate change in each of the 50 states. Variables are surface temperature, precipitation, maximum and minimum daily temperature, maximum 1-day precipitation, and growing season length for four scenarios and historical simulations.
- Temperature scaled by global temperature with different warming thresholds was carried out for the 50 states and 8 NCA regions in the United States using CMIP5 data.



Annual time series of the cold season (November – March) ETC occurrences in the Northern Hemisphere. The numbers of ETCs are multi-model means from 23 CMIP5 global climate simulations for the historical period (1950-2005), and under the RCP8.5 scenarios (2006-2100).

CICS-NC Performance Metrics	FY16		
# of new or improved products developed	89		
# of products or techniques submitted to NOAA for consideration in operations use	18		
# of peer reviewed papers	41		
# of non-peered reviewed papers	7		
# of invited presentations	52		
# of graduate students supported by a CICS task	3		
# of graduate students formally advised			
# of undergraduate students mentored during the year	9		

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