

CISA

CAROLINAS INTEGRATED
SCIENCES AND ASSESSMENTS

2019-2020 ANNUAL REPORT
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Photo Source: Elijah Charette
Tennent Mountain, NC

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THE CISA PROGRAM

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. A key component of the RISA program is working at the regional level to address significant and timely climate issues of concern.

Working at the intersection of climate with water, coasts, and health, the CISA team creates, tailors, and provides climate information to improve planning and management approaches that build healthier, safer communities in the Carolinas. CISA has established long-term partnerships with federal, state, and local government agencies, resource managers, non-governmental organizations, and the private sector. As a trusted source of climate information for the Carolinas, CISA supports state and local climate adaptation through project-specific engagements as well as reaching broader audiences with other communications and outreach efforts

CISA BY THE NUMBERS



Photo Source: Elijah Charette

11	journal articles
15	project reports
16	newsletters
52	presentations
13	student researchers
45	collaborating organizations
14	stakeholder conferences, training sessions, and workshops
\$700,684	leveraged grant funds

HIGHLIGHTED ACCOMPLISHMENT

Supporting Drought Planning and Preparedness in South Carolina

CISA initiated a **collaboration with the South Carolina State Climatology Office (SC SCO)** in 2017 on the heels of an extreme drought and wildfire season in the Western Carolinas. The partnership has involved a variety of research and engagement activities to help the SC SCO enhance the State's Drought Response Program and improve drought planning and preparedness across the State.

Following the first statewide drought tabletop exercise in 2017, stakeholders recommended conducting a similar exercise every 1 to 2 years. **CISA co-hosted a second statewide exercise on July 24, 2019**, in partnership with the SC SCO, SC Emergency Management Division, and SC Water Resources Center. There were **92 participants from 48 different organizations** including members of the State's Drought Response Committee and representatives from the agriculture, forestry, water resources, emergency management, energy, non-profit and private sectors at the federal, state, and local level. The **exercise** simulated the South Carolina drought monitoring and response process, allowed participants to identify gaps in existing processes and prioritize follow-up actions, and increased participants' awareness of each actors' roles and responsibilities for drought response and planning.

“The resources and points of contact available were invaluable. [I] will note these in our plan. [I] documented several improvements to incorporate into our plan – revise triggers and communication templates to customers.”

“The holistic approach at a state level was great to learn about actions and plans of those in other basins. Coordination at the basin level also seems extremely important - and the tabletop exercise provided a nice balance between state and basin coordination.”

Translating Climate Science & Information for Decision Making

To accompany the 2019 SC Drought Tabletop Exercise, CISA developed a series of handouts to help State Drought Response Committee members navigate the **drought monitoring and response process**.

Participants at both the 2017 and 2019 exercises identified a need for more education and communications materials about drought, specifically information for emergency managers. With input from the SC EMD and SC SCO, CISA produced a **“South Carolina Drought Guide for Emergency Managers.”**

The **scdrought.com** website was developed by the SC SCO with input from CISA as a follow up to the 2017 exercise. During the flash drought in fall 2019, the website provided a centralized information portal for SC Drought Response Committee members who used the website to access the drought indicators and indices they are required to use to determine drought levels. The website is also a public hub for press releases and drought declarations.



Photo Source: Ekaterina Altman

Incorporating Stakeholder Input and Feedback

The tabletop exercise discussions highlighted important strengths, challenges, and needs related to South Carolina's drought response policies and procedures. For example:

- **Communications, education, and awareness:** Participants recommended earlier and more frequent communications about drought between utilities and agencies as well as with the public to help the public better understand drought impacts and what responses they should take.
- **Plans and procedures:** Participants recommended earlier and more consistent response actions by the various entities involved in water management. They also highlighted the need for greater coordination in communications with the public. Managing transitions between drought levels, determining the curtailment of water use, and enforcing water use restrictions pose challenges which a review and update of the Drought Response Act and regulations could mitigate. Participants also favored involving organizations and groups that are not typically part of drought response and planning conversations. Elected officials, professional news media, and representatives from manufacturing, recreation, tourism, and insurance sectors and agencies were among those suggested.
- **Data and information:** Participants identified an ongoing need for more reliable and regularly collected impacts data to help improve understanding of the full costs of drought, mitigate adverse impacts for the most vulnerable communities and sectors, and enhance the effectiveness of drought monitoring, response, and planning activities.

Increasing Adaptive Capacity in the Carolinas

In the post-exercise survey attendees noted specific follow-up actions they planned to take, to include:

- Collaborating to host a tabletop exercise with other utilities to increase consistency and knowledge sharing
 - Meeting with organizational leadership to discuss creating internal drought response plans
 - Participating in CoCoRaHS and national drought impacts reporting
 - Reviewing town ordinances
 - Revising drought triggers and conservation goals
 - Revising communications materials for customers
- Organizational efforts such as these exponentially increase the footprint of work done by CISA, the SC SCO, and partners through more coordinated drought planning and preparedness at all levels of governance.

Project Partners

South Carolina Emergency Management Division
South Carolina State Climatology Office
South Carolina Water Resources Center

Publications

2019 South Carolina Drought Tabletop Exercise Executive Summary and Final Report

2019 South Carolina Drought Tabletop Information Sheet

South Carolina Drought Guide for Emergency Managers



CLIMATE ADAPTATION IN THE CAROLINAS

Supporting Sea Level Rise Adaptation and Planning in Beaufort County, SC

“I can’t thank you enough for all that you’re doing for us. It’s like having another staff person with the expertise we need.” – Rob Merchant, Deputy Community Development Director, Beaufort County

In May 2019, Beaufort County reached out to CISA with a request to help explore ordinances to address impacts of recurrent flooding and sea level rise. This request followed **an earlier collaboration** which designed a vulnerability assessment and sea level rise adaptation strategy. The Beaufort County Lowcountry Regional Board transitioned the group exploring these ordinances into a Sea Level Rise Task Force with a directive to inform the 2020 comprehensive plan and revisions to the **2015 Sea Level Rise Adaptation Report**. The Task Force includes members from all municipalities within Beaufort County along with representatives of multiple County departments and stakeholder organizations.

Draft information for the comprehensive plan and sea level rise report update will be used to solicit more extensive feedback. The team is working to develop alternative engagement strategies to gather feedback and input effectively and fairly from residents and other stakeholders during the COVID-19 pandemic. Once the Sea Level Rise Adaptation Report revisions are finalized, the Task Force will seek to have the recommendations adopted by all Beaufort County municipalities to make their policies and ordinances consistent.

Translating Climate Science for Decision Making

A parcel-level, digital elevation model developed by partners at the College of Charleston and S.C. Sea Grant Consortium for a NOAA Regional Coastal Resilience Grant project was adapted for Beaufort County. This model, which incorporates precipitation projections developed by CISA, has a 1 meter resolution. The model was used to identify parcels affected by the proposed sea level rise overlay district as well as flood vulnerabilities related to intense rainfall. It will also be used by the contractor hired by the County to update the comprehensive plan.

Incorporating Stakeholder Input and Feedback

Two presentations by CISA to the Beaufort County Lowcountry Regional Board led to the creation of the Sea Level Rise Task Force. In collaboration with the Community Development Deputy Director, CISA has facilitated regular Sea Level Rise Task Force meetings, as they work to draft recommendations for the comprehensive plan and sea level rise report revisions.

Increasing Adaptive Capacity

The County is considering multiple ordinances and policy recommendations generated during discussions with the Task Force, along with approaches to integrating climate change and sea level rise into the county’s comprehensive plan.

Proposed policies include setting a standard base flood elevation that is separate from the FEMA flood insurance rate maps and establishing an overlay zone throughout the County that notifies property owners that they are in areas expected to experience changes to flood risks as sea level rises.

Project Partners

Beaufort County, City of Beaufort, Coastal Conservation League, College of Charleston Lowcountry Hazards Center, Lowcountry Institute, S.C. Sea Grant Consortium, Sea Island Coalition, Town of Hardeeville, Town of Hilton Head, and Town of Port Royal

CISA Conducts Sea Level Rise Vulnerability Assessment for the City of Beaufort, SC

At the request of the City of Beaufort, CISA partnered with the S.C. Sea Grant Consortium and the College of Charleston’s Lowcountry Hazards Center to conduct a flood vulnerability assessment. Bordered by rivers and the coast, the City is vulnerable to flooding from sea level rise and extreme precipitation events. CISA explored the effects of flooding by examining current trends, modeling future changes in flooding due to climate change, and investigating impacts to key city assets. The assessment investigated race and ethnicity of residents at risk as well as number of businesses, employees, and annual average sales. The assessment revealed that, within the next 20 years, the City may experience tidal flooding over 100 days each year.

Translating Climate Science for Decision Making

A localized GIS elevation model for flooding analysis was created for the City. These efforts responded to concerns about specific neighborhoods, populations, business districts, and historic sites. By modeling multiple scenarios of rainfall and tidal flooding for each individual district, the project mapped parcels most at risk in future flood events to identify population groups, businesses, and private property within these challenged areas and the wider city.

Project Partners

- City of Beaufort, SC
- College of Charleston Lowcountry Hazards Center
- S.C. Sea Grant Consortium

Increasing Adaptive Capacity

The **Flood Vulnerability Assessment: City of Beaufort, SC** provides data on critical assets and people that the City can use when developing flood mitigation strategies such as drainage projects and building codes, and to build risk and resilience thinking into city planning.

The Flood Vulnerability Assessment identifies areas where employment, sales, and business continuity could be threatened. Figure 1 (below) provides information on the *economic impact to businesses in areas most likely to be impacted by recurrent flooding and sea level rise*. By identifying these potential economic impacts, the vulnerability assessment aids future planning and coordination between local government and the business community.

Incorporating Stakeholder Input and Feedback

Upon completion of the final report, the project team presented findings to City Council in January 2020. The Council committed to act on flood mitigation and is participating in discussions with the Beaufort County Sea Level Rise Task Force to revise a county-wide Sea Level Rise Adaptation Strategy.

Publications

The **Flood Vulnerability Assessment: City of Beaufort, SC**, is available on the City’s Public Works Department web page along with other materials related to flooding in the community.

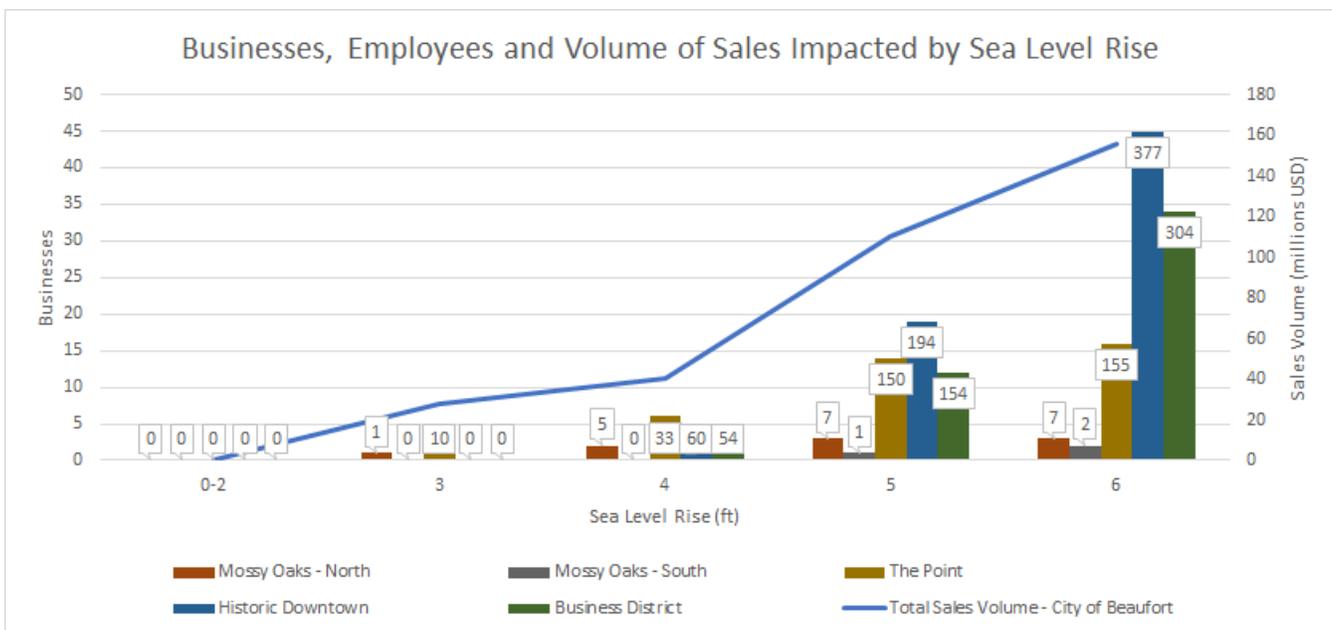


Figure 1: Business impacts in challenged areas from sea level rise modeled as feet above mean higher high water. Number of businesses is represented with colored bars. The total number of employees from those businesses is displayed in a text box on top of each bar. Total sales volume for the City of Beaufort is represented by a solid blue line. The names refer to “Challenged Areas” identified by the City as having current flood challenges.

Assessing Business Impacts of Hurricanes and Flooding in the Charleston, SC Region

Small- and medium-sized enterprises (SMEs) make up 99% of businesses in the United States and are critical to economic development, job creation, and community well-being. Working with leadership in the NOAA Climate Program Office, CISA established a partnership with researchers at the National Institute of Standards and Technology (NIST) to conduct a case study of Charleston's SMEs to understand preparation for and recovery from Hurricane Irma in 2017. The project team conducted 60 in-depth, in-person interviews to explore business owners' perceptions of hurricanes, the impacts they face from flooding, and barriers to recovery.

Though further work is needed to understand the dynamic relationship between businesses, hazards, and their communities, initial findings suggest that the presence of a hurricane plan, perception of changes in hurricane severity, and the purchase of flood insurance all correlate positively with business recovery.

Translating Climate Science for Decision Making

Results showed that water height and flood depth is highly and significantly correlated with SME reopening times and building damage, and that having flood insurance correlates with positive revenue change. This finding supports the need to mitigate flood and water heights in Charleston to help SMEs grow and remain profitable.

Incorporating Stakeholder Input and Feedback

In-depth interviews with business owners provided an opportunity for them to think through their experiences during recent extreme events and how consecutive years of hurricanes have increased planning and preparedness efforts. As a result of the surveying process, some local business owners are self-identifying as community leaders who could create or expand networks to increase resilience.

Increasing Adaptive Capacity

The research findings were presented to staff of the City of Charleston and Charleston Metropolitan Chamber of Commerce as well as members of the Charleston Resilience Network. By communicating results to local, state, and federal government agencies, CISA hopes to enhance understanding and interest in business impacts and needs before, during, and after hurricanes.

The College of Charleston estimated that Charleston businesses lost \$111.3 million due to Hurricane Florence (2018). Hurricane Irma (2017) and Hurricane Matthew (2016) caused similar losses. Every day a business is closed, revenue is lost. The College of Charleston's Office of Tourism Analysis estimates a daily loss of \$9.3 million to \$15.9 million to the local economy during hurricanes. This research seeks to reduce these devastating losses through improved understanding of business impacts.

Project Partners

National Institute of Standards and Technology
NOAA Climate Program Office



Advancing the Development and Use of the Coastal Salinity Index

In a collaborative effort, the U.S. Geological Survey (USGS) and CISA are advancing the development and use of the **Coastal Salinity Index (CSI)**. This project meets a need for a drought monitoring tool that captures coastal salinity conditions, as identified by stakeholders of the National Integrated Drought Information System (NIDIS) Coastal Carolinas Drought Early Warning System. The CSI is being applied in research supportive of NOAA's mission to conserve and manage coastal and marine ecosystems and resources.

The index characterizes short- and long-term coastal drought using salinity values along the freshwater-saltwater interface and helps users understand the effects of changing salinities on fresh and saltwater habitats, fisheries, and freshwater availability for municipal and industrial use. The CSI website, launched in October 2019, provides real-time CSI values in NC, SC, and GA, as well as other products (salinity data, maps, graphs, user guides) that help make the CSI information accessible to a variety of audiences. Through funding from the USGS Community of Data Integration, the real-time CSI network will expand to cover the entire eastern seaboard and Gulf of Mexico.

Translating Climate Science for Decision Making

The USGS maintains a **data portal** providing real-time CSI values across a network of monitoring stations in NC, SC and GA. This network will expand significantly in 2020 from the current 17 sites to over 100.

The USGS calculated **CSI values for 97 sites** from North Carolina to Texas to assist stakeholders in comparing their local values to a representative site.

Project partners developed a **programming package in R** that allows users to compute CSI data and graphs for any location using their own locally collected salinity data.

Incorporating Stakeholder Input and Feedback

Over the course of the project, input from the CSI Working Group has been used to refine the data portal and identify opportunities to apply the CSI for drought monitoring and resource management.

Project Partners

National Integrated Drought Information System
USGS South Atlantic Water Science Center
USGS St. Petersburg Coastal & Marine Science Center

Publications

Coastal Salinity Index along the Southeastern Atlantic Coast and the Gulf of Mexico, 1983 to 2018, a USGS Open File Report which includes the **Coastal Salinity Index: User Guide** and the **Coastal Salinity Index Website**

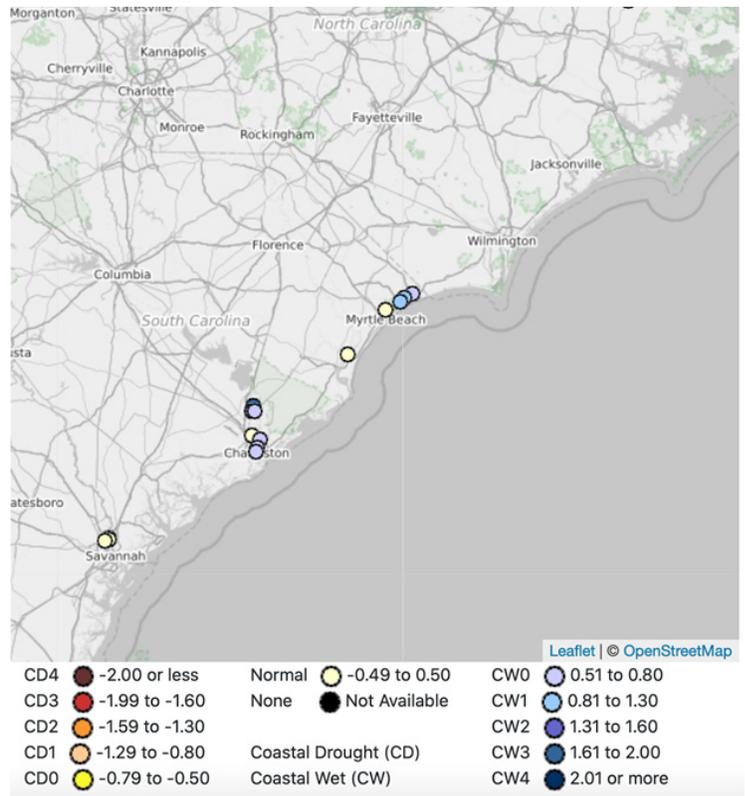


Figure 2: The Coastal Salinity Index real-time monitoring data is available via the CSI website. The index values represented here from June 2020 show that the CSI can be used to monitor wet (blue) as well as dry (orange) conditions.

Increasing Adaptive Capacity

The SC Department of Natural Resources Crustacean Research Section used the CSI to estimate blue crab abundance in South Carolina, a multi-million dollar commercial fishery.

Researchers at the University of Maryland are using the CSI to examine the relationship between climate variability and land management practices on water quality in the Chesapeake Bay.

USGS scientists are using the CSI to examine the relationships between salinity disturbance events that lead to harmful conditions for select fish species in Florida's Gulf Coast. This work will inform longer-term decisions about ecosystem restoration in wildlife refuges and conservation areas.

USGS scientists are also using the CSI to assess the effects of drought and flood events on salinity and marsh conditions in Louisiana.

Innovating Drought Communications for Decision Makers with the State Climate Office of North Carolina

In the aftermath of recent droughts, decision makers across North Carolina articulated needs for information and communications that enhance existing drought resources. This project, led by the State Climate Office of North Carolina (SCONC) with support from CISA, is developing sector-specific information for drought decisions, delivering accessible and actionable information, and improving the transparency of the drought monitoring process.

Dubbed **Project Nighthawk** after the common nighthawk (*Chordeiles minor*), a drought-resilient bird species native to NC, the project is designed as an iterative process that engages decision makers from multiple stakeholder groups. These groups include the North Carolina Drought Management Advisory Council (DMAC), Cooperative Extension agents, and public water system managers. The project team disseminates weekly drought status and short-range outlook infographics to a listserv of approximately 75 recipients.



Photo Source: Christopher Lumpp

Translating Climate Science for Decision Making

Weekly drought update infographics summarize current conditions for specific sectors (reservoir and streamflow levels, soil moisture levels, and crop updates), tell the reader what's changed from the previous week and projections for the week ahead, and provide maps of the current and previous weeks' drought monitor map.

Short-range outlooks provide summary information for the next one to four weeks ahead. The outlooks are based on forecasts from the National Weather Service and include maps of the region, short descriptions of temperature and precipitation forecasts, and an explanation of forecast confidence.

Publications

Project publications are available on the Project Nighthawk webpage.

"I think the graphics are top-notch, but maybe more importantly, the content is relevant, well-organized, and in plain language."

~ National Weather Service
hydrometeorologist

Incorporating Stakeholder Input and Feedback

In 2019-2020 the team convened target audiences through a mixture of planned meetings, webinars, and one-on-one conversations to obtain feedback and to formulate a plan for disseminating final versions of new resources and products. Additional feedback was gathered via eye-tracking software and an online survey and has been used in an iterative manner to continually improve the products.

Project Partners

State Climate Office of North Carolina

Increasing Adaptive Capacity

A variety of decision makers use the weekly drought status infographics and short-range outlooks to inform themselves and others about drought conditions and expected weather patterns. These include NWS offices, Cooperative Extension agents, growers and producers, water utilities, and fire managers. Specifically, stakeholders report using the communications documents

- to help water utilities explain water withdrawal restrictions during drought to their constituents.
- to inform timing of herbicide, insecticide, and fungicide applications by the agriculture sector.
- to help forest resource managers make decisions about burn bans during dry periods.
- to help cooperative extension agents understand what conditions are like in areas they aren't able to visit in-person due to the coronavirus pandemic.

Expanding Climate and Public Health Work to South Carolina

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. CISA investigates the linkages between climate and human health to improve understanding of vulnerabilities and interacting stressors. CISA has developed two decision support tools to help inform risk reduction strategies for public health impacts.

The Hazardous Extremes for Risk Assessment (HERA) tool is designed to assist community agencies in planning and preparedness for extreme events. The initial pilot version of the HERA tool was developed for North Carolina to provide information for a variety of often small entities, such as hospices, which receive funding from the U.S. Center for Medicaid and Medicare Services. As a condition of funding, these entities are required to have emergency preparedness plans and provide staff training. Coverage has expanded to also include South Carolina.

Wet Bulb Globe Temperature (WBGT) provides the best measure of human heat stress and is used by athletic departments in many states to dictate sports practice guidelines. CISA is collaborating with the Southeast Regional Climate Center (SERCC) and the State Climate Office of North Carolina (SCONC) on a **web-based tool that forecasts hourly values of WBGT** five days in advance. The beta version of the tool was developed for North Carolina and Virginia and will be expanded to cover the entire Southeast region in 2020.

Incorporating Stakeholder Input and Feedback

CISA team members gave a presentation on “Connecting Weather, Public Health, and Emergency Management: Tools for Decision Support” at the NC Emergency Management Association 2019 Fall Conference to solicit information about potential tool uses for emergency managers.

The project team hosted a roundtable discussion with members of the South Carolina Public Healthcare Coalitions in March 2020 to share information about the **HERA tool** and learn how it might be integrated into their annual hazard vulnerability assessment process.

CISA and SERCC hosted engagements with the NC High School Athletics Association and NC Sports Medicine Advisory Committee to discuss heat safety and use of the **WBGT forecast tool** to support decision making. Several of these trainers are helping to validate the tool by measuring WBGT across different practice fields (e.g., tennis court, track, baseball field, etc.) to note differences in WBGT, speculate on causes (i.e., difference in surface area, shade) and report findings to the research team.

Project Partners

**Southeast Regional Climate Center
State Climate Office of North Carolina**

Translating Climate Science for Decision Making

The **HERA tool** provides decision support through climate and weather data visualizations that provide probabilities of hazardous weather and extreme climate events at the county level. Users are able to compare information across counties and states.

Wet bulb globe temperature provides the best measure of human heat stress because it incorporates wind, solar radiation, moisture, and temperature. The **WBGT forecast tool** incorporates warning levels used by the North Carolina High School Athletics Association to inform practice schedules and necessary break periods. NC high school athletic trainers provide the WBGT forecast to their athletic directors and coaches, who use the forecasts to modify weekly workout plans.

Increasing Adaptive Capacity

Due to in-person training limitations caused by the COVID-19 pandemic, a training planned for the Mid-Atlantic Trainers Association was conducted via an online video course in May 2020. Sixty-nine athletic trainers from across the country accessed the training to learn about heat-related vulnerabilities and how to use the WBGT forecasting tool. Participants saved an estimated \$500 each through virtual participation while earning professional development credits through the course.



Photo Source: Caroline Jordan
Max Patch, North Carolina

EXPANDING OUR REACH

Providing Climate Information and Services through New Projects and Partnerships

Sea Level Rise Adaptation Planning for Edisto Beach, SC

The Town of Edisto Beach, SC is located on a small barrier island that is highly vulnerable to storm surge, extreme rainfall flooding, and sea level rise. The Town has explored its vulnerability to current and future flooding, but has not yet begun planning. The Town requested assistance to begin this type of planning after hearing about CISA and the S.C. Sea Grant Consortium's work with the City of Beaufort, SC. During initial engagements with town officials, results of flood modeling completed by the College of Charleston were shared to better understand the Town's challenges and information needs.

Next Steps

The project team plans to conduct at least two Vulnerability, Consequences, and Adaptation Planning Scenarios (**VCAPS**) exercises. The first exercise will be conducted with town staff. The second with town staff and community association leaders. Community engagements will be held to provide input on planning outcomes and public education. These engagements have been delayed by COVID-19 related pressures on town staff to address budget shortfalls due to closures and need to redesign the process as a virtual engagement. Using results of these engagements, a sea level rise adaptation report will be developed as a roadmap for future planning and grant applications. The report will highlight vulnerable places, provide timelines for sea level rise impacts, and identify next steps to reduce flooding in high impact locations.

Collaborating to Create a Drought Dashboard in North Carolina

One of the priorities identified by water utilities through Project Nighthawk was an interactive tool to show drought effects on shared water supplies. In March 2020 CISA and the State Climate Office of North Carolina partnered with the **Internet of Water** and water utilities in the Triangle region of NC to pilot a "water supply dashboard" that would integrate information about utilities' water supply status, water shortage plans, and water conservation measures from a variety of sources (i.e., federal, state, and local agencies) into one web-based tool. The dashboard will assist water resource managers in monitoring water supplies and providing information to staff, boards, and customers about drought conditions and any risk reduction measures or decisions (e.g., water conservation).

Next Steps

Internet of Water staff are leading the technical and data management aspects of the project. The Project Nighthawk team is assisting with ongoing engagements with water utilities, outreach to other relevant partners (e.g., NC Division of Water Resources), and incorporation of Project Nighthawk products and findings into the dashboard product.

Cross-RISA Collaboration: Co-Development of a Hazard Mitigation Planning Portal and Visualization Tool

The Federal Emergency Management Agency (FEMA) requires all state, local, and tribal governments to have Hazard Mitigation Plans (HMP) to be eligible for federal disaster mitigation grants. These plans often lack climate-informed hazard information which undermines the ability of communities to adequately communicate potential future vulnerabilities to their own residents and to state and federal authorities responsible for allocating resources for mitigation activities. This project is a partnership between the Mid-Atlantic RISA (MARISA), the Great Lakes RISA (GLISA), and CISA and will address this growing need through the co-development of a Hazard Mitigation Planning Portal and Visualization Tool with the Urban Sustainability Directors' Network (USDN). The Portal will provide users with a single point of entry to community- and region-specific historical and projected data visualizations of climate-related metrics and impacts.

Next Steps

The Mid-Atlantic RISA (MARISA) began working with the USDN in 2018 to develop this tool. Once a beta version is available, all three teams will work to develop feedback and evaluation instruments to create a consistent data collection process across the three regions. Each RISA will engage with stakeholders, including representatives from rural communities, to test the use of the tool to integrate climate data and information into their hazard mitigation plans. Stakeholders may include members of the Urban Sustainability Directors Network and other communities in the process of developing their HMP.

OUTREACH AND ENGAGEMENT



Photo Source: Stafford Mullin

CISA's Climate Communications and Outreach Materials

CISA has several different ways of communicating with the public and decision makers, including a website, social media channels, and email products (some project specific, such as the CoCoRaHS newsletter, and some general products like the CISA Quarterly Newsletter and Carolinas Climate Listserv). Public communication is a team effort and represents an important way for CISA to maintain regular contact with a network of partners and people in the Carolinas. Over the past 12 months, CISA emails had an overall open rate of 29%, which is 12% higher than the industry average. This indicates that content is matching users' needs. CISA's website and social media has a small but steady engagement with core followers and serves as a supplement to email communications.

- The **CISA website** provides a central location to share information about the program online. Website analytics show that about half of website visitors seek current event information, such as the Carolinas Climate Resilience Conference, and about half seek general information, with contact pages for CISA team members receiving the most hits in this category, and smaller hits for resources and projects.
- The **Carolinas Climate Connection newsletter** is circulated quarterly to 3,179 subscribers. Topics this past year included research highlights, project updates, event recaps, informational resources, and funding opportunities.
- CISA maintains communication channels with its stakeholders using social media including **Facebook** (267 followers) and **Twitter** (689 followers).
- A LinkedIn page was launched in March 2020, largely for internal use. This will allow us to track where CISA students are employed later in their careers and allow them to better highlight their CISA experience when networking and applying for jobs.
- The Carolinas Climate Listserv is circulated to 450 subscribers once or twice a week bringing information about events, research, funding opportunities, and local climate interests most relevant to the Carolinas.

Fourth Biennial Carolinas Climate Resilience Conference Postponed due to COVID-19

CISA hosts the **Carolinas Climate Resilience Conference (CCRC)** biennially as a forum for resource managers, community leaders, and regional experts to share lessons learned and discuss resources and tools for incorporating climate information into their work. The CCRC was initially scheduled for October 26 -28, 2020 in Durham, NC. Planning was well underway when the coronavirus pandemic emerged in the U.S. After several weeks of deliberation and consultation with planning committee members, CISA decided to postpone the conference to May 10 – 12, 2021 to ensure the health and safety of participants. The CISA team recognizes that the impacts of COVID-19 to stakeholders and partners extends beyond more immediate public health threats. In addition to postponing the conference, CISA will work with partners to provide additional travel scholarships, professional development credits, and other opportunities to support local partners and community leaders in attending the event.

Connecting with Partners and Stakeholders in the COVID-19 Era

As officials in North and South Carolina began closing schools, universities, government offices, and businesses in early March 2020 due to public health threats of the novel coronavirus, the CISA team and partners gathered for the monthly network call. During the discussion, it became clear that everyone would need new strategies for virtual engagement with stakeholders to continue work in a safe and effective manner. This led to the creation of a virtual engagement discussion group and resource collection portal. CISA and partners are drawing from the expertise of other agencies and organizations, such as the **NOAA Office for Coastal Management**, to compile and share resources. CISA also hosted representatives from the **South Atlantic Fishery Management Council (SAFMC)** during the monthly partners call. The SAFMC conducts regular virtual engagements as part of the public comment process for new fishery management plans and regulations. They shared valuable strategies to help us connect with stakeholders and decision makers in the COVID-19 era.



“Thank you for the updated information concerning the Condition Monitoring Reports! I have been trying to submit one each Saturday. I am a lifelong gardener and a beekeeper so have kept logs on “first day” occurrences of Spring Peepers, cicadas, etc. I know that I am not a professional but at 65 years of age I do have a lot of “real life” knowledge. Thank you for giving me the opportunity to share my observations to others, it means everything to me!”

~ CoCoRaHS Condition Monitoring Volunteer

Supporting a Network of Citizen Science Observers

The **Citizen Science Condition Monitoring** project engages volunteers with the **Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network** to promote drought impacts monitoring and reporting. This project addresses stakeholder needs for improved understanding of drought impacts and for tools to facilitate the use of local impacts in decision making. Decision makers noted consistency as key to report credibility and usefulness during project feedback surveys. CISA circulates a monthly newsletter to 2,446 CoCoRaHS volunteers in the Carolinas to support participant retention. In May 2020, CISA awarded certificates to 26 observers for their consistent reports over the year.

CISA **developed condition monitoring guidance documents** for six regions in the continental U.S. as well as Alaska, Hawaii, and Puerto Rico and the US Virgin Islands as an additional step to create consistency in reporting across different climates and geographies. A Spanish language version of the PR/USVI guidance document was also created. Region-specific information is intended to help observers recognize potential effects of weather and climate events and write more detailed and relevant reports, enhancing scientists’ ability to compare reports between locations and time periods.

17,226 condition monitoring reports were submitted during the reporting period (June 2019 – May 2020) by 1,743 observers. These reports are used to inform state and national-level drought designations, which, in turn, are used to assist sectors experiencing the most severe impacts of drought.

- The NC Drought Management Advisory Council incorporates condition monitoring report information into the weekly state drought map.
- NWS Forecast Offices use the reports to recommend the drought status in their county warning areas and for other projects and forecasts (e.g., fire weather warnings).
- US Drought Monitoring map authors download the reports weekly as a GIS layer to review as part of their “convergence of evidence” in drought designation.

Contributions to the NWS Service Assessment for Hurricanes Florence and Michael

Following the devastating impacts of Hurricanes Florence and Michael in 2018, the National Weather Service conducted a service assessment with support from regional experts. NWS Service Assessments evaluate performance after a significant event to determine the usefulness of NWS products and services. CISA’s Coastal Climate and Resilience Specialist, Sarah Watson, served as a consultant to the **Hurricanes Florence and Michael Service Assessment** on coastal climate communications. The final report serves as an evaluative tool to identify and share best practices in operations and procedures as well as to address areas for improvement.

THE CISA FOOTPRINT

Evaluating Our Impact in the Region

CISA's evaluation efforts measure how effectively the team is supporting and fostering the capacity of the Carolinas to respond to and prepare for climate variability and change and associated impacts on the region's resources and communities. The team works to achieve this goal through four key program elements:

- Research to advance understanding of climate and its impacts in the Carolinas
- Collaborations to support the implementation of climate adaptation strategies
- Providing decision support services
- Outreach and engagements to foster climate information networks throughout the region

Throughout the life of the CISA program, the team has adopted various approaches to monitor and evaluate program impact, including both quantitative metrics and qualitative analysis of individual projects and the program collectively. Individual projects integrate evaluation questions and metrics into research and engagement activities. Direct stakeholder feedback helps us understand what types of information are most important and how stakeholders intend to use the information. This, in turn, informs resource and tool development. Evaluation requests are circulated to all workshop and conference attendees to improve future events.

Follow Up to the 2018 Program Evaluation

In 2018, CISA conducted a program review to evaluate regional impact and assess future directions. Three external reviewers interviewed CISA Advisory Committee members, PIs, staff, collaborating researchers, stakeholders, and students. Reviewers returned recommendations encompassing program areas of coasts, health, drought, engagement, and program management. Efforts are ongoing to incorporate recommendations into the program. Follow up activities have included:

- Hiring the new CISA Climate Solutions Specialist, to expand technical assistance to support local climate adaptation. This position, held by Jory Fleming, was designed to support climate science translation and visualization for decision making.
- Working to expand public health work to South Carolina through geographic coverage of the Hazardous Extremes for Risk Assessment (HERA) tool and Wet Bulb Globe Temperature (WBGT) forecasting tool. CISA team members met with members of the SC public healthcare coalitions in March 2020 to share information about public health work and gather feedback on the HERA tool.
- Increasing engagement with Advisory Committee members and external partners to improve connections across the network. Advisory Committee members are invited to join monthly team calls and a mid-year webinar update in addition to the annual in-person meeting. Committee members also play an active role in planning for the Carolinas Climate Resilience Conference and on individual research projects. CISA also now leads a monthly Southeast Regional Climate Collaboration call with representatives from various federal, state, and local agencies. The calls were initiated by Linda Rimer, former Climate Liaison for EPA Region IV. CISA took up leadership of the monthly calls following Linda's retirement in December 2019 to maintain connections across the network.
- Expanding analysis of the Carolinas adaptation network through the development of a regional climate information needs assessment. The assessment will serve to collect information about current climate concerns in the region and how agencies and organizations are incorporating climate change into future planning. A summary of results will be shared with the network.

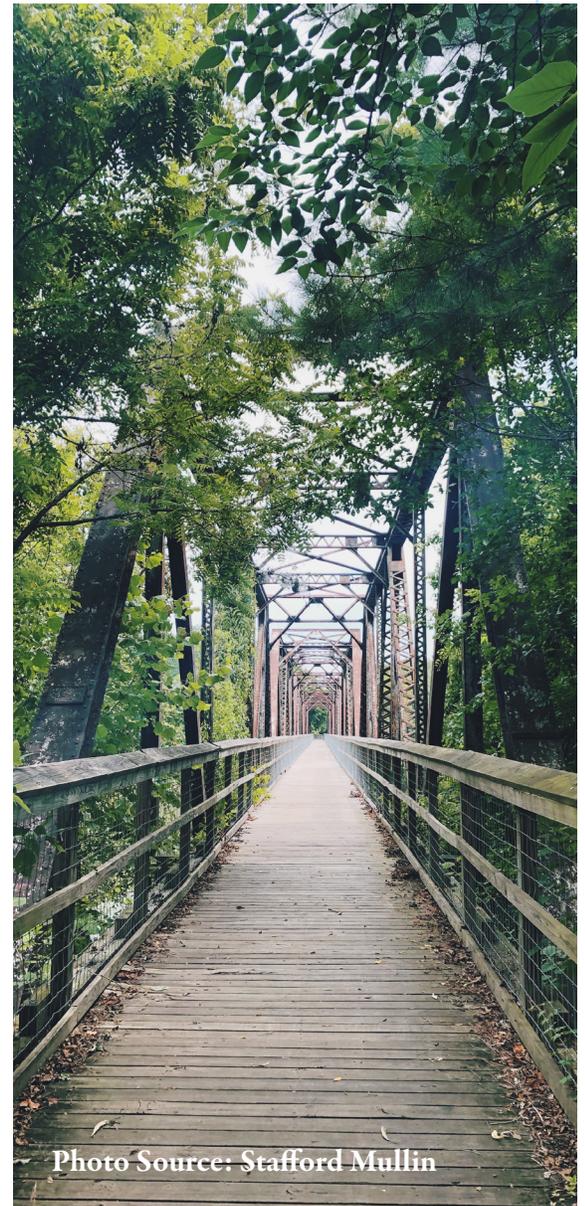


Photo Source: Stafford Mullin

OVERVIEW OF ONGOING PROJECTS

Contributions to the NIDIS Drought Early Warning System for the Coastal Carolinas

Launched in 2012, the Coastal Carolinas DEWS focuses 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. Several CISA projects contribute to the Coastal Carolinas DEWS, through building understanding of droughts' effects on the Carolinas' coastal ecosystems, developing new approaches and products to improve the use of drought information, and engaging with regional decision makers on drought issues.

The Coastal Salinity Index

Team members: Lackstrom, Rouen

Overview: The Coastal Salinity Index (CSI) was developed to characterize coastal drought by monitoring the freshwater-saltwater interface. The tool is intended to improve understanding of the effects of changing salinities on fresh and saltwater ecosystems, fish habitat, and freshwater availability for municipal and industrial use. CISA collaborates with the USGS South Atlantic Water Science Center to advance the development and use of the CSI.

Activities: CISA completed the development and initial implementation of the index, with the launch of the CSI website, hosted by USGS, in October 2019. More information is available on [page 8](#)

Deliverables:

- **CSI Website**
- CSI values for 97 sites from North Carolina to Texas available through USGS ScienceBase.
- The CSI R-package can be used to calculate the CSI using your own data or data downloaded from other sources, such as USGS or NERRS. It is available [here](#).
- A USGS Open-File Report documents the methods and results of activities. The **report** includes the “CSI User Guide” developed by CISA.

Data Management: All CSI products (data release, Open-File Report, real-time CSIs on the CSI website) are reviewed, approved, and managed by the USGS, following USGS data management requirements. Questions should be directed to Matthew Petkewich from USGS (mdpetkew@usgs.gov).

Citizen Science Condition Monitoring Project

Team members: Farris, Lackstrom, Blackwood, Charette, Fleming, Mullin, Ramthun, Román-Rivera, Ward

Overview: This project engages citizen scientists and the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network to promote drought impacts monitoring. Observers provide regular condition reports to document local effects of weather and climate. 17,226 reports were submitted during the reporting period (June 2019 – May 2020) by 1,743 observers throughout the U.S. This project addresses a need for improved understanding of drought impacts and for impacts information to facilitate decision making.

Activities:

- Developed regional guidance documents to support condition monitoring volunteers in different geographies and climates across the U.S.
- Continued to support Carolinas observers through regular communications via the monthly newsletter, as well as public recognition and awards for consistent observers
- Began to investigate how to increase usability of the reports for other weather and climate events

Deliverables:

- Condition Monitoring Regional **Guidance Documents** for regions across the U.S. as well as Alaska, Hawaii, and Puerto Rico and the US Virgin Islands, for which a Spanish-language version was also produced.
- See **Appendix: 2019-2020 Deliverables** for project documents, presentations, and newsletters.

Data Management: All CoCoRaHS Condition Monitoring Reports are publicly available on the CoCoRaHS website: www.cocorahs.org. Agency reports from the state climate offices, Southeast Regional Climate Center, and NCEI Storm Database that were used in project analysis are publicly available via each institution's website. Questions about project data can be directed to Amanda Farris (afarris@sc.edu).

Innovating Drought Communications with North Carolina Decision Makers

Team members: Lackstrom, C. Davis, Foster, Gupta, Ward

Overview: In the aftermath of recent droughts, decision makers across North Carolina articulated needs for information and communications that enhance existing drought resources. This project, led by the State Climate Office of North Carolina (SCONC) is developing sector-specific information for drought decisions, delivering accessible and actionable information, and improving the transparency of the drought monitoring process.

Activities:

- Continued development of drought communications and outreach infographics
- Hosted engagements and evaluations of these products with stakeholders to obtain feedback on how project outputs were being used
- Began a collaboration with the Internet of Water to create a drought dashboard which integrates information about drought, water supplies, utilities' water shortage plans, and water conservation measures using the findings from Project Nighthawk
- More information is available on [page 9](#).

Deliverables:

- SCONC hosts the project [website](#)
- Story [map](#) describing the NC DMAC weekly process to monitor and make drought designations
- See [Appendix: 2019-2020 Deliverables](#) for presentations and communications materials

Research to Advance Understanding of Climate & Related Impacts in the Region

Assessing the Impact of Climate Change on Longleaf Pine Ecosystem Management

Team members: Dow, E. Davis, Gao, Kupfer, Lackstrom

Overview: The longleaf pine ecosystem is iconic in the Southeast, but has been reduced to only a fraction of its previous acreage due to fire suppression, timber harvesting, and land conversion. Climate change will affect this ecosystem and the species that rely upon it. CISA is partnering with the Department of Interior, Southeast Climate Adaptation Science Center to coordinate conservation and management actions.

Activities: A survey on managers' practices is being compared to research on how climate change will narrow the window of optimal conditions optimal prescribed burning. The project team will use this research to recommend changes to management and adaptation strategies for the longleaf ecosystem.

Deliverables: Findings were presented at the Southeast Association of Fish and Wildlife Agencies Annual Meeting in Hilton Head, SC in October 2019.

Drought Transition Probabilities

Team members: Carbone, Hibbs

Overview: This project documents probabilities for transitioning from one drought class to another and attempted to move beyond standard linear techniques in constructing these probabilities. Machine learning approaches show promise for drought forecasting, particularly during winter months.

Activities: This research compared a suite of analytical approaches to calculate drought transition probabilities in NC and SC climate divisions. Approaches derived from machine learning algorithms delivered the best model performance, incorporating the ENSO index and temperature as predictor variables.

Deliverables: Hibbs, M. "Developing an analytical method for improved computation of drought transition probabilities." Honors Thesis. May 2020.

Data Management: The probabilistic statistics for drought transitions generated through this research are stored on a networked hard drive maintained by Greg Carbone. Questions should be directed to Greg Carbone (carbone@mailbox.sc.edu).

Organic Soil Moisture Monitoring in Coastal North Carolina

Team members: C. Davis, Heuser, Ward

Overview: With funding support from CISA, and in partnership with the NC Forest Service, The Nature Conservancy, US Fish & Wildlife Service, and NC State Parks, the State Climate Office of North Carolina established a system of soil moisture monitoring stations to inform fire risk decision making in eastern, coastal North Carolina, a region where wide variation in organic soil properties has made fire risk measurement difficult.

Activities: Final monitoring stations installed. There are now four organic soil moisture stations across eastern North Carolina. Data are being actively used for monitoring and can be accessed through the Fire Weather Intelligence Portal (<https://climate.ncsu.edu/fwip/>), maintained by the State Climate Office of North Carolina.

Deliverables:

- Current and archived station data are viewable on the Fire Weather Intelligence Portal map and on meteograms for each station showing change over time. Parameters include air temperature, relative humidity, precipitation, and volumetric soil moisture at five levels.
- See [Appendix: 2019-2020 Deliverables](#) for workshops, meetings, reports, and communications.

Data Management: Organic Soil Moisture (OSM) Monitoring Station Data, Created by the State Climate Office of North Carolina, Published beginning March 6, 2018, Housed in the SCONC's internal MySQL database, Access provided on the Fire Weather Intelligence Portal at <https://climate.ncsu.edu/fwip/>. Questions should be directed to Corey Davis (cndavis@ncsu.edu).

Collaborations to Support Climate Adaptation in the Carolinas

Building Regional Resilience to Water-Related Hazards in the Charleston, SC Region

Team members: Watson, Carbone, J. Davis, Dow, Ghanat, Knapp, Levine

Overview: CISA is providing technical and engagement support to the Charleston Resilience Network as part of a NOAA Regional Coastal Resilience Grant, awarded in 2016. This project is a two-pronged approach to identifying current and future flood risk and effectively communicating those results to residents and decision makers.

Activities:

Public engagements were hosted with the City of Folly Beach and the City of Charleston's Eastside neighborhood in July 2019 to educate participants about flood risk and collect information about what residents are doing to prepare for flooding. The GIS analysis and mapping approach for this project were used to create sea level rise and flood risk maps for the City of Beaufort, Beaufort County, and Edisto Beach.

Deliverables:

Hung, C.-L. J., L. A. James, G. J. Carbone, and J. M. Williams. 2020. **Impacts of Combined Land-use and Climate Change on Streamflow in Two Nested Catchments in the Southeastern United States**. *Ecological Engineering*, 143, 105665.

See **Appendix: 2019-2020 Deliverables** for additional reports, engagements, and media.

Data Management: Precipitation data were collected from the CORDEX-North America database for coastal South Carolina. These data, as well as historic annual precipitation maxima from them are stored on a hard drive maintained by Greg Carbone. Questions should be directed to Greg Carbone (carbone@mailbox.sc.edu).

Assessing Business Impacts of Hurricanes and Flooding in the Charleston, SC Region

Team members: E. Davis, Dow, Helgeson

Overview: Small- and medium-sized enterprises (SMEs) make up 99% of businesses in the United States and are critical to economic development, job creation, and community well-being. This case study of Charleston, SC's SMEs sought to understand preparation for and recovery from Hurricane Irma in 2017.

Activities: Sixty in-depth, in-person interviews were conducted to explore business owners' perceptions of hurricanes, the impacts faced from flooding, and barriers to recovery. More information is available on **page 7**.

Deliverables: Initial research suggests that the presence of a hurricane plan, perception of hurricane severity change, and the purchase of flood insurance all correlate positively with business recovery. These results were presented to City of Charleston and Chamber of Commerce staff as well as the Charleston Resilience Network.

Data Management: The Business Recovery from Hurricane Irma Dataset is not published due to IRB best management practices. For questions about this dataset, contact Kirstin Dow (KDow@sc.edu).

South Atlantic Regional Research on Coastal Community Resilience

Team members: Dow, Harris, Knapp, Watson

Overview: The four South Atlantic Sea Grant programs (GA, FL, NC, and SC) received funding from the NOAA Office of Coastal Management to begin a new South Atlantic Regional Research on Coastal Community Resilience program. The overall goal of the project is to help local governments build capacity to better visualize, understand, and plan for coastal hazard risks. CISA is partnering with the City of Beaufort, SC for our portion of this project.

Activities: The team worked with the Low Country Hazards Institute and S.C. Sea Grant Consortium to develop a comprehensive sea level rise vulnerability assessment for the City. The City will use the findings in their comprehensive planning and to direct funding for adaptation strategies to reduce risk and increase resilience. More information is available on **page 6**.

Deliverables:

- L. Knapp, K. Dow, M. Harris, A. Braud, N. Levine, and S. Watson. 2019. "Flood Vulnerability Assessment: City of Beaufort, SC." <https://cityofbeaufort.org/DocumentCenter/View/5219/Beaufort-Flood-Vulnerability-Final-Report?bidId=>
- See **Appendix: 2019-2020 Deliverables** for stakeholder presentations

Supporting Sea Level Rise Adaptation and Planning in Beaufort County, SC

Team members: Watson, Knapp

Overview: Building on previous collaborations with Beaufort County, CISA is working to help municipal leaders assess possible ordinances and sea level rise overlays that would inform an updated version of the 2015 Sea Level Rise Adaptation Plan and revisions to the County's comprehensive plan.

Activities: CISA has taken a leading role in coordinating a Beaufort County Sea Level Rise Task Force, which is working to draft recommendations to incorporate sea level rise and flood mitigation recommendations into the County's comprehensive planning process. More information is available on **page 5**.

Deliverables: See **Appendix: 2019-2020 Deliverables** for a full list of stakeholder engagements.

Support for South Carolina's Drought Response Program

Team members: Lackstrom, Altman, Farris, Fleming, Griffin, Mizzell, Mullin

Overview: CISA initiated this collaborative project in 2017 with the South Carolina State Climatology Office (SC SCO). It has involved a variety of research and engagement activities to help the SC SCO enhance the State's Drought Response Program and improve drought preparedness and response across the State.

Activities: CISA continued to build on needs identified in drought preparedness by conducting a second statewide drought tabletop exercise on July 24, 2019. A variety of education materials for different audiences were developed to help navigate the drought monitoring and response process, including the State Drought Response Committee and SC Emergency Management Division. More information is available on [page 3](#).

Deliverables: See [Appendix: 2019-2020 Deliverables](#) for reports, workshops, and communications materials.

Central Midlands Council of Governments Watershed-Based Planning

Team members: Carbone, Dow, Fleming, Sprouse

Overview: The Central Midlands Council of Governments asked CISA to help in incorporating climate change into a management plan for the three rivers watershed in Columbia, SC. CISA will provide technical support and research to support the climate change component of the Three Rivers Watershed plan.

Activities: To date CISA has collaborated with the Central Midlands COG to include climate change considerations as a component of the watershed planning process. Greg Carbone served as an advisor to the evaluation committee for the consultant proposals. CISA will work with the hired consultant to complete the analysis over the next year.

Providing Innovative Decision Support Services

Carolinas Precipitation Patterns & Probabilities Atlas

Team members: Carbone, Beidel, Gao, Lu

Overview: The Carolinas Precipitation Patterns & Probabilities Atlas (Atlas) provides downloadable maps and figures characterizing various measures of precipitation and drought. It offers information not readily available elsewhere, such as frequency and duration of both dry and wet events, photographs, videos, and narratives of the impacts of precipitation extremes in the Carolinas.

Activities: All historic drought and heavy precipitation data were updated through December 2018. This involved statistical analysis, downloading and reformatting data sets, and production of new graphics. Analysis of drought transition probabilities was conducted as a possible source of new information for the Atlas.

Deliverables: The Atlas is available at <https://www.cisa.sc.edu/atlas/>.

Data Management: The Atlas is a public resource and all maps and graphics are freely downloadable with appropriate citation. Sources of public datasets used to develop various Atlas products are listed under each graphic. Questions should be directed to Greg Carbone (carbone@mailbox.sc.edu).

Convergence: Climate-Health Vulnerabilities Website

Team members: Cochran, Clark, Konrad, Spitzer

Overview: The Convergence website provides a collection of resources to educate communities about the health impacts of climate and weather events. The project is rooted in a model of collaboration between experts and community stakeholders to foster public engagement and improve bidirectional communication and understanding of climate-health vulnerabilities.

Activities: Communications products on the website were updated, including a climate-health 2-pager and blog postings about the relationship between COVID-19 and severe weather.

Deliverables:

- The Convergence website is available at: <https://convergence.unc.edu>.
- Presentations at the NC Emergency Management Association Fall Conference and NC Recreation and Parks Association Rec+Tech Summit.

Hazardous Extremes for Risk Assessment (HERA) Tool

Team members: Cochran, Konrad, McConnell, Rayne, Spitzer

Overview: The Hazardous Extremes Risk Assessment (HERA) Tool compiles and presents impact data on weather and climate related hazards in a centralized online resource, featuring maps and data visualizations. The project is currently focused on making the tool more useful for Health Care Coalitions in developing their annual Hazard Vulnerability Assessments.

Activities: Engagements with stakeholders centered on connections with the Health Care Coalitions and ways to merge the data behind the HERA tool into emergency preparedness plans and Centers for Medicare and Medicaid Services compliance. The Tableau interface and weather and climate data visualizations are being updated based on user feedback.

Deliverables: The HERA tool is available at <https://convergence.unc.edu/tools/hera/>. See [Appendix: 2019-2020 Deliverables](#) for presentations and stakeholder workshops.

Data Management: All data for the HERA tool is publicly available. Data Includes the NCEI storm database, death certifications, 100 and 500 year flood plain parcels, heavy precipitation events, heat, and agricultural damage. For more information about the datasets used in the tool contact Ferdouz Cochran (ferdouz@email.unc.edu).

Heat Health Vulnerability Tool

Team members: Konrad, Clark, Cochran, Dello, Hiatt

Overview: This project investigates the statistical relationships between different climate and weather conditions and the rates of hospitalizations for heat-related illness. This has been used to develop a model, the Heat Health Vulnerability Tool (HHVT), which combines weather data with community resilience measures to forecast changes in heat-related hospitalization.

Activities:

- The State Climate Office of North Carolina upgraded the tool's model utilizing a longer time series of hospital admissions data and adding variables to the predictive model. This will allow model validation after a data use agreement is completed with the North Carolina Department of Health.
- CISA met with members of the Mid-Atlantic RISA and the Maryland Emergency Management Association to share information about the HHVT and discuss how they might develop a similar resource.

Deliverables: The HHVT is available at <https://convergence.unc.edu/tools/heat/>

Data Management: The HHVT model is comprised of data from NC DETECT, North Carolina's epidemiological syndromic surveillance system, and maximum temperature data and heat index forecast data from the National Weather Service. Data from NC DETECT is protected and not available for public use. Questions should be directed to Chip Konrad (cek@email.unc.edu).

Wet Bulb Globe Temperature Forecast Tool

Team members: Konrad, Bertrand, Clark, Cochran, Dello, Martin

Overview: Heat advisories in the southeast typically rely on heat indices that don't account for radiation or ventilation. This project seeks to address these inadequacies by exploring methodologies to estimate wet bulb globe temperature (WBGT) in the absence of WBGT monitors. This includes a collaboration with the State Climate Office of North Carolina to create a tool that converts NWS gridded weather data into WBGT hourly data.

Activities:

- Field tested wet bulb globe temperature in diverse contexts to reveal forecasting challenges and potential satellite-based products and mapping methods to quantify the factors that control these temperatures
- Continued tool development and refinement by the State Climate Office of North Carolina, including expansion to cover the entire Southeast
- Online video course produced for the Mid-Atlantic Trainers Association, viewed by 69 individuals to meet training requirements

Deliverables: The WBGT Forecasting Tool is available at <https://convergence.unc.edu/tools/wbgt/>. See **Appendix: 2019-2020 Deliverables** for meetings, presentations, and training courses.

Data Management: Mortality data for the state of North Carolina were obtained from North Carolina Vital Records, a division of the North Carolina Department of Health Human Services. Meteorological data was obtained through the NC State Climate Office CRONOS database. These data are freely downloadable with appropriate citation. Questions should be directed to Chip Konrad (cek@email.unc.edu).

APPENDIX: DELIVERABLES

Advisory Committees

Carbone, G. North Carolina State University Climate Change and Society Program, Advisory Board member.

Carbone, G. Technical advisor for the Three Rivers Watershed RFP selection committee, evaluating consultants' methodologies for RFP Task 5: Source Water Protection and Climate Change Considerations. April / May 2020.

Cochran, F. Planning Committee for North Carolina Drought and Health Workshop.

Cochran, F. & Fleming, J. 2020 Carolinas Regional Adaptation Leadership Award (RALA) Selection Committee.

Dow, K. NOAA Climate Working Group of the Science Advisory Board. 2016 -present.

Dow, K., Farris, A., & Konrad, C. Organizing Committee for the Climate Prediction Applications Workshop, NOAA, National Weather Service, Climate Services. Charleston, SC. June 2019.

Dow, K. Consultant to Climate Emergency Atlas by D.K. Publishing. (Forthcoming October 2020).

Farris, A. Program Committee for National Adaptation Forum. Atlanta, GA. May 2022.

Farris, A. Southeast & Caribbean Climate Community of Practice Steering Committee.

Lackstrom, K. Center for Oceans and Human Health and Climate Change Interactions (OHHC2I), University of South Carolina. Internal Advisory Committee member. 2019-ongoing.

Lackstrom, K. Planning Committee for US Drought Monitor Workshop: Forecasting, Monitoring, and Responding to Drought in the Southeast. Columbia, SC. February 2020.

Conferences, Meetings, Trainings, and Workshops

Carbone, G. (2019). Climate Change and Action. [workshop]. Taught a one-day workshop for 25 student leaders from Europe as part of the Dept. of State sponsored Institute in Civic Engagement for the Study of U.S. Institutes.

Konrad, C. & Ferdouz, C. (2019, June 17). NC High School Heat-Safety Working Group Engagement. [meeting]. Chapel Hill, North Carolina.

Farris, A. & Ramthun, J. (2019, June 18). Condition Monitoring Project Decision Maker Webinar. [training]. 6 Participants.

Watson, S. (2019, July 9). Be Flood Ready Eastside. City of Charleston, Public Engagement. [meeting]. Charleston, SC.

Watson, S. & co-organizers (S.C. Sea Grant Consortium, City of Folly Beach, College of Charleston). (2019, July 9). City of Folly Beach Family Fun Night. [meeting]. Folly Beach, SC.

Lackstrom, K., Allen, J., Altman, E., Farris, A., Griffin, M., Mizzell, H. & Wood, M. (2019, July 24). South Carolina Statewide Drought Tabletop Exercise. [workshop]. SC Emergency Operations Center, West Columbia, SC. 92 Participants.

Carbone, G. (2019, September 18). Invited "Ask a Meteorologist" session. [training]. Durham, NC Public School teachers. Durham, NC. Approximately 20 teachers.

Konrad, C. and Ferdouz, C. (2019, October 8) NC Sports Medicine Advisory Committee (SMAC) Engagement. [meeting].

Carbone, G. (2019, November 22). SC Weather Day. [training]. St. Peter's School, Columbia SC. 20 elementary school children.

Watson, S., Moser, S., & Kearns, F. (2020, February 5). Working Together Toward Trauma-Aware Risk Communication. [training]. Social Coast Forum. Charleston SC.

Cochran, F., Konrad, C., & A. Farris. (2020, March 5). CISA-SERCC Roundtable Event for HERA. [workshop]. Columbia, SC. 7 participants.

Konrad, C., Cochran, F. (2020, May). Heat Vulnerability and Safety in Athletic Activities: A Web-Based Tool to Forecast Wet Bulb Globe Temperature. [training] Online Video Course for the Mid-Atlantic Trainers Association. 69 participants.

Journal Articles

- Cochran, F.**, Jackson, L., Neale, A., Lovette, J., & Tran, L. (2019). A Community EcoHealth Index from EnviroAtlas Ecosystem Services Metrics. *International Journal of Environmental Research and Public Health*, 16(15), 2760. <https://doi.org/10.3390/ijerph16152760>
- Davis, E.**, Wang, C., & **Dow, K.** (2019). Comparing Sentinel-2 MSI and Landsat 8 OLI in soil salinity detection: a case study of agricultural lands in coastal North Carolina. *International Journal of Remote Sensing*, 40(16), 6134–6153. <https://doi.org/10.1080/01431161.2019.1587205>
- Lu, J., **Carbone, G.J.** & Grego, J.M. Uncertainty and hotspots in 21st century projections of agricultural drought from CMIP5 models. *Sci Rep* 9, 4922 (2019). <https://doi.org/10.1038/s41598-019-41196-z>
- Lu, J., **Carbone, G.J.**, & Gao, P. (2019). Mapping the agricultural drought based on the long-term AVHRR NDVI and North American Regional Reanalysis (NARR) in the United States, 1981–2013. *Applied Geography*, 104, 10–20. <https://doi.org/10.1016/j.apgeog.2019.01.005>
- Payne, Heather and Neubauer, Rebecca and **Dow, Kirstin** and **Davis, Eleanor** and Brown, Ian, Legal Issues When Managing Public Roads Affected by Sea Level Rise: South Carolina (June 1, 2019). Seton Hall Public Law Research Paper Forthcoming. Available at SSRN: <https://ssrn.com/abstract=3441440> or <http://dx.doi.org/10.2139/ssrn.3441440>
- Ward, A.**, **Clark, J.**, McLeod, J., Woodul, R., Moser, H., & **Konrad, C.** (2019). The impact of heat exposure on reduced gestational age in pregnant women in North Carolina, 2011–2015. *International journal of biometeorology*, 63(12), 1611-1620. <https://doi.org/10.1007/s00484-019-01773-3>
- Cochran, F.**, Daniel, J., Jackson, L., & Neale, A. (2020). Earth observation-based ecosystem services indicators for national and subnational reporting of the sustainable development goals. *Remote Sensing of Environment*, 244, 111796. <https://doi.org/10.1016/j.rse.2020.111796>
- Eck, M. A., Murray, A. R., **Ward, A. R.**, & **Konrad, C. E.** (2020). Influence of growing season temperature and precipitation anomalies on crop yield in the southeastern United States. *Agricultural and Forest Meteorology*, 291, 108053. <http://doi.org/10.1016/j.agrformet.2020.108053>
- Hung, C. L. J., James, L. A., **Carbone, G. J.**, & Williams, J. M. (2020). Impacts of combined land-use and climate change on streamflow in two nested catchments in the Southeastern United States. *Ecological Engineering*, 143, 105665. <https://doi.org/10.1016/j.ecoleng.2019.105665>
- Jurjonas, M., Seekamp, E., Rivers, L., and Cutts, B. (2020). Uncovering climate (in)justice with an adaptive capacity assessment: A multiple case study in rural coastal North Carolina. *Land Use Policy*, 94, 104547. <https://doi.org/10.1016/j.landusepol.2020.104547>
- >> **This article provides results of engagements with African American communities in coastal North Carolina to start a dialogue about potential sea level rise adaptation. The engagements highlighted the need for tailored outreach specific to communities of color and approaches that address inequality and racial injustice. The article recommends strategies to rethink engagement methods to improve inclusiveness in discussions around climate risks and adaptation.**
- Lu, J., **Carbone, G.J.**, Huang X., **Lackstrom, K.**, & Gao, P. (accepted). Mapping the sensitivity of agriculture to drought and estimating the effect of irrigation in the United States, 1950-2016. *Agricultural and Forest Meteorology*.
- Tsai, W.-L., Silva, R. A., Nash, M. S., **Cochran, F.V.**, Prince, S. E., Rosenbaum, D. J., ... Buckley, T. J. (2020). How do natural features in the residential environment influence women's self-reported general health? Results from cross-sectional analyses of a U.S. national cohort. *Environmental Research*, 183, 109176. <https://doi.org/10.1016/j.envres.2020.109176>

Media Interviews

- Carbone, G. (2019, July). Interviewed by Chloe Johnson, The Post and Courier. Clemson works to make a more resilient peach as warmer winters imperil SC's \$71M industry. **In The Post and Courier.**
- Konrad, C. (2019, July). Interviewed by Zoe Nicholson, The Greenville News. The danger zone: When heat meets humidity this summer in the Carolinas. **In The Greenville News.**
- Konrad, C. (2019, July). Interviewed by Sammy Fretwell, The State. Hate Columbia's heat now? It will be 'dangerously hot' in a few years, study says. **In The State.**
- Watson, S. (2019, September). Interviewed by A. Freedman, Washington Post. Hurricane Dorian is on track to bring historic coastal flooding to the Carolinas. **In The Washington Post.**
- Carbone, G. (2019, October). Interviewed by Alex Calamia (WLTX) on drought.
- Cochran, F. and Konrad, C. (2019, October). Interviewed by Veronica Penny, Columbia Journalism Investigations. Deadly heat is killing Americans: A decade of inaction on climate puts lives at risk. **In The Center for Public Integrity and The Guardian.**

Dow, K. (2019, November). Interviewed by WIS TV. 11,000 scientists say we're in a 'climate emergency,' but what is Columbia doing about it?. In **WIS TV**.

Konrad, C. (2019, December). Interviewed by Lee Ringer, Spectrum Cable News. Warming Climate Means More Variability in North Carolina's Winter Weather. In **Spectrum News**.

Watson, S. (2020, January). Interviewed by Kathryn Miles, REI. The effects of climate change on a heavily developed city imperil the future of Charleston, South Carolina. But instead of throwing up their hands and moving out, some residents are staying put. Here's why they feel hopeful about the future. In **the Uncommon Path**.

Carbone, G. (2020, February). Interviewed by Chloe Johnson, The Post and Courier. Record warm winter is making SC plants bloom weeks early, with skeeters and bugs out too. In **The Post and Courier**.

Carbone, G. (2020, March). Interviewed by Chloe Johnson, The Post and Courier. Climate change is stretching allergy season, but effects are less clear in SC. In **The Post and Courier**.

Dow, K. (2020, March). Interviewed by Tut Underwood, NPR. Weather Events to Become More Extreme with Climate Change. In **SC Public Radio**.

Fleming, J. (2020, March). Interviewed by Emily Pontecorvo, Grist. The 2020 census can help us fight climate change — if coronavirus doesn't get in the way. In **Grist.org**.

Konrad, C. (2020, March). Interviewed by James Bruggers, Inside Climate News. In Louisville and dozens of cities east of the Mississippi, winter never really happened. In **the courier journal**.

Newsletters

Mullin, S. & Farris, A. CISA and CoCoRaHS Condition Monitoring Newsletter. 12 Monthly Issues, June 2019 – May 2020. Web.

Farris, A., Dow, K., & Fleming, J. Carolinas Climate Listserv. Weekly updates on climate news and opportunities across the Carolinas. June 2019 - May 2020. Web.

Altman, E., Clark, J., Farris, A., Charette, E., Foster, E., Gupta, A., Cutts, B., Jurjonas, J., Rivers, L., Seekamp, E., & Mullin, S. Carolinas Climate Connection. 2nd-4th Quarters 2019, 1st Quarter 2020. Web.

Presentations and Organized Conference Sessions

Konrad, C. (2019, May 6). Trends in the Character of Hurricanes and Their Impact on Heavy Rainfall and Flooding in North Carolina. [presentation]. Invited Plenary Talk at the North Carolina Association of Floodplain Management. (NCAFPM) Conference. Wrightsville Beach, NC.

Konrad, C. (2019, June 10). Public Health Impacts of Climate Change: Extreme Heat and Hurricanes. [presentation]. Virginia Department of Health Public Health Impacts of Climate Summit. Richmond, VA.

Lackstrom, K., Davis, C., & Ward, R. (2019, June 11). Innovating Approaches to North Carolina Drought Communications. [organized session]. Catawba Wateree Drought Management Advisory Group Annual Meeting. Huntersville, NC.

Ward, R., Davis, C., & Lackstrom, K. (2019, June 11). Project Nighthawk Overview. [presentation]. Catawba-Wateree Drought Management Advisory Group Annual Meeting. Huntersville, NC.

Dow, K. (2019, June 11-13). Approaches to Engaging Decision-Makers in Design and Evaluation. [organized session]. Climate Predictions Applications Science Workshop. Charleston, SC.

DePodwin, B., Gilford, D., Moulton, R., Moser, S., & Watson, S. (2019, June 12). Addressing Emotional Well-Being and Empathy Drain in Climate and Weather Work. [organized session]. Climate Predictions Applications Science Workshop. Charleston, SC.

Watson, S. (2019, June 14). Swamped Coast: King Tides and Sea Level Rise in Seabrook and Kiawah. [presentation]. Town of Seabrook Island & Kiawah Island 2019 Disaster Awareness Day. Seabrook Island, SC.

Konrad, C. (2019, June 18). Use of NC DETECT Syndromic Surveillance Data to Identify Relationships Between Temperature and Heat-related Disease. [presentation]. National Syndromic Surveillance Program's Community of Practice Monthly Webinar.

Ward, R., Davis, C., & Lackstrom, K. (2019, June 18). Weather and Agriculture. [presentation]. 2019 NC Association of County Agricultural Agents Annual meeting. Southern Pines, NC.

- Davis, E. (2019, August). Presentations on the Charleston Business Disruption Project to the Chamber of Commerce and City of Charleston. [presentation]. Charleston, SC.
- Farris, A. (2019, September 9). Communicating Climate Change. [presentation]. Invited presentation to Communicating Science, Health, and Environment Seminar, USC College of Information and Communications. Columbia, SC.
- Lackstrom, K., & Farris, A. (2019, September 17-19). CoCoRaHS Condition Monitoring: Lessons Learned to Support a National Network of Citizen Scientists, Drought Monitoring, & Decision Making. [presentation]. Eleventh Biennial U.S. Drought Monitor Forum. Bowling Green, KY.
- Davis, C., Ward, R., and Lackstrom, K. (2019, September 17-19). Innovating Drought Communications with North Carolina Stakeholders. [presentation]. Eleventh Biennial U.S. Drought Monitor Forum. Bowling Green, KY.
- Farris, A., Ferguson, D., & Andresen, J. (2019, September 19). Adaptation Progress. [organized session]. RISA Annual Meeting. Honolulu, HI.
- Davis, C. (2019, October). Organic Soil Moisture Monitoring. [organized session]. Organic Soils and Fire Management Workshop. Hampstead, NC.
- Watson, S. (2019, October 3). Hawaii/Charleston Resilience Network Knowledge Exchange. [presentation]. Charleston, SC.
- Dow, K., Carbone, G., McKain, K., Pope, A., & Watson, S. (2019, October 4). Integrating Climate Science into Planning. [presentation]. South Carolina American Planning Association Annual Meeting. Columbia, SC.
- Lackstrom, K. & Petkewich, M. (2019, October 17). Coastal Salinity Index. [presentation]. Webinar for the National Integrated Drought Information (NIDIS) Coastal Carolinas Drought Early Warning System (DEWS).
- Watson, S., & Merchant, R. (2019, October 22). Coastal Resilience in Beaufort County. [presentation]. Presentation to the Beaufort County Southern Lowcountry Regional Board. Bluffton, SC.
- Konrad, C. (2019, October 24). The Delivery of Impact-Based Decision Support Tools: Lessons Learned from a Physical Scientist. [presentation]. Invited keynote at 44th Annual Climate Diagnostics and Prediction Workshop. Durham, NC.
- Watson, S. (2019, October 24). Swamped? Climate Change in South Carolina. [presentation]. Trees SC. Folly Beach, SC.
- Watson, S., & Merchant, R. (2019, October 25). Coastal Resilience in Beaufort County. [presentation]. Presentation to Beaufort County Northern Regional Planning Implementation Committee. Beaufort, SC.
- Terando, A., Kupfer, J., Gao, P., Teske, C., and Hiers, K. (2019, October 30) Modeling changing prescribed fire opportunities to inform the Southeast Conservation Adaptation Strategy. Southeastern Association of Fish and Wildlife Agencies Annual Meeting. Hilton Head, SC.
- Davis, C., Ward, R., and Lackstrom, K. (2019, October 30). Project Nighthawk Eye Tracking Studies. [organized session]. NC Cooperative Extension State Conference. Raleigh, NC.
- Cochran, F. (2019, November 5). Connecting Weather, Public Health, and Emergency Management – Tools for Decision Support. [organized session]. NC Emergency Management Association (NCEMA) 2019 Fall Conference. Wilmington, NC.
- Watson, S. (2019, November 14). Swamped Coast: Sea Level Rise and the Lowcountry. [presentation]. Beaufort County Stormwater Pond Conference. Beaufort, SC.
- Cochran, F. (2019, December 3). Introducing the Convergence Website and the WBGT Tool. [organized session]. NC Recreation and Parks Association (NCRPA) Rec+Tech Summit. Durham, NC.
- Cochran, F., Clark, J., Konrad, C., & Rayne, S. (2019, December 4). A Web-Based Tool to Forecast Wet Bulb Globe Temperature (WBGT) for Outdoor Recreation. [presentation]. North Carolina Recreation and Park Association Conference. Durham, NC.
- Watson, S. (2019, December 9-13). Always Giving Bad News: Meeting the emotional well-being needs of climate extension science communicators. [presentation]. American Geophysical Union Fall Meeting. San Francisco, CA.
- Ward, R., Lackstrom, K., & Davis, C. (2019, December 9-13). Communicating drought: Innovating approaches through engagement with decision makers. [presentation]. American Geophysical Union Fall Meeting. San Francisco, CA.
- Konrad, C. (2019, December 13). Climate Change in North Carolina. [presentation]. Invited presentation at the Amberly Retirement Community Meeting. Cary, NC.

Davis, C., Ward, R., & Lackstrom, K. (2020, January 12-16). Innovating Drought Communications in North Carolina through Decision-Maker Engagement. [presentation]. American Meteorological Society Annual Meeting. Boston, MA.

Rayne, S., Konrad, C., Clark, J., & Bertrand, D. (2020, January 14). Forecasting the Wet-Bulb Globe Temperature: A Web-Based Tool Designed for Populations Who Are Vulnerable to Heat-Related Illnesses. [presentation]. American Meteorological Society 100th Annual Meeting. Boston, MA.

Watson, S. (2020, January 14). Coastal Resilience in Beaufort County. [presentation]. Presentation to Beaufort County Sea Level Rise Taskforce. Beaufort, SC.

Dow, K. (2020, January 15). Fourth National Climate Assessment: Key Findings for Rural Southeast. [presentation]. Webinar hosted by the Southeast Climate Adaptation Science Center.

Dow K., Knapp, L., Harris, M., & Watson, S. (2020, January 28). Beaufort Flood Vulnerability Assessment: Briefing for Beaufort City Council. [presentation]. City of Beaufort City Council Worksession. Beaufort, SC.

Ward, R., Davis, C., & Lackstrom, K. (2020, February 4-5). Communicating Drought: What, When, How and Why? [presentation]. U.S. Drought Monitor Workshop: Forecasting, Monitoring and Responding to Drought in the Southeast. Columbia, SC.

Watson, S. (2020, February 5). Engaging the Over-Engaged: Tell us something we don't already know. [presentation]. Social Coast Forum, Charleston SC.

Davis, C., Ward, R., and Lackstrom, K. (2020, February 7). Project Nighthawk Presentation and Stakeholder Feedback. [organized session]. Triangle Water Supply Partnership Meeting. Cary, NC.

Watson, S. (2020, February 20). Swamped? Climate Change in South Carolina. [presentation]. S.C. State Park Service Interpreters Meeting. Myrtle Beach, SC.

Dow, K. (2020, April 22). Earth Day, SC Addresses Climate Crisis. [presentation]. Online talk, rescheduled from the Statehouse grounds, as part of the Earth Day SC coalition.

Davis, C., Ward, R., and Lackstrom, K. (2020, May 18). [organized session]. Organized webinar at the NC Fire Environment Committee semi-annual meeting.

Farris, A. & Lackstrom, K. (2020, May 19). CoCoRaHS Condition Monitoring: Supporting a National Network of Citizen Scientists, Drought Monitoring, and Decision Making. [presentation]. CoCoRaHS Virtual Annual Meeting.

Poster Presentations

Carbone, G., & Griffin, M. (2019). The Carolinas Precipitation Patterns and Probabilities Atlas. Climate Predictions Applications Science Workshop. June 11, 2019. Charleston, SC. Poster Presentation.

Lackstrom, K., Farris, A., Davis, E., Doesken, N., Guisepe, K., Mullin, S., Newman, N., Reges, H., Smith, K., Turner, J., & Ward, R. (2019). Assessing the Usefulness of Citizen Science Information in Drought-Related Decision Making. Climate Predictions Applications Science Workshop. June 11, 2019. Charleston, SC. Poster Presentation.

Watson, S., Levine, N., Knapp, L. (2019). The Flood Disruption Scale: Communicating High Resolution Flood Hazard Modeling and Mapping in the Charleston South Carolina Region. American Geophysical Union. December 11, 2019. San Francisco, CA. Poster Presentation.

Project & Information Documents

Davis, C., Lackstrom, K., & Ward, R. (2019). **Project Nighthawk: project updates and quick reference guide** [Monitoring Drought: The NC DMAC Weekly Process]. 2-pagers

Rouen, L. F., Lackstrom, K., Petkewich, M. D., & McCloskey, B. J. (2019). **Coastal Salinity Index: User Guide**. Appendix 1 of Open-File Report 2019-1090.

Davis, C., Lackstrom, K., & Ward, R. (2019, August). **North Carolina Drought Management Advisory Council Story Map**. Online Resource.

Lackstrom, K., Farris, A., & Mullin, S. (2019, September). **South Carolina Drought Tabletop Exercise**. 2-Page.

Davis, E & Dow, K. (2020). *Charleston Business Disruption Pilot Study*. Component of PhD dissertation. Survey instrument is published through NIST.

Lackstrom, K., Davis, C. & Ward, R. (2020, January) **Organic Soil Moisture Monitoring in Coastal North Carolina: Assisting Coastal Zone Fire Risk Monitoring and Management**. Project informational 2-Pager.

Lackstrom, K., Farris, A., Fleming, J., & Mullin, S. (2020, April). **South Carolina Drought Guide for Emergency Managers**. Online Resource.

Ramthun, J., Blackwood, L., Charette, E., Farris, A., Lackstrom, K., Roman-Rivera, M., & J. Fleming, J. (2020, May). **Regional Condition Monitoring Guidance Documents**. Online Resource.

Dow, K. (2020, May). *Summary of Survey Findings for Subcontract to Building Regional Resilience to Water-Related Hazards in the Charleston, SC Region*. A Charleston Resilience Network Initiative.

Farris, A., Lackstrom, K., Mullin, S., & Ramthun, J. (2020, May). **Regional Guidance for Condition Monitoring Observers**. 1-page summary. Online Resource.

Reports

National Weather Service. (2020, March). **Service Assessment: 2018 Hurricane Florence and Michael**. Sarah Watson consulted on Florence impacts in SC.

Davis, C., Lackstrom, K., and Ward, R. (2019, August 31). *Organic Soil Moisture Monitoring in Coastal North Carolina: Project Update*.

Lackstrom, K. (2020, March) **2019 South Carolina Drought Tabletop Exercise: Final Report**. Carolinas Integrated Sciences and Assessments. Columbia, SC. 77 pp.

>> **The 2019 SC Drought Tabletop Final Report reveals important insights about drought planning and preparedness in the state. Key challenges associated with the implementation of state-level response actions, inconsistent or uncoordinated communications, and a lack of impact information to assess the true cost of drought are outlined along with recommendations to address these challenges based on stakeholder discussions and feedback. The document provides a pathway to improve the state's capacity to plan for and respond to the impacts of drought at different levels of governance and water resources management.**

Lackstrom, K. **2019 South Carolina Drought Tabletop Exercise: Report Summary**. Carolinas Integrated Sciences and Assessments. Columbia, SC. 7 pp.

Petkewich, M. D., Lackstrom, K., McCloskey, B.J., Rouen, L.F., & Conrads, P.A. (2019). *Coastal Salinity Index along the southeastern Atlantic coast and the Gulf of Mexico, 1983 to 2018*. U.S. Geological Survey Open-File Report 2019-1090, 26 pp. <https://doi.org/10.3133/ofr20191090>

Petkewich, M. D., McCloskey, B. J, Rouen, L. F., & Conrads, P. A. (2019). *Coastal Salinity Index for monitoring drought*. U.S. Geological Survey data release. <https://doi.org/10.5066/P9MQLNL2>.

Carbone, G. Reviewer for NC State Climate Report:

Kunkel, K.E., D.R. Easterling, A. Ballinger, S. Bililign, S.M. Champion, D.R. Corbett, K.D. Dello, J. Dissen, G.M. Lackmann, R.A. Luettich,

Jr., L.B. Perry, W.A. Robinson, L.E. Stevens, B.C. Stewart, and A.J. Terando, 2020: North Carolina Climate Science Report. North Carolina

Institute for Climate Studies, 233 pp. <https://ncics.org/nccsr>

Knapp, L., Dow, K., Harris, M., Braud, A., Levine, N., & Watson, S. (2019). **Flood Vulnerability Assessment: City of Beaufort, SC**.

>> **The Flood Vulnerability Assessment: City of Beaufort, SC provides data on critical assets and people that the City can use when developing flood mitigation strategies such as for drainage projects and building codes, and to build risk and resilience thinking into city planning. The Assessment identifies areas where employment, sales, and business continuity could be threatened, including information on the economic impact to businesses in areas most likely to be impacted by recurrent flooding and sea level rise. By identifying these potential economic impacts, the vulnerability assessment aids future planning and coordination between local government and the business community.**

Student Deliverables

Hibbs, M. (2020, May). *Developing an analytical method for improved computation of drought transition probabilities*. Honors Thesis. University of South Carolina.

Mullin, S. (2020). Review of Heat Illnesses in the State of South Carolina.