

Carolinas Integrated Sciences & Assessments

2014 - 2015 Annual Report

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The CISA Program

The Carolinas Integrated Sciences & Assessments (CISA) program is 1 of 11 NOAA-funded Regional Integrated Sciences & Assessments (RISA) teams, working to integrate climate science into decision-making processes and improve society’s ability to respond to climatic events and stresses. CISA conducts applied climate research in collaboration with a wide range of stakeholders across the Carolinas, including federal, state and local agencies, resource managers, non-governmental organizations, and the private sector. Working at the intersection of climate with water, coasts, and health, CISA’s cross-cutting activities seek to advance scientific understanding of climate and hydrological processes in the Carolinas, improve the assessment of climate-related vulnerabilities and impacts, and provide timely and relevant information and tools for decision makers.

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CISA's Activities and Focus Areas

The CISA team connects climate science and decision making in the Carolinas through:

- Applied research to produce relevant climate information
- Assessments of climate impacts and adaptation strategies
- Processes to support and inform community planning
- Fostering climate networks and climate communities of practices

CISA's work is conducted at the intersection of climate with water, coasts, and health, with an overarching goal of increasing adaptive capacity throughout the region. CISA team members collaborate with local and regional stakeholders to assess specific needs and produce tailored information, tools, and resources to support decision making in the Carolinas.

Water

CISA's water projects address questions about the impacts of climate variability and change on water supply and quality. CISA incorporates climate data into watershed-scale hydrologic models, develops resources to demonstrate the significance of water in the Carolinas, and provides information about water and climate interactions and impacts. Drought-related projects seek to advance monitoring and planning on local, state, regional and national levels.

Coasts

The purpose of CISA's coastal work is to provide tailored information to coastal stakeholders about the implications of climate variability and change and strategies to increase resilience to those impacts. CISA works

directly with communities on topics related to waterfront management, sea level rise, saltwater intrusion, natural hazards, and community planning. CISA supports a coastal climate extension specialist to facilitate these interactions and improve understanding of coastal community decision processes and information needs in order to provide relevant information in a meaningful way.

Health

Diverse geographies and populations in the Carolinas are subject to a wide range of climate conditions and weather extremes, such as heat waves, hurricanes, and drought. Long-term climate trends, such as increasing temperature, can lead to shifts in the presence of harmful bacteria species and waterborne disease and increase health risks and vulnerabilities. A key component of CISA's health work is to investigate the linkages between climate and human health and improve understanding of vulnerabilities and interacting stressors in order to inform the adoption of strategies to reduce risks.

Adaptation

Supporting the development of adaptive capacity to address current climate variability and projected climate change is a cross-cutting element of CISA's activities. CISA facilitates dialogue, in-person interaction, and information sharing among stakeholders through direct engagement as well as broader, network-building communication and outreach activities. Using the Vulnerability and Consequence Adaptation Planning Scenarios (VCAPS) participatory modeling process, the CISA team helps communities engage in dialogue about weather and climate impacts, integrate local knowledge and experiences with scientific information, and think strategically about actions to address climate-related threats.

New Areas of Focus and Partnership

Assessing Climate Sensitivity and Long-Term Water Supply Reliability with a NC Water System

Water resource managers often have questions about the utility of climate change information, particularly model-based projections, for informing their long-term planning. In this project, CISA researchers are working with the Orange Water and Sewer Authority (OWASA) in Carrboro, NC, to conduct a vulnerability-based, or bottom-up, assessment of the water system supply's vulnerability to climate variability and change. Drawing from the "Decision Scaling" approach, CISA researchers will conduct systematic climate sensitivity testing to identify the climate variables that threaten the system's ability to perform within pre-defined thresholds and then develop climate change projections to explore the plausibility of unfavorable climate conditions in the future. The goal of this project is to provide tailored climate change information that has specific relevance for the water utility and can be used in strategic planning processes by the utility's managers and Board of Directors.

CISA Fosters a Sea Level Rise Task Force in Beaufort and Port Royal, SC

Stakeholders in the City of Beaufort and Town of Port Royal have formed a task force to address the area's vulnerability to sea level rise and develop adaptation strategies. The task force has thirteen members, including Beaufort's mayor and Port Royal's planning administrator. The SC Small Business Chamber of Commerce, who helped to convene the group, asked CISA to provide technical assistance in the form of identifying vulnerable areas and developing flood mitigation strategies. In spring 2015, the task force presented its mission statement and recommendations to Beaufort City Council and Port Royal Town Council. Both councils encouraged the task force to continue its work and engage neighborhood groups. Local news outlets have also covered the initiative.¹

¹ Moody, E. May 8, 2015. [Rising sea level concerns northern Beaufort County task force](#). *The Beaufort Gazette*.

Implementing Adaptation Strategies through the Community Rating System

There are clear connections between adaptation strategies to address sea level rise impacts and opportunities to mitigate flood risk as part of the National Flood Insurance Program's Community Rating System (CRS). Conversations with both extension agents and community members revealed that CRS allows communities to engage in climate adaptation planning in a region where few resources are dedicated to addressing climate change impacts directly. As part of CISA's support for the Southeast and Caribbean Climate Community of Practice (CCoP), Fly and Brennan have worked to raise awareness and provide training and resources to engage stakeholders around this opportunity. Activities to date include participation in a one day CRS training and a webinar for CCoP members showcasing communities in the region that have implemented CRS flood mitigation strategies.

Expanding the Public Health Toolbox to Assess Waterborne Disease in NC

Working with data from the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT), CISA researchers are developing a toolbox based on empirical relationships between recent, current, and predicted weather/climate conditions and emergency room admissions data. Work to date has assessed heat vulnerability, and a stakeholder workshop is planned for summer 2015 to share research findings and obtain feedback about on-the-ground conditions which might contribute to higher hospital admissions rates in rural areas. Building on this research, a new effort has begun to assess rates of waterborne disease in North Carolina. Preliminary analyses of waterborne disease counts reveal much variability across the state, with higher rates found in rural areas.

A Community-Wide Health Risk Assessment of Vulnerable Water Infrastructure in Coastal Cities

This project, recommended for funding by NOAA's Coastal and Climate Applications (COCA) program, seeks to expand the capacity of decision makers, including public health officials, environmental agencies, emergency managers and water/wastewater utility operators, around the issues of critical coastal water infrastructure and public health. To do so, the team will analyze water and wastewater infrastructure vulnerability to extreme events, engage stakeholders to develop a community-level susceptibility index of vulnerable populations, test the index through a table top exercise, and develop a guidebook for transferability to other communities. Pilot communities include Morehead City, NC, and Charleston, SC. This project builds upon methodologies developed in a previous CISA-supported project to address the potential vulnerability of municipal water and wastewater infrastructure to coastal hazards, using the towns of Manteo, New Bern and Plymouth, NC, as case study sites.

Adaptation

CISA investigators are leveraging their understanding of adaptation and decision making to initiate new efforts:

- **VCAPS.** CISA uses VCAPS to support community-led adaptation and continually works to improve the process by assessing the learning that emerges as communities engage in collaborative decision making and planning. In the past year, *new community partners* included Hyde County, NC, and St. Marys, GA.
- **CoastWeb.** CISA PI Kirstin Dow is leading the establishment of the Coastal Well-Being, Adaptation, and Sustainability Research Engagement Collaborative (CoastWeb) involving over 20 faculty members at the University of South Carolina. Seed funding has been provided for faculty to work with decision makers to address challenges of economic and environmental change and potential impacts on public and environmental health.
- **SECAS.** CISA researchers are partnering with the National Wildlife Federation and North Carolina State University faculty on a project to support the Southeast Conservation Adaption Strategy (SECAS) process. The project will examine how climate and landscape changes could influence the ability of resource managers to achieve long-term, regional conservation goals and objectives. This proposal has been recommended for funding by the DOI Southeast Climate Science Center. Work is expected to begin in summer 2015.

Supporting Continuing Education for Teachers in Ocean and Atmospheric Science

The American Meteorological Society (AMS) offers courses to fulfill continuing education credits K-12 teachers. Fly supported a Local Implementation Team (LIT) offering the AMS DataStreme courses in Ocean and Atmosphere to teachers in Beaufort and Jasper counties (SC) and Effingham County (GA). Ten teachers participated in the courses, earning continuing education credits and developing lesson plans shared nationwide. These teachers are now extending their new knowledge to students and other teachers in their districts.

CISA Video Series Highlights Climate Influences on Water Resources in SC

CISA has produced thirteen 3-minute videos featuring topics related to water use, community water system management, wastewater challenges, water planning and conservation initiatives, and ecosystems. Interviewees represented resource agencies, NGOs, and the private sector. The documentary-style videos define abstract concepts such as drought and climate variability through interviewees' easy to understand, on-the-job observations. Identifying subjects for the original thirteen videos helped to uncover new stakeholders and reconnect with previous partners. Future use of these videos may include incorporation into an online version of the hydroclimate extremes atlas for the Carolinas. Access the videos at: www.cisa.sc.edu/videos.html.

Research Highlights

Development of an Atlas of Hydroclimate Extremes for the Carolinas

Through interaction with coastal land managers, fishers, and others dependent on coastal resources and ecosystems in the Carolinas, CISA identified a need for an improved baseline understanding and information about drought and normal precipitation in the Carolinas. In response, CISA has undertaken the development of an atlas of hydroclimate extremes. Initial work has included the development of core material on temporal and spatial patterns of hydroclimate extremes (see **Figure 1**). Specifically, researchers utilized high resolution daily and monthly PRISM datasets to identify spatial patterns of precipitation.

- Analyses of daily PRISM data reveal a marked gradient of summer season precipitation with exceptionally low values along portions of the immediate coastal line, in contrast to very high values 10+ kilometers inland, especially over the South Carolina coastal plain. This pattern has implications with respect to return periods for drought and very heavy rainfall.
- With respect to temporal variation, analyses of monthly PRISM data from 1895-2014 reveal a decreasing mean summer precipitation trend, especially over the western Carolinas and Piedmont region of North Carolina. A marked positive trend is identified in mean fall precipitation, especially over the coastal Plain and Piedmont regions in North Carolina.
- The atlas will also provide information about drought impacts. As a first step, CISA researchers used long-term county-level agriculture statistics to examine corn, cotton, soybean, and wheat yield impacts in North and South Carolina from 1950 to 2013. Statistical models were compared to determine which best replicated yield with respect to both long-term trends and high-frequency yield variation caused by climate variability. Drought indices were also assessed to determine which correlated best to crop yield. Study results indicated that the 1) the 3-Month SPI performs best to correlate with crop yield among a variety of drought indices and 2) that corn and soybean yields were most affected by drought, with the corn yield showing a higher level of correlation with the 3-Month SPI in June, July, and August and the soybean yield showed a higher level of correlation with the 3-Month SPI in July, August, and September.

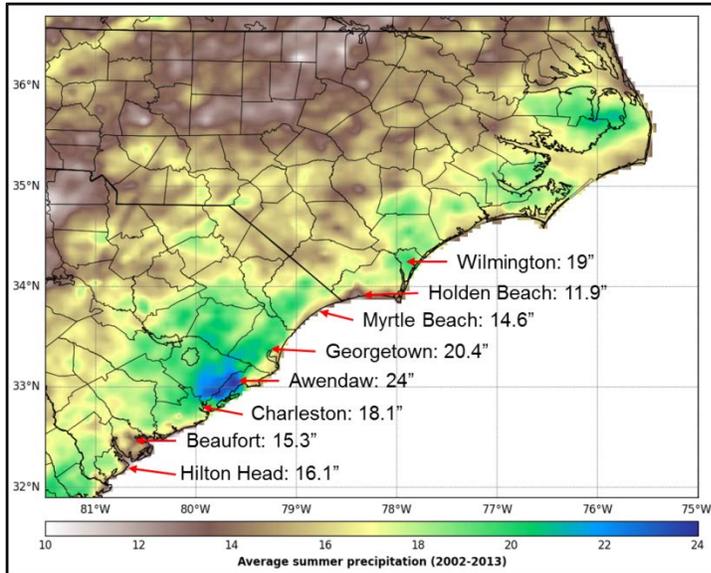


Figure 1: Based on daily PRISM data, this map shows the average summer (JJA) precipitation across the Carolinas coastal plain during 2002-2013. The highlighted locations indicate the marked gradient in summer season precipitation within the coastal plain, which is characterized by relative dryness along the immediate coastline (e.g., Myrtle Beach, SC) and a ribbon of wetter conditions beginning ~10 kilometers inland (e.g., Georgetown, SC).

Needs Assessment of Coastal Land Managers for Drought Indicators in the Carolinas

While many drought indices and indicators exist (focusing on, for example, agriculture or reservoir management), little attention has been given to impacts, monitoring and early warning for coastal ecological resources. This project, which is supported by the NOAA Sectoral Applications Research Program (SARP), seeks to improve understanding of coastal resources that are adapted to or dependent upon particular spatial and temporal patterns of precipitation, salinity, or streamflow to determine stress caused by drought. As a first step, CISA collaborating investigators at East Carolina University conducted a series of interviews with 30 land managers and natural resource specialists in the coastal Carolinas. Key findings include:

- A need for early drought detection (83%), but a lack of awareness of current drought indicators. All interviewees who indicated a need for an early-warning drought indicator also emphasized the need for indicator parameters that reflected freshwater availability and impacts on ecological resources.
- Agreement that drought indicators should be specifically focused on specific kinds of habitats (50%); although, 90% thought that a single index could be useful for multiple habitats that have broad similarities. More specifically, 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.
- A lack of resources to collect needed data for a drought indicator (86%). Specific concerns included, practical constraints (e.g., staff time), broad spatial gaps in data that limit extrapolation, and the extent to which an indicator was relevant among neighboring habitat types. Suggestions by interviewees to overcome these constraints include coordinated data collection among managers of similar habitats, a focus on ecological variables most common across habitats (e.g., soil salinity), and selection of input parameters that coincide with other management plans in order to increase relevance and, in turn, regular use of the indicator.

Climate Change Impacts of Air Pollution on Morbidity in Vulnerable Populations

CISA collaborating investigator Karin Yeatts, UNC Chapel Hill Gillings School of Public Health, estimated current 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. Stakeholders included the 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. In addition, the director of Climate Ready NC, a CDC Building Resilience Against Climate Effects (BRACE) program, indicated that she would use the results when prioritizing future projects, particularly given the small changes in air pollution and small increases in ED visits indicated by this project's findings.

Assessment of Regional Climate Models in Simulating Extreme Rainfall Events

Capturing the intensity and return period of extreme rainfall events in the historic record and projecting them into the future would benefit infrastructure design, planning, and management. Building on work conducted to inform the *Low Impact Development in Coastal South Carolina: Planning and Design Guide*, CISA team members Carbone and Gao assessed the performance of nested regional climate models in simulating historic extreme rainfall events and investigated potential future changes in rainfall patterns. A combination of four General Circulation Models (GCMs) and six Regional Climate Models (RCMs) from the North American Regional Climate Change Assessment Program (NARCCAP) were used to evaluate performance across the United States. Researchers compared model output for twelve regions in the continental U.S. with relatively homogenous annual maximum 24-hour rainfall patterns using Intensity-Duration-Frequency (IDF) curves. Spatially, models replicated the historical record reasonably well in many parts of the country; although, model performance was poorest in the Southeast. The GCM used to provide boundary conditions for the RCM strongly influenced model output. Researchers found that models driven by the Community Climate System Model (CCSM) and Canadian Global Climate Model version 3 (CGCM3) performed best. With respect to future precipitation change, most models projected intensified 24-hour rainfall events (exceptions include some decreases in southern California, the extreme north-central U.S., Florida, and the Texas Plains). This study provides a valuable means of assessing NARCCAP models' performance in simulating regional-scale rainfall extremes and understanding how GCMs, RCMs, and spatial variability affect model performance.

Vulnerability and Consequences Adaptation Planning Scenarios (VCAPS) process

Evaluations from work with eight coastal communities identified four assets of the VCAPS process: promoting synthesis of local and scientific knowledge, stimulating systems thinking and learning, facilitating governance by producing action plans with transparent justifications, and accommodating participant time constraints and preferences. Engaging with local governments through VCAPS also revealed the specific challenges they face in synthesizing potential impacts across sectors and addressing the unique and vulnerable geography of barrier islands. Findings regarding the various types of learning that emerge through VCAPS processes (e.g., knowledge acquisition, mastery of skills, and understanding different perspectives) will be used to inform the design and evaluation of future VCAPS projects.

Outreach Activities

Climate Communications and Outreach in the Carolinas

CISA's Climate Outreach Specialist, Amanda Brennan, plays a key role in CISA's work to support state and local adaptation projects and capacity-building by providing opportunities for information exchange and translating scientific data into useable formats for decision makers and the public. Specific outreach activities include:

- The Carolinas Climate Connection, a quarterly newsletter circulated to over 1,000 stakeholders

- The Carolinas Climate Listserv, launched in June 2013, which currently has 197 subscribers
- An online presence via the CISA website and social media accounts
- Organization of [water and climate sessions](#) at the NC Water Resources Research Institute annual conference, March 2015, which highlighted various CISA-supported projects and activities
- Exhibitor booths at the NC Water Resources Research Institute conference and the National Adaptation Forum

CISA's Coastal Climate program was established as the Carolinas Coastal Climate Outreach Initiative (CCCOI) in 2007. Currently led by CISA PI Elizabeth Fly, this program has strengthened collaboration between CISA and the Sea Grant programs in North and South Carolina and has served coastal stakeholders as a trusted source of climate information and products. Many projects are conducted in collaboration with Jessica Whitehead, the NC Sea Grant Coastal Hazards Extension Specialist. Specific efforts conducted by Fly are noted in the "*CISA Impacts*" section.

The CISA team regularly participates in local, regional, and national conferences, workshops, and meetings to share information about CISA projects. Audiences include project stakeholders, government agencies, academics, and other outreach communities. The appendix provides a full list of CISA's 100+ outreach and engagement efforts.

Regional and National Engagement and Outreach

In order to identify opportunities for collaboration and to seek synergies with other efforts, CISA team members share research findings and interact with climate practitioners and stakeholders throughout the Southeast region and at the national level as well. Specific efforts include:

- Steering committee co-chairs of the [Southeast and Caribbean Climate Community of Practice](#) (Brennan, Fly). More information on this partnership is provided below.
- Co-chair of the NIDIS Engaging Preparedness Communities Working Group (Lackstrom)
- Participation in the South Carolina Coastal Information Network and its quarterly meetings (Fly, Brennan)
- Participation at the Governor's South Atlantic Alliance annual meeting held September 3-5, 2014 (Fly)
- Participation in the National Adaptation Forum [program committee](#) and [regional adaptation conferences session](#) (Brennan)
- National Adaptation Forum session – [Identifying Decision-Focused Climate Adaptation Activities and Aligning Priorities across Multiple Sectors and Scales in the Southeast U.S.](#) (Brennan, Dow, Fly, Whitehead)
- National Adaptation Forum session – [Building Drought Resilience Across Sectors and Scales](#) (Lackstrom)
- Participation in collaboration calls with [NCAnet](#) (Brennan)

Southeast and 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. The CCoP also provides education and networking opportunities to increase their members' knowledge and awareness of climate science and, ultimately, to increase adaptive capacity in the region.

Over the past year, co-chairs Fly and Brennan have supported the CCoP through a monthly e-mail round-up of webinars, events, and other resources of interest to the CCoP members, information sharing via the StormSmart webpage, and two webinars, "Risky Business: The Economic Risks of Climate Change in the United States" and "Leveraging the Community Rating System for Climate Adaptation." Fly and Brennan have also participated in other workshops in order to bring resources and information to the CCoP, including the [Community Rating System workshop](#) (Carl Vinson Institute of Government, August 2014) and the [Gulf of Mexico Climate Community of](#)

[Practice annual meeting](#) (May 2015). The team submitted a proposal to the National Sea Grant Office in June 2015 to support an in-person CCoP workshop in which CRS and climate adaptation will be a key topic.

Selected Stakeholder Engagement Activities

Understanding rapid environmental change at Alligator River National Wildlife Refuge

In many places at Alligator River National Wildlife Refuge, marsh grass communities are now replacing the native pond pine pocosin ecosystem due to sea level rise and changes in soil conditions. These habitat changes are also leading to changes in animal species distributions. Collaborating investigators from North Carolina State University hosted a stakeholder and community workshop on December 5, 2014, to share information about the habitat changes occurring at the Refuge and the research being conducted to understand the causes of those changes (see **Figure 2**). The US Fish and Wildlife Service is using 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. The workshop included a tour of the Refuge to see some of the changes first-hand, presentations on the research being conducted to understand the causes, and breakout group discussions during which participants created prioritized lists of future research and public engagement needs.



Figure 2: John King (at right) shares information about the changing ecology of Alligator River National Wildlife Refuge with local stakeholders during a workshop on December 14, 2015. Fewer pine trees are seen in the landscape to the left of the road, as this area transitions from pond pine pocosin to marsh due to changing salinity levels caused by sea level rise.

Public workshops to prioritize climate-resilient planning strategies for Beaufort County, SC

Stakeholder engagement was a key component of the Beaufort County climate-resilient planning project, the goal of which was to assist the County in writing a plan for priority actions to update existing planning processes (e.g., Comprehensive Plan) and encourage climate resilience in the County. As part of this project, CISA team members hosted two public workshops, attended by 77 people, in August 2014. The goal of the workshop was to provide information about the latest sea level rise science and project background information, discuss Beaufort County's vulnerabilities to sea level rise, and solicit participant feedback on potential adaptation strategies in order to prioritize them in the final report to the County's planning commission. In addition to a ranking exercise, in which participants selected three adaptation priorities, key discussion topics included recommendations for alternative strategies, important trade-offs to consider with each strategy, and actions which could be pursued with currently available resources and political agreement.

Fostering volunteer retention in drought impacts monitoring and reporting

A significant part of the CISA and CoCoRaHS citizen science drought monitoring project has been building and maintaining the network of observers who submit weekly reports about on-the-ground conditions in their local areas. Building on best practices developed through other citizen science efforts, CISA has sustained a continuous stream of information sharing and engagement with project volunteers. Efforts include the "[Cuckoo for CoCoRaHS in the Carolinas](#)" blog, a monthly newsletter, and a [project webpage](#) where education and training materials are

available for reference (see **Figure 3**). CISA team members also conduct quarterly conference calls with observers to provide project updates and an opportunity for observers to ask questions and share feedback. In order to assess the usefulness of these information-sharing materials and interactions, a series of online surveys have been circulated to volunteers during the 1-year commitment period. The team will use survey results to improve ongoing efforts and establish best practices in the next phase of the project.



Figure 3: CISA team members provided in-person trainings to volunteer observers for the CISA & CoCoRaHS citizen science condition monitoring project. Volunteers submit weekly observations connecting local conditions with recent weather and rainfall patterns.

CISA Impacts

Contributions to Improved Drought Impacts Monitoring and Reporting

“We’ve been watching conditions quickly deteriorate in the western half of NC over the last few weeks and these [condition monitoring reports] have been invaluable sources of on-the-ground information. This is a time of year where there still aren’t many impacts to be felt in more ‘typical’ sectors such as agriculture. The wealth and detail of information in these reports is amazing...”

“Connecting the information in these reports with objective indicators such as streamflow levels or SPI really gives us a fuller picture of what’s happening in parts of the state.”

E-mail correspondence on April 8, 2015, from Rebecca Cumbie, a representative to the NC Drought Management Advisory Council

CISA is engaging with citizen scientists to improve the reporting of drought impacts that are not as well documented as impacts to sectors such as agriculture and water supply. Additionally, the reports are intended to improve understanding of the onset, intensification, and recovery of drought conditions by providing a baseline against which to compare when precipitation levels vary. Interviews with drought decision makers indicate that the 1,000+ reports submitted through the CoCoRaHS website since September 2013 have begun to achieve these goals and are being used to verify data from other, more traditional quantitative indicators.

Future work to improve the reporting process and expand the network of observers to other parts of the U.S. will increase the impact these citizen scientists have in efforts to better document and understand the drought phenomenon.

Using Participatory Scenario Building to Encourage Climate-Resilient Planning in the Coastal Carolinas

Funded through a NOAA National Sea Grant Office Coastal Community Climate Adaptation Initiative (CCCAI) grant, CISA partnered with the SC Sea Grant Consortium, Social and Environmental Research Institute, and North Carolina Sea Grant to assist the Beaufort County, SC, Planning Department in identifying priority actions that encourage climate resilience and which could be incorporated into existing planning processes (e.g., Comprehensive Plan). The process has focused on identifying local strategies and actions to directly or indirectly reduce community vulnerability to sea level rise. Based on stakeholder engagements conducted between summer 2013 and spring 2014, including targeted interviews and a VCAPS workshop with 19 local decision makers, a list of potential sea level rise adaptation strategies was compiled. In August 2014, two public workshops were hosted to seek local input on the list of adaptation strategies. During the workshops, participants critiqued, expanded, and combined adaptation actions, then ranked their top three in order to prioritize the list for a final report.

The [final report](#) includes 23 priority adaptation strategies. These strategies include consideration of future sea levels in long-term land, water, transportation, and emergency management planning processes; enhanced research and monitoring efforts to improve understanding of current and future change and associated impacts; coordination, cooperation, and collaboration across local governments and between the public and private sectors; and education and outreach to create a more knowledgeable community of engaged stakeholders. The final report, tailored to the needs of County officials, details local sea level rise vulnerability and the community input process that generated the adaptation strategies. The report also includes case studies from other communities faced with similar challenges and tools to facilitate implementation of the adaptation strategies.

The 23 priority adaptation strategies are being considering for possible incorporation into the County's Comprehensive Plan. Following on this work, Fly was invited to work with the County's Disaster Recovery Coordinator to begin the process of incorporating sea level rise and future storm surge considerations into Hazard Mitigation and Disaster Recovery Plan updates. A sea level rise task force, with representatives from the City of Beaufort and Town of Port Royal, is using information in the report to inform members' understanding of potential sea level rise impacts and assessing the adaptation strategies for possible implementation in their own municipalities.

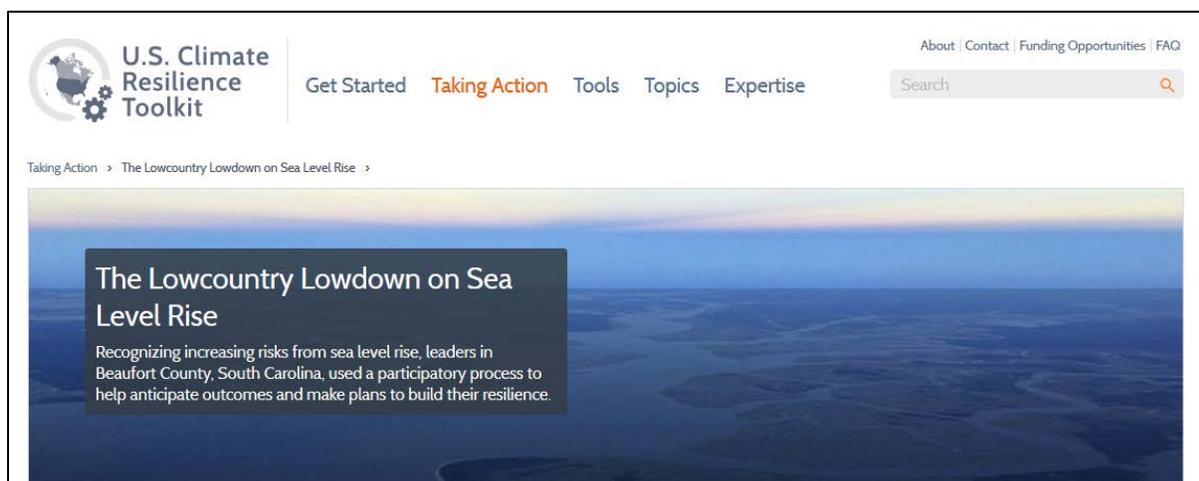


Figure 4: The U.S. Climate Resilience Toolkit highlighted the Beaufort County (SC) project as a [“Taking Action” case study](#), where it will serve as a model for other communities seeking to increase resilience to the impacts of climate change and sea level rise.

Addressing Short- and Long-Term Weather and Climate Impacts on a South Carolina Barrier Island

This project was initiated in February 2014 when the members of the City of Folly Beach, SC, Planning Commission contacted CISA's coastal climate extension specialist, Fly. Folly Beach is a small barrier island city just outside of Charleston, SC, that experiences chronic beach erosion issues due to the placement of jetties in the Charleston harbor. Folly Beach is typically renourished every 5-7 years. The city wishes to become more knowledgeable on the state of their beach erosion and the various options available for erosion control, as well as address longer-term climate issues in their Local Comprehensive Beach Management Plan (LCBMP) updates.

Fly worked with the SC Sea Grant Consortium's Coastal Processes Extension Specialist to provide technical support at planning meetings and input on the LCBMP. This included beachfront monitoring and erosion data in GIS and .KMZ (Google Earth compatible) formats, as well as additional mapping and survey support. An inventory of all beachfront structures was completed and used to produce GIS products for use in the plan. Folly Beach also consulted with the extension specialists on possible alternatives or enhancements to their renourishment strategy. The SC Department of Health and Environmental Control's Office of Ocean and Coastal Resource Management has preliminarily approved the updated LCBMP.

Increasing Resilience and Adaptive Capacity in the Charleston, SC, Region

Several efforts are currently underway in the Charleston, SC, region to build resilience and increase adaptive capacity. Fly has participated in these efforts from early planning stages and will continue to provide support for a regional network of decision makers and stakeholders.

- 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. The table top exercise was piloted in Charleston, SC, in June 2014. Fly participated in planning meetings and helped to facilitate the exercise, attended by 75 participants.
- The creation of the Charleston Resilience Network (CRN) was a major outcome of the DHS IP tabletop exercise. Fly is partnering with representatives from the Berkeley-Charleston-Dorchester Council of Governments, Charleston County Emergency Management, City of Charleston, SC Sea Grant Consortium, SCANA Corporation, and SC Department of Health and Environmental Control's Office of Ocean and Coastal Resources Management as founding members of the CRN. The group hopes to develop and foster a platform to share information, educate stakeholders, and enhance long-term planning decisions that result in effective pre-hazard mitigation strategies and post-hazard recovery efforts. Organizational meetings were held in fall 2014 and winter 2015 to help define the mission and scope of the network. The CRN officially launched in spring 2015 in conjunction with the National Academy of Sciences Resilient America Roundtable workshop.
- The [National Academy of Sciences \(NAS\) Resilient America Roundtable \(RAR\)](#) initiative selected Berkeley, Charleston, and Dorchester Counties as a pilot area. The purpose of the RAR is to work with a community over a three-year period to better understand risks and define a resilience strategy. To kick off the Charleston process, NAS hosted a workshop in April 2015. Fly helped to plan the workshop, which was attended by 60 people from regional public and private organizations. The workshop consisted of several components, including examples of local resilience initiatives, a participatory exercise to demonstrate response needs after an extreme event at a community level, and breakout group discussions focused on components of resilience in social, natural, economic and built environments. Future activities are expected to include a "lessons learned, lessons applied" mini-workshop series, expert meetings, video webcasts, and outreach programs so that community members can learn from one another and from experts about how to build resilience.

Key Publications

- Kettle, N. P., K. Dow, S. Tuler, T. Webler, J. Whitehead, and K. M. Miller. 2014. Integrating scientific and local knowledge to inform risk-based management approaches for climate adaptation. *Climate Risk Management* 4-5: 17-31.
- Kabela, E.D. and G.J. Carbone. 2015. NARCCAP Model Skill and Bias for the Southeast United States. *American Journal of Climate Change* 4 (1): 94-114.
- Kovach, M. M., C. E. Konrad II, and C. M. Fuhrmann. 2015. Area-level risk factors for heat-related illness in rural and urban locations across North Carolina, USA. *Applied Geography* 60: 175-183.
- Petes, L. E., J. F. Howard, B. S. Helmuth, and E. K. Fly. 2014. Science integration into US climate and ocean policy. *Nature Climate Change* 4: 671-677.
- Webler, T., S. Tuler, K. Dow, J. Whitehead, and N. Kettle. 2014. Design and evaluation of a local analytic-deliberative process for climate adaptation planning. *Local Environment: The International Journal of Justice and Sustainability*. DOI: 10.1080/13549839.2014.930425

Metrics of Success

CISA is currently completing Year 4 of its 5-year (2011-2016) grant. In summer 2014, the team conducted a program evaluation to assess overall program progress and to identify opportunities to continue to strengthen the program. There were two components of the evaluation. The internal aspect of the evaluation, conducted by CISA team members, solicited feedback from stakeholders to determine the value of products such as the Carolinas Climate Listserv and quarterly newsletters. Results of these surveys have been used to improve content and circulation of these communications and outreach materials.

In the external evaluation component, three external reviewers conducted interviews with PIs, other team members, advisory committee members, and stakeholders to evaluate work to date and to help CISA think creatively about future directions. Key questions posed for the external evaluation include:

- How is CISA doing in terms of developing decision-relevant science and information for the Carolinas?
- What has been accomplished? What progress has been made?
- Should research focus areas continue in the same direction, should existing projects and partnerships be expanded or should new or alternate paths and partnerships be pursued?

External evaluators produced a final report based on interview findings. This report was shared with the CISA advisory committee at an in-person meeting in fall 2014 in order to discuss results and next steps for the research team. The evaluation team commended the CISA program for its accomplishments, including the execution of a highly regarded research agenda, development of climate communications and outreach capabilities, building of collaborative partnerships, and providing respected leadership on climate issues and concerns in the Carolinas. In response to some of the challenges and opportunities noted in the evaluation, CISA has initiated new health-related projects and is working to connect climate with other decision making processes of regional interest. New projects and initiatives, for example, address the resilience of local infrastructure, emergency management, and flood risk mitigation through the Community Rating System. The CISA staff also continues to refine strategies for communicating and engaging with a variety of audiences about climate, including educators, elected officials, and the private sector.

Overview of Ongoing Projects

NIDIS Drought Early Warning System Pilot Program

CISA collaborates with the National Integrated Drought Information System (NIDIS) to build understanding of drought's effects on the Carolinas' coastal ecosystems, conduct related research, and engage decision makers as part of the Coastal Carolinas Drought Early Warning System (DEWS) pilot program. Goals of the pilot program include increasing awareness of coastal drought and to develop information that can be integrated into drought and resource management decisions making processes. This section describes NIDIS-related projects conducted by the CISA PIs and staff, which will also inform other NIDIS-Carolinas pilot projects led by CISA partners, to include:

- Paul Conrads' (USGS South Atlantic Water Science Center) development of a coastal drought index (CDI) based on salinity. This index will be linked to ecological impacts or outcomes in order to inform the development of ecological indicators of drought and to support adaptation planning for coastal resource managers.
- Michael Childress' (Clemson University) work to examine the sensitivity of blue crabs to salinity changes and development of a model to project landings under current and projected freshwater discharge changes.
- Ryan Boyles' (NC State Climate Office) efforts to evaluate existing drought indices to determine which best represent local fire risk in the organic soils of the coastal Carolinas posed during periods of drought.

Drought Impacts Monitoring and Reporting through Citizen Science Engagement

Team Members: Brennan, Davis, Dow, Eckhardt, Lackstrom, Sayre, Selvaraj

Partners: Community Collaborative Rain, Hail and Snow (CoCoRaHS) network, National Integrated Drought Information System (NIDIS), National Drought Mitigation Center, NC and SC National Weather Service Offices, State Climate Office of NC, SC State Climatology Office

Stakeholders: CoCoRaHS observers, Master Gardeners and Master Naturalists groups, drought managers and decision makers in NC and SC, US Drought Monitor authors, National Drought Mitigation Center

Overview: CISA researchers are engaging citizen scientists in on-the-ground data collection to improve understanding of the impacts of rainfall, or a lack thereof, on local ecosystems and communities. Using tools developed by the CoCoRaHS network, CISA recruited volunteers to enter daily precipitation measurements and weekly status reports about the condition of ecosystems and communities in their area. The focus on regular reporting, in contrast to intermittent drought impact reports, is intended to create a baseline for comparison of change through time and to improve understanding of the onset, intensification, and recovery of drought. Researchers are also conducting decision-maker interviews to understand how the collected information can be used for drought response decisions. The project seeks to build knowledge about the viability of citizen scientists as a means of data collection and how their information might improve understanding of drought impacts.

Progress & Results:

- As of May 2015, 43 volunteers from throughout the Carolinas have submitted over 1,000 condition monitoring reports through the CoCoRaHS website. Reports are also uploaded to the National Drought Impact Reporter.
- Report content is coded and analyzed using a coding scheme derived from the US Drought Monitor drought impact categories, types of weather information, and degrees of dryness indicated by reports. A series of maps and graphics was generated based on the coded data to summarize and visualize report content.
- Interviews have been conducted with 11 decision makers representing NC and SC drought response committees, the US Drought Monitor, the National Drought Impacts Reporter, and CoCoRaHS. Interviewees find utility in the reports, particularly as additional data to verify information provided by quantitative indicators related to precipitation, agricultural conditions, streamflow, and fire hazard risks. Reports were utilized in different manners based on the interviewee's current use of citizen science information,

perceptions of reliability, and the organizational context within which drought planning and management decisions are made. Aggregation of the data into maps, graphs and charts was noted as particularly useful for quickly assessing general conditions in order to determine where to focus attention.

Indicators and Indices of Drought in Southeastern Coastal Ecosystems

Team Members: Chalcraft, Nolan, Tufford

Partners: East Carolina University, National Integrated Drought Information System (NIDIS), NOAA Sectoral Applications Research Program (SARP)

Stakeholders: Coastal resources managers, land managers, drought managers and decision makers in NC and SC

Overview: While many drought indices and indicators exist (focusing on, for example, agriculture or reservoir management), coastal ecological resources receive little attention. This project seeks to improve understanding of coastal resources that are adapted to or dependent upon particular spatial and temporal patterns of precipitation, salinity, or streamflow to determine stress caused by drought. The project is conducted in two phases.

Progress & Results:

- First, a needs assessment was conducted through structured interviews with 30 coastal resource managers along the Carolinas' coast to identify opportunities for drought early warning and monitoring through the use of existing or potential new indicators or indices as well as additional data and research needed to effectively understand and monitor drought in coastal ecosystems. Findings from this phase of the project are provided in the "*Research Highlights*" section of this report.
- The second component of this project will involve collaboration with USGS to inform the development of the coastal drought index (CDI). Utilizing priorities identified through stakeholder interviews, researchers will work to determine linkages between ecological indicators and varying salinity levels expressed by the CDI.

Development of an Atlas of Hydroclimate Extremes in the Carolinas

Team Members: Carbone, Konrad, McLeod

Partners: National Integrated Drought Information System (NIDIS), Southeast Regional Climate Center

Overview: Through interviews and meetings with coastal land managers, fishers and others dependent on the Carolinas coastal resources and ecosystems, decision makers indicated the need for an improved baseline understanding and information about drought and normal precipitation in the Carolinas. In order to meet this need, CISA is developing an atlas of hydroclimate extremes.

Progress & Results:

- Initial steps have included the development of core material on temporal and spatial patterns of hydroclimate extremes. This foundational work can be built upon as more analysis and data become available. In order to further support decision making, the atlas will provide information on related impacts. Results of work conducted during 2014-2015 can be found in the "*Research Highlights*" section of this report.
- The final iteration of the atlas, which will be made available in an online format, will provide information such as the average frequency of drought events, conditions necessary to support drought recovery, and rates of groundwater and aquifer recharge following a drought.

Future Streamflow Forecasts for a Coastal Plain River

Team Members: Carbone, Childress, Lu, Tufford

Overview: 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 but adversely affected by recent droughts. Low levels of freshwater discharge into the estuary changes the salinity profile which influences crab

growth, movement and survival. This project aims to identify and examine a range of possible changes in Edisto River discharge between now and 2030. Streamflow projections will be used as input for an individual-based blue crab model, developed by Childress for the NIDIS Carolinas DEWS pilot, to forecast future SC blue crab landings.

Progress & Results:

- As an initial step, CISA researchers used NOAA's Open-source Nonpoint Source Pollution and Erosion Comparison Tool (OpenNSPECT) to simulate seasonal streamflow, a screening tool to estimate the possible watershed-scale impact of climate and land cover changes on runoff and nonpoint source (NPS) pollution.
- The team used seasonal estimates of precipitation and evaporation for 2011-2030 from the Netherlands Meteorological Institute (KNMI) Climate Explorer website. They bracketed the range of variability of climate forecasts using the CMIP5 ensemble means for the four representative concentration pathways (RCPs 2.6, 4.5, 6.0, and 8.5). Total streamflow was derived by adding the model's runoff forecasts to estimates of seasonal baseflow, derived by baseflow separation analysis of a 30-year record (1981-2010) of Edisto River streamflow.
- The 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 resulted in a decreasing streamflow trend.

Climate

Dynamic Drought Index Tool (DDIT)

Team Member: Carbone

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)

Overview: CISA researchers developed the DDIT in response to drought decision makers' requests for an interactive tool that allows drought monitoring with user control of index, time frame, and spatial aggregation unit. SC DNR maintains the tool which currently provides the ability to examine historical droughts up to 2009. The Northeast Regional Climate Center continues work to implement a near-real time, grid-based version of the DDIT, for access through their ACIS data with the intent to cover eighteen states in the eastern U.S. Carbone authored a chapter summarizing lessons learned from the DDIT development and transfer process for *Climate in Context*.

Drought Sensitivity Testing

Team Member: Boyles, Cumbie

Partners: NC State Climate Office, Texas A&M University

Stakeholders: National Integrated Drought Information System, NC Department of Environment and Natural Resources (DENR) Water Resources Division, NC Drought Management Advisory Council (DMAC)

Overview: Stakeholders with the NC DMAC and NC DENR Water Resources Division, in addition to other resource managers, are interested in using high-resolution drought indicators (HRDI). In particular, the NC DMAC provides weekly guidance to the US Drought Monitor and would like to be able to ensure accurate depictions of local drought severity. Therefore, this project was designed to test how sensitive drought estimates are to the input data set specifically by comparing drought indices derived from point-based inputs from surface gauge networks and drought products based on gridded inputs including multi-sensor precipitation estimates (MPE) and gridded temperature products. This work leverages a partnership with Texas A & M University.

Progress & Results:

- MPE derived from radar, and corrected against surface gauge and satellite observations are increasingly incorporated into drought monitoring, as the use of radar gives MPE the ability to estimate precipitation in

locations with no or few surface gauges. This project compared the MPE-based Standardized Precipitation Index (SPI) with other monitoring tools, including the DDIT, and evaluated the MPE-based SPI for application in the Carolinas. Findings indicated that the MPE-based SPI provides similar information to independently-generated and station-based SPI. However, nuances exist in the spatial extent and variability of drought severity indicated by the different tools, suggesting that operational use might vary depending on needs for more localized or regional detail.

- The NC DMAC uses HRDI products and gridded drought maps routinely in weekly drought discussions and as input to the US Drought Monitor.

Water

Modeling of the Winyah Bay Watersheds

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

Overview: CISA integrates climate data with hydrological models to assess the potential impacts of climate variability and change on water resources in the Southeast. CISA researchers are using 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 have been 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.

Progress & Results:

- CISA researchers completed the assessment of the sensitivity of the HSPF watershed model to four rainfall disaggregation methods. Findings indicate that HSPF is not very sensitive to these different methods at the spatial scale of the watersheds used in the study, though distributing daily rainfall evenly across 24 hours resulted in the poorest model performance compared to the other three methods. These findings provide valuable information for understanding the sensitivity of hydrologic models to temporal patterns of rainfall and the selection of proper rainfall disaggregation methods.
- The second project involved calibrating the HSPF model for the Waccamaw River watershed for dissolved oxygen (DO) to improve understanding of the drivers of DO dynamics in the watershed. DO is a significant stress in this watershed and has drawn the attention of regulators and stakeholder groups.

Assessing Climate Sensitivity and Long-Term Water Supply Reliability with a North Carolina Water System

Team Members: Carbone, Patel

Stakeholder: Orange Water and Sewer Authority (Carrboro, NC)

Overview: In collaboration with utility representatives, team members are assessing the raw water supply of a North Carolina utility to determine its vulnerability to changing climatic conditions. The project is informed by the "Decision Scaling" approach where focus is placed on modeling a system's response to climate in order to understand its vulnerability, rather than starting with a top-down impact assessment based on climate change projections produced from GCMs. As a result, this project is expected to facilitate the consideration of climate change in the utility's long-range planning.

Progress & Results:

- Initial meetings have been held to understand the planning context, the current system configuration, future expansion options, long-range planning processes, and stakeholder expectations, and to provide information about the advantages and limitations of climate change information. Together, utility representatives and CISA identified water supply metrics and the scales at which they would be useful for planning.

- The research team is also collaborating with the utility’s engineering consulting firm to take advantage of the firm’s expertise in modeling the current yield of the water supply system and to identify potential modifications to the yield model in order to suit the needs of the climate sensitivity assessment.
- The next step will involve developing a hydrologic model of stream flows into the utility’s reservoir. When integrated with the existing yield model, the hydrologic model will allow the simulation of climate change impacts in terms of the system performance metrics that are directly relevant for strategic planning.

Coasts

Promoting Climate Change Awareness and Adaptive Planning in Atlantic Fisheries Communities

Team Members: Fly, Whitehead

Partners: NC Sea Grant, SC Sea Grant Consortium

Stakeholders: Beaufort County, SC blue crab fishers

Overview: This project aims 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. It also investigates the role of a structured dialogue and participatory modeling process to support decision makers in fishing communities address vulnerabilities, consequences, and adaptive strategies in the context of climate stressors. At the end of the project, the methodology will have been demonstrated in three diverse fishing communities: South Thomaston, ME; Wellfleet, MA; and Beaufort County, SC.

Progress & Results:

- In SC, interviews, VCAPS workshops, and a system dynamics (SD) workshop took place. Five crabbers attended a workshop in October 2015 to learn about the individual-based blue crab model developed by Michael Childress 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. Workshop participants agreed that fisher involvement in data collection would enhance current fisheries data that could populate this forecasting tool and allow the fishery to more readily adapt to a changing climate.
- Workshop participants 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. Once a week, fishermen complete a datasheet that was developed in collaboration with the SC Sea Grant Consortium’s Living Marine Resources Specialist, Julie Davis, and record information from crab pots and associated environmental data. There are plans to expand the volunteer network upon successful establishment in the Beaufort County area.
- Data collected by the volunteers are also 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. The model is also designed to inform how future climate conditions (i.e., changes in precipitation regimes which influence salinity levels) might impact the fishery.

Fostering a Citizen-Driven Sea Level Rise Task Force in the South Carolina Low Country

Team Members: Dow, Fly, Selvaraj

Partners: SC Sea Grant Consortium, SC Small Business Chamber of Commerce

Stakeholders: City of Beaufort, SC; Town of Port Royal, SC

Overview: Stakeholders in the city of Beaufort and town of Port Royal, SC, have formed a task force to address the area’s vulnerability to sea level rise and develop adaptation strategies to address potential impacts. The task force

has thirteen members, including the mayor of Beaufort and planning administrator for Port Royal. The task force has met regularly (monthly or bi-monthly) since December 2014.

Progress & Results:

- Using graphics and visualizations developed by CISA team members, the task force has identified eight areas in Beaufort and Port Royal particularly vulnerable to sea level rise. CISA team members facilitated meetings with task force members and the public works directors for the two municipalities to discuss these areas and identify potential strategies to mitigate future flood risk.
- Information and resources developed by CISA were used to develop the [task force webpage](#).
- In spring 2015, the task force presented its mission statement and recommendations to Beaufort City Council and Port Royal Town Council. Both councils encouraged the task force to continue its work.

Influence of Historical Drainage on Coastal Ecosystem Resilience to Rising Sea Level: Implications for Natural Resources Management and Terrestrial Carbon Storage of the Alligator River National Wildlife Refuge

Team Members: Brown, King

Partners: DOI Climate 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

Stakeholders: Alligator River National Wildlife Refuge (ARNWR), US Fish and Wildlife Service, Dare and Tyrell Counties

Overview: When it was established in 1984, much of the Alligator River National Wildlife Refuge (ARNWR) was a pocosin, characterized by poorly drained soils high in organic matter. Rising sea levels is impeding drainage in the Refuge, leaving the soil wetter for a longer period of time throughout the year. Researchers hypothesize that changes in soil moisture and salinity levels have led to a cascade of ecosystem transitions, affecting wildlife habitat quality in the Refuge. This project aims to quantify the carbon (C) contained in vegetation and soils of ARNWR’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 are focusing on the effects of historical ditching and drainage on soil water dynamics and salinity and quantifying the role of extreme events such as flood tides and hurricanes. This information will be combined with a GIS-remote sensing analysis of ecosystem vulnerability to transition across the Refuge, which will inform management efforts to implement mitigation procedures (e.g. planting flood tolerant tree species) or adapt (e.g. start managing for future wildlife habitat conditions).

Progress & Results:

- The project team hosted a workshop for 50 stakeholders and community members on December 5, 2014. Information is provided in the “*Outreach Activities*” section.
- Organic soils samples have revealed an interesting stratigraphy of alternating coarse wood layers and organic soil layers suggesting past intervals of static sea level punctuated by periods of rapid sea level rise. Samples are being prepared for Carbon-14 dating to further inform a historical understanding of environmental change at the Refuge.

Health

Assessing Climate-Related Health Vulnerabilities in North Carolina

Team Members: Hartley, Konrad, Kovach

Partners: NC Division of Public Health, NC State Climate Office, Southeast Regional Climate Center, UNC Chapel Hill School of Emergency Medicine, UNC School of Public Health

Stakeholders: Farmworker organizations, the National Weather Service, NC Division of Public Health

Overview: CISA is collaborating with the Southeast Regional Climate Center (SERCC) to investigate linkages between climate and human health, with respect to heat stress vulnerability and waterborne disease. Working with data from the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT), researchers are developing empirical relationships which can be exploited to build a public health toolbox that translates recent, current, and predicted weather/climate conditions across the Carolinas into useful information regarding the probability of public health emergencies. The toolbox 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).

Progress & Results:

- The first working version of a web-based heat vulnerability tool is under development. This tool predicts the number of emergency department (ED) visits using National Weather Service daily temperature forecasts and empirical relationships identified between ED visits and temperature. The tool will allow the user to estimate levels of heat morbidity for different demographic groups across various regions of NC.
- Using this tool, work continues on the investigation of temporal and spatial patterns in heat morbidity across the state. 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.
- The project team is currently partnering 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.
- A new component of this work includes assessing relationships between climate variables and waterborne disease. Preliminary analyses of waterborne disease counts reveal much county-to-county variability across North Carolina, with higher rates found over rural areas.

Assessing the Impacts of Climate Variability on Water Quality Conditions and *Vibrio* in a South Carolina Estuary

Team Members: Dow, Moore, Scott, Tufford

Partners: NOAA Center for Coastal Environmental Health and Biomolecular Research (CCEHBR)

Overview: This project integrates work on watersheds, coastal climate, and drought to investigate the health threats posed by the marine bacterium *Vibrio*, the spread of which is believed to be associated with changing temperature and salinity conditions. In 2012 CISA researchers and partners conducted monthly sampling of surface and bottom water in the Winyah Bay and Waccamaw River for *Vibrio vulnificus* and *Vibrio parahaemolyticus*. They examined these samples to evaluate empirical relationships with potential environmental drivers such as temperature and salinity. In 2014, CISA provided funding to conduct DNA sequencing to assess the virulence of the *Vibrio* samples.

Progress & Results:

- The start of the project was delayed by several months due to personnel changes at the NOAA CCEHBR in Charleston and major analytical equipment changes at the University of South Carolina in Columbia. DNA sequencing of two batches of *Vibrio* isolates from the 2012 field collection was completed in spring 2015. Next steps include analysis of the sequencing results.

Appendix: CISA Deliverables, 2014-2015

Journal Articles

- Dilling, L., K. Lackstrom, B. Haywood, K. Dow, M. C. Lemos, J. Berggren, and S. Kalafatis. 2015. What Stakeholder Needs Tell Us about Enabling Adaptive Capacity: The Intersection of Context and Information Provision across Regions in the United States. *Weather, Climate, and Society* 7: 5-17.
- Fly, E. K., T. J. Hilbish, D. S. Weithy, and R. L. Rognstad. 2015. Physiology and biogeography: The response of European mussels (*Mytilus* spp.) to climate change. *American Malacological Bulletin* 33: 136-149.
- Kabela, E. D. and G. J. Carbone. 2015. NARCCAP Model Skill and Bias for the Southeast United States. *American Journal of Climate Change* 4 (1): 94-114.
- Kettle, N. and K. Dow. 2014. Cross-level differences and similarities in coastal climate change adaptation planning. *Journal of Environmental Science and Policy* 44: 279-290.
- Kettle, N. and K. Dow. 2014. The role of perceived risk, uncertainty, and trust on coastal climate change adaptation planning. *Environment and Behavior*. DOI: 10.1177/0013916514551049
- Kettle, N. and K. Dow. 2014. Comparing coastal planner expectations of climate change to climate science projections. *Journal of Environmental Policy and Planning*. DOI: 10.1080/1523908X.2014.968916
- Kettle, N. P., K. Dow, S. Tuler, T. Webler, J. Whitehead, and K. M. Miller. 2014. Integrating scientific and local knowledge to inform risk-based management approaches for climate adaptation. *Climate Risk Management* 4-5: 17-31.
- Kovach, M. M., C. E. Konrad II, and C. M. Fuhrmann. 2015. Area-level risk factors for heat-related illness in rural and urban locations across North Carolina, USA. *Applied Geography* 60: 175-183.
- Mizzell H., M. Malsick, and I. Abramyan. 2014. South Carolina's Climate Report Card: Understanding South Carolina's Climate Trends and Variability. *Journal of South Carolinas Water Resources* 1 (1): 4-9.
- Petes, L. E., J. F. Howard, B. S. Helmuth, and E. K. Fly. 2014. Science integration into US climate and ocean policy. *Nature Climate Change* 4: 671-677.
- Smith, K. H., M. Svoboda, M. Hayes, H. Reges, N. Doesken, K. Lackstrom, K. Dow, and A. Brennan. 2014. Local Observers Fill in the Details on Drought Impact Reporter Maps. *Bulletin of the American Meteorological Society* 95 (11): 1659-1662.
- Webler, T., S. Tuler, K. Dow, J. Whitehead, and N. Kettle. 2014. Design and evaluation of a local analytic-deliberative process for climate adaptation planning. *Local Environment: The International Journal of Justice and Sustainability*. DOI: 10.1080/13549839.2014.930425

Books, Book Chapters

- Carbone, G. J., A. DeGaetano, K. Dow, J. Fowler, G. Garfin, H. Hartmann, E. Lay, and J. Rhee. *In press*. Challenges, pitfalls, and lessons learned in developing a drought decision-support tool. In A. Parris, G. Garfin, K. Dow, and R. Meyer, eds. *Climate in Context*. Wiley and Sons: New York.
- Parris, A., G. Garfin, K. Dow, and R. Meyer, eds. *In Press. Climate in Context*. Wiley and Sons: New York.
- Simpson, C. F., L. Dilling, K. Dow, K. Lackstrom, M. C. Lemos, and R. E. Riley. *In press*. Assessing needs and decision contexts: RISA approaches to engagement research *In Press*. In A. Parris, G. Garfin, K. Dow, and R. Meyer, eds. *Climate in Context*. Wiley and Sons: New York.
- Tuler, S., K. Dow, T. Webler, and J. Whitehead. *forthcoming*. Learning through participatory modeling: Reflections on what it means and how it is measured. In M. Paolisso and S. Gray, eds. *Integrating Stakeholders in Environmental Modelling: Considerations, Methods, and Applications*. Springer.

Conference Proceedings

Lackstrom, K., B. Haywood, A. Brennan, J. Davis, and K. Dow. 2014. Drought and Coastal Ecosystems: Identifying Impacts and Opportunities to Inform Management. *Proceedings of the 2014 South Carolina Water Resources Conference*, held October 15-16, 2014, Columbia, SC.

Reports

Cumby, R. 2014. *An Evaluation of MPE-based SPI over the Carolinas in 2007-2008*.

Fly, E. K., S. C. Bath, J. Whitehead, S. Tuler, T. Webler, A. Turner, and R. Merchant. 2015. *Beaufort County Sea Level Rise Adaptation Report*. S.C. Sea Grant Consortium Product # SCSGC-T-15-02.

Theses and Dissertations

Bath, S. 2015. A Participatory Approach to Preparing for Sea Level Rise in Beaufort County, South Carolina. Internship Report for the MS/MPA Dual Degree, University of Charleston, Charleston, SC.

Davis, J. 2015. *A Tale of Two Landscapes: Examining Alienation and Non-Visitation Among Local African American Fishers at Congaree National Park*. Master's Thesis, University of South Carolina, Columbia, SC.

Kovach, M. 2015. *Climate-Human Health Vulnerability: Identifying Relationships between Maximum Temperature and Heat-Related Illness across North Carolina, USA*. PhD Dissertation, University of North Carolina, Chapel Hill, NC.

Lackstrom, K. 2015. *Institutional Adaptation and Drought Management in the Carolinas*. PhD Dissertation, University of South Carolina, Columbia, SC.

Oyer, Z. 2014. *Water infrastructure vulnerability to coastal flood hazards: A space-place analysis of Manteo, New Bern, and Plymouth, North Carolina*. Master's Thesis, East Carolina University, Greenville, NC.

Web-based Tools

Carbone, G. and C. Green. 2014. *Water and Climate Videos*. Available from <http://www.cisa.sc.edu/videos.html>.

Fly, E. K., S. Bath, and A. Brennan. 2015. *The Low Country Lowdown on Sea Level Rise*. U.S. Climate Resilience Toolkit. Available from <http://toolkit.climate.gov/taking-action/lowcountry-lowdown-sea-level-rise>.

2-Pagers

Brennan, A. 2015. *CISA Fact Sheet*. Carolinas Integrated Sciences & Assessments, Columbia, SC.

Brennan, A. 2015. *CISA Focus Area: Water & Climate Fact Sheet*. Carolinas Integrated Sciences & Assessments, Columbia, SC.

CISA and the Beaufort and Port Royal Sea Level Rise Task Force. 2015. *Sea Level Rise, Storm Surge, and Planning for the Future*.

Newsletters

Brennan, A. 2015. *Carolinas Climate Connection*, 1st Quarter – April 2015.

Brennan, A. 2014. *Carolinas Climate Connection*, 2nd Quarter – June 2014.

Brennan, A. 2014. *Carolinas Climate Connection*, 3rd Quarter – September 2014.

Brennan, A. 2014. *Carolinas Climate Connection*, 4th Quarter – December 2014.

Conferences, Meetings, Trainings, and Workshops

Beaufort County, SC, Public Workshop on Sea Level Rise Adaptation Strategies. August 25, 2014, Bluffton, SC, 35 attendees.

Beaufort County, SC, Public Workshop on Sea Level Rise Adaptation Strategies. August 26, 2014, St. Helena, SC, 42 attendees.

Brennan, A. 2014. Volunteer training for the NIDIS Carolinas Citizen Science Condition Monitoring project. Webinar with SC Master Gardeners and Master Naturalists, June 3, 22 attendees.

Brennan, A. 2014. Volunteer training for the NIDIS Carolinas Citizen Science Condition Monitoring project, Conference call with volunteers, July 22, 8 attendees.

- Brennan, A. 2015. Volunteer training for the NIDIS Carolinas Citizen Science Condition Monitoring project. Conference call with volunteers, February 12, 10 attendees.
- Brennan, A. and E. Fly. 2015. Leveraging the Community Rating System for Climate Adaptation. Webinar for the Southeast and Caribbean Climate Community of Practice, March 23, 58 attendees.
- Brennan, A. and E. Fly. 2014. Risky Business: The Economic Risks of Climate Change in the United States. Webinar for the Southeast and Caribbean Climate Community of Practice, October 17, 60 attendees.
- Fly, E., K. Dow, S. Bath, and S. Selvaraj. 2014-2015. Beaufort and Port Royal SLR Task Force Meetings. Monthly meetings beginning in December 2014, average 10 attendees
- King, J., C. Brown, J. Whitehead, and D. Stewart. 2014. Healthy communities and sustainable ecosystems: understanding and adapting to coastal environmental change. Alligator River National Wildlife Refuge Stakeholder Workshop. Manteo, NC, December 5, 50 attendees.
- Whitehead, J., A. Turner, and H. Cheng. 2015. Joint Meeting of the Sea Grant Sustainable Coastal Communities and Sea Grant Climate Networks: Building Sea Grant's Resilience Toolbox. Side Meeting at the National Adaptation Forum, May 11, St. Louis, MO.

Organized Conference Sessions

- Brennan, A. 2015. Climate Implications for Water Supply Planning. North Carolina Water Resources Research Institute Annual Meeting, March 18-19, Raleigh, NC.
- Brennan, A. 2015. Drought and Hazards for Coastal Communities. North Carolina Water Resources Research Institute Annual Meeting, March 18-19, Raleigh, NC.
- Brennan, A. and R. Cumbie. 2015. Drought Planning & Preparedness in North Carolina. North Carolina Water Resources Research Institute Annual Meeting, March 18-19, Raleigh, NC.
- Fouladbash, L., H. Morris, A. Wooten, S. Krantz, C. Furiness, D. Figg, W. Gould, J. Whitehead, T. Jones, A. Lascrain, K. Dow, and R. Gregg. 2015. Identifying Decision-Focused Climate Adaptation Activities and Aligning Priorities Across Multiple Sectors and Scales in the Southeast United States. National Adaptation Forum, May 12-14, St. Louis, MO.
- Grace, A., K. Scheuer, A. Walton, A. Brennan, L. Hansen, and W. Gewiss. 2015. Organizing and Coordinating Regional Adaptation Forums. National Adaptation Forum, May 12-14, St. Louis, MO.
- Lackstrom, K., D. Bathke, and N. Wall, 2015. Building Drought Resilience Across Scales and Sectors. National Adaptation Forum, May 12-14, St. Louis, MO.

Presentations

- Bath, S. and L. Fly. 2015. A Participatory Approach to Prepare for Sea Level Rise in Beaufort County, South Carolina. 2nd National Adaptation Forum, May 12-14, St. Louis, MO.
- Bath, S. 2014. Mapping SLR in Beaufort County. Beaufort County Public Workshops on Sea Level Rise Adaptation Strategies, August 25-26, Bluffton and St. Helena, SC.
- Brennan, A. 2014. From Global Climate Models to Local Choices: Lessons Learned about Providing and Using Climate Information in the Carolinas. North Carolina Water Education Summit, September 8-10, Asheville, NC.
- Brennan, A., J. Davis, K. Dow, K. Lackstrom, and S. Selvaraj. 2015. Improving Understanding of Drought Impacts through Citizen Science. North Carolina Water Resources Research Institute Annual Meeting, March 18-19, Raleigh, NC.
- Carbone, G. 2014. Climate Change and the Catawba Wateree Basin. Catawba-Water Relicensing Coalition Regional Water Issues Conference, October 28, Mooresville, NC.
- Cumbie, R. 2015. Year-in-Review: Precipitation and Temperatures. North Carolina Drought Management Advisory Council Annual In-Person Meeting, April 30, Raleigh, NC.

- Cumbie, R. 2014. Eastern Drought. American Association of State Climatologists Annual Meeting, July 8-11, Stevenson, WA.
- Darby, L, K. Dow, K. Lackstrom, A. Brennan, D. Tufford, P. Conrads, M. Childress, R. Boyles, D. Chalcraft. 2014. Expanding on successful activities to enhance drought information for the coastal Carolinas. AMS 21st Conference on Applied Climatology, June 9-13, Westminster, CO.
- Dow, K. 2015. Managing Coastal Environments: Organizational Responses to Uncertainty. Invited presentation at UCSB Bren School workshop on Planning in Changing Coastal Environments: Adaptation to Sea Level Rise, April 20-21, Santa Barbara, CA.
- Dow, K. 2014. Climate Change and Variability in the Carolinas. Bachman Chapter of the Sierra Club in South Carolina, November 20, Columbia, SC.
- Dow, K. 2014. Climate Change and Variability in the Carolinas. Wake Forest University Center for Energy, Environment and Sustainability, October 31, Winston-Salem, NC.
- Dow, K. 2014. Climate change impacts and adaptation in the Carolinas. Greater Piedmont Chapter of the Explorers Club, September 14, Columbia, SC.
- Dow, K. 2014. Climate 101. Climate Friendly Parks Workshop, September 9, Congaree National Park, SC.
- Dow, K. 2014. Climate changes and choices. Public Policy Luncheon, League of Women Voters, October 16, Columbia, SC.
- Fly, E. K. 2015. Coastal Infrastructure Vulnerability. Conversation with Conservationists, SC Senate Briefing, January 21, Columbia, SC.
- Fly, E. K. 2015. Helping coastal communities strategize adaptations to climate change: How to implement a structured dialogue using an interactive diagramming process. Webinar for stakeholders in Maryland (including MD Sea Grant, Eastern Shore Land Conservancy, and Kent County, MD), May 8.
- Fly, E. K. 2015. Stemming the Tide: Global Climate Change and Local Impacts in South Carolina. Bulls Bay Chamber of Commerce Meeting, April 30.
- Fly, E. K. 2015. Stemming the Tide: Global Climate Change and Local Impacts in South Carolina. League of Women Voters Annual State-wide Conference, April 25, Hilton Head Island, SC.
- Fly, E. K. 2015. Stemming the tide: Global sea level change and local impacts in South Carolina. SC Chapter of Chartered Property and Casualty Underwriters Monthly Meeting, January 20, Cayce, SC.
- Fly, E. K. 2015. Stemming the tide: Stakeholder-driven adaptation planning in South Carolina. Department of Homeland Security Office of Infrastructure Protection Webinar on "Regional Adaptation Strategies for Addressing Sea Level Rise and its Cascading Effects," January 30.
- Fly, E. K. 2014. A participatory approach to preparing for sea level rise in Beaufort County, SC. Sea Grant Climate Network Webinar, October 29.
- Fly, E. K. 2014. Sea Level Rise in Beaufort County, SC. Beaufort County Public Workshops on Sea Level Rise Adaptation Strategies, August 25-26, Bluffton and St. Helena, SC.
- Fly, E. K. 2014. Sea Level Science. Beaufort County Public Workshops on Sea Level Rise Adaptation Strategies, August 25-26, Bluffton and St. Helena, SC.
- Fly, E. K. and J. Whitehead. 2014. Introduction to Vulnerability and Consequences Adaptation Planning Scenarios (VCAPS) Process. Governor's South Atlantic Alliance Webinar, August 20.
- Gao, P. and G. Carbone. 2015. NARCCAP Model Comparison of Extreme Rainfall Intensity in the Continental US. Association of American Geographers Annual Meeting, April 21-25, Chicago, IL.
- Green, C. 2014. Educational Videos Characterizing South Carolina's Water Resources. North Carolina Water Education Summit, September 8-10, Asheville, NC.
- King, J.S., A. Noormets, and J-C. Domec. 2014. Alligator River National Wildlife Refuge's role in global monitoring of environmental change: Flux tower project. Healthy Communities and Sustainable Ecosystems:

- Understanding and Adapting to Coastal Environmental Change Stakeholder Workshop, December 5, Manteo, NC.
- Konrad, C. and J. McLeod. 2015. Determining Climatological Patterns of Wetness and Drought at a Regional to Local Scale across the Carolinas. Climate Prediction Applications Science Workshop, March 24-26, Las Cruces, NM.
- Kovach, M.M., C.E. Konrad, and C.M. Fuhrmann. 2015. Heat-Related Illness in Rural and Urban Settings across North Carolina. Association of American Geographers Annual Meeting, April 21-25, Chicago, IL.
- Lackstrom, K., 2015. Collaborative approaches to managing drought: the role of stakeholder networks and institutional change in the Carolinas. Association of American Geographers Annual Meeting, April 21-25, Chicago, IL.
- Lackstrom, K., A. Brennan, K. Dow, 2015. Drought and Coastal Ecosystems: An Assessment of Decision Maker Needs for Information. Presented at the Interagency Conference on Research on the Watersheds, March 2-5, Charleston, SC.
- Lackstrom, K. 2014. CISA Overview and Drought Early Warning System Needs. National Drought Mitigation Center DrIVER Project Drought Monitoring and Early Warning Workshop, December 9, Durham, NC.
- Lackstrom, K., A. Brennan, P. Conrads, L. Darby, K. Dow, D. Tufford. 2014. Drought and Coastal Ecosystems: Identifying Impacts and Opportunities to Inform Management. South Carolina Water Resources Conference, October 15-16, Columbia, SC.
- Lu, J. and G. Carbone. 2015. Understanding the Impact of Drought on Crop Yield in South and North Carolina. Association of American Geographers Annual Meeting, April 21-25, Chicago, IL.
- McLeod, J. and C. Konrad. 2015. Determining Climatological Patterns of Dryness and Drought at a Regional to Local Scale across the Carolinas. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- Montz, B., T. Allen, and Z. Oyer. 2015. Multi-Hazard Vulnerability of Coastal Water Infrastructure to Sea Level, Storm Surges, and Riverine Flooding. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- Nolan, C., D. Tufford, and D. Chalcraft. 2015. Needs Assessment of Coastal Land Managers for Drought Indicators in the Southeastern U.S. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- Patel, A. and G. Carbone. 2015. Climate Change Information for Long-Term Water Supply Planning. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- Samadi, S., D. L. Tufford, and G. J. Carbone, 2014. Improving the robustness of uncertainty algorithms in quantification of uncertainty in water balance forecasting. South Carolina Water Resources Conference, October 15-16, Columbia, SC.
- Tufford, D. L., R. Deeb, G. Scott, J. Moore, K. Dow, and E. Fly. 2015. Streamflow and Climate Change Influence on Vibrio Occurrence in the Winyah Bay, SC Estuary. Interagency Conference on Research on the Watersheds, March 2-5, North Charleston, SC.
- Tufford, D. L., S. Altan-Ochir, and W. Hankinson, 2015. A watershed-scale characterization of dissolved organic carbon and nutrients on the South Carolina Coastal Plain. Interagency Conference on Research on the Watersheds, March 2-5, North Charleston, SC.
- Tufford, D. L., R. Deeb, J. Moore, G. Scott, K. Dow, and E. Fly, 2014. Indicators of the Occurrence of Vibrio in the Winyah Bay, South Carolina Estuary. South Carolina Water Resources Conference, October 15-16, Columbia, SC.
- Whitehead, J. 2015. Panel Member. Engaging Coastal Communities: Success and Lessons Learned from Sea Grant Climate Extension. National Adaptation Forum, May 12-14, St. Louis, MO.

- Whitehead, J. 2015. Lessons learned from climate awareness and adaptive planning in three Atlantic fisheries communities using the VCAPS process for dialogue-based participatory vulnerability analysis, collaborative systems dynamic modeling, and citizen science. National Adaptation Forum, May 12-14, St. Louis, MO.
- Whitehead, J. 2015. Improving coastal water resilience to climate variability and change through participatory dialogue. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- Whitehead, J. 2014. Potential Options for Adapting to Sea Level Rise in Beaufort County, SC. Beaufort County Public Workshops on Sea Level Rise Adaptation Strategies, August 25-26, Bluffton and St. Helena, SC.
- Whitehead, J. C. and E. K. Fly. 2014. Using the Vulnerability, Consequences and Adaptation Planning Scenario (VCAPS) process to facilitate community discussion. Governor's South Atlantic Alliance Webinar, August 20.
- Whitehead, J., E. Fly, S. Tuler, and K. Dow. 2015. Engaging Coastal Communities on Resilience with the Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) Process. The Joint Meeting of the Sea Grant Sustainable Coastal Communities and Sea Grant Climate Networks: Building Sea Grant's Resilience Toolbox. Side Meeting at the National Adaptation Forum, May 11, St. Louis, MO.

Posters

- Altan-Ochir, S. and D. Tufford, 2014. Hydrogeomorphic and landscape influences on dissolved organic matter in streams and rivers on the South Carolina Coastal Plain. South Carolina Water Resources Conference, October 15-16, Columbia, SC.
- Bath, S. 2015. Stakeholder-Generated Climate Adaptation Recommendations for a Coastal County Comprehensive Plan. National Adaptation Forum, May 12-14, St. Louis, MO.
- Bath, S. 2015. Climate Communication Insights from a Sea Level Rise Adaptation Planning Project in Beaufort County, South Carolina. 15th National Conference and Global Forum on Science, Policy and the Environment, January 27-29, Washington, D.C.
- Brennan, A., K. Lackstrom, R. Boyles, D. Chalcraft, M. Childress, P. Conrads, K. Dow, C. Konrad, and D. Tufford. 2015. Developing a Drought Early Warning Information System for Coastal Ecosystems in the Carolinas. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- Brennan, A., K. Lackstrom, R. Boyles, D. Chalcraft, M. Childress, P. Conrads, K. Dow, C. Konrad, and D. Tufford. 2015. Developing a Drought Early Warning System for Coastal Ecosystems in the Carolinas. Interagency Conference on Research on the Watersheds, March 2-5, North Charleston, SC.
- Dow, K., S. Tuler, and J. Whitehead. 2015. Fostering and Evaluating Learning in Participatory Adaptation Processes. National Adaptation Forum, May 12-14, St. Louis, MO.
- Patel, A. 2015. Climate Change Information for Long-term Water Supply Planning. Association of American Geographers Annual Meeting, April 21-25, Chicago, IL.
- Samadi, S., D. L. Tufford, and G. J. Carbone, 2014. Improving hydrologic predictions of distributed watershed model via uncertainty quantification of evapotranspiration methods. South Carolina Water Resources Conference, October 15-16, Columbia, SC.
- Whitehead, J. and M. Covi. 2015. Preparing Plymouth, North Carolina for Future Flood Risks. National Adaptation Forum, May 12-14, St. Louis, MO.