



CISA

2011 - 2018 FINAL GRANT REPORT

*Flooded Charleston Peninsula after Hurricane Matthew, October 2016
Photo Credit: US Coast Guard, Flickr Creative Commons*

CAROLINAS INTEGRATED SCIENCES & ASSESSMENTS

PROJECT REPORT: 1 SEPTEMBER 2011 - 31 AUGUST 2018

NOAA AWARD NA11OAR4310148



RISA
Regional Integrated Sciences
and Assessments

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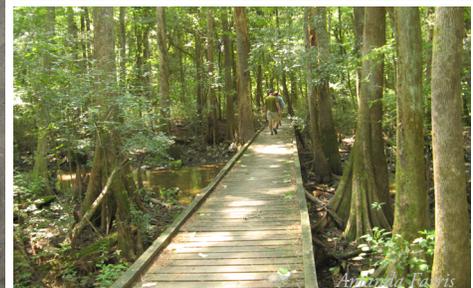
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THE CISA TEAM

CISA's interdisciplinary, multi-state research team works with partners, stakeholders, and decision makers across the Carolinas. Our core team consists of principal investigators, staff, and students based at the University of South Carolina, the University of North Carolina at Chapel Hill, and the South Carolina Sea Grant Consortium. Long-term partnerships with many of our collaborating investigators enables us to leverage expertise from other agencies and organizations to build robust and coordinated efforts around climate research and decision support. We look to our Advisory Committee to help us stay connected to other work in the region, keep a finger on the pulse of stakeholder needs, and advise on the balance of efforts and impact. The efforts of each of these team members is essential to the success of the program.



CISA Team Members at the 2016 Carolinas Climate Resilience Conference

CISA EXECUTIVE TEAM MEMBERS*

Kirstin Dow (Lead-PI), University of South Carolina
Greg Carbone (CoPI), University of South Carolina
Amanda Farris (Climate Outreach Specialist, Program Manager), University of South Carolina
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Kerry Guiseppe (Program Coordinator), University of South Carolina, 2017-2018
Chip Konrad (CoPI), University of North Carolina at Chapel Hill, NOAA Southeast Regional Climate Center

Kirsten Lackstrom (Program Manager) University of South Carolina
Ashley (Brosius) Stevenson (Climate Outreach Specialist), University of South Carolina, 2011-2012
Dan Tufford (CoPI), University of South Carolina
Jessica Whitehead (CoPI), North Carolina Sea Grant, South Carolina Sea Grant Consortium, 2011-2014
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Dates are included for team members who either joined or left during the reporting period. All others were active team members from September 2011 through August 2018.

EXTERNAL PARTNERS AND ORGANIZATIONS

COLLABORATING INVESTIGATORS

Tom Allen, East Carolina University , Old Dominion University
Ryan Boyles, State Climate Office of North Carolina, DOI Southeast Climate Adaptation Science Center
Dave Chalcraft, East Carolina University
Michael Childress, Clemson University
Paul Conrads, USGS South Atlantic Water Science Center
Michelle Covi, Virginia Sea Grant, Old Dominion University
Chris Fuhrmann, Southeast Regional Climate Center, Mississippi State University
Greg Kearney, East Carolina University
John King, North Carolina State University
Susan Lovelace, South Carolina Sea Grant Consortium
Hope Mizzell, South Carolina State Climatology Office
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Jan Moore, NOAA Center for Coastal Environmental Health and Biomolecular Research
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Thomas Webler, Social and Environmental Research Institute
Jessica Whitehead, North Carolina Sea Grant
Karin Yeatts, University of North Carolina at Chapel Hill



CISA team members with stakeholders and partners at the 2012 NIDIS Coastal Carolina DEWS Scoping Workshop



The CISA Team at work in the USC Geography Department Climate Lab

ADVISORY COMMITTEE MEMBERS

Jeff Allen, SC Water Resources Center at Clemson University
Frank Alsheimer, National Weather Service Columbia, SC
Jesse Bell, NC Cooperative Institute for Climate and Satellites
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Jerry McMahon, DOI Southeast Climate Adaptation Science Center
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Ellen Mecray, NOAA Eastern Region Climate Services
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Tim Owen, NOAA National Climatic Data Center
Linda Rimer, US EPA Region 4 Liaison to NC and SC
Gregory Sprouse, Central Midlands Council of Governments
Adam Stein, NOAA Office for Coastal Management
David Stoney, Kitchen Table Study Group, McClellanville, SC
Lauren Thie, NC Division of Public Health
Susan White, NC Sea Grant, NC Water Resources Research Institute

CISA'S ROLE IN THE REGION

Serving as a trusted source of climate information in the Carolinas



Photo Credit: Chandler Green

Established in 2003, the [Carolinas Integrated Sciences & Assessments \(CISA\)](#) is 1 of 11 [NOAA Regional Integrated Sciences & Assessments \(RISA\)](#) teams. RISAs are interdisciplinary research teams that work to expand and build the nation's capacity to prepare for and adapt to climate impacts by addressing science questions facing decision makers. RISA teams work at the regional level to address significant and timely climate issues.

The CISA team works to increase resilience in the Carolinas and the Southeast through decision-relevant climate research in collaboration with a wide range of stakeholders. We have established long-term partnerships with federal, state, and local government agencies, resource managers, nongovernmental organizations, and the private sector. Working at the intersection of climate with water, coasts, and health, we provide decision makers with tailored information that can be integrated into management and planning processes across multiple sectors. Our role is complemented by the [Southeast Regional Climate Center](#), part of the CISA core team.

We bring expertise on climate-related impacts to key management issues in the Carolinas. We are well-known for contributing to drought preparedness in the region, often working in collaboration with the offices of the North Carolina and South Carolina state climatologists to connect state efforts to the National Integrated Drought Information System (NIDIS), the US Drought Monitor process, and the National Drought Mitigation Center (NDMC).

Within the network of organizations working to address coastal climate impacts, CISA brings climate information and expertise in adaptation to collaborations with communities and other partners. We have developed long-term partnerships with the North Carolina and South Carolina Sea Grant programs and also work with Sea Grant programs in Florida, Georgia, Puerto Rico, and Virginia.

Over the course of this grant period, we have expanded work to better understand the implications of climate variability and change for public health, bringing significant capacity to the public health community, particularly in North Carolina.

This grant period has also been punctuated by a series of [extreme events](#) that have significantly impacted the region, including the [October 2015 heavy rainfall and flooding event](#), Hurricanes Matthew and Irma, drought and wildfires in the Western Carolinas, and excessive heat events. Our work is guided and informed by the information needs that arise following these events.

In addition to these projects and partnerships, CISA seeks to support the overall network of climate resilience providers in the region by connecting people across sectors and expertise within the Carolinas and facilitating the exchange of lessons between the Carolinas and Southeastern states facing similar issues. We organize the [Carolinas Climate Resilience Conference](#) and provide leadership to the [Southeast and Caribbean Climate Community of Practice](#), organizing their biannual meetings, to facilitate the development of a network among practitioners, communities, and academics working to enhance climate resilience. The Carolinas Climate Connections Listserv, our quarterly newsletter, and multiple social media accounts serve a niche role by focusing specifically on climate news relevant to the Carolinas.

The partnerships and collaborations we have established since we first began our work in the Carolinas are the foundation upon which we continue to build adaptive capacity in the region, serving as a trusted source of climate information for over fifteen years.

CISA

BY THE NUMBERS

Stakeholder Interactions

3,285 Stakeholders Engaged
representing over

530 Organizations



33 Projects



64 Stakeholder Events

Research

80 Journal Articles, Reports, Books, Book Chapters, Theses, and Dissertations



36 Student Research Assistants



10 Research Associates

Outreach

296 Oral Presentations, Posters, Panel Discussions, and Webinars



24 Newsletters



28 Federal, State, Local, and NGO External Committees Served

PARTNER & STAKEHOLDER ENGAGEMENT

The following series of maps represents the location of CISA team members, partners, and individuals who have participated in CISA-organized projects and events during this grant reporting period (September 2011 – August 2018). The placement of the symbols represents the county location of the individuals’ organization. The size of the circles reflects the number of participants. Weighted participation values were used to demonstrate the extent to which individuals participated in projects or events, with dark blue representing more in-depth or longer-term involvement, for example, by participating in multiple capacities and/or over multiple years.

CISA works with partners from the mountains to the coast of the Carolinas (Figure 1). Three areas show particularly high levels of engagement, although the work originating in these areas generally has a regional or statewide footprint. Raleigh, North Carolina stands out as many CISA advisory committee members work for state and federal agencies based there. The University of South Carolina in Columbia, SC houses CISA’s main office. The high level of engagement in Charleston reflects our long-term relationship with the SC Sea Grant Consortium and support of the Charleston Resilience Network.

CISA collaborates to share lessons throughout the Southeastern US where partners and stakeholders face similar challenges (Figure 2). Other partnerships extend across the country primarily by virtue of our work with other RISA teams and with the National Integrated Drought Information System (Figure 3).

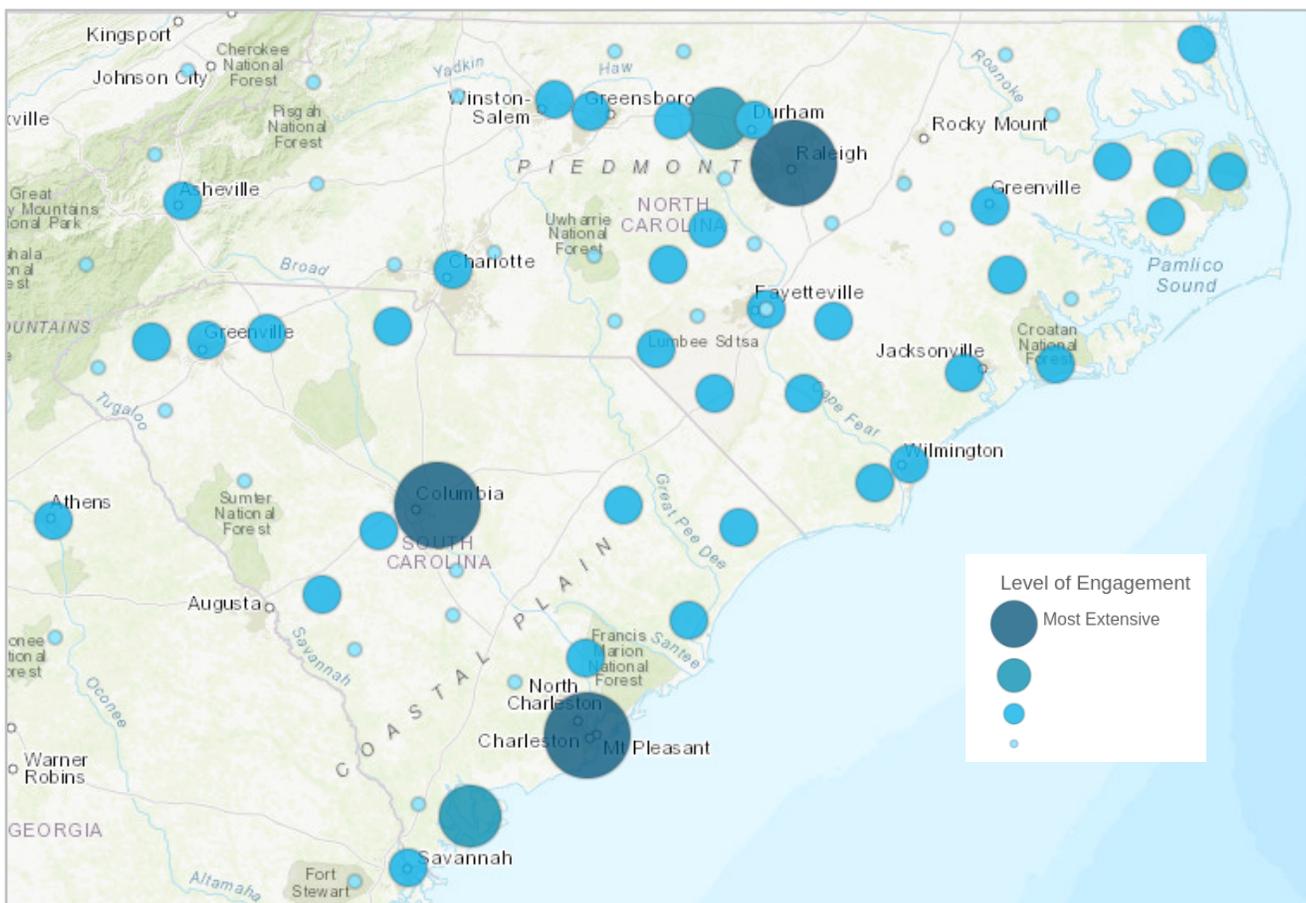


Figure 1: CISA team members work with project partners and stakeholders in the Carolinas from the mountains to the coast

2011 - 2018 CISA GRANT REPORT

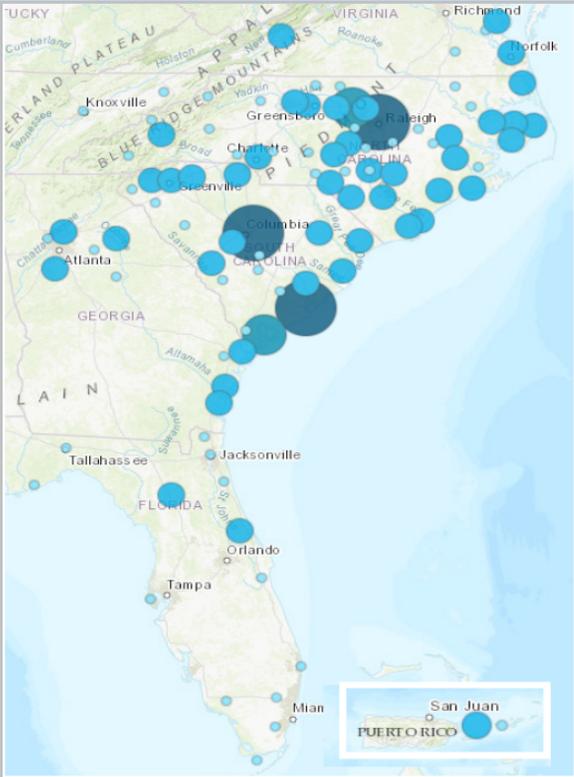


Figure 2: CISA engages with project partners and stakeholders throughout the Southeast, particularly through the Southeast & Caribbean Climate Community of Practice

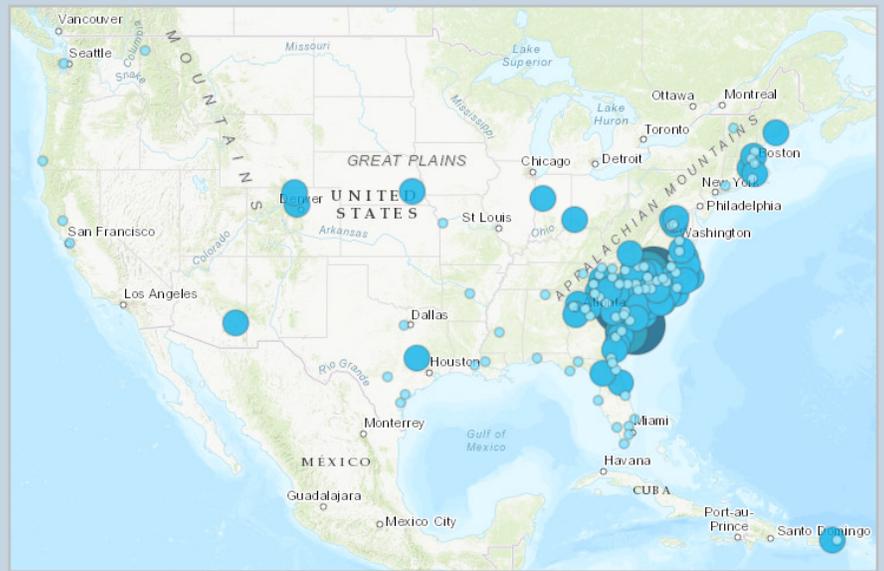
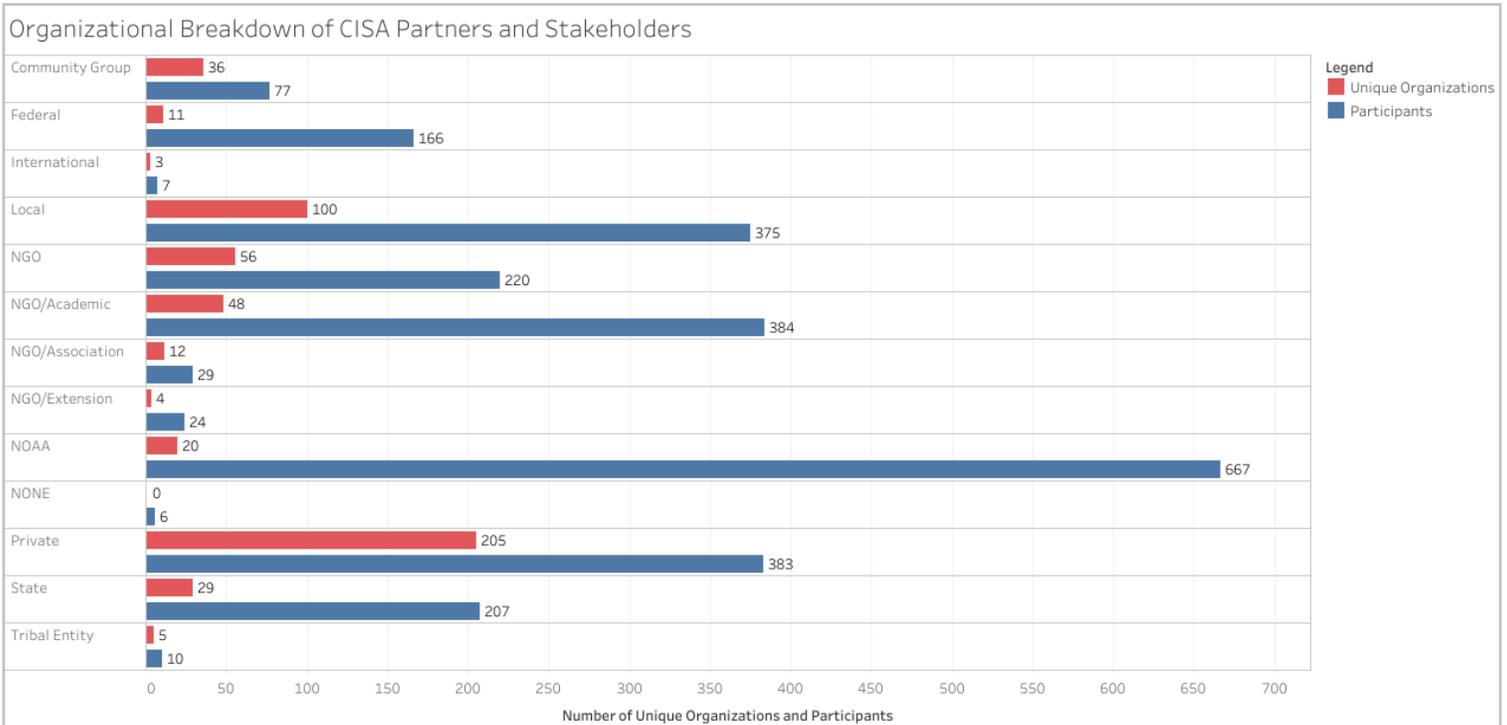
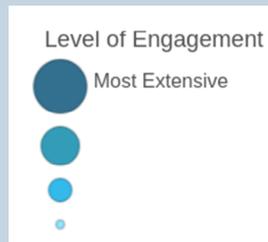


Figure 3: CISA engagement throughout the United States and Caribbean



The table above represents the number of unique organizations and individuals with whom we interacted as project partners, stakeholders, and event (workshops, conferences, etc.) attendees. The red bars represent the breakdown of “unique” organizations (i.e., each organization is counted once, regardless of the number of times someone from that organization may have participated in one or multiple activities). The blue bars represent the total number of individuals from each organization type who participated in a CISA activity. Using this measure, NOAA, local, NGO/Academic, and private sector organizations are the most “active” participants. Many of the private sector participants were engaged through Charleston Resilience Network activities .

CISA'S FOCUS AREAS

Our activities encapsulate five primary project and research focus areas

CLIMATE AND WATERSHED MODELING

The acquisition, generation, and processing of climate change scenarios was interwoven with a variety of CISA projects to meet the demands of an increasingly curious group of decision makers, eager to use the latest, most constructive climate change scenarios available for the Southeast. Assessing model projections of future precipitation patterns as well as evaluating impacts on infrastructure allowed us to provide stakeholders with information about both short and long term effects of climate variability and change. Considerable climate modeling and downscaling research efforts went into developing approaches to process and integrate climate information into watershed modeling projects as well. These hydrological modeling projects addressed a regional need for a comprehensive analysis of watersheds to understand how climate variability and change, including drought, affect water supply and quality.

DROUGHT

CISA's drought work included efforts to improve monitoring methods, develop a more comprehensive understanding of regional impacts, and support drought planning and early warning activities. Over the years the CISA team has worked with the National Integrated Drought Information System (NIDIS), the National Drought Mitigation Center (NDMC), and other RISAs on many efforts to advance drought monitoring and planning on local, state, regional, and national levels. Severe regional droughts in 1998-2003, 2007-2009, 2010-2013, and 2016-2017 served as the impetus for specific projects. This includes the Dynamic Drought Index Tool (DDIT) and projects identified through the NIDIS Carolinas Drought Early Warning System (DEWS) stakeholder workshop held in summer 2012.

COASTAL CLIMATE

The Carolinas coastline is vulnerable to both episodic and long-term climate and weather. The region is susceptible to hurricanes and strong coastal storms as well as flooding, erosion, degraded air and water quality, and habitat disturbance. CISA's coastal climate work centered on providing tailored, decision-relevant information to coastal communities and decision makers about the implications of climate variability and change and strategies to increase resilience to those impacts. Team members worked directly with communities to address needs related to waterfront management, sea level rise, saltwater intrusion, natural hazards, and community planning.

CLIMATE AND HEALTH

Weather and climate events, such as heat waves, heavy precipitation, and droughts, can have broad and significant impacts on human and ecosystem health. These impacts can be felt directly through increased morbidity and mortality associated with extreme events, as well as indirectly through the alteration and redistribution of disease transmission processes and environmental stressors. Team members sought to better understand the relationships between climate and human health with projects focused on the development of a heat health vulnerability tool, projected ozone impacts on air quality, and identification of patterns of climate and waterborne disease-related health outcomes. They also modeled how altered water quality conditions associated with changing temperature and salinity related to sea level rise may increase the habitat for *Vibrio vulnificus*.

COMMUNICATIONS AND OUTREACH

Increasing regional understanding of climate variability and identifying user needs for climate information, motivated CISA to refine investigations that lead to effective communication of results. CISA worked to support climate adaptation by providing opportunities for information exchange to increase awareness and utilization of climate knowledge. Team members facilitated climate workshops and a biannual conference to allow for environments in which stakeholders shared their knowledge and exchanged information about climate related activities. Using fact sheets, newsletters, and social media, CISA translated scientific data into usable formats for decision-makers and the public and promoted networks for sharing information.

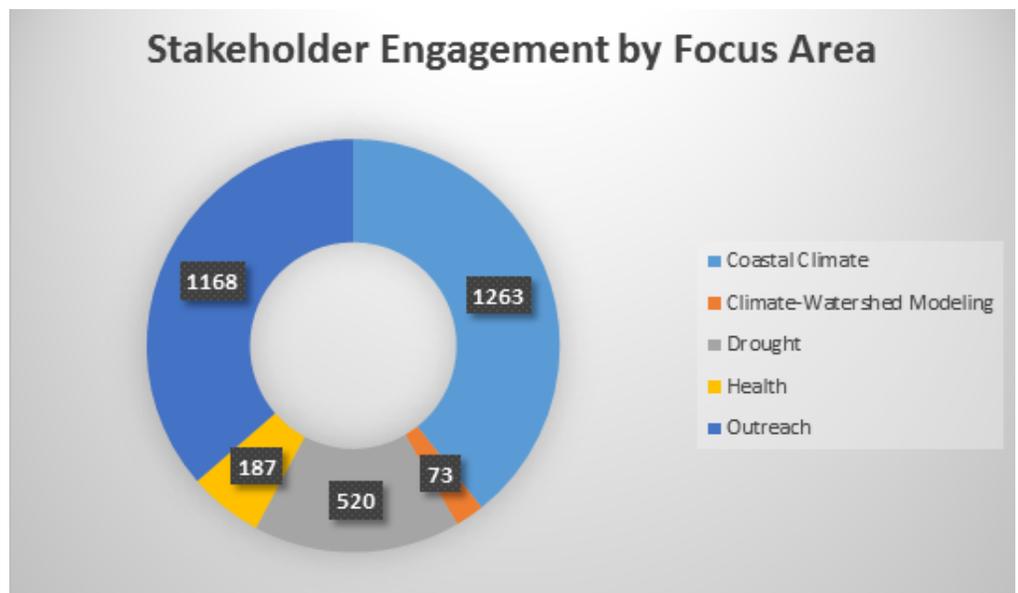


Figure 4: The number of individuals who participated in project and outreach events for the reporting period according to the focus area of the event

2011 - 2018 HIGHLIGHTS & ACCOMPLISHMENTS

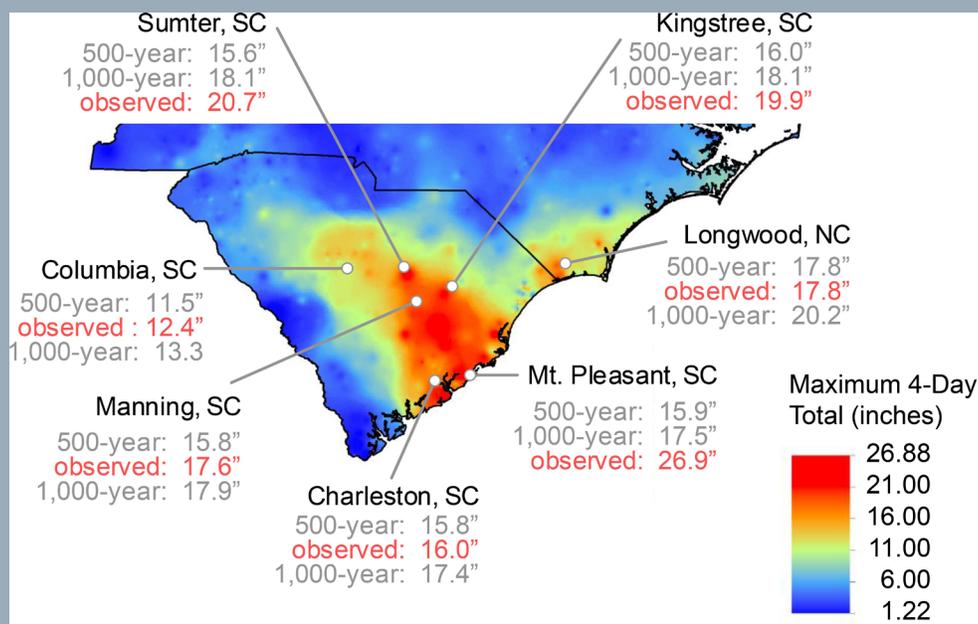
ASSESSING CLIMATE MODEL PROJECTIONS IN THE SOUTHEAST

In order to inform an assessment of regional climate models for the Southeast, CISA researchers evaluated climate data from the North American Regional Climate Change Assessment Program (NARCCAP). The goal of the research was to understand how well the regional climate models replicate the historical record (1970-1999) in order to assess their skill level in projecting future climate (2040-2069) in the region.

- Most models demonstrated high skill for temperature during the historical period, but precipitation skill was mixed due to the overestimation of the frequency of extreme precipitation events by several models.
- Projected minimum temperatures showed an ensemble mean increase between 1° and 2°C in the winter and early spring, and an increase between 2° and 3°C for all other months.
- Projected maximum temperatures showed an ensemble mean increase between 1° and 2°C in winter and early spring with increases between 2° and 4°C from mid spring through fall.
- Projected precipitation increased up to 10% in the eastern part of the region from late summer through early spring. Ensemble mean decreases of up to 10% occurred in January, April, June, and July.
- In western portions of the region, precipitation was projected to increase up to 10% in January through March, August, September, and November with an up to 12% decrease in precipitation in May through July, and October.

RESEARCH AND RESPONSE TO THE OCTOBER 2015 EXTREME RAINFALL AND FLOOD EVENT

A combination of meteorological conditions contributed to a historic rainfall and flooding event in the Carolinas in early October 2015. A trifecta of systems led to record-breaking precipitation totals, ranging from 6 to 21 inches, and devastating impacts, including loss of life. Infrastructure failures, including multiple dam breaches, were a major cause of the spatial extent and depth of the flooding in parts of Columbia, SC. Flood waters crested downstream in the days following the extreme rainfall leading to coastal flooding impacts and record streamflow. In order to provide a comprehensive assessment of the event from a climatological and meteorological perspective as well as to initiate conversation about rebuilding with resilience to future, similar events in mind, CISA produced an [informational 4-pager](#) focused on correcting misconceptions of the flood risk which was distributed throughout networks in the Carolinas. Carbone and Gao have continued research to assess the event as part of the [Climatological Assessment of Extreme Rainfall Events](#) project .



October 2015 Rainfall Totals - This map , created by CISA post doc Peng Gao, shows the maximum rainfall totals that fell over a 4-day period during this event as well as data from weather stations where 500 and 1,000 year recurrence intervals were exceeded. This graphic appears in the Southeast chapter of the Fourth National Climate Assessment.



Photo Credit: Amanda Farris

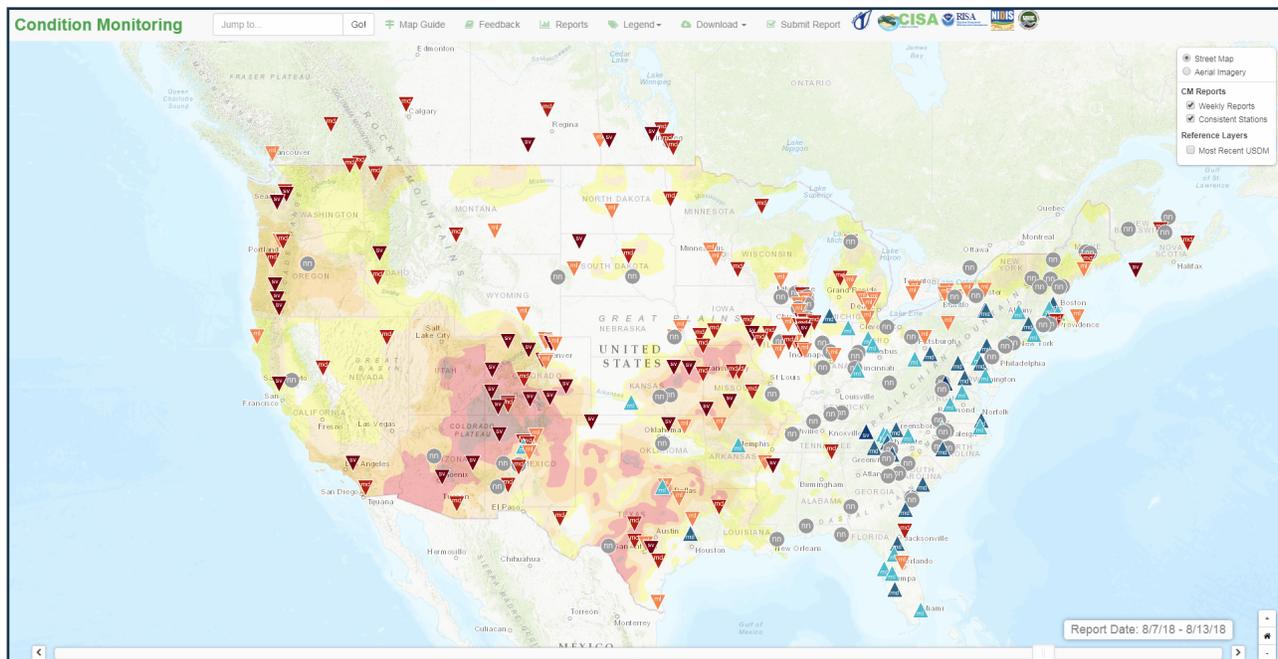
CREATING A NATIONAL NETWORK OF DROUGHT IMPACT REPORTERS

In early 2013 CISA team members organized a workshop to identify best practices for implementing a drought impacts reporting system and to develop a path forward for identifying and addressing challenges. Participants represented other RISA programs (CLIMAS, SCIPP, SECC), the CoCoRaHS network, the Southwest Climate Science Center, the National Drought Mitigation Center (NDMC), and NIDIS. Workshop findings were documented in “The Missing Piece: Drought Impacts Monitoring” and incorporated into the development of the citizen science condition monitoring project.

The Carolinas condition monitoring pilot project was launched in September 2013 focusing on the coastal Carolinas. Citizen science observers submit weekly reports through the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) website describing how the precipitation they have (or have not) received has impacted their community and local environment. The concept of condition monitoring, in contrast to traditional drought impacts reporting which sometimes only occurs once drought has become severe, is intended to create a baseline of information to assess gradual change over time and capture impacts of the slow-moving phenomenon on drought. This approach was also easier for observers as they did not have to define a drought versus dry conditions.

- In Phase 1 (September 2013-December 2015), 68 project volunteers provided 1,572 condition monitoring reports. Feedback interviews with decision makers found the reports to be relevant and suggested ways to improve the usefulness and usability of the information.
- In response to this feedback, Phase 2 (January 2016-December 2017) focused on developing a condition monitoring scale bar and Carolinas web map, and new tools to streamline the processes of submitting and accessing condition monitoring reports. 303 volunteers submitted 3,165 reports. Interviewees from the State Climate Office of North Carolina, National Weather Service Offices, and the US Drought Monitor author list indicated using reports to assess conditions and make drought designations.
- During Phase 2 the project was expanded to a national effort. CISA collaborated with CoCoRaHS and NDMC partners to modify the web map, training materials, and other informational resources for the national network of CoCoRaHS observers. The condition monitoring report form launched to the national network in October 2016 and the national web map was made available in September 2017.

Between October 2016 and May 2018, 3,617 CoCoRaHS volunteers across all 50 states, Puerto Rico, and the Bahamas submitted 29,236 condition monitoring reports.

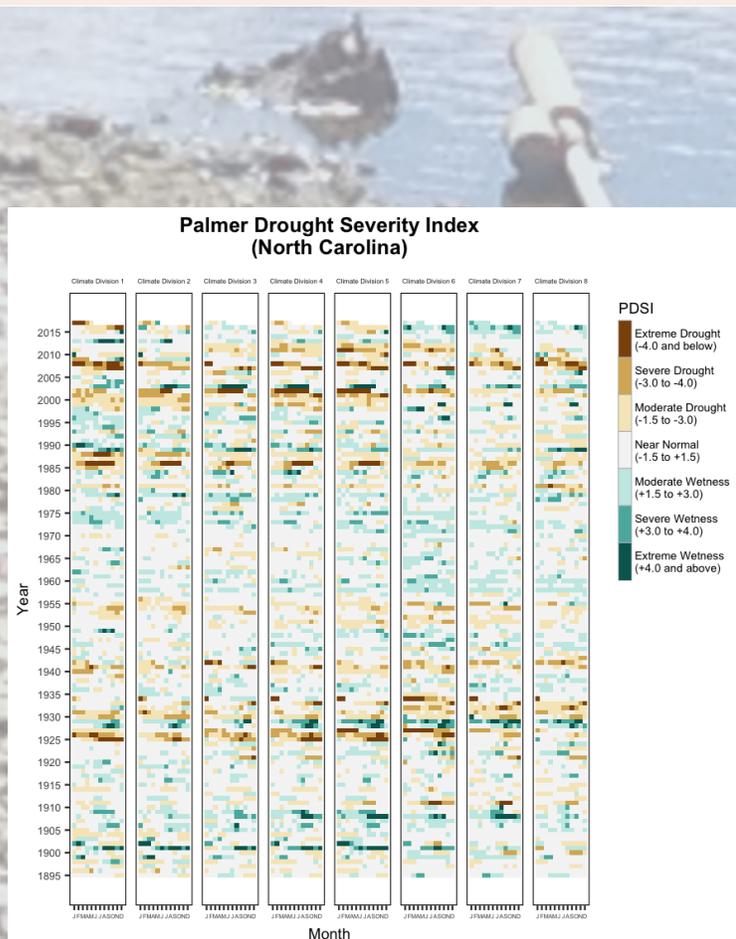


The Condition Monitoring Web Map displays observer reports through a color coded symbology to represent levels of dryness or wetness according to citizen scientists’ observations. The interactive map allows users to search by geographic region, key words, or CoCoRaHS station number. The weekly US Drought Monitor map is displayed as the basemap.

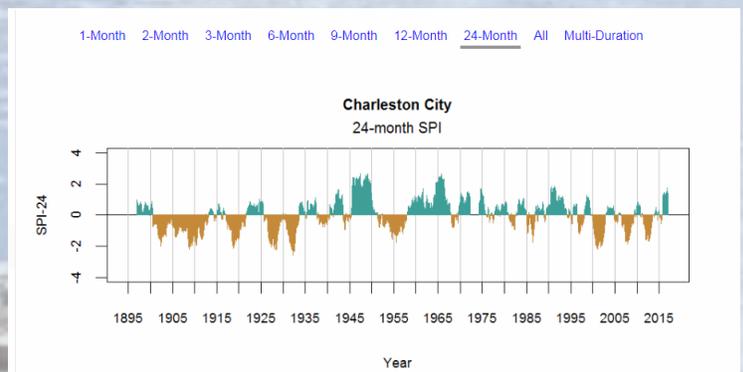
THE CAROLINAS PRECIPITATION PATTERNS & PROBABILITIES ATLAS

The *Carolinas Precipitation Patterns & Probabilities Atlas* is an interactive online resource for drought response committees, water resource managers, and other decision makers who plan for and manage water-related climate risks. It offers information not available from other sources, including frequency and duration of both dry and wet events, contextualized with photographs, videos, graphics, and narratives of the impacts of drought and heavy precipitation events in the Carolinas.

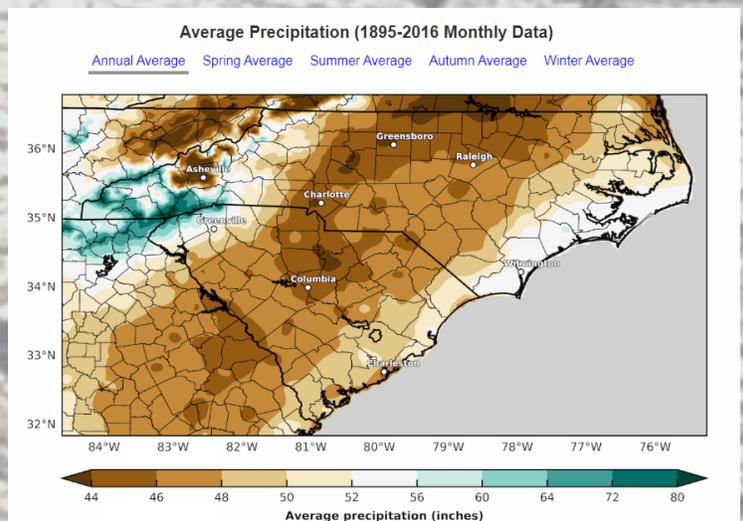
- CISA researchers conducted statistical analyses on precipitation data for 135 individual weather stations and climatic divisions across the Carolinas. The Atlas includes over 1,000 downloadable maps and figures characterizing these statistics, providing users with a range of tools to visualize various measures of precipitation and drought.
- Narratives with photographs, videos, graphics, and descriptions of the impacts of drought and heavy precipitation events in the Carolinas help to tell the full story of these extremes. Examples include the [1920s](#) and [1998-2002 droughts](#) and the [October 2015 extreme rainfall and flood event](#).
- In a project to complement the Atlas, CISA researchers tested methods to show the connections between growing season droughts and reductions in crop yield. The research aimed to “detrend” the time series to account for the technological changes that have improved crop yields through time. Maps displaying [NC and SC county-level yield anomalies](#) for corn (1925-2016), soybean (1972-2016), and hay (1950-2008) are available in the Atlas.
- CISA team members have used the Atlas to provide tailored products and information for the South Carolina Hazard Mitigation Plan update, the Central Midlands Council of Governments, South Carolina’s Drought Response Program, and the State Climatology Office.



This heat map from the Atlas shows the Palmer Drought Severity Index in North Carolina for each month from 1895-2015. Each row represents a single year; each column a single month, January through December from left to right. These charts give a visual overview of dry and wet periods over the climatological record.



Data for 135 individual weather stations is available in the Atlas for many different variables, including average monthly precipitation, heavy precipitation totals, drought indices, and drought recurrence intervals. The City of Charleston, SC’s data record, pictured here for the 24-month Standard Precipitation Drought Index, extends back to 1895, providing a wealth of information about precipitation patterns in the City.



Maps such as the one pictured above provide information about annual and seasonal precipitation patterns across the Carolinas, with color ramps accessible for color blind individuals.

CISA'S EXPERTISE CONTRIBUTES TO SEA LEVEL RISE STRATEGIES IN SOUTH CAROLINA

CISA's Coastal Climate Extension Specialist works directly with communities to assess climate vulnerabilities, identify potential adaptation strategies, and consider avenues for implementation in order to foster greater resilience. Local collaborations supported three coastal communities in South Carolina in creating adaptation and sea level rise strategies.

- **Beaufort County** incorporated adaptation strategies into the [Natural Resources chapter of the 2017 Comprehensive Plan](#), including recommendations to strengthen development and building standards, natural resource protection, and infrastructure and public facilities management. There are also recommendations in the plan to encourage communication and joint activities among government agencies and the private sector, noting the importance of cooperation to address the challenges faced by the community.
- The **City of Folly Beach** created a [Sea Level Rise Adaptation Report](#) based on adaptation strategies identified by City officials during a 2016 [Vulnerability, Consequences, and Adaptation Planning Scenarios \(VCAPS\)](#) workshop and prioritized during public workshops in April and May 2017.
- The **City of Charleston** has made a concerted effort to incorporate planning for future inundation into all activities by developing a [Sea Level Rise Strategy](#), which includes a comprehensive inventory of initiatives that are a guiding framework to make the city more resilient to sea level rise and recurrent flooding. In consultation with CISA and NOAA, the City determined that planning for sea level rise rates of 1.5 ft by 2040 and 2.5 ft by 2060 worked best for the City's current needs. The City will reassess these projections every five years.

BRIDGING THE DIVIDE: CONNECTING THE NETWORK OF CHARLESTON COMMUNITIES ADAPTING TO SEA LEVEL RISE

The [Charleston Resilience Network \(CRN\)](#) is a collaboration of public, private, and non-profit organizations seeking to enhance the resilience of the greater Charleston region and communities. The CRN mission is to foster a unified regional strategy and provide a forum to share science-based information, educate stakeholders, and enhance long-term planning decisions that support resilience. Serving over 700,000 people in the greater Charleston region, the CRN is working to protect a myriad of cultural and infrastructure assets throughout the region.

Through support of the **Resilience Program Coordinator for the CRN**, jointly funded by CISA and the S.C. Sea Grant Consortium, CISA supported the growth of the CRN network, providing education and outreach opportunities for members and stakeholders to better understand coastal climate hazards and the threat of sea level rise. Open meetings and other events such as the [March 2018 CRN Expo](#) provided opportunities for members to connect and showcase their work.

CISA coordinated and provided travel support to host a 2-day [Coastal Resilience Knowledge Exchange](#) between officials from Charleston and Hampton Roads, VA. The Hampton Roads region, comprised of 1.7 million people, is also actively working to mitigate chronic flooding. The knowledge exchange provided attendees (made up largely of local professionals such as engineers, planners, legislators, academics) with information on the Charleston region, followed by presentations from 8 local/regional staff and other practitioners from the Hampton Roads region. Then, breakout sessions made deeper dives into specific issues. One prominent idea resonating from these discussions was the concept of seeing water as an asset, rather than a nuisance, and applying this approach to the development of engineering resilience projects. Bringing together city staff established a peer-to-peer connection that has continued to grow.

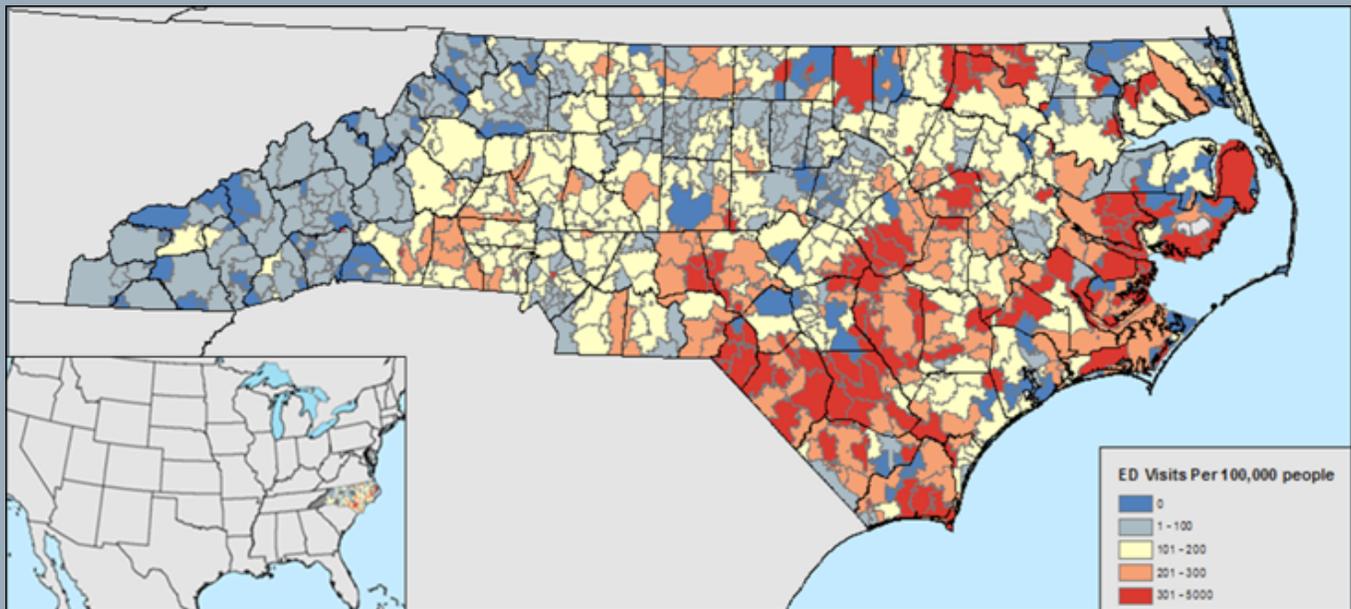
At the "[Living with Water: Dutch Approaches and Charleston's Future](#)" event, held on March 27, 2018, over 300 members of the Charleston community gathered to hear His Excellency Henne Schuwer, Ambassador of the Kingdom of the Netherlands to the United States and other senior Dutch officials. These representatives discussed Dutch approaches to water management and how Dutch planning principles and processes have been integrated in other regions of the United States.

In total, these CRN activities have engaged nearly 800 people from throughout the region to discuss climate resilience and adaptation.



ADDRESSING HEAT-HEALTH VULNERABILITIES IN NORTH CAROLINA

CISA team members have extensively studied the relationship between heat and public health in North Carolina, finding that it is not only the extremely high temperature days that pose the greatest threats to vulnerable populations. Researchers examined the relationship between maximum temperatures and morbidity due to heat-related illness (HRI) in NC for warm seasons from 2007 to 2012. Results were in significant contrast to the frequent focus on HRI in urban areas and indicate that HRI is more prevalent in rural, agricultural areas and for males aged 15-44. The data showed that heat affects more people between 31 °C (87.8 °F) and 38 °C (100.4 °F) than temperatures above 38 °C. While most early warning systems target the highest temperatures, this study suggests a need for awareness regarding heat-related risks at lower temperatures and across a wider range of vulnerable populations



Heat-related illness (HRI) in North Carolina at the zip code scale from 2007 to 2012

Using these findings, the CISA team worked with the State Climate Office of North Carolina to create the [Heat Health Vulnerability Tool \(HHVT\)](#). The HHVT translates recent, current, and predicted weather/climate conditions across the Carolinas into useful information regarding the probability of public health emergencies. Specifically, the HHVT predicts the number of emergency department (ED) visits using National Weather Service daily maximum heat index forecasts and empirical relationships identified between ED visits and the daily maximum heat index. The tool allows users to estimate levels of heat morbidity for different demographic groups across sub-regions of NC.

In 2015-2016, Climate Ready NC partners organized meetings focused on obtaining user feedback regarding the usefulness and accessibility of the tool. The first stakeholder meeting was conducted in September 2015, to coincide with the launch of the first version of the tool. HHVT Version 2.0 incorporated stakeholder input and was launched in May 2016, and a second meeting was held to elicit additional feedback. Both meetings were conducted in Fayetteville, NC, part of the “Sandhills” region that experiences some of the highest incidences of HRI in North Carolina. Participants represented county health and emergency management departments, the NC Department of Health and Human Services, healthcare systems, school systems, cooperative extension, and Fort Bragg.

Heat-health work continues to expand from this original research, as the CISA team investigates new ways to monitor exposure and better ways to communicate heat risks.

EXPANDING CISA'S CLIMATE COMMUNICATIONS AND OUTREACH

Funding was allocated in this grant period to hire CISA's first Climate Outreach Specialist to enhance our ability to support state and local adaptation projects by providing opportunities for information exchange, translating scientific data into a usable format for decision makers and the public (e.g., fact sheets, newsletters), and integrating local information needs into tools and products.

Regular communications efforts include:

- The [CISA website](#), which provides general information about the CISA program, news items, project information, CISA publications, and links to outside climate information resources.
- The [Carolinas Climate Connection](#), CISA's quarterly newsletter, was first published in fall 2012 and is now circulated to over 3,000 recipients. Newsletter content includes information about upcoming events, summaries of CISA projects and research findings, and introductions to team members. Based on evaluation results from the 2016 Carolinas Climate Resilience Conference, we revised the newsletter format to include highlights from specific case studies presented at the conference that demonstrate successful climate adaptation examples in the region, thereby extending the reach of this in-person event to additional education materials.
- The [Carolinas Climate Listserv](#), launched in June 2013, is circulated to over 300 subscribers once to twice per week as Carolinas-relevant news becomes available.
- We maintain social media accounts on Facebook and Twitter. These accounts were established at the time of the 2014 Carolinas Climate Resilience Conference to promote the event and continue to be used to promote the newsletter and listserv items and other relevant news items to a broader audience.



These photos depict a small portion of the damage to homes in the Carolinas that has been caused in recent years by extreme events such as the October 2015 flood as well as Hurricanes Matthew and Irma. The CISA team has produced tailored communications and outreach materials to answer stakeholders' questions about the climatological context of these events. Conferences and workshops have centered around climate adaptation strategies to increase resilience to future impacts.

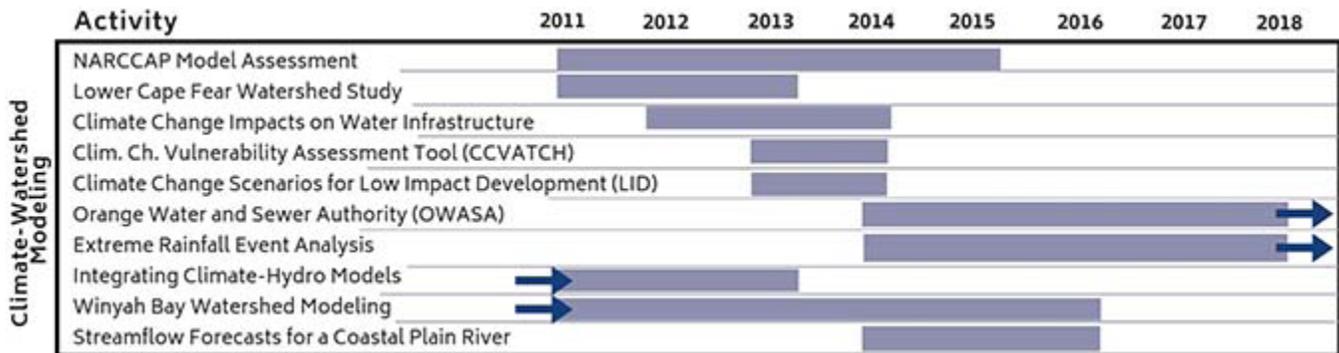
IN-PERSON ENGAGEMENTS FOSTER A NETWORK OF CLIMATE ADAPTATION PRACTITIONERS IN THE CAROLINAS

Through years of working with stakeholders in the Carolinas, CISA team members have learned that there is no substitute for in-person interactions to help bridge the gap between climate science and decision making. Therefore, significant effort has been allocated to creating networking opportunities for our stakeholders in addition to project-specific engagements. These workshops and conferences have become a key element of CISA's work in the Carolinas.

- CISA hosted nearly 200 people at the first Carolinas Climate Resilience Conference, held in [April 2014](#) in Charlotte, NC. Overwhelmingly positive feedback from attendees motivated the team to dedicate resources to a recurring biennial event. Conference participation increased by nearly 40% for the 2nd CCRC held in [September 2016](#) and included a more diverse representation of communities and stakeholders. Keynote speakers have included Kathy Jacobs, director of the Third National Climate Assessment, and Bob Ingles, former U.S. Congressman for South Carolina's 4th congressional district.
- Expanding beyond the Carolinas, CISA provides leadership for the [Southeast and Caribbean Climate Community of Practice](#). Both the Climate Outreach Specialist and Coastal Climate and Resilience Specialist lead efforts to plan, what has become, a biennial workshop attended by stakeholders from Georgia, Florida, North Carolina, South Carolina, Puerto Rico, and Virginia.

RESEARCH & PROJECT SUMMARIES

CLIMATE AND WATERSHED MODELING



Climate and Watershed Modeling Projects Timeline - Arrows indicate ongoing projects

NARCCAP MODEL ASSESSMENTS FOR THE SOUTHEAST

In this project, downscaling efforts centered on regional climate model (RCM) output from the North American Regional Climate Change Assessment Program (NARCCAP). The team evaluated NARCCAP data in the Southeast, including summer and winter maximum and minimum temperature and precipitation for nine pairs of general circulation models and regional climate models during the control period, 1970-1999. The historical analysis set the stage for interpreting future projections (2040-2069) of minimum and maximum temperature and mean precipitation change, and helped to quantify associated uncertainties in these scenarios. A [summary of findings](#) is available in the Highlights and Accomplishments section above. This work serves as a template for the type of in-depth analysis needed to provide added confidence in a models' ability to simulate all aspects of the climate system.

Team Members: Carbone, Kabela

LOWER CAPE FEAR WATERSHED STUDY

Using the Lower Cape Fear watershed and its subwatersheds as a study area, this project assessed water availability and use over time, under different scenarios, at several temporal and spatial scales. This project involved documenting past, current, and potential future patterns of water availability (i.e., supply) and past, current, and potential future patterns of demand, by land use and by sector and incorporated various climate change scenarios. Analysis indicated potential water stress in the basin and many systems where demand will surpass supply by 2060. Although this resulted from population growth and impervious cover projections, not only varying climate projections. Supply data does not account from some water uses, such as water system maintenance, and are likely to underestimate the full effects of demand on future supplies. Research was presented to stakeholders and planners in New Hanover County, a major area of concern.

Team Members: Montz

Partners: East Carolina University, NC Department of Environmental Quality

CLIMATE CHANGE IMPACTS ON WATER INFRASTRUCTURE

This project assessed the vulnerability of municipal water infrastructure to coastal hazards in North Carolina communities. The project brought together GIS and water management expertise as well as experience modeling sea level rise and future climate change impacts to produce a series of detailed maps visualizing the vulnerability of water and wastewater infrastructure. Maps and graphics produced for the participating communities were comparative across jurisdictions using a common symbology and reporting format. The approach focused on individual hazards and a multi-hazard symbolization, to aid individual jurisdiction as well as intercomparisons. The maps illustrated what height of relative sea level rise poses serious risk to various infrastructure components. Graphics also highlighted the relative quantity of assets that are vulnerable. Further consultation with local officials and planners was used to draw site-specific implications. Mapping methodologies from this project were used to inform the [Highlights and Accomplishments section](#) project.

Team Members: Allen, Montz, Oyer

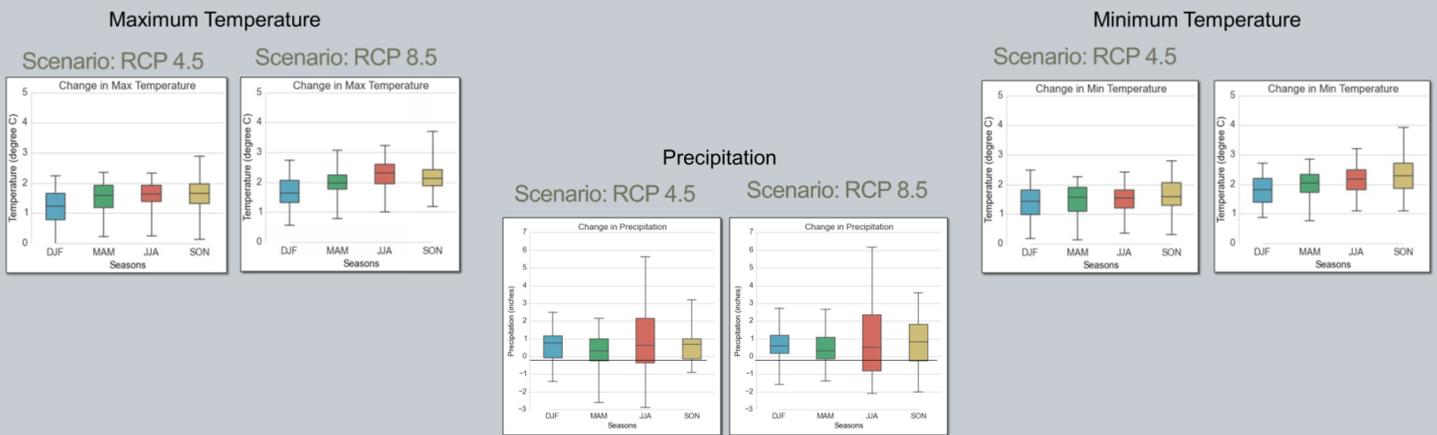
Partners: East Carolina University, NC Sea Grant

CLIMATE CHANGE PROJECTIONS FOR THE CLIMATE CHANGE VULNERABILITY ASSESSMENT TOOL FOR COASTAL HABITATS

The goal of this effort was to provide regionally-specific climate change projections to use with the [Climate Change Vulnerability Assessment Tool for Coastal Habitats \(CCVATCH\)](#), developed by National Estuarine Research Reserves (NERR) in South Carolina and Virginia. The CISA team produced graphics showing the spread of projections for seasonal changes in temperature and precipitation for mid-21st century (relative to 1980-2010 baseline) for two future scenarios. Valuable insights regarding the usefulness and application of downscaled climate information emerged through this effort. The project illustrated that decision makers may not always require highly refined or localized climate information, particularly in the early stages of considering climate change vulnerability. While it may be easy to assume that the plethora of publicly available climate data and tools would meet the information needs in such cases, this is not always true. Team members learned that NERR resource managers required significant guidance on choosing the source of information as well as how to use it. In the end, climate projections data were used to produce information specifically tailored for the vulnerability assessment tool. The tool will be used to help coastal resource managers identify 1) habitats that are likely to be adversely affected by climate change and 2) management options for adaptation to or mitigation of climate impacts.

Team Members: Carbone, Patel

Partners: Chesapeake Bay and North Inlet-Winyah Bay National Estuarine Research Reserves (NERR)



Examples of RCP scenarios produced for the CCVATCH project

CLIMATE CHANGE SCENARIOS FOR LOW IMPACT DEVELOPMENT

This project was initiated to inform the development of and generate material to be included in a [Low Impact Development \(LID\) Manual for Coastal South Carolina](#). The development team was specifically concerned with ensuring that LID practices included in the manual are able to withstand potential climate changes over the expected 30-50 year lifetime of LID site designs. CISA's participation with this group aimed to aid in the understanding of the variability, trends, and potential future changes in precipitation in a manner that is particularly important for stormwater/LID engineering practices and design. CISA synthesized and provided information on observed or anticipated changes to the coastal climate, specifically in regards to changes in precipitation intensity, design storm depth, and frequency of the water quality design event.

Team Members: Carbone, Gao, Rodgers

Partners: ACE Basin and North Inlet-Winyah Bay National Estuarine Research Reserve (NERR), Center for Watershed Protection, SC Sea Grant Consortium

ASSESSING CLIMATE SENSITIVITY AND LONG-TERM WATER SUPPLY RELIABILITY WITH A NORTH CAROLINA WATER SYSTEM

In collaboration with the Orange Water and Sewer Authority (OWASA), a water utility in Carrboro, NC, researchers assessed the vulnerability of the utility's raw water supply to changing climatic conditions. The goal of the project was to help the utility incorporate climate change into their long-range planning. The vulnerability analysis showed that the combined effect of the length of a drought and its severity can indicate when reservoir storage drops below the 20% capacity – a storage level deemed critical to maintain in dry conditions while meeting projected demands. In most cases, only intense droughts lasting approximately 24 months or longer reduced the reservoir levels to critically low levels.

Team Members: Carbone, Patel

Partners: Orange Water and Sewer Authority

CLIMATOLOGICAL ASSESSMENT OF EXTREME RAINFALL EVENTS

Following the extreme rainfall event in October 2015 in South Carolina, CISA researchers began to investigate the nature of heavy precipitation events in the Carolinas to improve information available to water resource managers in the region (see [Highlights and Accomplishments section](#) above). By analyzing the historical record, probabilities for exceeding heavy precipitation thresholds were produced using basin-level precipitation totals. Considerable differences were found between point-based and area-based estimates of 1-, 2-, and 4-day annual maximum precipitation totals. This finding suggests that caveats are needed when using point-based estimates to represent areal estimates as model inputs for the purpose of storm water management and flood risk assessment. The data analysis method researchers used complements the point-based measurements available through NOAA’s Atlas-14 product. Results have been shared with the SC State Climatology Office and hydrologists at the Columbia, SC National Weather Service Office, USGS South Atlantic Water Science Center, the SC Department of Natural Resources, and the SC Department of Health and Environmental Control. Analysis has also been incorporated into interactive maps visualizing 1- to 5- day heavy precipitation events on the [Carolinas Precipitation Patterns & Probabilities Atlas](#) website.

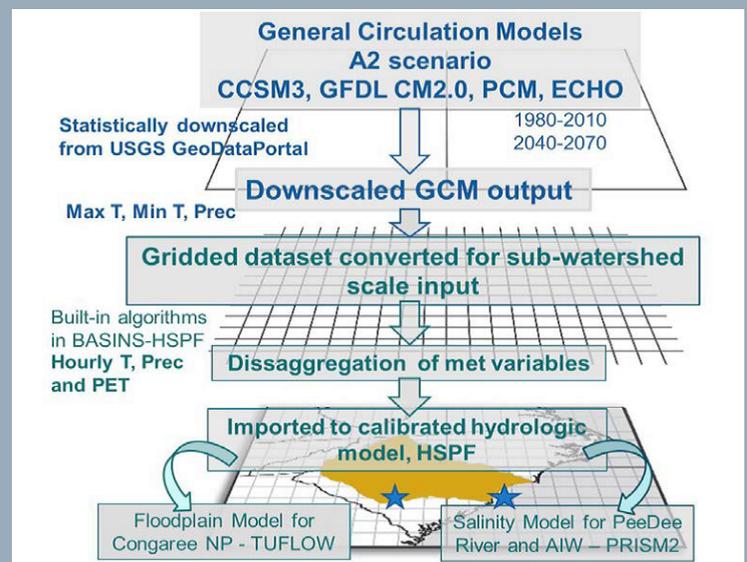
Team Members: Carbone, Gao

INTEGRATING REGIONAL DOWNSCALING AND HYDROLOGICAL MODELS

Researchers used statistical downscaling to assess the regional impacts of climate variability and change on water resources, including streamflow and water quality. Efforts centered on processing and using statistically downscaled data as input for two different HSPF modeling projects: 1) CISA’s Winyah Bay watershed project and 2) a collaborative project conducted for Congaree National Park. A fundamental issue involved understanding how to disaggregate data to a local spatial scale and hourly temporal scale for input into the HSPF model. This work also included analysis of model output to understand potential impacts of future climate at the HUC8 scale.

Team Members: Carbone, Conrads, Gao, Patel, Tufford

Partners: USGS South Atlantic Water Science Center



The process of integrating climate information into hydrological models involves multiple stages of data processing

MODELING OF THE WINYAH BAY WATERSHEDS

CISA integrates climate data with hydrological models to assess the potential impacts of climate variability and change on water resources in the Southeast. Researchers used EPA’s BASINS Hydrologic Simulation Program-Fortran (HSPF) and the Soil and Water Analysis Tool (SWAT) model to simulate the Yadkin Pee-Dee, Waccamaw, and Black Rivers at the 8-digit HUC level. These basin-wide models were used to aid in assessing salinity intrusion in the future for public water supply managers along the Waccamaw River and the occurrence and potential range expansion of *Vibrio* in the Winyah Bay estuary.

Team Members: Tufford, Carbone, Gao, Lu, Patel, Rouen, Samadi

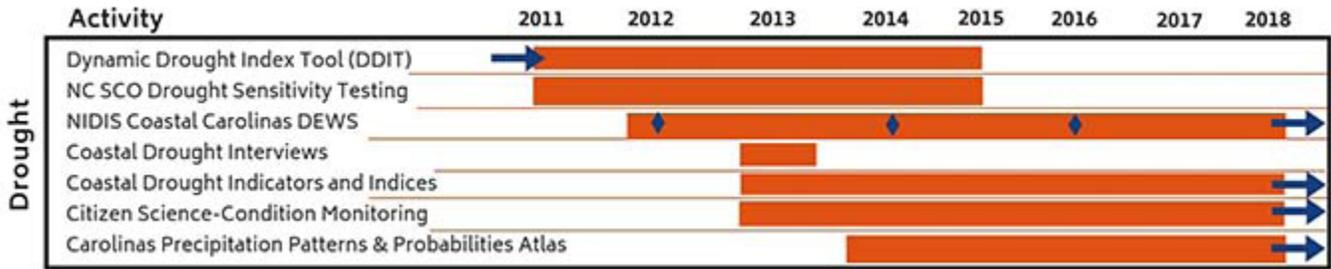
STREAMFLOW FORECASTS FOR A COASTAL PLAIN RIVER

There is considerable interest in forecasting future river-discharge levels and their downstream effects on blue crabs, one of the most important commercial fisheries in the Southeast which is adversely affected by drought. Low levels of freshwater discharge into the estuary changes the salinity profile which influences crab growth, movement and survival. This project identified and examined a range of possible changes in Edisto River discharge through 2030. Climate scenarios showed increasing temperature and precipitation. Projected precipitation increases are greatest in summer, but moisture availability decreases because warmer temperatures cause higher evaporation. Projections for all four emissions scenarios developed for the project resulted in a decreasing streamflow trend. These streamflow projections were used as input for an individual-based blue crab model to [forecast future SC blue crab landings](#). Although future projections of drought are highly uncertain, the individual-based model can be used to forecast landing trends using climate model input.

Team Members: Carbone, Childress, Lu, Tufford

Partners: Clemson University

DROUGHT



Drought Projects Timeline - Arrows indicate ongoing projects, Diamonds indicate major stakeholder engagement events

DYNAMIC DROUGHT INDEX TOOL

CISA researchers developed the [Dynamic Drought Index Tool \(DDIT\)](#) for the Carolinas in response to decision makers’ requests for an interactive drought monitoring tool that allows user control of index, time frame, and spatial aggregation unit. It consists of three parts: a numerical model for calculating percentiles of each drought index and performing spatial interpolation and averaging; a database storing the results from the numerical model; and a graphical user interface that allows the selection of drought indices and their percentages for blending as well as resultant maps, graphs, and tables. The tool was launched in 2007 and is located on the SC Department of Natural Resources website where it provides the ability to examine historical droughts up to 2009. From 2011 to 2015, efforts focused on expanding the coverage of the tool from the Carolinas to the eighteen states served by the Northeast and Southeast Regional Climate Centers, integrating the tool with the near-real time [Applied Climate Information System \(ACIS\) database](#), and adjusting the tool’s functionality and user interface based on user feedback. Carbone et al. summarized lessons learned from the DDIT development and technology transfer process for [Climate in Context](#). The chapter provides insights regarding the necessary elements of an effective research-to-operations process. These include a range of technical considerations pertinent to software development, deployment, and maintenance, as well as protocols for incorporating user feedback into tool development and supporting communications and collaboration between team members.

Team Members: Carbone, Rhee

Partners: Northeast Regional Climate Center (NERCC), Southeast Regional Climate Center (SERCC), South Carolina State Climatology Office of the South Carolina Department of Natural Resources (SC DNR)



Photo Credit: Amanda Farris

DROUGHT SENSITIVITY TESTING

The State Climate Office of North Carolina partnered with several organizations, including CISA, to develop a high-resolution drought trigger tool that uses gridded inputs including multi-sensor precipitation estimates (MPE) and gridded temperature products. The tool was designed for use by drought experts, such as the NC Drought Management Advisory Council (DMAC) members, and US Drought Monitor authors, who want to accurately depict drought severity in locations with no or few surface gauges. One component of the project included developing an MPE-based Standardized Precipitation Index (SPI), comparing it with other monitoring tools and indices, and using CISA’s Dynamic Drought Index Tool (DDIT) to assess its usefulness for different geographic contexts and drought types. The data and information produced through this research is used weekly by the NC DMAC and is incorporated into the NC SCO’s [drought monitoring portal](#). User-defined map extents and product views also allow stakeholders to embed the tool directly into their own websites. As an example, the [Texas State Climate Office](#) has embedded a Texas-focused version of this tool in their site.

Team Members: Boyles, Ward

Partners: Southeast Regional Climate Center (SERCC), Texas A&M University, Purdue University

SUPPORT FOR THE NIDIS COASTAL CAROLINA DROUGHT EARLY WARNING SYSTEM

The Coastal Carolinas Drought Early Warning System (DEWS) is one of several National Integrated Drought Information System (NIDIS) regional DEWS programs in place across the United States. As different parts of the country are affected by drought in different ways, DEWS provide tools, resources, management strategies, and opportunities for information exchange around salient drought issues at the regional scale. Launched in 2012, the Coastal Carolinas DEWS has focused on 1) improving understanding of the unique vulnerabilities and impacts of drought on coastal ecosystems and 2) developing tools, information, and other resources that will help managers and decision makers integrate drought- and coastal resource management activities. Priority project areas and goals were developed at a stakeholder scoping workshop in summer 2012, with over fifty individuals from federal and state agencies, community agencies, non-profit organizations, and academia participating.

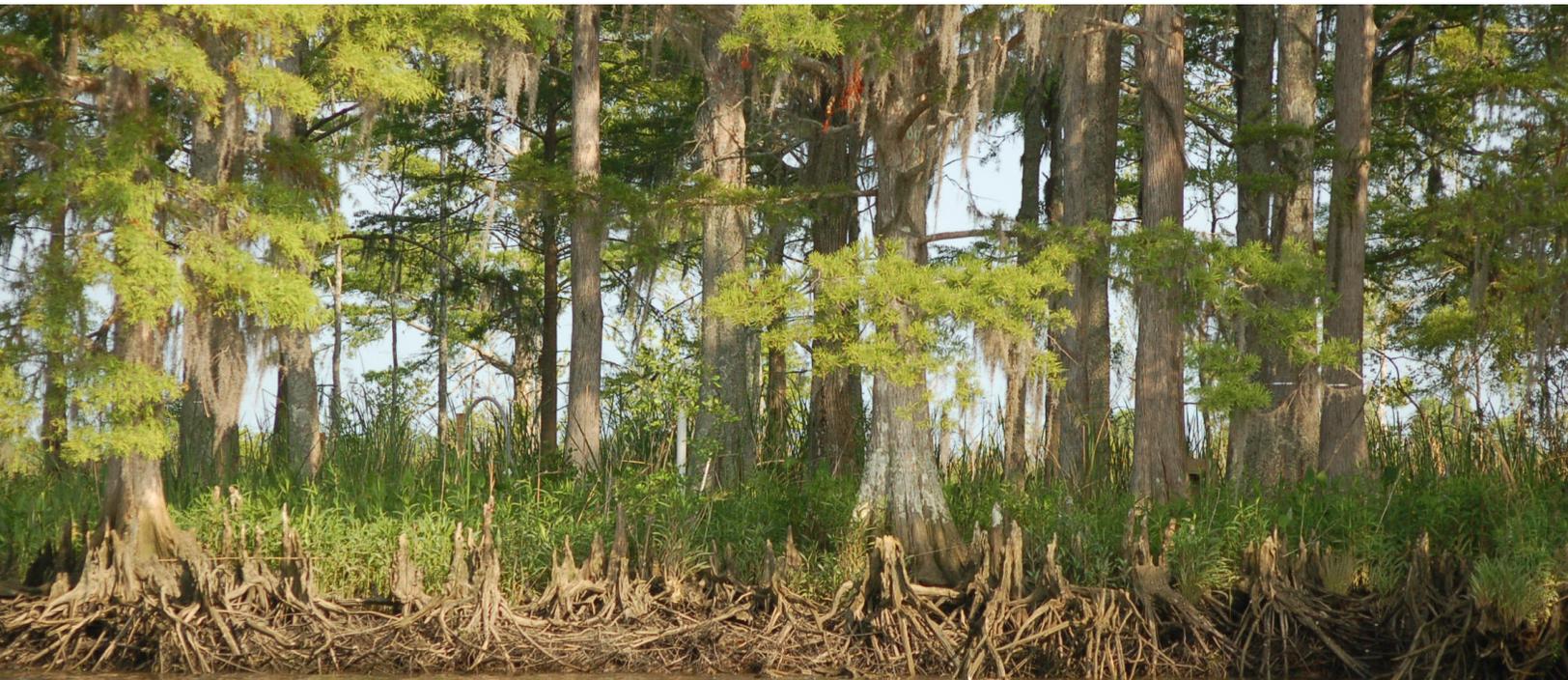
CISA has provided significant leadership for the Coastal Carolinas DEWS.

- CISA has served as a point-of-contact for DEWS activities in the region, co-organizing stakeholder workshops in 2012, 2014, and 2016 and assisting NIDIS in developing the 2017-2018 Coastal Carolinas DEWS Strategic Plan.
- CISA staff have assisted NIDIS with communications to DEWS stakeholders and partners. CISA has given numerous in-person presentations and disseminated coastal drought information through a variety of online mechanisms, including fact sheets, newsletters, listservs, blog posts, and [story maps](#).
- The CISA team has conducted several applied research projects to meet needs identified through engagements with DEWS stakeholders. These projects center on evaluating and developing drought indicators appropriate for coastal ecosystems, improving drought impacts reporting and monitoring, and facilitating the use of drought forecasts and other products in decision making. More details are provided in the project descriptions below.

COASTAL DROUGHT INTERVIEWS

In 2013, the CISA team took advantage of drought conditions to conduct semi-structured interviews with 50 fishermen, outdoor recreationalists, business owners, and land managers in the Beaufort County, SC, and Carteret County, NC, areas. The intent of this effort was to document observed and perceived drought impacts on coastal resources. Findings were used to inform subsequent Coastal Carolinas DEWS activities. Although coastal resources users are affected by drought, interviewees reported minimal use of existing drought tools and products. Participants also indicated that drought is not a stand-alone issue or stressor for them, and many interviewees articulated a need for improved understanding and information about drought impacts and risks within the broader hydroclimate context (both norms and extremes, too little or too much rainfall). Moreover, responses indicated that to increase relevance and suitability for decision making, drought information, tools, and resources need to fit locale-specific risks and sector-specific management decision time frames and uses of information.

Team Members: J. Davis, Dow, Farris, Haywood, Lackstrom



COASTAL DROUGHT INDICATORS AND INDICES

With separate funding from the NOAA Climate Program Office (2013-2017), CISA led the “Indicators and Indices of Drought in Southeastern Coastal Ecosystems” project. In the first phase of the project (2013-2015), a [needs assessment](#) was conducted through 30 structured interviews with coastal resource managers. The interviews identified use of, and needs for, specific drought indices and indicators to effectively understand and monitor drought in coastal ecosystems. 83% of interviewees indicated a need for an early warning drought indicator but a lack of awareness of current drought indicators. Freshwater wetlands, especially those with organic soils, were identified as the habitat most sensitive to drought impacts. Variables related to freshwater availability and salinity measures were identified as the most useful for early drought warning and identification of potential impacts.

The second component of this project (2016-2017) involved collaboration with the USGS South Atlantic Water Science Center to 1) improve the characterization of ecological drought in coastal systems and 2) advance the development and use of the [Coastal Salinity Index \(CSI\)](#). Commonly-used drought indices characterize hydrological, agricultural, and meteorological conditions; however, they do not incorporate salinity, a key stressor associated with coastal drought. The CSI uses an approach modeled on the Standardized Precipitation Index (SPI), substituting total monthly precipitation with average monthly salinity data. The tool is intended to improve understanding of the effects of changing salinities in coastal surface-water bodies and the associated effects on estuarine habitats freshwater availability for ecological, municipal, and industrial needs. Activities included the identification and documentation of salinity and ecological response datasets, review of existing information about drought and salinity effects on coastal ecological resources, and engagement with project stakeholders. Project information is posted on the [CISA website](#) and continues to inform ongoing efforts by USGS and CISA to further refine the CSI.

Team Members: Chalcraft, Nolan, Tufford, Lackstrom, Rouen

Partners: US Geological Survey (USGS) South Atlantic Water Science Center

CITIZEN SCIENCE CONDITION MONITORING

CISA created and piloted the [Citizen Science Condition Monitoring](#) project in response to decision maker requests for more on-the-ground drought impacts information, at the 2012 Coastal Carolinas DEWS Scoping Workshop. The project engages citizen scientists, and uses existing tools developed by the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network, to promote “condition monitoring” first in the Carolinas and ultimately, nationally. Through this approach, volunteers document the effects of weather and climate on their local communities and environments in weekly status reports in addition to their daily precipitation measurements. Regular reporting, in contrast to intermittent drought impact reports, creates a baseline for comparison of change through time and to improve understanding of different stages of drought. Iterative feedback from participants and partners has guided project improvements and expansion. Major [project highlights and accomplishments](#) are included in the section above .

Team Members: E. Davis, J. Davis, Dow, Eckhardt, Farris, Guiseppe, Haywood, Lackstrom, Sayre, Selvaraj, Sullivan, R. Ward, Westerkam

Partners: CLIMAS, Community Collaborative Rain, Hail & Snow (CoCoRaHS) Network, National Integrated Drought Information System (NIDIS), National Drought Mitigation Center (NDMC), SCIPP, SECC, South Carolina State Climatology Office, Southwest Climate Science Center, State Climate Office of North Carolina



Photo Credit: Amanda Farris

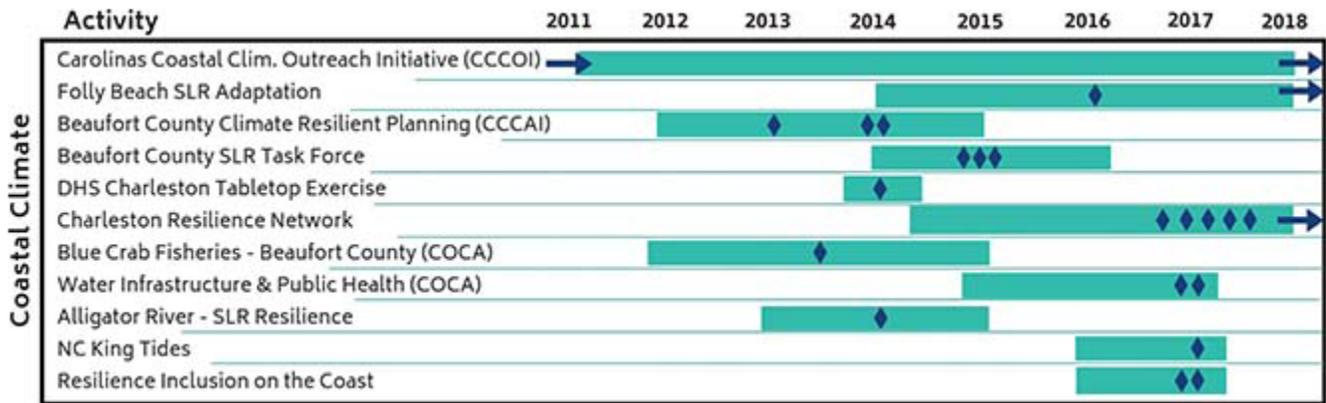
CAROLINAS PRECIPITATION PATTERNS AND PROBABILITIES ATLAS

Decision makers indicated the need for Carolinas-focused information about extremes (drought, heavy rainfall) and normal precipitation patterns in order to help them prepare for and manage future events. The [Carolinas Precipitation Patterns and Probabilities Atlas](#) (Atlas) is an online resource that provides this information in map and graphic form, at various spatial scales (state, climate division, station-specific), and in conjunction with other contextual information to better associate extreme hydroclimate events with their impacts. Major components of this project are included in the [highlights and accomplishments](#) section above .

Team Members: Beidel, Carbone, Gao, Konrad, Lu, McLeod

Partners: US Geological Survey (USGS) South Atlantic Water Science Center, National Integrated Drought Information System (NIDIS)

COASTAL CLIMATE



Coastal Climate Projects Timeline - Arrows indicate ongoing projects, Diamonds indicate major stakeholder engagement events

COASTAL CLIMATE OUTREACH INITIATIVE

Beginning in 2007, the Coastal Climate Outreach Initiative (CCCOI) has solidified a key partnership between CISA and the NOAA Sea Grant programs in the Carolinas. The coastal climate extension specialist, co-funded by CISA and the SC Sea Grant Consortium, provides coastal stakeholders with a trusted source of climate information and products specific to their needs. Specific activities comprise cultivating relationships with many stakeholder groups, including coastal zone management, local municipalities, and local non-government organizations in order to bridge the gap between coastal climate science and decision making; serving as a scientific consultant for the [Charleston Resilience Network](#), a regional working group consisting of public and private partners seeking to develop and foster a platform to share information, educate stakeholders, and enhance long-term planning decisions that result in increased regional resilience; working closely with climate extension specialists from other Sea Grant programs throughout the Southeast to extend the reach of these efforts. This position has served as a model for Sea Grant programs around the country, many of whom now have coastal climate extension specialists in-house and in collaboration with other RISAs.

Team Members: Dow, Fly, Watson, Whitehead

Partners: NC Sea Grant, SC Sea Grant Consortium



Photo Credit: Kirstin Dow

CITY OF FOLLY BEACH, SC PLANS FOR SEA LEVEL RISE

The City of Folly Beach is a small barrier island community that faces a variety of coastal hazards, including the threat of rising seas from both the ocean and marsh sides of the island. The City requested technical assistance to take a more proactive approach in planning for current and future sea level rise hazards. Fly helped facilitate public discussions about the threats of these hazards to the City. Scenarios from NOAA’s Sea Level Rise Viewer were used to help visualize potential future inundation. Fly also provided information on the nature of the impacts which would result from inundation. This outreach effort enhanced understanding among City leaders about the options available to plan for sea level rise, which led the City to take a significant step in increasing resilience by including consideration of this threat in its municipal Comprehensive Plan. A VCAPS workshop was held in August 2016 with key decision makers from the City. The adaptation strategies identified during this workshop were then prioritized during three public workshops in April and May 2017. These strategies are laid out in the [City’s Sea Level Rise Adaptation Report](#). The City continues to work with CISA as they consider long-term zoning and development regulations to create a resilient island for residents and tourists alike.

Team Members: Dow, Fly, Watson

Partners: SC Sea Grant Consortium, City of Folly Beach



Photo Credit: Kirstin Dow

BEAUFORT COUNTY CLIMATE RESILIENT PLANNING

Beaufort County is in the heart of the South Carolina LowCountry, sitting just above sea level. County planners recognized their vulnerability to rising sea levels several years ago and initiated a collaboration with CISA and other partners to develop risk management strategies that could be integrated into the County's Comprehensive Plan. A series of interactions followed including decision maker interviews to gauge climate-related concerns, a 2013 VCAPS workshop to identify potential impacts of sea level rise as well as possible adaptation strategies, two 2014 public workshops during which local residents were able to weigh in on potential adaptation options, development of a detailed report outlining prioritized strategies in 2015, and finally, in 2017, the incorporation of findings into the Natural Resources chapter of the [Beaufort County Comprehensive Plan](#). The plan includes recommendations to strengthen development and building standards, natural resource protection, and infrastructure and public facilities management. There are also recommendations to encourage communication and joint activities among government agencies and the private sector, noting the importance of cooperation to address the challenges faced by the community.

Team Members: Dow, Bath, Fly, Tuler, Whitehead

Partners: SC Sea Grant Consortium, Social and Environmental Research Institute, NC Sea Grant

BEAUFORT COUNTY SEA LEVEL RISE TASK FORCE

Stakeholders in the City of Beaufort and Town of Port Royal formed a [task force](#) to address the area's vulnerability to sea level rise (SLR) and develop adaptation strategies. The task force was composed of thirteen members, including Beaufort's mayor and Port Royal's planning administrator. CISA provided technical assistance in identifying vulnerable areas and understanding types of flood mitigation options for public and private entities. After receiving approval and encouragement from the Beaufort City Council and Port Royal Town Council to continue work and engage neighborhood groups, the task force created materials for public education and outreach. CISA provided content for these materials on sea level rise vulnerability and flood resilience strategies and maps produced from data visualization of sea level rise projections. Presentations were given to seven neighborhood associations as well as to the Director of the Lady's Island Airport, where plans to construct additional runways directly coincide with areas projected to be impacted by SLR. CISA assisted the task force in writing a letter to the Federal Aviation Administration (FAA), requesting that the FAA require Lady's Island Airport to consider future SLR in airport improvements and design standards.

Team Members: Dow, Fly, Selvaraj

Partners: City of Beaufort, SC, Town of Port Royal, SC, LowCountry Institute, SC Small Business Chamber of Commerce

SUPPORT FOR THE DEPARTMENT OF HOMELAND SECURITY’S CLIMATE CHANGE TABLETOP EXERCISE

The U.S. Department of Homeland Security’s (DHS) Office of Infrastructure Protection (IP) developed a Climate Change Tabletop Exercise to engage decision makers and stakeholders in conversation about climate change threats to the nation’s critical infrastructure. CISA’s Coastal Climate Extension Specialist participated in planning meetings and helped to facilitate the pilot of the tabletop exercise in Charleston, SC, in June 2014. The idea to form the Charleston Resilience Network (CRN) was a major outcome of the exercise.

Team Members: Fly

Partners: SC Sea Grant Consortium



SUPPORT FOR THE CHARLESTON RESILIENCE NETWORK

Established in 2015, the [Charleston Resilience Network \(CRN\)](#) is a collaboration of public, private, and non-profit organizations seeking to enhance the resilience of the greater Charleston region and communities. CISA team members have served on the Organizing Committee for the CRN since its inception, providing technical support to ensure that the most up-to-date science is available to the group. Through support of a Resilience Program Coordinator for the CRN, jointly funded by CISA and the SC Sea Grant Consortium, CISA has also played a key role in expanding the CRN network and providing education and outreach opportunities for members and stakeholders to better understand coastal climate hazards and the threat of sea level rise. More details about this collaboration can be found in the [Highlights and Accomplishments section](#) above .

Team Members: Dow, Fly, Foster, Sassard, Watson

Partners: SC Sea Grant Consortium, SC Department of Health and Environmental Control Ocean and Coastal Resources Management

PROMOTING CLIMATE CHANGE AWARENESS AND ADAPTIVE PLANNING IN ATLANTIC FISHERIES

With funding from NOAA’s Coastal and Climate Applications (COCA) program, CISA and partners worked with members of fisheries in three communities along the Atlantic coast (South Thomaston, ME, Wellfleet, MA, and Beaufort County, SC) to improve understanding of how a changing climate will affect fishing communities’ abilities to maintain marine fisheries and the local economies historically dependent upon them. [Vulnerability, Consequences, and Adaptation Planning Scenarios \(VCAPS\)](#) exercises were conducted to help decision makers deliberate on the vulnerabilities of their fisheries in the context of climate stressors. In South Carolina, members of the blue crab fishing community not only attended a VCAPS workshop, they also learned about the [individual-based blue crab model](#) developed by Michael Childress (Clemson University) which takes into account environmental, fishery, and economic data that can help crabbers adapt to annual climate-related variability and strengthen the sustainable management of the fishery. These crabbers volunteered to become members of the “Crabbers Who Care” research network and collect environmental and fishery data. CISA provided refractometers for each member, allowing for real-time salinity measurements. Data collected by the volunteers were used to calibrate Childress’ blue crab population model to help inform how different environmental (e.g., water conditions, predation) and societal (e.g., crab fishery) conditions impact blue crab populations.

Team Members: Fly, Whitehead

Partners: SC Sea Grant Consortium, NC Sea Grant, Clemson University

A COMMUNITY-WIDE HEALTH RISK ASSESSMENT OF VULNERABLE WATER INFRASTRUCTURE IN COASTAL CITIES

This project, funded by NOAA’s Coastal and Climate Applications (COCA) program, was a four-step process to determine health-related impacts that result from coastal water and wastewater infrastructure vulnerability to extreme events and sea level rise. Stakeholder interviews and workshops were conducted in the two pilot communities, Morehead City, NC and Charleston, SC, to assess perceptions of water and wastewater infrastructure and public health vulnerabilities. Discussions encouraged stakeholders to consider what adaptation they have or have not enacted to prepare for climate change. Information from these engagements was used to develop a susceptibility index, which was [tested at tabletop exercises](#) in the pilot communities. Online portals for stakeholders to view hazard and sector layers were developed for the engagement workshops. The [Morehead City, NC portal](#) is publicly available. Charleston, SC, contains sensitive water infrastructure data and thus was only available to workshop attendees. Researchers also created a guidebook, in order to make the process and products transferable to other coastal communities.

Team Members: Allen, Fly, Hanks, Lovelace, Montz, Whitehead

Partners: SC Sea Grant Consortium, NC Sea Grant, East Carolina University, Old Dominion University

SEA LEVEL RISE IMPACTS AT THE ALLIGATOR RIVER NATIONAL WILDLIFE REFUGE

When it was established in 1984, much of the Alligator River National Wildlife Refuge was a pocosin, a type of isolated wetland characterized by poorly drained soils high in organic matter. Rising sea levels are impeding drainage in the Refuge, leaving the soil wetter for a longer period of time throughout the year. In many places, marsh grass communities are now replacing the native pond pine pocosin ecosystem. These habitat changes are also leading to changes in animal species distributions. Researchers hypothesized that changes in soil moisture and salinity levels have led to a cascade of ecosystem transitions. This project aimed to quantify the carbon (C) contained in vegetation and soils of the Refuge's predominant ecosystems and identify thresholds of salinity and hydro-period (number of days per year the soil is flooded) that result in ecosystem transitions. Researchers focused on the effects of historical ditching and drainage on soil water dynamics and salinity and quantified the role of extreme events such as flood tides and hurricanes. The project team hosted a [stakeholder and community workshop](#) on December 5, 2014 (50 attendees), to share information about the habitat changes occurring at the Refuge and the research being conducted to understand the causes of those changes. The US Fish and Wildlife Service used information from this project to implement adaptation strategies to protect the Refuge's wildlife habitat quality for decades to come and to prepare for change where it is inevitable.

Team Members: King, Brown

Partners: DOI Climate Adaptation Science Center, NASA, USDA Forest Service, NC State University Tree Physiology and Ecosystem Science Laboratory, USDA National Institute of Food and Agriculture, US Department of Energy

DOCUMENTING WATER LEVELS IN NORTH CAROLINA ESTUARIES THROUGH THE NC KING TIDES PROJECT

As high water-level events become increasingly common and coastal areas experience more frequent recurrent flooding, there is a growing need for more spatially explicit water-level data throughout the North Carolina estuaries. In NC, the intermingling of natural forces including astronomical tides and meteorological forcing (wind) can lead to water levels that deviate significantly from those predicted, making such predictions a difficult task, especially on a local scale. This subaward to researchers at UNC-Chapel Hill expanded the [North Carolina King Tides Project](#) to include [installation of water-level gauging stations](#), monitored and reported by trained citizen scientists. The resulting water-level database is both spatially and temporally specific, creating a more holistic understanding of water-level patterns throughout the State's coastal zone. The data and photographs produced from the [citizen science water-level monitoring effort](#) are intended for use by the scientific, regulatory, and management communities, as well as the public, to gain a better understanding of the forces that drive water levels in North Carolina as well as stimulate thinking about rising sea levels. In addition, this database begins to fill the void in water-level records that exists between USGS stream gauges and NOAA Tides and Currents coastal stations.

Team Members: Voss, Tomczak, Rowe

Partners: UNC Chapel Hill, NC Association of State Floodplain Managers



Photo Credit: Kirstin Dow

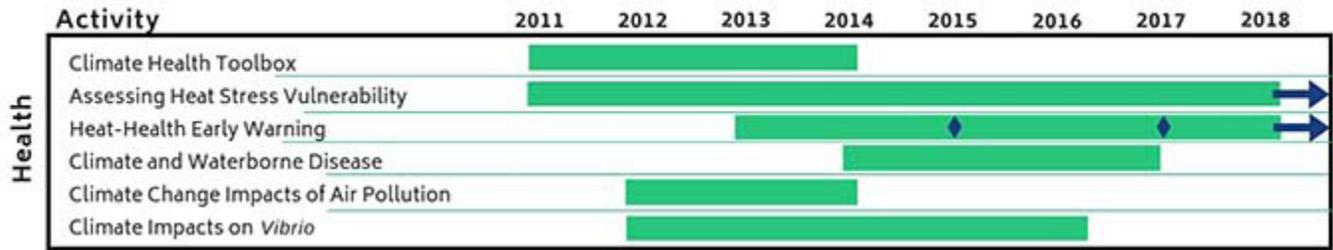
RESILIENCE INCLUSION ON THE COAST: EXPLORING SEA LEVEL RISE IN DIVERSE COMMUNITIES ON THE ALBEMARLE PAMLICO PENINSULA OF NORTH CAROLINA

This project was designed to engage low-lying, rural, minority communities that are highly vulnerable to coastal flooding and sea level rise impacts on the Albemarle Pamlico Peninsula of eastern North Carolina. Using the Rural Coastal Community Resilience framework, stakeholder engagements brought to light perceptions of adaptive capacity and barriers to flood management at multiple scales of government. The project contributes to the understanding of climate justice and climate resilience by expanding research to be inclusive of minority residents within rural coastal communities. The project also fostered new network opportunities as NC Sea Grant had not engaged the study's communities before and firsthand connections were made between local leaders and the Sea Grant coastal hazards specialist. Additionally, by hiring a local leader to work with the project, the communities gained someone with more technical expertise for coastal hazard planning.

Team Members: Seekamp, Jurjonas, Spencer, Rivers

Partners: NC State University

CLIMATE AND PUBLIC HEALTH



Climate and Public Health Projects Timeline - Arrows indicate ongoing projects, Diamonds indicate major stakeholder engagement events

CLIMATE-HEALTH TOOLBOX

CISA team members based at the Southeast Regional Climate Center developed a web-based climate-health toolbox that provides a platform to study, visualize, and predict the health impacts of weather and climate events. Working with data from the [North Carolina Disease Event Tracking and Epidemiologic Collection Tool \(NC DETECT\)](#), researchers developed empirical relationships which were used to build a climate-health toolbox that integrates NC DETECT data, climate and weather data, and geographic information in order to identify climate-public health vulnerabilities across different regions (e.g., coastal plain, Piedmont, mountains) and populations (e.g., rural vs. urban). Stakeholder engagements to obtain feedback about the toolbox were conducted in Chapel Hill, NC (February 25, 2013) and Charleston, SC (March 22, 2013). To protect the public health data in NC DETECT, data use agreements have limited access of the tool to those on the research team. However, CISA and SERCC researchers continue to use the tool internally to inform research on relationships between climate and public health impacts, including the heat health and waterborne disease projects described below.

Team Members: Konrad

Partners: Southeast Regional Climate Center

ASSESSING HEAT-HEALTH VULNERABILITIES IN NORTH CAROLINA

CISA researchers used the climate-health toolbox to investigate the linkages between heat-related illness in different geographies across North Carolina and among different demographics. The findings of this work revealed that the largest differences in vulnerability are between rural and urban areas across NC, especially at the highest temperatures. The highest rates of heat vulnerability are found in rural areas where labor-intensive crops are grown. Demographically, the highest rates are found for males in the 21-45 year age group, many of whom engage in outdoor labor. More information about these research findings is described in the [Highlights and Accomplishments](#) section above.

Team Members: Konrad, Kovach

Partners: Southeast Regional Climate Center

HEAT-HEALTH EARLY WARNING

The heat health research described above was used to inform the development of the web-based Heat Health Vulnerability Tool (HHVT) in partnership with the State Climate Office of North Carolina. The tool has the capacity to predict heat-related Emergency Department (ED) visits at the county level based on National Weather Service daily maximum heat index. It is geared towards public health officials and emergency management personnel across NC. The project team partnered with Climate Ready NC, a CDC Building Resilience Against Climate Effects (BRACE) program, to engage health officials on heat illness through the use of the web-based heat-health vulnerability tool. More information about these early engagements are described in the [Highlights and Accomplishments](#) section above.

Team Members: Konrad, Hyatt, Kovach, Ward

Partners: Climate Ready NC, State Climate Office of North Carolina



Photo Credit: News & Observer



Photo Credit: Flickr Creative Commons

SPATIAL AND TEMPORAL PATTERNS OF WATERBORNE DISEASE AND RELATIONSHIPS WITH PRECIPITATION ACROSS NORTH CAROLINA

CISA researchers used the NC DETECT climate-health toolbox to assess relationships between precipitation patterns and waterborne disease in NC between 2008 and 2012. Correlations between incidences of emergency department (ED) admissions for gastrointestinal illness (GI) and precipitation patterns were analyzed in conjunction with demographic information to improve understanding of populations most vulnerable to these diseases. Results indicate that there are significant correlations between rates of ED admissions and poverty elements. Additionally, there is significant clustering of disease after “heavy” rain, categorized as 2” or more. Several geographically explicit areas of high GI occurrence were identified at the county level, with seven counties showing 300% or greater increases in admissions after heavy rainfall.

Team Members: Downs, Hartley, Konrad

CLIMATE CHANGE IMPACTS OF AIR POLLUTION ON MORBIDITY IN VULNERABLE POPULATIONS ACROSS THE LIFE STAGES IN 2050

CISA provided funding to researchers at the UNC Chapel Hill Gillings School of Public Health to research associations between ozone levels and respiratory and cardiovascular morbidity and projected ozone-related morbidity for North Carolina in 2050. Findings indicated that climate change, air quality regulation, and population dynamics are likely to alter future emergency department (ED) service demands, but not to a substantial degree. The projected impact of increased ED visits in 2050 due to ozone-related illness is not significant. Efforts to reduce emissions will help to offset any potential increased health risk, particularly for vulnerable populations such as children and the elderly. Project stakeholders included Charlotte Area Air Awareness, Clean Air Carolina, the NC Hospital Association, Piedmont Together, and Triangle Air Awareness. These stakeholders found project results to be particularly useful for understanding how climate change will impact future air quality, public education and outreach programs, and supporting regional plans for public transit systems and other emissions reductions strategies.

Team Members: Lippmann, Yeatts

Partners: Environmental Protection Agency, NC Division of Public Health Climate Ready Program, UNC Gillings School of Global Public Health

ASSESSING THE IMPACTS OF CLIMATE VARIABILITY ON VIBRIO IN SOUTH CAROLINA ESTUARIES

This project investigated the human health threats posed by the marine bacterium *Vibrio*. While there are several studies on the distribution of *Vibrio vulnificus* and *Vibrio parahaemolyticus* in estuarine waters around the world, there is little information on the distribution of these organisms in South Carolina waters. Monthly sampling of surface and bottom water from 9 sites in Winyah Bay was conducted over the period April-October 2012. The *Vibrio vulnificus* counts were the highest when salinity ranged between 5 ppt and 20 ppt. *Vibrio parahaemolyticus* did not show a clear pattern with salinity, indicating the possibility of other factors that interact to control its occurrence and abundance. Turbidity on the other hand showed a positive association with both bacteria. Temperature values were within *Vibrio*'s optimal range for growth and seemed to have a lesser effect. The PRISM2 model, which integrates predictions of future streamflow and sea level in an artificial neural network model, was used to estimate future conductivity upper levels and the potential for increased *Vibrio* occurrence in the Winyah Bay estuary. Results show that the increased relative risks of optimum *Vibrio* growth based on specific conductance will increase up to 36X based upon location and range of sea level rise. These increased periods of optimal growth conditions for *Vibri*os may result in increased risk for swimmers and shellfish consumers, if virulent forms occur with more regularity.

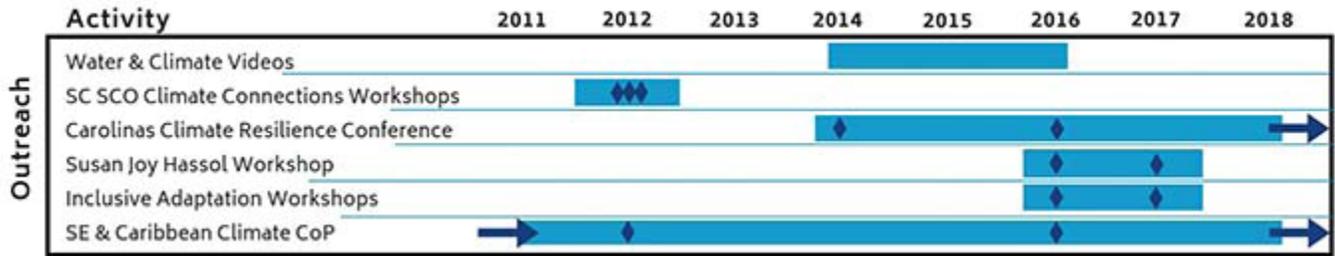
Team Members: Deeb, Dow, Tufford

Partners: NOAA Center for Coastal Environmental Health and Biomolecular Research



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COMMUNICATIONS AND OUTREACH



Communications & Outreach Projects Timeline - Arrows indicate ongoing projects, Diamonds indicate major stakeholder engagement events

WATER AND CLIMATE VIDEOS

CISA produced 21 short documentary style videos illustrating the many ways climate affects water resources and impacts the lives of South Carolinians. Topics range from species conservation to basin level water resources management to changing water demand in a booming tourist area. Stories come from varying perspectives around the state including federal, state and local government, land and water resource managers, and NGOs. Videos have been used in South Carolina high school and university geography courses to complement lesson plans and are available to all formal and informal educators through our website.

Team Members: Carbone, Green

Partners: Anderson Regional Joint Water System, American Rivers, City of Columbia, City of North Myrtle Beach, City of Rock Hill, Congaree National Park, Congaree Riverkeeper Farmers Exchange, Low Country Institute, Low Falls Wholesale Nursery, Mount Pleasant Waterworks, National Audubon Society, The Nature Conservancy, South Carolina Department of Natural Resources, Spartanburg Water, Town of Arcadia Lakes, United States Corps of Engineers

SC CLIMATE CONNECTIONS WORKSHOP SERIES

In collaboration with the South Carolina Department of Natural Resources (SC DNR) State Climatology Office, CISA hosted a series of three stakeholder workshops about climate and its impacts on South Carolina's natural resources. The purpose of the workshops was to increase awareness and utilization of climate information to improve natural resource management. A total of 151 participants attended the workshops including representatives from federal, state and local government, scientists, land and water resource managers, utility representatives, NGOs, and the private sector. Drought, sea level rise, and temperature extremes were the priority climate related concerns. Information from these workshops was included in the 2015 South Carolina State Wildlife Action Plan, the first version to address climate change threats to statewide conservation efforts. SC DNR hosts a [workshop website](#) with links to all presentations, research publications, and other relevant trainings and workshop results.

Team Members: Abramyan, Farris, Mizzell

Partners: South Carolina State Climatology Office



Photo Credit: Ivettia Abramyan

CAROLINAS CLIMATE RESILIENCE CONFERENCE

The idea for a [Carolinas Climate Resilience Conference \(CCRC\)](#) was emerged from discussions with stakeholders designed to inform the Third National Climate Assessment about the information needs and major climate sensitive decisions in the Carolinas. Through these interviews, CISA researchers learned that in-person engagements are pivotal to sharing and understanding climate-related impacts and solutions in the region. In 2014, CISA hosted the first CCRC in Charlotte, NC. The event drew nearly 200 attendees and included over 100 presentations on topics ranging from water resources management and local adaptation actions to climate model downscaling and climate communications in the Carolinas. The 2nd CCRC, held in September 2016, was nearly 40% larger (272 attendees) and much more diverse representation of sectors and individuals. In addition to the 100+ individual posters and presentations, this CCRC included two pre-conference workshops and three plenary sessions.

Team Members: Dow, Farris, Fly, Lackstrom

Partners: See [2014 Carolinas Climate Resilience Conference Report](#) and [2016 Carolinas Climate Resilience Report](#)

CLIMATE COMMUNICATIONS WORKSHOPS WITH SUSAN JOY HASSOL

Following public engagement and science communication training as a fellow of the American Association for the Advancement of Science Leshner Leadership Institute for Public Engagement with Science, Dow arranged a day-long climate communication training to share lessons learned. Twenty people attended the workshop including CISA staff, stakeholder partners, and University of South Carolina faculty interested in improving their science communication skills and doing more public engagement. The training was led by Susan Joy Hassol, the Director of [Climate Communication](#). Hassol led a similar workshop for participants at the 2016 Carolinas Climate Resilience Conference.

Team Members: Dow, Farris

Partners: American Association for the Advancement of Science, Climate Communication

INCLUSIVE CLIMATE ADAPTATION WORKSHOPS

Climate variability and change can disproportionately affect communities of color, low income, tribal and other marginalized communities that have less resources to prepare and recover from impacts. During the 2016 Carolinas Climate Resilience Conference in Charlotte, NC, 30 attendees participated in a workshop to facilitate dialogue between community members and climate professionals seeking to provide communities with information and support. The discussion led to the creation of a small network of individuals who are actively seeking to advance this conversation through the establishment of the Carolinas Climate Action Faith Leaders Network. With travel support from CISA, this group conducted a similar session at the 2017 National Adaptation Forum in order to connect to the national network.

Team Members: Farris, Guiseppe

Partners: East Carolina University, Hip Hop Caucus, National Association for the Advancement of Colored People (NAACP), North Carolina Environmental Justice Network, North Carolina Interfaith Power and Light, and Woodberry & Associates/Kingdom Living Temple

SOUTHEAST & CARIBBEAN CLIMATE COMMUNITY OF PRACTICE

Initiated by NOAA's Southeast and Caribbean Regional Team (SECART) and regional Sea Grant programs, the Southeast and Caribbean Climate Community of Practice (CCoP) was created in 2010 in response to the growing need for climate extension professionals to bridge the gap between science and decision makers. Comprised of individuals from government, academic, non-profit, and private sectors, the CCoP provides a forum for sharing lessons learned and best practices related to climate communication and adaptation. CISA supports the CCoP through monthly e-mail round-ups of webinars, events, and other resources of interest, information sharing through a [CCoP webpage](#), [webinars](#), and in-person workshops. In 2016, 64 people from Florida, Georgia, North Carolina, South Carolina, Virginia, and Puerto Rico attended the in-person workshop in Tybee Island, Georgia. The workshop included presentations on climate communications, vulnerability assessments, and using the National Flood Insurance Program's Community Rating System (CRS) to support climate adaptation. In 2017, the in-person workshop hosted 90 people from throughout the CCoP region. Discussions included impacts and resilience to recent extreme events in the area including Hurricane Matthew.

Team Members: Farris, Foster, Fly, Guiseppe, Sassard

Partners: See the [2016 Workshop Report](#) and [2017 Workshop Report](#) for lists of Steering and Workshop Planning Committee Members



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