



## ANNUAL REPORT

1 May 2011 – 30 April 2012

### Awards

1. Integrating Climate Science and Water Management in North and South Carolina (NA06OAR4310007)
2. Carolinas Integrated Sciences & Assessments (NA11OAR4310148)

## 1. TEAM MEMBERS

### Principal Investigators

Greg Carbone (University of South Carolina)

Kirstin Dow (University of South Carolina)

Chip Konrad (University of North Carolina-Chapel Hill, Southeast Regional Climate Center)

Dan Tufford (University of South Carolina)

Jessica Whitehead (North Carolina Sea Grant, South Carolina Sea Grant Consortium)

### Collaborating Investigators

Ryan Boyles (State Climate Office of North Carolina)

Hope Mizzell (South Carolina State Climatology Office)

Burrell Montz (East Carolina University)

Jan Moore (NOAA Center for Coastal Environmental Health and Biomolecular Research)

Geoff Scott (NOAA Center for Coastal Environmental Health and Biomolecular Research)

### Research and Support Staff (University of South Carolina)

**Research Associates:** Kirsten Lackstrom, Jinyoung Rhee, Vidya Samadi

**Climate Outreach Specialist:** Ashley Brosius

**Research Assistants:** Ivetta Abramyan, Amanda Brennan, Dylan Foster, Jay Fowler, Peng Gao, Benjamin Haywood, Erik Kabelo, Nathan Kettle, Julia Lam, Aashka Patel, Lauren Felker Rouen

## 2. FOCUS AREAS

CISA conducts applied climate research in collaboration with a wide range of water and coastal stakeholders across the Carolinas. CISA's work includes several cross-cutting activities that 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.

During this reporting period, CISA has continued its work on drought, watershed/climate modeling, and coastal climate. In addition, CISA has received funding for the 2012-2016 period. Increased funding levels have allowed us to extend our science and outreach activities to include two new focus areas – health and adaptation – and to expand our research partnerships. For example, Chip Konrad of the Southeast Regional Climate Center (located at UNC-CH) is a CISA

principal investigator and serves as the lead for health projects. Other new collaborators are located at the NOAA Center for Coastal Environmental Health and Biomolecular Research (CCEHBR) located in Charleston, SC, and at East Carolina University in Greenville, NC.

### **National Climate Assessment**

During the 2011-2012 reporting period, CISA also conducted additional research and several projects to support the National Climate Assessment. The first project entailed systematically documenting and evaluating climate information requests made of the State Climate Offices served by the SERCC. The second project involved assessing the capacity of five climate-sensitive sectors (forestry, government, tourism, water, and wildlife) to adapt to climate change. This project also included a systematic review of publications identifying climate information needs for the region and which was done in collaboration with research teams from the Great Lakes Integrated Sciences and Assessments (GLISA) and Western Water Assessment (WWA). Third, CISA partnered with the Southeast Climate Consortium (SECC), the Southern Climate Impacts Planning Program (SCIPP), and other regional partners, to create a technical report that will be used to write the Southeast regional chapter of the 2013 National Climate Assessment.

These projects have provided CISA with information about adaptive capacity in the Carolinas and needs for climate information and decision support. These insights will be used to inform future outreach activities. We are currently planning to initiate a CISA newsletter that will synthesize and circulate science findings of relevance to decision makers in the Carolinas and provide them with information regarding new resources or regional events involving climate and/or related topics. We also plan to organize – with regional partners – a “Carolinas Climate Conference” to help facilitate communications and information sharing among climate service providers, climate researchers, and decision makers in the region. We will continue to participate in NCA through NCA Net. In addition, we are continuing to work with SECC and SCIPP to coordinate the publication of the Southeast Technical Report.

## **3. RESEARCH FINDINGS**

### **Vulnerability Consequence Adaptation Planning Scenarios (VCAPS)**

Applications of the VCAPS mediated modeling approach verified that community adaptation planning is enhanced by working within a structured mediated modeling setting supported by interactive mapping of vulnerability, consequences, and management options. VCAPS was tested in two communities, and efforts for further dissemination of the model are underway.

### **Assessing the Impact of Salt-Water Intrusion in the Carolinas under Future Climatic and Sea-Level Conditions**

The Pee Dee River and Atlantic Intracoastal Waterway Salinity Intrusion Model 2 (PRISM2) tool allows users to explore the threat of salt-water intrusion in the Yadkin-Pee Dee River basin under conditions influenced by ongoing and future climatic change, with an emphasis on changes in the frequency of salt-water intrusion events with increasing sea levels. The tool is based on an integration of climate downscaling, hydrologic modeling and Artificial Neural Network analysis of tides coupled with sea level rise estimates. Model results from the Pawleys Island (SC) stream gage, just downstream from a municipal water intake, indicate that over a 14 year period 1 foot of sea-level rise would double the number of days the municipal intake is unavailable (defined as

conductivity exceeding 2,000 $\mu$ S/cm) to 400 days and a 2-ft. rise in SLR increases the unavailability to nearly 2 years. A 1-ft. SLR combined with a 25-percent decrease in historical streamflow would increase the days the intake is unavailable to over 700.

### **The Impact of Drought on Coastal Ecosystems in the Carolinas**

The research reviewed for this report indicates that drought is discussed primarily in terms of the hydrology-related impacts that affect coastal ecosystems, such as changes to river discharge, freshwater inflows, water level, and water table depth. The severity of these effects depends upon the longevity and recurrence interval of drought event(s) and may be compounded by other anthropogenic stressors on the system. In addition, some drought-related research considers how sea level interacts with freshwater precipitation and runoff to influence the salinity levels experienced by these systems. The review identified the most critical needs for future research including: examining drought impacts in ecosystems not studied by existing research, implementing long term studies to identify and examine causal relationships, and developing a set of indicators with which to monitor ecological change and impacts. More research and information is needed regarding drought impacts on groundwater resources, the significance of drought during different seasons, the longevity of droughts in relation to long-term impacts and/or length of recovery, and responses to potential future changes in salinity regimes.

### **National Climate Assessment**

CISA submitted three reports as technical inputs to the National Climate Assessment. Findings from these reports are highlighted here.

*Collaboration with Key Climate Service Providers:* Data gathered through this project demonstrated the diversity of clients served by State Climate Offices and the Southeast Regional Climate Center. Although the media, colleges and universities, and personal interests were the most frequent users of climate information, there was a wide range of other users across the Southeast. These climate-sensitive sectors include agriculture, construction, economic development, energy, engineering, insurance, and tourism. Information on precipitation and extreme events were the two most frequently requested sources of climate information across all users and sectors. However, there was great variability within each information request category. For example, precipitation requests varied according to measurement interval (annual, seasonal, daily, hourly), geographic area of interest, and data type (observational, annual, or 30-year normal). The broad range of engaged clients and the detail of their information needs is suggestive of a larger, more diverse group of advanced climate information users that are typically acknowledged by the climate adaptation community.

*Engaging Climate-Sensitive sectors in the Carolinas:* This project yielded significant information regarding existing adaptive capacity to respond and adapt to climate change. At this stage, adaptation is limited in the Carolinas, although some current activities indicate emerging action related to climate change – for example, efforts to improve climate-related data collection and monitoring, emissions reduction programs, education and outreach to increase awareness of climate information and issues, risk and vulnerability assessments for emergency management planning, and habitat protection and conservation projects. Factors that have facilitated climate change (and related) activities in the Carolinas include opportunities to engage in networks and collaborative projects, availability of resources (including availability of staff and expertise),

availability of relevant data and information, and the existence of laws, policies, or regulations that support or motivate action on climate issues.

*Climate Adaptation in the Southeast:* The majority of current climate adaptation efforts in the Southeast are aimed at initial steps of identifying the relevant climate risks and conducting risk and vulnerability assessments. Coastal areas, where risks of severe storms and sea level rise are highly salient, are frequently the focus of attention. Many efforts are working also to mainstream climate adaptation into existing institutions and processes. Partly as a consequence of that mainstreaming approach, adaptation efforts are being conducted under a variety of different names and terminologies, including resilience and sustainability. The adaptation process is much more complex and less linear than conveyed by basic models. Significant effort is going into building necessary partnerships for coordinated response of jurisdictional authorities and financial, technical, and other resources. In the future, as more groups advance from conducting risk and vulnerability assessments to strategic adaptation planning and implementation, we anticipate a shift in activities and information needs to place great emphasis on information on the costs, benefits and co-benefits of adaptations. As efforts advance, support for evaluation of adaptation efforts will also become a greater information need in decision making.

#### **4. ACCOMPLISHMENTS**

##### **Core Office**

CISA added two new full-time people to its core office at the University of South Carolina. Ashley Brosius, Climate Outreach Specialist, provides information about climate and CISA's projects to decision makers. Vidya Samadi, post-doctoral researcher, is working on the "Integrating Regional Downscaling and Hydrological Models" project.

##### **CISA Advisory Committee**

The CISA Advisory Committee met on March 14, 2012 in Charleston, SC. The purpose of the Committee is to provide guidance to the CISA PIs and staff about developing regional collaborations, identifying and addressing key decision maker needs in the Carolinas, and implementing new projects. Members include Jeff Allen (Clemson, SC Water Resources Center), Margaret Davidson (NOAA Coastal Services Center), Braxton Davis (NC Division of Coastal Management), Rick DeVoe (SC Sea Grant Consortium), Jerry McMahon (DOI Southeast Climate Science Center), Tim Owen (NCDC), Linda Rimer (EPA Region 4), David Stoney (Kitchen Table Climate Study Group, McClellanville, SC), Lauren Thie (NC Division of Public Health), and Mike Voiland (NC Sea Grant, Water Resources Research Institute), and Ellen Mecray (NOAA Regional Climate Services Director-Eastern Region, ex officio).

##### **Stakeholder Interactions and Presentations**

The team offered a total of 18 presentations to mostly mixed audiences. The focus of the events ranged from education and outreach communities, to agencies, academics, and stakeholders.

##### **Completed Projects**

CISA completed four research projects during 2011-2012.

## **1. Informing Coastal Management Adaptation Planning and Decision Making for Climate Change Using an Interactive Risk-based Vulnerability Assessment Tool (Whitehead, Dow, Kettle)**

**Partners:** Town of McClellanville, SC; Town of Plymouth, NC; Social and Environmental Research Institute (SERI); SC Sea Grant Consortium; NC Sea Grant

The purpose of this research was to create a tool that will help decision-makers in small municipalities to explore the potential outcomes and consequences of climate change in their towns, along with pathways through which they and individuals may respond. This approach integrates locally specific knowledge about social stressors with generalized scientific information about potential impacts and promotes deliberative-analytical dialogue among researchers and community managers and representatives.

Community-based projects were completed in McClellanville, SC and Plymouth, NC. In McClellanville, SC, CISA staff and partners, including a PhD student from ECU-RENCI conducted a VCAPS exercise focusing on stormwater and climate issues. We authored a 4-page summary document of the case and conducting follow-up participant interviews with six members of McClellanville's management boards who participated in the VCAPS exercise. In October 2001, CISA met with seven community leaders and managers in Plymouth, NC. The group met for a total of five hours for a discussion and scenario building process focused on a complex discussion of stormwater management and the town's wastewater infrastructure.

Another set of activities entailed providing VCAPS training to other outreach specialists. Because VCAPS communities all expressed the value of outside facilitation, the research team turned its attention to how to train appropriate outside facilitators who could use the VCAPS process in their communities. The team completed a user guide designed to help outreach staff facilitate VCAPS exercises and conducted VCAPS training workshops at the following events:

- Tuler, S. Gulf of Mexico Climate Outreach Community of Practice workshop on June 1-2, 2011 in Biloxi, Mississippi.
- Tuler, S. and J. Whitehead. Coastal Zone 2011 meeting, Chicago, IL 17 July 2011, entitled Helping Coastal Communities Strategize Adaptations to Climate Change: How to Implement a Structured Dialogue Using an Interactive Diagramming Program.
- Tuler, S. and J. Whitehead. Social Coast Forum, Charleston, SC. 15-16 February 2012. February, 2012. We participated in a Tool and Job Aid Demonstration Roundtable to illustrate the use of VCAPS "Helping Coastal Communities Adapt to Climate Change Using the Vulnerability and Consequences Adaptation Planning Scenarios (VCAPS) Process"
- Tuler, S. and J. Whitehead. Mississippi-Alabama Sea Grant Consortium webinar, 1 March 2012.

### **Leveraged Funding Sources**

- "Informing Coastal Management Adaptation Planning Using an Interactive Risk-Based Vulnerability Assessment Tool." S. Tuler, Social and Environmental Research Institute, Greenfield, MA, PI; T. Webler, SERI, co-I; K. Dow, Dept. of Geography, Univ. of South Carolina, co-I; J. Whitehead, SC Sea Grant Consortium, co-I. NOAA SARP

#NA09OAR4310151. Duration of study: August 2009 – March 2011 (1-year no-cost extension until March 2012). Funds awarded: \$213,886.

- “Using Citizen Social Science to Investigate Climate Change Vulnerability and Resilience in McClellanville, SC.” J. Whitehead, SC Sea Grant Consortium & NC Sea Grant, PI; R. Bacon, SC Sea Grant Extension, co-I, S; D. Stoney, Kitchen Table Climate Study Group, McClellanville, co-I. Subcontract of SARP project “Mobilizing the NOAA Sea Grant Network for Coastal Community Climate Resilience” (J. Cone, OR Sea Grant, PI). Project duration: September 2010-June 2012. Funds awarded: \$14,000. (McClellanville, SC project)
- “Preparing for Climate Change: Helping Small Coastal Communities Develop Adaptive Strategies.” J. Thigpen, NC Sea Grant, PI; G. Putnam, NC Sea Grant, J. Whitehead, SC Sea Grant Consortium, co-PIs. NOAA National Sea Grant Coastal Communities Climate Adaptation Initiative (CCCAI) program. Project duration: May 2010-October 2011. Funds awarded: \$30,000. (Plymouth, NC project)
- “Preparing for Climate Change: Helping Small Coastal Communities Develop Adaptive Strategies.” J. Thigpen, NC Sea Grant, PI; G. Putnam, NC Sea Grant, co-I; J. Whitehead, SC Sea Grant Consortium & NC Sea Grant, co-I. Subcontract of SARP project “Mobilizing the NOAA Sea Grant Network for Coastal Community Climate Resilience” (J. Cone, OR Sea Grant, PI). Project duration: May 2010-June 2011. Funds awarded: \$14,000. (Plymouth, NC)
- “Improving understandings of consequences, vulnerabilities, and adaptation strategies to climate change related hazards. “ Tuler, Webler, and Dow. MIT Sea Grant. NA10-OAR-4170086 2/12011-1/31/2013. \$237,543

### **Presentations**

- Whitehead, J. The 2011 State of the Sounds Symposium, Albemarle-Pamlico National Estuary Program, New Bern, NC, 17 November 2011.
- Tuler, S. Invited presentation, Improving Understandings of Consequences, Vulnerabilities, and Adaptation Strategies to Climate Change Related Hazards, MIT Sea Grant, Cambridge, MA, 8 February 2012. See: [http://seagrant.mit.edu/press\\_releases.php?ID=292](http://seagrant.mit.edu/press_releases.php?ID=292)
- Whitehead, J. Invited presentation, NOAA in the Carolinas meeting, Charleston, SC, 15 March 2012.

## **2. Assessing the Impact of Salt-Water Intrusion in the Carolinas under Future Climatic and Sea-Level Conditions** (Whitehead, Tufford, Dow, Carbone, Felker Rouen)

**Partners:** USGS SC Water Science Center (P. Conrads), Advanced Data Mining (E. Roehls)

This project assists stakeholders in the Yadkin-Pee Dee River basin of NC and SC prepare for potential changes in the frequency and magnitude of salt water intrusion under future climatic conditions. The project uses the EPA BASINS HSPF model and the “Pee Dee River and Atlantic Intracoastal Waterway Salinity Model” (PRISM) (Conrads and Roehl (2007)).<sup>1</sup> The final product is the new, excel-based PRISM(2) Decision Support System (DSS) for decision makers to examine potential salinity intrusion scenarios and provide information that will help

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<sup>1</sup> Conrads, P.A. and Roehl, E.A., Jr. 2007. Analysis of salinity intrusion in the Waccamaw River and Atlantic Intracoastal Waterway near Myrtle Beach, South Carolina, 1995-2002. U.S. Geological Survey Scientific Investigations Report 2007-2110, 41 p.

them plan for future severe events (e.g., positioning fresh-water intakes and treatment facilities, preparing for increased treatment costs).

### **Stakeholder Interactions and Presentations**

A follow-up workshop was held on December 14, 2011, in Georgetown, SC. There were 22 attendees, including applied researchers, resource managers, water/sewer utility managers, and education and advocacy specialists engaged at the federal-, state-, and local levels. The format for the workshop included introducing three climate change scenarios and potential impacts on the frequency and longevity of saltwater intrusion events in relation to decreased streamflow, rising sea levels, and a combination of the two. Breakout sessions allowed attendees to discuss the models and provide feedback on how to improve them.

- Carbone, G.J., “Downscaling climate change scenarios for salinity modeling”. Invited presentation at the Drought and salinity intrusion: Past, present, and future conditions in the Coastal Yadkin-Pee Dee River Basin Workshop, 14 December 2011.
- Conrads, P., “A Short Primer on the PRISM2 DSS”. Invited presentation at the Drought and salinity intrusion: Past, present, and future conditions in the Coastal Yadkin-Pee Dee River Basin Workshop, 14 December 2011.
- Tufford, D., “Drought Impacts in the Yadkin-Pee Dee River Watershed”. Invited presentation at the Drought and Salinity Intrusion: Past, Present and Future Conditions in the Coastal Yadkin-Pee Dee River Basin Workshop, 14 December 2011.

### **Leveraged Funding Source**

- “Assessing the impact of salt-water intrusion in the Carolinas under future climatic and sea-level conditions.” J. Whitehead, PI (originally G. Zielinsky, PI); D. Tufford, Dept. of Biology, Univ. of South Carolina, Co-PI; K. Dow and G. Carbone, Dept. of Geography, Univ. of South Carolina, Co-PIs. NOAA SARP #NA08OAR4310715. Duration of Study: May 2008 – extended to June 2011. Funds awarded: \$235,717.

### **3. The Impact of Drought on Coastal Ecosystems in the Carolinas (Tufford, Lackstrom)**

This report provides a synthesis and analysis of the peer-reviewed literature regarding drought impacts on coastal ecosystems in the Carolinas. Its objective is to expand current, limited understanding of drought impacts on coastal ecosystems, to identify critical gaps, to inform future research efforts, and to suggest measures to facilitate drought adaptation. The report focuses on coastal ecosystems of North and South Carolina and concentrates on the portion bordered inland by the extent of tidal freshwater. The report has generated interest at local and national levels and is being utilized to guide potential ideas for the NIDIS Carolinas pilot project.

**Leveraged Funding Source:** We received a supplement to our core funding from NIDIS/Coping with Drought.

### **4. National Climate Assessment Projects**

In support of the National Climate Assessment (NCA), CISA conducted an array of studies to identify key climate sensitive decisions, improve our understanding of decision-support needs, and assess the multiple dimensions of adaptive capacity in the region. CISA staff contributed three technical reports to the NCA on March 1, 2012, and partnered with the Southeast Climate

Consortium (SECC) and Southern Climate Impacts Planning Program (SCIPP) to coordinate writing of the technical input for the Southeast regional chapter. We received a supplement to our core funding from the National Climate Assessment for this work. Individual projects are discussed below.

*Collaboration with Key Climate Service Providers* (Dow, Boyles, Konrad, Mizzell, Abramyan)

We partnered with the Southeast Regional Climate Center (SERCC), the Southeast Climate Consortium (SECC), and the state climatologists of the SERCC (Alabama, Georgia, Florida, North Carolina, Puerto Rico, South Carolina, and Virginia) to document and evaluate climate information requests made of their offices. We collaboratively developed an on-line climate information request reporting system for the region's state climate offices (SCOs). CISA coordinated the data coding and production of summaries. This systematic effort was designed to help us identify shared concerns and needs and inform the coordination and development of climate service efforts.

**Leveraged Funding Source:** The SERCC provided funding to support the data collection efforts in Virginia and Puerto Rico.

*Engaging Climate-Sensitive Sectors in the Carolinas* (Lackstrom, Dow, Brennan, Brosius, Foster, Haywood, Kettle, Lam)

This project assessed the regional capacity of five significant sectors in the Carolinas (forestry, government, tourism, water, and wildlife) to adapt to climate variability and change. Document analysis and coupled questionnaires-interviews with 117 decision makers engaged in climate decisions and activities informed this project. The study focused on three sets of issues. First, the study identified and examined primary climate and weather concerns, the major providers of climate information, what types of climate and weather information are used in decision making, and the factors that influence why specific sources are used. Second, the project identified and examined what types of climate change activities are planned or underway, how these activities are framed, and the factors that have facilitated or constrained these activities. Third, the study assessed the existing adaptive capacity to respond and adapt to climate change, the current needs and recommendations to increase adaptive capacity, and how those needs may be met. Three articles based on project findings are in preparation for submission to peer-reviewed journals.

### **Presentations**

- Lackstrom, K, B Haywood, K Dow, S Ferguson, D Foster, N Kettle, C Rappold, E Weeks. 2011. "Assessing climate-sensitive sectors, decisions, and peoples in the Carolinas." Solutions for a Warming World: AMS Conference on Climate Adaptation, Asheville, NC, 18-20 July 2011.
- Dilling, L, K Dow, MC Lemos, K Lackstrom, J Berggren, S Kalafatis, B Haywood, R Henry. 2011. "A comparison of stakeholder needs and constraints for adaptation across three regions." Solutions for a Warming World: AMS Conference on Climate Adaptation, Asheville, NC, 18-20 July 2011.
- Dilling, L, K Dow, MC Lemos, K Lackstrom, J Berggren, S Kalafatis, B Haywood, R Henry. 2012. "Toward a framework for assessing stakeholder needs in responding to climate change across spatial and temporal scales." 92<sup>nd</sup> American Meteorological Society Annual Meeting, New Orleans, LA, 22-26 January 2012.



*Contributions to the Southeast regional technical report (Dow, Brosius)*

CISA, the Southeast Climate Consortium (SECC), the Southern Climate Impacts Planning Program (SCIPP), and other regional partners, helped to create a technical report that will be used to write the Southeast regional chapter of the 2013 National Climate Assessment. Chip Konrad, Director of the SERCC and a CISA PI, was the lead author for the climate chapter, developing the regional climatology and information on observed trends. Kirstin Dow led the chapter, “Climate Adaptation in the Southeast,” with Lynne Carter of SCIPP. This chapter identified and examined the types of climate adaptation activities taking place in the Southeast.

**Partners:** Centers for Disease Control and Prevention; Eastern Forest Environmental Threat Assessment Center, US Forest Service; Georgia Sea Grant; Louisiana State University, School of Renewable Natural Resources; Marshall Space Flight Center, NASA; Mississippi and Alabama Sea Grant; NC State University, Forestry and Environmental Resources; SECC; SERCC; SCIPP; University of Georgia, Department of Marine Sciences; US Department of Transportation – Region IV; US EPA – Region IV.

### **Stakeholder Interactions**

In November 2011, we hosted a webinar introducing the NCA process and soliciting contributions to the SE Technical Assessment. Invitations were sent to over 300 senior staff of state agencies in Alabama, Georgia, Florida, Kentucky, Louisiana, Mississippi, North Carolina, Puerto Rico, South Carolina, Tennessee, and the US Virgin Islands. Invitees were encouraged to forward the invitations to appropriate personnel within their organization.

## **5. RESEARCH PROJECTS AND COLLABORATIONS IN-PROGRESS**

### **5.1 DROUGHT**

Our drought work seeks to improve monitoring methods, to develop a more comprehensive understanding of regional impacts, and to assess drought planning and early warning needs.

#### **5.1.1 Implementation of a Drought Mapping Tool in the Eastern United States (Carbone, Rhee, Dow)**

**Partners:** Northeast Regional Climate Center (A. DeGaetano, B. Noon, K. Eggleston), Southeast Regional Climate Center

**Abstract:** The Carolinas Dynamic Drought Index Tool (DDIT) provides a prototype that allows the display of multiple drought indices for different time scales and across user-specified regions. Project goals include expanding the coverage of the tool from the Carolinas to the states served by the Northeast and Southeast Regional Climate Centers, integrating the tool with the stable, near-real time Applied Climate Information System (ACIS) database, and adjusting the interface and functionality of the tool to ongoing user response.

**Progress and Results:** Work with the Northeast Regional Climate Center has resulted in the redesigning of the DDIT to accommodate gridded (vs. station) data and to transfer from SVG to web service calls. The sensitivity of drought indices to missing data is also being tested. The

study analyzes data shortcoming issues for drought index estimation and investigates various methods for filling missing daily precipitation data, handling short-term records, and obtaining drought information for unsampled locations. We found that the best strategy is to spatially interpolate missing daily precipitation data from nearby stations and then calculate SPI values. The western climate region produced different results from other regions because of the effect of its high elevation; the spatially interpolated SPI showed smaller mean absolute error (MAE) values than the SPI values based on the spatially interpolated daily precipitation data with missing days longer than 20 for 3–12-month SPI. Based on this result, the 3/5 rule of World Meteorological Organization (WMO) is generally appropriate but a somewhat more lenient rule may be applied, especially in non-mountainous regions. Including weather stations with short-term records (usually at least 10 years) could improve the representation of the spatial–temporal variability of drought conditions. The drought index values based on the NWS hybrid precipitation data and the remotely sensed precipitation data from Tropical Rainfall Measuring Mission (TRMM) could not outperform the spatially interpolated daily precipitation values in most regions. Only the western climate region showed that the use of TRMM-based precipitation produced smaller MAE values than the spatially interpolated daily precipitation data. The use of those precipitation sources, however, may improve drought monitoring with longer records and enhanced spatial resolution through remote sensing techniques such as data fusion. Our tests demonstrate the possibility of the use of precipitation data from other sources for drought monitoring for areas without any in-situ measurements.

#### **Leveraged Funding Source**

- “Implementation of a drought mapping tool in the eastern United States”. Carbone, G.J., A. DeGaetano, K. Dow, H. Mizzell, J. Rhee. NOAA TRACS. September 2007. 1 May 2008 – 30 April 2012. \$249,570.

#### **Presentation**

- Carbone, G.J., “Improving the characterization of drought and understanding of impacts on water and ecological resources”. Invited presentation at the NOAA in the Carolinas Meeting, 15 March 2012. Charleston, SC.

#### **5.1.2. Drought Sensitivity Testing** (Boyles)

**Partners:** SERCC (C. Konrad), Texas A&M University (J. Nielsen-Gammon), Purdue University (D. Niyogi)

**Abstract:** The State Climate Office of North Carolina is partnering with CISA to test the sensitivity of the DDIT with a variety of new data sets. These include high-resolution data sets not currently used, long-lead forecast information, and radar-based precipitation estimates. Activities include: providing access to surface and ground water data sets to enhance the spatial resolution and range of the DDIT’s drought indicators, developing methods to operationalize the DDIT’s use of long-lead forecast data, and using research on radar-based SPI estimates to evaluate the methods and if appropriate make radar-based SPI available for the DDIT.

**Progress and Results:** NCSU has worked with TAMU on technology and methods transfer. A graduate student was recruited to help develop software for automation and visualization. NCSU

researchers visited TAMU in October 2011 to learn the methods and discuss implementation strategies and technical challenges. NCSU has made progress on drought calculations including:

- Finding stations and associated metadata for desired locations;
- For given station, querying for all available precipitation data;
- Parsing through precipitation data, calculating precipitation accumulations for various monthly timescales (1-month, 2-month, 3-month,...,36-month) - the function that does is flexible and can be used later in the project to calculate sub-monthly timescale accumulations;
- Calculating annual sample L-moment ratios for each station;
- Calculating L-moment ratios for each date for each accumulation period for each station;
- Determining station characteristics, such as ratio of minimum 2-month accumulated precipitation to maximum 2-month accumulated precipitation and months with maximum/minimum precipitation for use later in clustering;
- Station clustering using the Hoskings FORTRAN code base as reference.

#### **Leveraged Funding Source**

- “Development of a High-Resolution Drought Trigger Tool (HiRD TT) for the United States” USDA/NIFA/AFRI (Subcontract from Texas A&M University) \$116,424, Dec 2012 – Nov 2013.

#### **5.1.3. Advancing Regional and Local Capacity to Cope with Drought** (Dow, Tufford, Lackstrom)

**Partners:** National Integrated Drought Information System (NIDIS), NC and SC State Climate Offices, Southeast Indigenous Peoples’ Center (SIPC)

**Abstract:** We engage with a range of stakeholders to determine their decision-support needs, prioritize and initiate projects, develop ways to transfer tools and information to stakeholders, and identify opportunities and regional activities through which NIDIS can support those needs.

**Progress and Results:** In 2011-2012 we have continued several projects to advance regional and local capacity to cope with drought. These projects center on understanding drought impacts on social and environmental systems currently under-represented in regional drought assessments, specifically coastal ecosystems and indigenous people.

**Leveraged Funding Source:** We received a supplement to our core funding from NIDIS/Coping with Drought.

*Research to Understand Regional Needs for a Drought Early Warning System.* Recent and ongoing projects have been conducted with support from and in collaboration with NIDIS to support their efforts to develop a drought early warning system pilots in the Carolinas. An informational meeting was held at NOAA in the Carolinas on March 15, 2012. Approximately 25 people from various federal and state agencies attended. Next steps have entailed establishing a Carolinas NIDIS Pilot Project Steering Committee and preparing for an initial meeting (May 1, 2012 in Charleston, SC). Represented organizations include the DOI Southeast Climate Science Center, EPA Region 4, Hollings Marine Laboratory, National Drought Mitigation Center,

NERRS (North Inlet-Winyah Bay), NOAA's Center for Coastal Environmental Health and Biomolecular Research, NOAA's Center for Excellence for Oceans and Human Health, NOAA's Coastal Services Center, NOAA Fisheries, NOAA Regional Climate Services, The Nature Conservancy, USFWS Coastal Programs, and USGS (SC Water Science Center).

*Southeast Indigenous Peoples' Center (SIPC) domestic water quality monitoring project.* Concerns about drought impacts on groundwater quantity and quality for rural populations led us to partner initially with SIPC to understand whether vulnerability to water quality problems is elevated during drought and determine whether water level or water quality provide early indicators of drought onset or severity. CISA is conducting well monitoring and data analysis activities in order to investigate the relationships between drought and domestic water supply and quality. Contact was made with Walker Dan Davis, Chief of the Georgia Tribe of the Eastern Cherokee in Dahlonega, GA, and Vonnie McCormick, Principle Chief of the Lower Muskogee Creek Tribe outside Whigham, GA. Tufford visited with these tribal representatives in fall 2011-winter 2012 to discuss the project and assess their property for suitable study sites. Tufford and a field technician installed small shallow monitoring wells at the two locations in April 2012. The Chiefs and spouses were trained how to use the monitor device and will take measurements once every two weeks. Water samples from the wells were also collected and brought to USC for laboratory analysis.

## **5.2 WATERSHED MODELING**

Our hydrological modeling projects address a regional need for a comprehensive analysis of watersheds to understand how climate variability and change affects water supply and quality from the mountains to the coast. Our focus on climate as a driving force and our use of models that cover large watersheds at sub-watershed scales provide meaningful information for local and regional decision making. The projects and modeling work described below are interrelated and have evolved as we have received feedback from decision-makers about their interests in understanding the plausible range of climate change scenarios for the region.

### **5.2.1 Modeling of the Winyah Bay Watersheds** (Tufford, Patel, Felker Rouen, Gao, Carbone)

**Abstract:** We use EPA's BASINS Hydrologic Simulation Program-Fortran (HSPF) model to address hydroclimatological variability in the Winyah Bay watershed. We have calibrated HSPF simulation models for the Yadkin Pee-Dee (from the NC mountains to the SC coast), Waccamaw, and Black Rivers at the 8-digit HUC level so that local variability within each watershed can be adequately addressed. This basin-wide approach to hydrological modeling appeals to a range of stakeholders, including water managers, natural resource managers (e.g. National Wildlife Refuges, state parks), Riverkeepers, citizen-advocates, Native American peoples, and state and national regulatory agency staff.

**Progress and Results:** Most of the effort this year was focused on three tasks. One is to understand disaggregation from daily to hourly precipitation time series for input to the HSPF model. There are several task focused on how the model simulates streamflow response to various options for disaggregation. One method comes with the BASINS model and others are found in the literature. We selected one from the literature and have been working with it and comparing its performance and utility to the one that comes with BASINS. The second task

focused on how to set up HSPF to simulate reservoirs. For the initial calibration and testing of the Yadkin Pee Dee River we were able to bypass reservoir simulation using an empirical model that predicts streamflow downstream from the reservoirs based on streamflow upriver. This bypass was acceptable initially but we want to be able to run continuous, coupled HSPF simulations from the top to the bottom of the watershed. The third task was the writing of two manuscripts about the modeling work. The first manuscript will cover the basic setup, calibration, and verification of streamflow and water quality in the Winyah Bay watersheds. The second manuscript describes use of the HSPF model to address some specific questions relating to climate change scenarios and the relative impacts on water quality of adaptation versus mitigation options.

### ***5.2.2 Integrating Regional Downscaling and Hydrological Models*** (Carbone, Gao, Kabela, Samadi)

**Partner:** USGS South Carolina Water Science Center (P. Conrads)

**Abstract:** Stakeholders have expressed interest in the development of climate scenarios for water planning. To this end, CISA is using dynamical and statistical downscaling to assess the regional impacts of climate variability and change in the southeast. We are exploring the effects climate-related changes may have on water quality, particularly on dissolved oxygen. Our downscaling efforts center around two data sets: regional climate model (RCM) output from the North American Regional Climate Change Assessment Program (NARCCAP) and statistically downscaled data from the Department of Interior/United States Geological Survey (DOI/USGS).

**Progress and Results:** We have been working with climate change scenarios produced for the USGS (Geo Data Portal). These data are derived from nearly 20 general circulation models (GCMs) as part of the Intergovernmental Panel on Climate Change (IPCC). Values of maximum and minimum temperature and precipitation were downscaled to a 12 km grid, commensurate with a widely-used observed gridded data set (Maurer et al. 2007)<sup>2</sup>. We have processed downscaled data from four GCMs, including CCSM3, ECHO-2, GFDL2.0, and PCM. We have begun to work with a statistical downscaling data set from the DOI/USGS. These data for the Southeast represent the historical period, 1980-2009 and include daily precipitation, daily maximum and minimum temperature. We have been processing data as it becomes available and conforming it to serve as input for our hydrological modeling work. The gridded downscaling has been aggregated to sub-basins within and beyond the Santee Basin. Aggregation at this scale matched that required for hydrological modeling with HSPF. Data preparation also required disaggregating daily precipitation to hourly time steps. We have done extensive testing to evaluate HSPF performance with various disaggregation methods. We also have been evaluating NARCCAP data in the Southeast. We have evaluated summer and winter maximum and minimum temperature, and precipitation for nine pairs of general circulation models and regional climate models.

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<sup>2</sup> Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy. 2007. Fine-resolution climate projections enhance regional climate change impact studies, *Eos Trans. AGU*, 88(47), 504.

### **Leveraged Funding Sources**

- “Climate change-induced changes in flow regime, floodplain inundation and species habitats.” Kupfer, J.A., G. Carbone, D. Tufford and K. Meitzen. US Department of the Interior, National Park Service, Climate Change Program., Congaree National Park. 2010-2013: \$310,000 awarded. (2011 funding: \$140,000).
- “Coastal Climate Extension Specialist Support.” Carbone, G.J. SC Sea Grant Consortium/NOAA, \$18,429, 1 July 2011–30 June 2012.

#### **5.2.3 Lower Cape Fear Watershed Study (Montz)**

**Partners:** NC Department of Environment and Natural Resources (W. Howard, D. Rayno)

**Abstract:** Using the Lower Cape Fear watershed and its subwatersheds as a study area, this project aims to assess water availability and use over time, under different scenarios, at several temporal and spatial scales. This project will involve documenting past, current, and potential future patterns of water availability (i.e., supply) and past, current, and potential future patterns of demand, by land use and by sector and will incorporate various climate change scenarios.

**Progress and Results:** To date, progress has been made in a number of the focal points of the Cape Fear Basin climate induced water resource research. Watersheds showing potential stress in the future have been identified, based not only on varying climate predictions, but population growth and impervious cover projections. Additionally, a thorough review of the local water supply “plans” (which are more like water distribution data tables that include projections) has aided our research in identifying potential at risk areas in the future (published by North Carolina Department of Environment and Natural Resources).

#### **Presentation**

- Griffin, M.T., Montz, B., 2012. Emerging Water Stress in Southeast North Carolina. Presentation. *Association of American Geographers Annual Conference*. New York, NY. February 2012.

### **5.3 COASTAL CLIMATE**

CISA partners with North and South Carolina Sea Grant to assist coastal communities and stakeholders in addressing potential impacts of climate variability and change on major coastal issues including: erosion, invasive species, land use change, salt water intrusion, health of fisheries, agriculture, tourism, coastal community development, and natural hazards. The project works with government agencies in both states to better inform those individuals and to evaluate possible impacts through an applied research program. Our long-term goal is for stakeholders in the coastal Carolinas to mainstream climate information into decision-making processes.

#### **5.3.1 The Carolinas Coastal Climate Outreach Initiative (CCCOI) (Whitehead, Carbone, Dow, Tufford)**

**Partners:** NC Sea Grant, SC Sea Grant Consortium, NOAA Coastal Services Center, College of Charleston (CofC), Environmental Protection Agency (EPA), Kitchen Table Climate Study Group of McClellanville, SC, Town of McClellanville, SC, Beaufort County (SC) Planning

Department, National Sea Grant Office (DOC, NOAA, OAR, NSGO), National Weather Service (Newport, NC, NOAA), National Weather Service (Charleston, SC, NOAA), NC National Estuarine Research Reserves, NC Department of Environment and Natural Resources (DENR), NC Interagency Leadership Task Force Climate Working Group, North Inlet-Winyah Bay National Estuarine Research Reserve, Oregon Sea Grant, Town of Plymouth, NC, Renaissance Computing Institute at East Carolina University, SC Department of Health and Environmental Control (SC DHEC), SC Department of Natural Resources (SC DNR), US Federal Emergency Management Agency (DHS, FEMA), Georgia Sea Grant, Florida Sea Grant, Mississippi-Alabama Sea Grant, Governor's South Atlantic Alliance, NOAA/NCDC Southern Region Climate Services Director, NOAA/NCDC Eastern Region Climate Services Director

**Abstract:** The primary goals of the CCCOI are to:

- Develop the capacity of NC/SC Sea Grant to inform and educate coastal decision-makers of the implications of climate variability and change for major coastal issues.
- Provide tailored, decision-relevant information on (a) the implications of climate variability and change and (b) adaptation strategies that increase resilience to those impacts to coastal decision-makers, ranging from residents to government officials to business people.
- Increase the capacity of the Sea Grant network, on a regional and national scale, to target and support relevant research and deliver directed outreach programs on the impacts of climate variability, climate change, and adaptation strategies for coastal stakeholders.
- Evaluate and review enhancements in Sea Grant climate education and outreach capacity and approaches.

### **Progress and Results**

- We provided information on climate impacts and adaptation through 16 formal extension presentations this year (12 in SC or out of the region; 4 for NC audiences). As a part of the VCAPS project, we provided the Towns of McClellanville, SC, and Plymouth, NC with information about climate change.
- To increase capacity for educating decision-makers on climate variability and change, the CCCOI helped support the saltwater intrusion and VCAPS projects, both of which are described in Section 4 (Accomplishments).
- Whitehead has also been consulted as an expert in coastal climate outreach by the North Carolina Interagency Leadership Team's Climate Adaptation Working Group, which is assembling a statewide report on climate adaptation priorities in North Carolina.
- As co-chair for the Steering Committee of the Sea Grant Climate Network, Whitehead assists with coordinating grassroots support for climate outreach throughout the Sea Grant network. Regional networking opportunities allow our program to support regional collaboration among climate outreach professionals in the Southeast, such as the SECART Climate Outreach Community of Practice, which she worked with over the year to secure funding for and begin planning a 2012 workshop.
- Evidence is growing that the CCCOI is acquiring a reputation for coastal climate outreach both in the region and nationwide. Whitehead's expertise was sought for reviewing grant proposals submitted to NOAA's Great Lakes Climate Extension Capacity Building program, Michigan Sea Grant, the Mississippi-Alabama Sea Grant Consortium, Georgia Sea Grant, Virginia Sea Grant, and the NOAA RISA program. She served as an advisory committee

member for the development and proposal process for the EPA/FEMA smart growth and climate change partnerships for community technical assistance in North Carolina.

### **Leveraged Funding Sources**

- “Carolinas Coastal Climate Outreach Initiative – Phase II – 2010-12.” M.R. DeVoe, SC Sea Grant and M. Voiland, NC Sea Grant, PIs; R. Bacon, SC Sea Grant Extension, and G. Carbone, Univ. of South Carolina, co-PIs; J.C. Whitehead, SC Sea Grant Consortium/NC Sea Grant, J.F. Thigpen III, NC Sea Grant, K. Dow, Univ. of South Carolina, and D. Tufford, Univ. of South Carolina, additional investigators. Project duration: July 2010 – June 2012. Funds awarded \$192,702 (matching funds: \$48,176).

### **Presentation**

- Whitehead, J.C., G. Carbone, K. Dow, D. L. Tufford, R. H. Bacon, and J. F. Thigpen III, Using climate extension to support adaptation: The Carolinas Coastal Climate Outreach Initiative, American Meteorological Society, Applied Climate Conference, Asheville, 20 July 2012.

### **5.3.2 Community Climate Adaptation and Resilience Projects** (Whitehead, Dow, Carbone)

**Partners:** Beaufort County, SC; NC Sea Grant; SC Sea Grant Consortium; Massachusetts Sea Grant; Maine Sea Grant; Social and Environmental Research Institute (SERI).

**Abstract:** The purpose of these projects is to work with coastal communities to facilitate climate resilience and adaptation planning and to identify infrastructure vulnerabilities and adaptation options for current climatic events as well as expected future risks associated with climate change (e.g., increased tidal flooding frequency under sea level rise).

**Progress and Results:** Projects with the Town of McClellanville, SC and the Town of Plymouth, NC were completed in 2011-2012 (see Section 4 of this report). Planning is underway for several new projects. These projects will expand upon previous VCAPS work and related research. First, Whitehead has initiated a new partnership with Beaufort County, SC, on climate change planning and sea level rise. A second project entitled “Promoting climate change awareness and adaptive planning in Atlantic fisheries communities” will involve working with VCAPS in three new towns (South Thomaston, Maine, New Bedford, Massachusetts, and Beaufort, SC).

### **Leveraged Funding Sources**

- “Promoting climate change awareness and adaptive planning in Atlantic fisheries communities using dialogue-based participatory vulnerability analysis, mapping, and collaborative systems dynamic modeling.” T. Webler, S. Tuler, J.Whitehead, and E. Stancioff. NOAA Climate Program Office Coastal and Ocean Climate Applications (COCA). \$268,600. September 2012 – August 2014.
- “Sea Grant Climate Adaptation 2011: Beaufort County, SC – Using Participatory Scenario Building to Encourage Climate-Resilient Zoning in the Coastal Carolinas.” J. Whitehead, A. Turner, T. Webler, and S. Tuler. NOAA National Sea Grant Coastal Communities Climate Adaptation Initiative (CCCAI). Awarded, \$99,778. April 2012 – January 2014.



## 5.4 HEALTH

### 5.4.1 *Assessing Heat Stress Vulnerability* (Konrad)

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

**Abstract:** Researchers at the Southeast Regional Climate Center (SERCC) are investigating heat stress vulnerability and assessing methods to improve existing warning systems. The SERCC is presently working with data from the North Carolina Disease Event Tracking and Epidemiologic Collect Tool (NC DETECT) to examine relationships between heat and morbidity across North Carolina. The long term goals of this research are to 1) identify climate-public health vulnerabilities across different regions (e.g. coastal plain, piedmont, mountains) and populations (e.g. rural vs. urban) of North and South Carolina and 2) develop empirical relationships that can be exploited to build tools that translate recent, current, and predicted weather/climate conditions across the Carolinas into useful information regarding the probability of different types of public health emergencies (e.g. spikes in heat related morbidity/mortality).

**Progress and Results:** The project lead was able to incorporate a much longer and detailed time series of the NC Detect database, which records most emergency room visits in North Carolina, into a relational database. The data was expanded from a 3-yr time series with only a primary diagnosis to a 5-yr series with secondary, tertiary diagnoses, etc. This work also included pilot work to investigate demographic patterns of heat morbidity at the census tract level across the Piedmont and Coastal Plain regions of North Carolina. The pilot work indicates that the increased heat morbidity observed in rural areas is especially prevalent in agricultural areas, especially where labor-intensive crops (e.g. tobacco and vegetables) are grown. There is, however, much intra-census tract variability that relates partly to the vagaries of a small sample size (e.g. two warm seasons of admissions data). With the much longer time series currently under investigation, we will be in better position to test this working hypothesis.

#### **Stakeholder Interactions and Presentations**

- The SERCC co-sponsored and Konrad presented at a workshop entitled “Climate and Public Health in NC: Emerging Risks and Opportunities” in Chapel Hill, NC, 19 August 2011.
- Konrad, C. Writer’s workshop for NCA SE Technical Report in Atlanta, GA 26-27 September 2011.
- Konrad, C. Climate Conversations Workshop in Charleston, SC, 13 January 2012.
- Konrad, C. Southeast NCA Health Sector Meeting in Charleston, SC, 13-14 February 2012.

#### **Leveraged Funding Source**

- Southeast Regional Climate Center, NOAA, \$643,688, April 1 2011-March 31 2012.

### 5.4.2. *Assessing the Impacts of Climate Variability on Water Quality Conditions and Vibrio in North Carolina and South Carolina Estuaries* (Tufford, Scott, Moore)

**Partners:** UNC Institute of Marine Science (R. Nobel), USC Department of Environmental Health Science

**Abstract:** This project integrates our work on watersheds, coastal adaptation, and drought and will investigate human health threats posed by the marine bacterium *Vibrio* in shellfish. The spread of *Vibrio* is believed to be associated with changing temperature and salinity conditions. Models in North and South Carolina will be developed to monitor and assess the potential for increased exposure to *Vibrio* bacterial hazards in the southeastern U.S. coastal water under changing salinity trends. Potential human health impacts make this work of value to both North and South Carolina Shellfish programs.

**Progress and Results:** Detailed project planning was completed as well as the recruitment of a graduate student to do work at the CCEHBR on laboratory analysis of water and sediment samples for *Vibrio*. Water and sediment sampling sites were selected - five on the Waccamaw River, one at the mouth of the Black River, and three in Winyah Bay. In order to establish a sampling plan and protocol, researchers worked with the field sampling crew at CCEHBR. The first sampling trip occurred April 2012, analysis is currently underway. Sampling is scheduled for every month through October 2012. The Neuse River Estuary in North Carolina was selected as the second research site. No additional sampling is required for this project because our partners, Dr. Rachel Nobel and her staff and students of the UNC Institute of Marine Science, are already sampling and have been for several years. Nobel and colleagues will share their results with CISA. A USC graduate student has been hired to take the *Vibrio* sampling results and integrate them with results from the salinity intrusion modeling work CISA completed as part of the SARP project, “Assessing the Impact of Salt-Water Intrusion in the Carolinas under Future Climatic and Sea-Level Conditions.”

**Leveraged Funding Sources:** CCEHBR is contributing significant personnel time and expense to perform their part of the project. Additional personnel include six members of the field sampling crew and supervisor. Additional resources provided by CCEHBR include trucks, boats, gasoline, and expendable field and lab supplies.

## 5.5 ADAPTATION

### 5.5.1. *Supporting Improved Natural Resource Planning through Climate Workshops* (Mizzell, Abramyan)

**Abstract:** CISA is assisting the SC DNR State Climatology Office in hosting workshops about climate and its impacts on South Carolina’s natural resources. These workshops are intended to engage DNR staff and stakeholders, including non-governmental organizations, local government leaders, elected officials, corporate landowners, and utility representatives. The goal is to discuss how climate information can lead to improved natural resource planning and decisions and how species and ecosystems in South Carolina are affected by climate.

**Progress and Results:** The idea for the workshops was discussed with a number of agencies, including the Association of Fish and Wildlife Agencies, the National Estuarine Research Reserve System (NERRS), SC Sea Grant Consortium, U.S. Fish and Wildlife Service Landscape

Conservation Cooperatives, NOAA Southeast Regional Climate Center, SC Wildlife Federation, and NOAA Coastal Services Center. Several meetings were conducted with the SC Department of Natural Resources State Wildlife Action Plan coordinator and her Deputy Director to identify potential workshop participants and workshop goals. The workshops were also discussed with the SCDNR Climate Change Technical Working Group. Mizzell met with CISA staff to seek input on the agenda and workshop goals. Mizzell also spoke with representatives that published the National Fish, Wildlife and Plants (NFWP) Climate Adaptation Strategy and attended two of their public comment workshops. The goal of this Strategy is to nationally facilitate principles and practices and safeguard the nation's biodiversity, ecosystem functions and human use of fish, wildlife and plants in a changing climate. This group is interested in participating in the workshops to share expertise and determine how the NFWP strategy can assist and improve SC's response capability. Lastly, research on South Carolina climate trends and variability, including the influence of ENSO on winter weather, was conducted. This research will be presented at the climate workshops.

### **Stakeholder Interactions and Presentations**

- Mizzell, H. Public Workshop on the National Fish, Wildlife and Plants Climate Adaptation Strategy, Charleston, SC, Charleston County Library, 7 February 2012.
- Mizzell, H. Online Webinar on the National Fish, Wildlife and Plants Climate Adaptation Strategy, 22 February 2012.
- Mizzell, H. SCDNR Climate Change Technical Working Group Meeting, Rembert Dennis Building, Columbia, SC, 22 February 2012.
- Mizzell, H. "South Carolina's Climate Report Card: Understanding South Carolina's Climate Trends and Variability", Palmetto Chapter of the American Meteorological Society Annual Mini-Technical Conference, Columbia, SC, SC Department of Health and Environmental Control Conference Room, 15 March 2012.
- Abrayman, I. "The Influence of ENSO Cold and Warm Event Cycles on South Carolina's Winter Weather", Palmetto Chapter of the American Meteorological Society Annual Mini-Technical Conference, Columbia, SC, SC Department of Health and Environmental Control Conference Room, 15 March 2012.

## **6. PUBLICATIONS**

CISA, S.C. Sea Grant Consortium, Social and Environmental Research Institute (SERI). "Diagramming Climate Change-Related Vulnerability-Consequence Adaptation Planning Scenarios: A Facilitation Guide and Tutorial". 2011.

CISA, S.C. Sea Grant Consortium, Social and Environmental Research Institute (SERI). "Executive Summary: Preparing McClellanville's Stormwater Management for a Changing Future". 2011.

Dow, K.. 2012. Climate Information Needs in the Southeast: Analysis of Requests. Research Report: CISA-2012-02. Columbia, SC: Carolinas Integrated Sciences and Assessments.

Dow, K., Carter, L. Eds. 2012. "Southeast Region Technical Report" Submitted to the US National Climate Assessment. with contributions from A. Brosius, E. Diaz, R. Durbrow, R. Evans, S. Fauver, T. Hayden, B. Howard, K. Jacobs, G. Landers, S. McNulty, J. Nicholson, D. Quattrochi, L. Rimer, S. Shuford, S. Stiles, and A. Terando. 2012. "Climate Adaptation in the Southeast." In K. T. Ingram, K. Dow, L. Carter, Eds. 2012.

“Southeast Region Technical Report.” Submitted to the US National Climate Assessment. Peer Reviewed.

Felker, L. “Increased Perviousness Versus Urban Densification: Trade-offs Between Adaptation and Mitigation in a Changing Climate”. 2011. Columbia, SC: University of South Carolina. 74 pps. AAT: 1498147

Fowler, J. “Cartographic Communication of Point Level Uncertainty”. 2008. Columbia, SC. UMI: 1492260.

Gilbert, S., K. Lackstrom, and D. Tufford. 2012. The Impact of Drought on Coastal Ecosystems in the Carolinas. Research Report: CISA-2012-01. Columbia, SC: Carolinas Integrated Sciences and Assessments.

Ingram, K.T. , Dow, K., Carter, L., Kettle, N. P. 2012. Exposing compounding uncertainties in sea level rise assessments. *Journal of Coastal Research*. 28:1 161-173. doi: 10.2112/JCOASTRES-D-10-00011.1

Konrad II, C.E., Fuhrmann, C. M. with contributions from K. E. Kunkel, B. D. Keim, L. Stevens, M. C. Kruk, H. Needham, A. Billot, M. Shafer. 2011. “Climate of the Southeast United States: Past, Present, and Future” In K. T. Ingram, K. Dow, L. Carter, Eds. 2012. “Southeast Region Technical Report.” Submitted to the US National Climate Assessment. Peer Reviewed.

Lackstrom et al. 2012. Engaging Climate-Sensitive Sectors in the Carolinas. CISA Technical Report CISA-2012-03.

## 7. LINKS WITH OTHER NOAA PROGRAMS

<b>Organization/Agency/Division</b>	<b>Project Title/Role</b>
Center for Coastal Environmental Health and Biomolecular Research (CCEHBR)	<i>Assessing the Impacts of Climate Variability on Water Quality Conditions and Vibrio in North Carolina and South Carolina Estuaries</i>
National Estuarine Research Reserve System	CCCOI
NCDC	Advisory Committee
NIDIS	<i>Coping with Drought Projects</i>
NOAA Coastal Services Center	CCCOI
North Carolina Sea Grant	CCCOI; Co-PI
North Carolina State Climate Office	<i>Drought Sensitivity Training</i>
Northeast Regional Climate Center	DDIT
NWS	CCCOI
South Carolina Sea Grant Consortium	Co-PI; CCCOI
South Carolina State Climate Office	<i>Supporting Improved Natural Resource Planning through Climate Workshops</i>
Southeast Regional Climate Center	Co-PI, DDIT, <i>Assessing Heat Stress Vulnerability</i>
Southeast and Caribbean Regional Team	Co-PI, CCCOI