Science and Partnerships for Adaptation and Resilience to Climate Change and Climate Variability

2010–2015

Southeast Climate Consortium

Final Report

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For more information, contact Senthold Asseng: sasseng@ufl.edu.

www.seclimate.org.
June 2016

Southeast Climate Consortium

Introduction

Authors: Senthold Asseng (SECC Principal Investigator) and Shelby Krantz (SECC Coordinator)

Welcome to the final report of the Southeast Climate Consortium (SECC) 2010–2015 funding cycle. SECC is a multidisciplinary, multi-institutional, multistate team conducting diverse activities to engage stakeholders and provide timely, relevant, and reliable products and information to help manage their climate-related risks. The SECC is funded by the Regional Integrated Sciences and Assessments program within the Climate Program Office of the National Oceanic and Atmospheric Administration (NOAA). SECC is one of 11 Regional Integrated Sciences and Assessments (RISAs) that comprise a national network focused on adaptation to climate change and variability.

The SECC consists of a series of relationships between research areas, adaptation sectors, and application sciences. The areas of science research include climate, agriculture, decision support, drought, water resources, coasts, and social sciences. The mission of the SECC is to improve climate risk management through advances in education, information technology, outreach, and decision support. That mission includes the following:

- Improve the understanding of decision contexts for using climate variability and change information within water, land, and coastal systems by considering their integrated linkages.
- Develop actionable knowledge for decision support through interdisciplinary research in close collaboration with stakeholders and policy makers.
- Maintain diverse and flexible networks of scientists, including leveraging existing organizations such as Extension and stakeholder groups in the Southeast United States (SE US).
- Explore the role of innovative science-practice networks as incubators for the collaborative development of tools and adaptation options that enhance the use of climate science in decision making.
- Experiment with new approaches for connecting science, science-outreach and science-stakeholder interactions by exploring and expanding established communication pathways and new social media.

These goals require that the SECC team conduct interdisciplinary research to integrate sectors. To meet these goals, the SECC created synergistic and creative processes to build opportunities that facilitated integration.

In the past five years, SECC faculty, staff, and students have done cutting-edge disciplinary and interdisciplinary research as well as outreach. The articles in this report reflect the progress of these efforts and summarize some of the accomplishments SECC has made in these areas.

Team Members

Figure 1. Group photo taken at SECC Fall Meeting 2013.

Auburn University (AU)

Puneet Srivastava, Brenda Ortiz, Suresh Sharma, Golbahar Mirhosseini, Damianos Damianidis, Nafiul Islam, S. Mitra, S. Singh, Prem Woli.

Florida State University (FSU)

Vasu Misra, James J. O'Brien, David Zierden, Melissa Griffin, Lydia Stefanova, Julie Harrington, Dong-Wook Shin, Meredith Fields.

University of Alabama Huntsville (UAH)

John Christy, Richard T. McNider, Cameron Handyside, Lee Ellenberg, Kevin Doty.

University of Florida (UF)

Senthold Asseng, Clyde W. Fraisse, Davide Cammarano, Wendy-Lin Bartels, Chris Martinez, James W. Jones, Wendy Graham, Lisette Staal, Melissa Rodrigues, Jessica Bolson, Syewoon Hwang…

UF (continued)

Daniel Dourte, David Diehl, Fred Royce, David Wright, Jim Marois, Heather Kent, Tracy Irani, Sebastian Galindo, Tatiana Borosova,Keith T. Ingram, Shelby Krantz, Belay Kassie, Melissa Ramirez Rodrigues, Di Tian, Ixchel Hernandez-Ochoa, Rubi Raymundo, Jose Guarin.

University of Georgia (UGA)

George Vellidis, Yawen Bao, Jason Evans, Ian Flitcroft, Carrie Furman, Gerrit Hoogenboom, Pam Knox, Mark Risse, Shana Jones, Jill Gambill, David Stooksbury, Michael Tucker, Stamatia Voulgaraki, Vasileois Liakos, Camden Lowrance, Xi Liang.

University of Miami (UM)

David Letson, Norman E. Breuer, Daniel Solís, Jessica Bolson, Ben Kirtman.

Focus Areas

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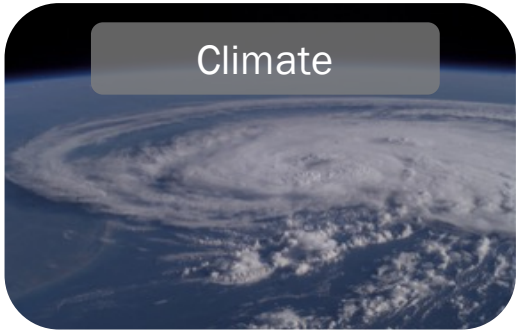

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Pages 12, 32, 29

Towards Seasonal Forecasts for Agriculture in the Southeast United States

Author: S. Asseng
SECC RISA investigators: D.Tian, S. Asseng, C.J. Martinez, V. Misra, D. Cammarano, B.V. Ortiz, M. Ramírez-Rodrigues, L. Stefanova
Other collaborators: A. Eisenkolbi, P. McIntosh
Leveraged funding sources: Grains Research and Development Corporation Australia
Focus areas: Agriculture, Climate, Decision Support, Drought

Discussions with farmers in the early years of SECC work indicated interest in climate information for seasonal decision making. Myron Johnson, an Alabama row crop producer, said, "The El Niño and La Niña are new terms for me. But, we know they're there. They're facts…there's no doubt about it. What we want to know is how exactly they are going to influence the weather, and how that will influence us (video: https://www.youtube.com/watch?v=O7143iLW-ic)."

Without knowing the outcome of the growing season ahead, it is difficult for farmers to decide on inputs like fertilizer or pesticides, which are often due early in a season. Adjusting the inputs according to a likely seasonal outcome may increase the chances of using the appropriate inputs for the highest profit yield. Recent advances in weather forecasts (up to 10 days) and seasonal forecasts (up to 6 months) in predicting the probability of above or below average rainfall and temperatures allows the exploration of the potential for such forecasts to assist in agricultural decision making. A key component for exploring such forecasts are crop simulation models, developed at the University of Florida in collaboration with international crop modeling networks (Asseng et al., 2015). Working together with international scientists has shown the potential of applying 10-day-weather (Asseng et al., 2016) and 6-month-seaonal forecasts (Asseng et al., 2012a; Asseng et al., 2012b) in variable, low-rainfall cropping systems. However, the skill of a forecast, i.e., how often it predicts a wet or dry season correctly, is often not adequate to translate into agricultural decision making (Ramírez Rodrigues et al., 2014). Rainfall and temperatures vary substantially between seasons in the Southeast United States (SE US), and the predictability is low. Similarly, forecasts based on Global Circulation Models (Asseng et al., 2012a) also have limited potential in seasonal forecasts in the Southeast (Ramírez-Rodrigues, 2014).

A new avenue to increase the skill of forecasts emerged when the team discovered how decadal variability explains some of the

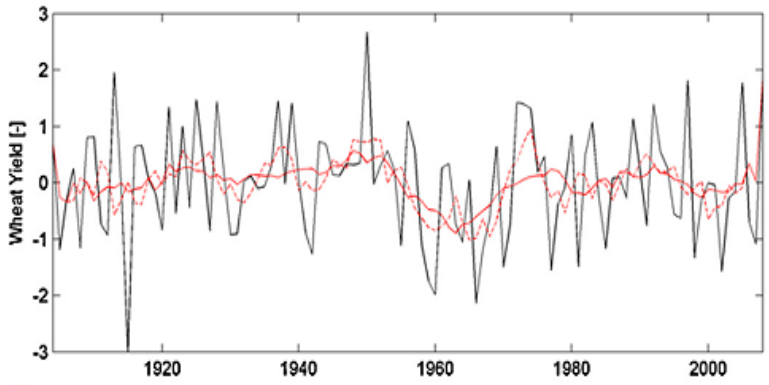

Figure 2. Time series plot of simulated wheat yields from 1903 to 2008 at a location in South Georgia. Black line: original time series; red full line: 11-year moving average; red dotted line: 5-year moving average indicating decadal variability of simulated yields due to decadal variability in rainfall. After Tian et al. (2015).

variability of long-term crop yields (Tian et al., 2015). Using a new statistical tool called "cross-wavelet analysis," we found that winter crop yields were dominated by 10- and 22-year decadal oscillations, as shown for a location in South Georgia in Figure 2. Winter crop yields were driven by decadal variations of winter temperature and spring precipitation. No decadal variations were detected for summer crop yields and summer precipitation and temperature. Linking seasonal forecasts with decadal variability could supply the needed breakthrough for improving seasonal climate forecast skill for assisting winter crop management decisions. Combining decadal variability indices like the Atlantic Multi-decadal Oscillation (AMO), the annual Pacific Decadal Oscillation (PDO), and the winter North Atlantic Oscillation (NAO) with weather and seasonal forecasts might therefore supply the forecast skill needed for making forecasts part of future agricultural decision making in the SE US. Weather and seasonal forecasts with high forecast skill will improve crop productivity and reduce environmental impacts by tailoring inputs to the season-specific needs of a crop. The last five years of work helped us to understand the limited skill of existing forecasts and the potential to link decadal variation with weather forecasts to help scientists and farmers make better decisions (video here https://www.youtube.com/watch?v=5qjJezdKB3k).

Bottom line: Combining weather and seasonal forecasts with decadal variability indices has the potential to supply the forecast skill needed to transform agricultural decision making in the SE US.

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Long-Term, Purposeful Stakeholder Engagement: Three SECC Case Studies

Evidence shows that mismatches between the supply side of climate-related information (research outputs) and the demand side (user needs) can result in scientific products that are not adopted widely by stakeholder groups. In order to align cutting-edge science with stakeholder needs, researchers, Extension agents, and users must co-produce climate information and adaptation options. Such coproduction emerges from meaningful, repeated stakeholder-scientist interactions – a process of purposeful engagement.

Social scientists within the SECC have been coordinating and researching long-term engagement processes that hinge on relationship building and the accumulation of knowledge, which are both fundamental to guiding, designing, and assessing future directions. The following three case studies by Bartels, Bolson and Furman demonstrate how scientist-stakeholder interactions move through three distinct engagement stages from 1) Fact finding & relationship building to stage 2) Incubation & collaborative learning, and finally stage 3) Informed engagement & broad dissemination (Figure 4). During this process, scientists examine the needs of specific stakeholder groups and create spaces for researchers to learn from and with stakeholders before broader outreach materials and decision support tools are developed.

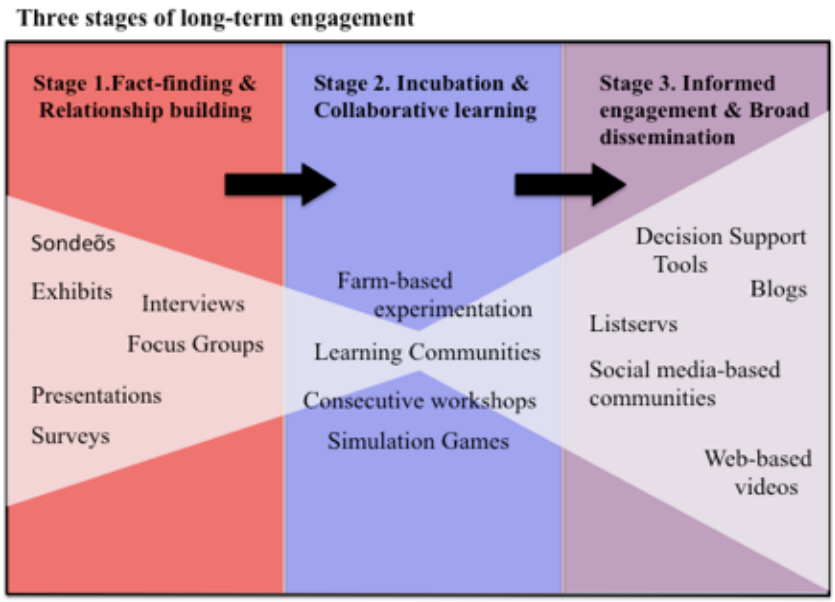

Figure 4. Long-term stakeholder engagement: A three-stage iterative process. Source: Furman, C.A., Bartels, W. and J. Bolson. 2016. Diversity, process, and partnerships: Enhancing climate change adaptation through meaningful stakeholder engagement USDA/NIFA Climate & Extension Project Fact Sheet. Available online: http://www.seclimate.org/wp-content/uploads/2014/07/2016-Furman-et-al.pdf.

The Tri-State Climate Learning Network: Linking Research with Practice to Collaboratively Examine Adaptation

Authors: W. Bartels, C. Furman, D. Zierden, B. Ortiz, and C. Fraisse
Other collaborators: Row crop producers (K. Brock, M. Johnson, M. Newberry, T. Kirkland, T. Brannon, J. Scott, S. Brannon, W. Kirkland); UF Research and Institute of Food and Agricultural Sciences (IFAS) Extension (L. Johnson, J. Love, E. Toro, J. Dillard, M. Bauer, F. Royce, J. Marois, W. Sheftall, D. Dourte); Auburn University Research & Extension (W. Birdsong, B. Dillard, J. Beasley, L. Wells, K. Balkcom, J. Jones, B. Gamble); UGA Research and Extension (B. Kemerait, B. Haddock, C. Perry, R. Barentine).
Partners: UF/IFAS Extension, UGA, and Auburn; Producers; Farm Bureau
Leveraged funding sources: United States Department of Agriculture's (USDA) National Institute for Food and Agriculture (NIFA) grant, Southeast Climate Extension, PI Clyde Fraisse; and a two-year grant from the Bipartisan Policy Center was leveraged for a study on Iconic Agricultural Crops: Climate Change Impacts on Peanut, Cotton, and Corn in Georgia and Florida (2009), PI Jim Jones.
Focus areas: Agriculture, Climate, Decision Support, Drought

Decision-support systems and climate-communication initiatives that aim to improve climate-risk management must be situated within socio-historical contexts and co-produced with stakeholders in order to serve their diverse needs and priorities (Breuer et al., 2008; Crane et al., 2011; Bartels et al., 2012; Furman et al., 2014; Diehl et al., 2015). In 2009, the Tri-state Climate Working Group for Row Crop Agriculture was initiated to establish the social infrastructure for on-going knowledge and co-production around climate-related risks and adaptation. The network, which convenes researchers, Extension agents, and row crop producers, has reached 150 participants over 12 meetings. Repeat attendees of these biannual gatherings constitute a core group of 35 people who meet in various locations across Florida, Georgia, and Alabama (Figures 5, 6, and 7). Over time, new types of stakeholder groups have begun participating, such as farmers' associations (Farm Bureau), water management districts, peanut industry professionals, environmental consulting companies, and even state representatives.

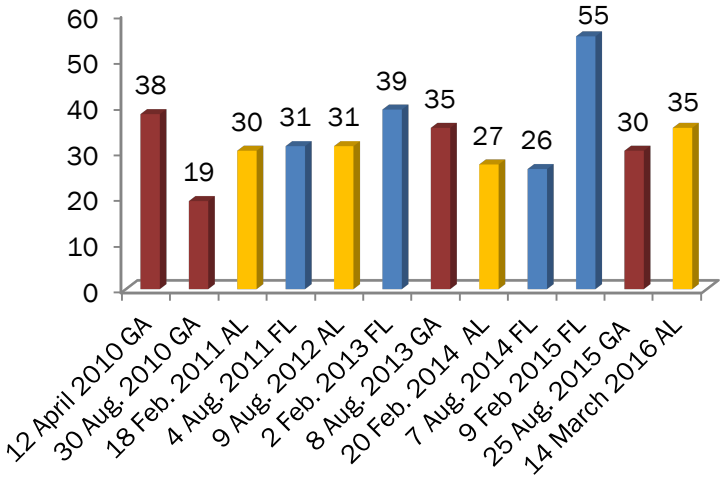

Figure 5. Location and participation changes in the tri-state climate learning network over six years, (2010–2016).

Meeting agendas are designed to stimulate experiential learning and to maximize participant interactions through farm tours, group reflections, presentations and debates (Bartels et al.,

2012). Discussions emphasize the translation of climate information into management strategies as participants seek practical solutions to climate risks. The group has examined a range of potential adaptation options, such as drip irrigation, pond-water harvesting, and planting new drought-tolerant crops, like sesame (Bartels, 2013). Between meetings, participants posted questions and challenges related to climate risks online, documenting examples of successful adaptation (www.siftag.org).

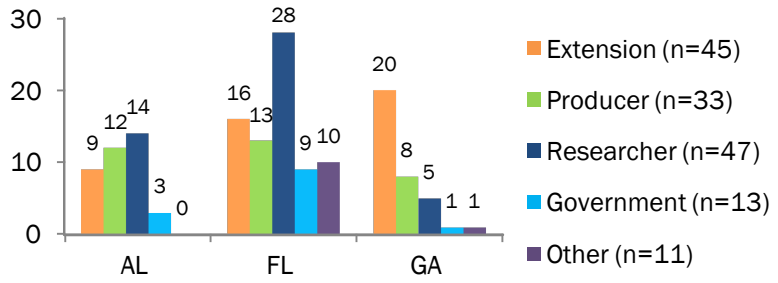

Figure 6. Tri-state participants categorized by role by state, (2010–2016).

Over the past six years, tri-state participants have explored climate risks across multiple timescales from seasonal variability to long-term climate change. El Niño Southern-Oscillation (ENSO) forecasts, provided by the Florida State climatologist, generate significant discussion at each meeting. Recent predictions for a "super" or "Godzilla" El Niño motivated a collaborative assessment of impacts and management implications (Bartels, 2016b). Results from an interactive survey indicate that all except one of 17 people changed decisions (or advised particular management adaptations) in response to the forecast received at the August 2015 meeting. Producers (8) most often sited changes related to planting date (e.g., planted early or planned to get grazing (winter) in earlier); harvesting practice (e.g., harvested fast, purchased additional harvest equipment to speed up harvest, hired custom operation to harvest cotton and crop management, or worked extra-long hours to get harvest completed before the rains set in); and disease management (e.g., sprayed more fungicide on peanuts). In reviewing the data, it was evident that participants from Alabama experienced what they had expected and evaluated the decisions that they made in response to the El Niño forecast as worth it, with some commenting, "I wish I had done more!" Those from Florida, however, mentioned differences between what they thought El Niño would bring and what actually happened. One Extension agent, for instance, mentioned his experience of a warm and dry fall, "An island of dryness among a sea of rain! Never wore a jacket." Despite these unusual conditions in Florida when compared to the rest of the region, his overall evaluation of the seasonal forecast, like others, was that it was extremely useful.

Figure 7. Tri-state participants in Monticello, Florida in February 2013.

When invited to consider long-term changes in climate and the capacity for the row crop industry in the SE US to adapt, tri-state participants appear optimistic. The goal of the February 2015 meeting was to discuss future scenarios for row crop production in the SE US based on past trends, potential changes in climate, competing land uses, and water availability. Results from an interactive survey show that 86% of 54 respondents strongly agree, agree, or somewhat agree with the statement, *If climate is changing, the row crop industry is willing to adapt.* However, some participants raised concerns about the ability for the industry to adapt; for instance, a GA peanut buying point director asked, "How do we prepare for future crops as crop handlers?"

During discussions about long-term changes in climate, tri-state producers have reported changes in rainfall intensity: "When it rains, it pours!" At a meeting in 2013, participants asked whether it really does pour more than it used to in the SE US. In response, SECC researchers reexamined trends in historical rainfall data. Further dialog stimulated researchers to reconsider the way they define extreme rainfall events, leading to a paper published in *Climate Risk Management* that assessed trends in precipitation intensity based on stakeholder contributions (Dourte, Bartels, and Fraisse, 2015).

Outcomes of tri-state climate network include: 3 peer-reviewed publications; 3 invited-speaker exchange events to advise the development of similar networks (Arizona cattle ranchers via CLIMAS, Nebraska Extension Agents, and Soil Health Network - Southern SARE cover crop event); 5 videos; 6 conference presentations; an interactive exchange website www.siftag.org; 4 grant proposals; on-going participation; ownership of meeting coordination by Extension; and continued interest in developing new collaborative projects. For more about this group, access this video: https://www.youtube.com/watch?v=R5Vx-cmQbx8.

Bottom line: One of the most innovative aspects of the tri-state network is the opportunity it provides to actively engage agricultural stakeholders in discussions that blend local knowledge and experience with innovative science to coproduce new understandings of climate risks and evaluations of potential solutions. By creating a space for researchers to learn *with* stakeholders over time, the network demonstrates evolution through the three distinct stages that constitute a long-term purposeful engagement process (Figure 4).

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Engaging Water Stakeholders to Improve Resilience to Climate Variability and Change

Author: J. Bolson
SECC RISA investigators: W. Bartels
Partners: South Florida Water Management District, Tampa Bay Water, Peace River Manasota Regional Water Supply Authority, Orlando Utility Commission
Leveraged funding sources: National Oceanic and Atmospheric Administration (NOAA) Ocean and Atmospheric Research (OAR), NOAA Sectoral Applications Research Program (SARP), National Science Foundation (NSF) Sustainability Research Networks (SRN), NSF Water Sustainability and Climate (WSC)
Focus areas: Social Sciences, Decision Support, Water Resources, Coasts

Within the context of a changing and variable climate, scientists are called upon to provide information that can support decision making and guide adaptive responses. The utility of such information, however, decreases without either a holistic understanding of the context within which it could be used or targeted efforts to translate the information into usable form. This ultimately limits the adoption of advances in climate science by potential users. For example, recent survey work (supported by NOAA SARP efforts) reveals that adoption of climate information among water managers has been highly limited and suggests that more interactions and/or a more iterative process for communication and information sharing might be needed for improved integration (Bolson & Broad, 2013; Bolson et al., 2014). However, there are gaps in the understanding of the most effective methods for interacting with and reaching diverse stakeholder communities, even within the water sector alone. Through ongoing and direct engagements with potential and existing climate information users from the water community, social scientists affiliated with the SECC have been better able to understand the water decision context, including the types of information that might be most relevant to user needs and the barriers to its use. Through engagement with the Florida Water and Climate Alliance (FloridaWCA), a climate learning network that has been convening scientists and practitioners in an

Figure 8. Florida Water and Climate Alliance meeting.

iterative process of knowledge co-production since 2009, regular interactions with stakeholders have led to successes in climate information translation and improvements in adaptive capacity. The FloridaWCA has engaged interested stakeholders from academic institutions, public water supply utilities, local governments, and water management districts in Florida, ultimately facilitating the types of sustained and two-way interactions that have been shown to be critical to climate information translation (Bartels et al., 2013; Figure 8). In addition to sustaining relationships with regional water stakeholders, the SECC researchers working on this project are collaborating on publications that demonstrate lessons learned, which may be applicable to other groups involved in multi-stakeholder process development, suggesting that the careful design of such engagement can strengthen adaptive capacity by increasing social capital among networks of stakeholders and researchers.

In addition to water stakeholders, SECC researchers have been working with stakeholders from coastal areas including the City of Miami Beach and NGOs such as the Miami Waterkeepers, the Everglades Foundation, and Catalyst to improve understanding of priorities for action in response to sea level rise and to build an understanding of needs for information. As a result of these interactions, the team is working to co-develop educational materials that focus on Biscayne Bay and sea level rise impacts. Furthermore, a publication is in preparation that will document the transitions that are enabling adaptation on Miami Beach. The reach into coastal adaptation research and engagement has been supported by successful collaboration of SECC team members Bolson, Letson, and Martinez with other research teams on two large NSF proposals, the South Florida Water Sustainability and Climate Project, and the Urban Water Innovations Network.

Bottom line: Climate information and decision support in the form of risk management are in great demand in coastal regions of the Southeast, especially in highly vulnerable areas like southeast Florida. There are many ongoing efforts that provide opportunities to align research efforts with stakeholders. There is a great need to organize stakeholder-based efforts and provide innovative methods for interaction and decision support.

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Looking beyond the low hanging fruit: Engaging with underserved limited resource farmers in the SE US

Author: C. Furman
SECC RISA investigators: C. Furman, W. Bartels
Other collaborators: C. Roncoli, F. Royce, P. Knox
Partners: Federation of Southern Cooperatives, Southwest Georgia Project, FAMU
Leveraged funding sources: USDA National Institute for Food and Agriculture (NIFA)-funded project (Grant no. 2011-67003-30347) is entitled "Climate Variability to Climate Change: Extension Challenges and Opportunities in the Southeast USA" and was awarded to C. Fraisse (PI) from UF.
Focus Areas: Agriculture, Climate, Social Sciences

Since 2008, SECC social scientists have been working with farming communities that had not traditionally been reached through Extension, African American farms. Because these communities were new to the SECC and climate risk management, the focus of inquiry centered on fact finding and relationship building (see Furman et al., 2016). Furman and Roncoli initiated climate outreach and engagement with this farming population in 2008. The goal was to address the glaring lack of African American farmer perspectives in the design of tools and information services, while also increasing general climate-related knowledge as it related to farm-based decision making. A NOAA SARP funded project granted in 2009 helped initiate research and outreach. This grant also initiated a partnership with the Federation of Southern Cooperatives Land Assistance Fund (FSC/LAF), a civil rights organization with a 50-year history of advocacy for the African American farming community that focuses on risk management and land retention issues through farmer services and outreach programs. The

FSC/LAF was chosen as a partner for both programmatic and practical reasons. The organization, which represents farmers from across the SE US and has an interest in risk management, was enthusiastic about the project. FSC/LAF engaged with the project from the beginning, and as subcontractors on the SARP grant helped formulate the initial research agenda. The

Figure 9. C. Furman interviews a farmer in Mississippi.

overarching plan was to develop a long-term research, outreach and engagement project that would span multiple years and funding opportunities. Due to the fact that African American farmers had not previously been included in SECC decision support, the SARP project research was designed to fulfill the first

stage of a long-term engagement process (Figure 4) from which further work, if deemed appropriate, would be launched (Furman, Bartels, & Bolson, 2016).

> "Treat farmers as part of your family. We cease to exist without farmers... Immediately start including this information in your programs! Find out what farmers are seeking. Open the door for further dialog and collaboration." – L. Carter (Florida A&M University Cooperative Extension)

Activities focused on collecting background information and gaining insight into potential tool development. Research centered on African American farmers' climate needs, adaptation strategies, extant sources related to weather, and climate information and potential uses for climate information. Second, the project aimed to develop pathways to share information and begin to develop a platform for future co-production of knowledge. To determine how best to share information, the research team wanted to know where African American farmers sought weather and climate information, how general information was shared formally and informally within the group, and where they went to obtain trusted sources of knowledge. The research design combined quantitative and qualitative methods (Figure 9). A phone survey was conducted with 160 farmers, and face-to-face interviews were conducted with 47 farmers in Alabama, Georgia, Kentucky, Mississippi, and South Carolina. The findings show that these farmers are vulnerable to drought given their relatively limited access to resources and risk management mechanisms. Climate forecasts may be helpful to move these farmers from coping strategies for dealing with the effects of climate anomalies to proactive planning to anticipate and mitigate climate effects.

Following the completion of the SARP project, a USDA NIFA funded project allowed researchers to continue to engage with this community. As part of the NIFA project, two focus groups (in 2011 and 2012) with farmers, FSC/LAF Extension professionals, and scientists were conducted—one in Georgia with 45 participants and one in Alabama with 43 participants. During the focus groups, farmers, agents, and scientists discussed local farming history from the farmers' perspectives, climate adaption options, barriers and opportunities related to these options, and the El Niño Southern Oscillation (ENSO) cycle and the upcoming climate outlook. In addition, a roundtable conference was conducted with key members of the FSC/LAF staff and SECC/NIFA-funded scientists in 2014. The goals of this roundtable were to (1) develop a common framework for working together in the future; (2) develop a way to conduct responsible research, build capacity, and maintain relationships with the FSC/LAF and African American Farmers in the Southeast United States (SE US); and (3) establish a common language to aid in developing an enduring climate risk management partnership. The roundtable further solidified the need to continue to engage with this community, whose interests lie primarily in linking climate more directly to risk perception and African American land-loss, and include a wide range of production categories (e.g., row-crop, livestock, timber, produce). Future engagement with this community would benefit from the development of a more concentrated collaborative learning environment and the inclusion of topics related to climate that are closely aligned with general risk management.

Figure 10. FSC/LAF member shares some turnips with W. Bartels.

More recent work with African American farmers has included a workshop on rainwater harvesting and climate information in Albany, Georgia, organized by the Southwest Georgia Project, a partner organization with the FSC/LAF. The participant farmers learned about different rainwater harvesting options and how these options can help farmers meet water needs in their agricultural systems; learned how to design a harvesting system and calculate potential water requirements for a specific farm; shared past extreme rainfall, drought, and other climate related experiences and discussed adaptation options; and learned about climate in the Southeast US, past and present, to assist farmers and extension in seasonal decision making.

In January 2016, the NIFA project funded researchers to host a regional professional development workshop in Tallahassee, Florida, to build capacity among 1890s Extension agents in addressing climate variability and change. This workshop was the first of its kind at an 1890s institution and the goal is that this meeting was a catalyst for similar workshops in the future.

Bottom line: Agriculture in the SE US was built and sustained because of the work, knowledge, and perseverance of African American farmers. The SECC has worked for many years to establish and maintain relationships with African American farmers and support organizations (Figure 10). Working with this underserved community takes time and the desire to modify decision support to address specific production needs. To continue the long-term engagement protocol, future work could move into the realm of Stage 2. Incubation and Collaborative learning where in, for example small groups of scientists and stakeholders are brought together and guided by a facilitator to maximize knowledge exchange, reflection and learning. These activities would help move toward more informed outreach activities and tools (Stage 3) wherein modifications to decision support would more directly match the mixed production systems of African American farmers in the SE US and increase outreach to match the program goals of their support organizations.

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Measuring the Value of Climate Variability on the Agricultural Sector

Authors: D. Letson and D. Solís
SECC RISA investigators: D. Letson and D. Solís
Other collaborators: F. Horsfall
Partners: National Weather Service/Climate Prediction Center/Climate Test Bed
Leveraged funding sources: National Weather Service/Climate Prediction Center/Climate Test Bed
Focus Areas: Agriculture, Climate, Decision Support, Drought, Social Sciences

Climate variability influences agricultural yields and incomes. Drought has negative effects on crop and dairy production and increases the likelihood for wildfire, which has effects on the forestry sector. Variability in extreme temperatures (i.e., freezes and heat waves) also affects agricultural and livestock production (Fuglie et al., 2007). In addition, the impact of El Niño Southern Oscillation (ENSO) on crop production has been well documented around the world (Cabrera et al., 2009). Climate information offers a potential to tailor agricultural management to mitigate the impacts of variability and to take advantage of favorable conditions.

Although there is strong evidence that climate variability impacts the agricultural sector, the economic literature has, in general, neglected climate in empirical production analysis. Indeed, a recent review of the agricultural productivity and efficiency literature reports very few studies that include climate-related variables in their empirical models (Bravo-Ureta et al., 2007). In general, authors have justified such an omission by arguing that weather and climate can be considered as stochastic shocks, since they are beyond control of the farmers. However, in recent years, some authors have questioned this approach, claiming that the omission of environmental variables could bias the results of empirical production models. Advances in climate forecasting and the consequent ability to predict climate fluctuations provide opportunities to improve the management of climate-related issues in agriculture.

The main goal of this project was to evaluate the impact of climate variability and prediction on agricultural production. A regional Stochastic Production Frontier (SPF) analysis for the Southeast U.S (Figure 11) was implemented. The SPF method was used because of its ability to measure the marginal effect of climate variability on aggregate production levels as well as on technical efficiency of agriculture. To evaluate this impact in economic terms, agricultural production was measured as the total value-added, i.e., the monetary change in the contribution of this sector to the whole economy was measured in relation to the use of climate information. Additionally, a sensitivity analysis measured the impact for different climatic scenarios. The difference between the SPF estimates and the estimates obtained from the sensitivity analysis provided an estimate of the potential economic value of climate prediction.

The Southeast United States (SE US) (i.e., Alabama, Florida, Georgia, North Carolina, and South Carolina) is an appropriate region of study because ENSO is a driver of the regional climate variability, and there is a significant amount of agricultural production, making it ideal for studying the interaction of climate variability and agriculture.

Following are the specific goals of this study:

1) Measure the current marginal effect of climate variability on aggregate agricultural production as well as on its three major subsectors: crop, forestry and livestock.
2) Perform a sensitivity analysis to evaluate the economic impact of alternative climatic scenarios.
3) Measure the impact of climate variability on the technical efficiency of aggregate agricultural sector as well as on its three subsectors.
4) Evaluate regional and temporal disparities on the impact of climate variability on agricultural production.

This study found that information on seasonal rainfall and temperature forecasts showed a positive effect on the economic performance of agriculture. However, ENSO-based forecasts offered no significant economic value to this regional sector. Previous research suggests that the use of discrete types of forecasts missed important intrinsic climatic features such as the duration and strength of the event. In addition, ENSO displays a greater effect in coastal areas, so the impact of the ENSO signal could be diluted in a regional study, like this one, where most of the cultivated land is located inland. It is worth noticing that some local-level studies conducted in Florida and Georgia have found value for ENSO-based forecasts. Conversely, a quantitative type of forecast, such as seasonal rainfall and temperature, seems to offer a greater value to agricultural production. This type of information was easier for farmers and producers to understand and appeared to better contribute to the production decision making process.

Bottom line: Our work was designed to help NOAA achieve two of its Next Generation Strategic Plan goals: Goal 2, *Understand Climate Variability and Change to Enhance Society's Ability to Plan and Respond*; and Goal 3, *Serve Society's Needs for Weather and Water Information*. Specifically, the ongoing objective is to offer detailed information to improve the understanding of the southeastern agriculture to inform resource management decisions, and to provide agricultural decision makers the necessary knowledge to adapt to the impacts of climate variability and change.

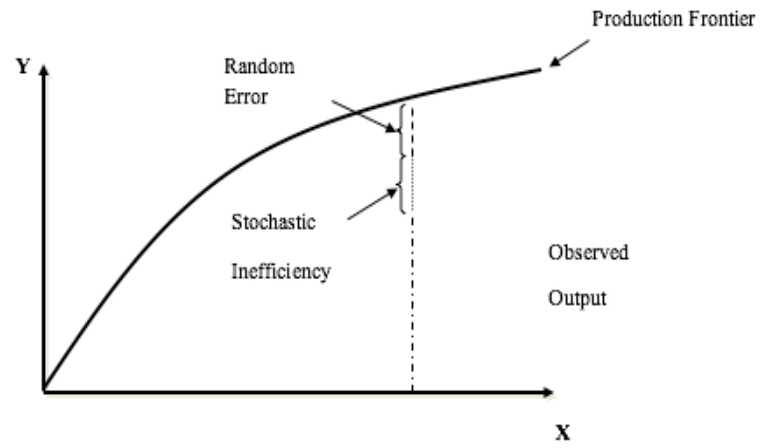

Figure 11. Stochastic Production Frontier.

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Gridded Real-time Crop Model for Drought Designations and Economics of Drought in the Southeast

Author: R. McNider
SECC RISA investigators: R. McNider, J. Christy, C. Handyside, G. Hoogenboom, D. Zierden
Other collaborators: M. Svoboda
Partners: Alabama Farmers Federation, National Agricultural Statistics Service (NASS) Alabama, National Drought Mitigation Center
Leveraged funding sources: NASA Applied Science Program, Alabama Office of State Climatologist, USDA-NIFA
Focus Areas: Agriculture, Drought

The Southeast United States (SE US), with substantial rain-fed agriculture and large temporal and spatial variability in growing season precipitation, is especially vulnerable to drought. The US Drought Monitor (DM) is used to delineate and categorize drought severity throughout the US from "D0" (abnormally dry) to "D4" (Exceptional Drought). These designations play a major role in disaster relief and eligibility for loans, grants, and other assistance under several US Farm Bill and US Small Business Administration programs. The weekly Drought Monitor is created through a combination of numerous short, medium, and long term drought indicators. It includes both quantitative and qualitative indicators from local, state, regional, and national stakeholders. This results in a map that provides a "macro" view of regional drought but provides little consideration for the physiological state of a specific crop.

In the SE US, small scale air mass convection is often the major source of growing season rainfall. These are the localized "pop up" storms most common during the summertime versus the large scale fronts that bring precipitation to the entire region. Additionally, soil characteristics vary on extremely small spatial scales. Thus, in contrast to what the DM may report, significant variation in soil moisture can occur on the subcounty scale and even the subfarm scale. Unlike agriculture in the West, which is protected from drought by irrigation, and the Midwest, which is largely insulated by deep water-holding soils, the SE US has relatively poor water-holding soils and is thereby sensitive to even short-term droughts of 7 to10 days. Thus, other tools beyond the DM are needed to characterize SE agricultural drought in order to understand its agricultural impacts.

In order to meet these special needs in the SE US, a high spatial resolution crop model tied to a high resolution weather data set was developed. The spatial crop model is based upon the Decision Support System for Agrotechnology Transfer (DSSAT) (see Jones et al., 2003; Hoogenboom et al., 2010). DSSAT is widely used in crop modeling across the world. Originally developed as a field scale model, a spatially gridded version (GriDSSAT) was developed by McNider et al. (2011) to provide maps of agricultural drought stress. The spatial weather data used in GriDSSAT are high resolution radar-derived precipitation data and satellite-derived insolation and land surface model temperature data. In addition to predicting crop yield, GriDSSAT can also assess water demand for supplemental irrigation and associated nutrient uptake and was recently linked to a regional hydrologic model (McNider, 2015).

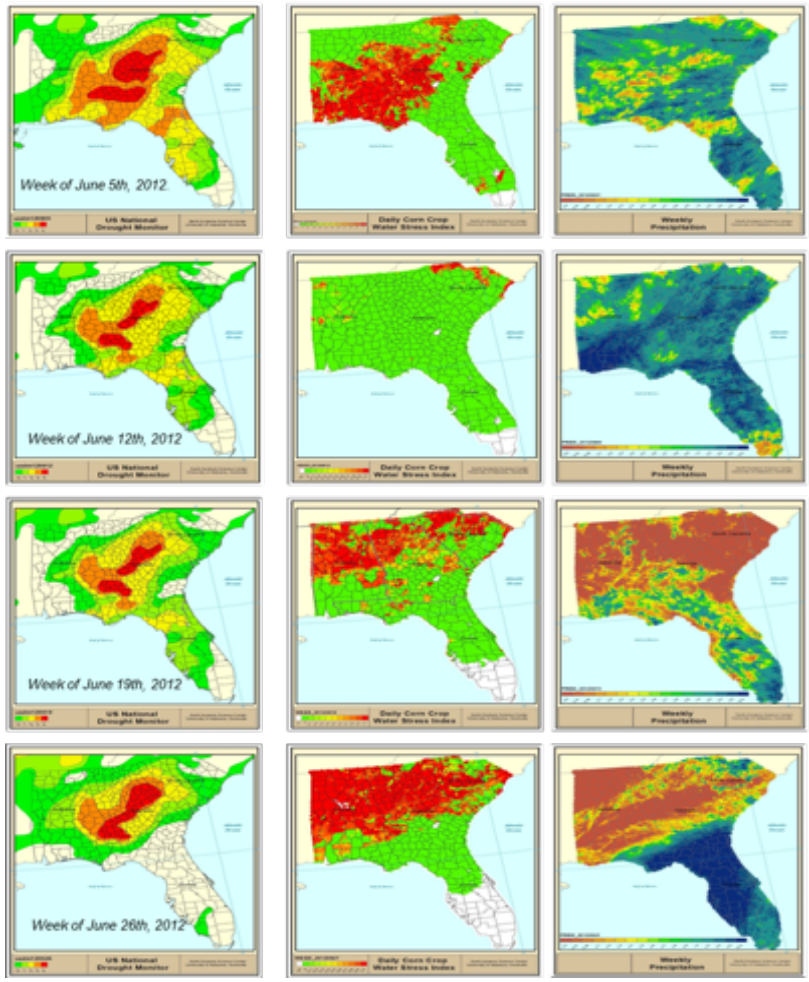

Figure 12. Depiction of 2012 Flash Drought impacting maize in North Alabama using GriDSSAT. Left panel shows the Drought Monitor (red indicates strongest drought). The middle panel shows GriDSSAT water stress (red indicates high stress). Right panel shows 7-day cumulative radar derived precipitation.

Figure 12 provides an example of a brief but intense drought in the Southeast in 2012 captured by the GriDSSAT. This drought was devastating to the maize crop but was inadequately captured in the DM. Figure 12 shows the DM, the GriDSSAT Corn Crop Water Stress Index, and the radar derived 7-day cumulative precipitation mapped over the SE region. For the week of June 5 the water stress from GriDSSAT generally corresponds to the DM. However, significant precipitation at the end of the week reduced the crop water stress over the region. Then, a period of significant drying developed, especially over North Alabama, increasing crop stress to the point that by July, the maize crop was severely stressed and in many locations, lost (indicated in 'week of June 19' in Figure 12). However, the Drought Monitor was slow to respond to this "flash drought." Only by the week of July 5 does the DM designate a "D2" (Severe) drought in small part of North Alabama. Thus, a region like northwest Alabama was classified in less severe drought designations even though the area suffered severe maize losses. Final yields estimated by the crop model in the drought-stressed area were 2830–3460 kg/ha (45–55 bu/ac), which is well below the normal yields of 7547–9435 kg/ha (120–150 bu/ac). These low yields were also verified in observed USDA National Agricultural Statistical Service (NASS) county yields (approximately 3145 kg/ha (50 bu/ac) in North Alabama during this time.

The GriDSSAT results were used as input to the DM process during the flash drought by the Alabama State Climatologist. But because the DM is designed to reflect inputs and indicators from numerous water sectors, it cannot precisely reflect "agricultural-only droughts," or droughts that more severely or specifically impact agriculture.

While the GriDSSAT was only able to influence the DM marginally, after the drought it made a big impact on agricultural water policy

in Alabama. SECC investigators were part of an initiative of Alabama universities to expand irrigation in Alabama because of the role drought losses had in significantly reducing row crop yields in the state. In order to increase irrigated acres, a tax credit bill for investment in irrigation was introduced in the state legislature. At a legislative hearing for the bill, the GriDSSAT results were used to demonstrate the lost tax revenues due to the short-term drought. Further, GriDSSAT results were used to corroborate that if farmers had been able to irrigate during the flash drought, there would have been an increase in revenues. This was a key point in passage of the bill and signing by the Governor.

Bottom line: In the Southeast, small scale air mass convection is often the major source of growing season rainfall. Additionally, soil characteristics vary on extremely small spatial scales. Thus, in contrast to the smooth Drought Monitor, significant variation in soil moisture can occur on the subcounty scale and even the subfarm scale. The SE, with its relatively poor water holding soils, is sensitive to even short-term droughts of even 7 to 10 days. Thus, other tools beyond the Drought Monitor, such as the GriDSSAT, are needed to characterize SE agricultural drought for agricultural impact.

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US Drought Monitor is produced in partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. Map courtesy of NDMC-UNL.

Irrigation Scheduling Tools to Build Resiliency under a Changing Climate

Author: G. Vellidis
SECC RISA investigators: C. Fraisse, K. Migliaccio
Other collaborators: C. Cox, I. Flitcroft, V. Liakos, K. Morgan, C. Perry, W. Porter
Partners: Flint River Soil & Water Conservation District, Georgia Environmental Monitoring Network, Florida Agricultural Weather Network
Leveraged funding sources: USDA National Institute for Food and Agriculture (NIFA), USDA Natural Resource Conservation Service (NRCS) Conservation Innovation Grant (CIG), Georgia Cotton Commission, Cotton Incorporated, Georgia Peanut Commission
Focus Areas: Decision Support, Agriculture, Water Resources, Drought

In the Southeast United States (SE US), despite relatively high annual precipitation, irrigation has increased steadily over the past two decades because it serves both to reduce risk of crop loss and to build yield stability and resiliency in the face of drought. As a result, the competition for available fresh water supplies is increasing rapidly and during periods of drought, surface and ground water resources are frequently stressed. If irrigated agriculture is to survive in this competitive environment, irrigation water must be used more efficiently. A large number of techniques and tools have been developed to assist irrigation system users (irrigators) and producers to estimate when and how much water to apply to crops. Despite the availability of these techniques and tools, the vast majority of irrigators still rely either on a fixed schedule or on visual cues of plant stress such as wilting. Typically, irrigators will apply a standard amount (e.g., 2.5 cm) at each irrigation event. As a result, both the timing and depths of irrigation may be inappropriate and may lead to under-application or over-application of water and to yield, nutrient, and soil losses. The purpose of this project was to develop irrigation scheduling tools that are easier to use, are responsive to environmental conditions, and significantly improve water use efficiency (WUE), thus building resiliency to climate variability and climate change.

Researchers took two approaches to solving this problem. The first was to develop an easy-to-use and engaging suite of irrigation scheduling tools that operate on a smartphone platform (Figure 13). The suite of SmartIrrigation apps provide real-time irrigation schedules for avocado, citrus, cotton, peanut, strawberry, turf, and vegetables. (Information about these apps can be found at www.smartirrigationapps.org.) The SmartIrrigation Cotton app (Cotton app) is used here to demonstrate the interactive evapotranspiration-based soil water balance model which drives the SmartIrrigation apps. The Cotton app uses meteorological data from weather station networks, soil parameters, crop phenology, crop coefficients, and irrigation applications to estimate root zone soil water deficits (RZSWD) in terms of percent as well as inches of water. The Cotton app sends notifications to the user when the RZSWD exceeds 40% indicating that irrigation should be considered, when phenological changes occur, and when rain is recorded at the nearest weather station. The app

Figure 13. The SmartIrrigation Cotton app.

was released in March 2014 and operates on both iOS and Android operating systems. The soil water balance model was calibrated and validated during 2012 and 2013 using data from replicated plot experiments and commercial fields. The Cotton app was evaluated in field trials for three years and has outperformed most other irrigation scheduling tools. The Cotton app is currently limited for use in Georgia and Florida because uses meteorological data only from weather station networks in these states. A new version is currently under development and will use national gridded meteorological data sets that will allow the Cotton App to be used in most cotton growing areas of the US.

The second approach was to develop smart soil moisture sensing networks which, when coupled with variable rate irrigation (VRI), enabled center pivot irrigation systems to prescribe the amount of water needed to replenish the soil profile within individual irrigation management zones (IMZs) of a field. The University of Georgia Smart Sensor Array (UGA SSA) consists of smart sensor nodes and a base station. Sensor nodes refers to the combination of electronics and sensor probes installed within a field including a circuit board, a radio frequency (RF) transmitter, soil moisture sensors, and temperature sensors. Each sensor probe includes up to three Watermark® (Irrometer, Riverside, California, USA) soil moisture sensors and up to two thermocouples for measuring soil and/or canopy temperature. The three Watermark® sensors are integrated into a probe. In this study, the probes contained sensors at 8, 16, and 24 inches. Soil moisture is measured in terms of soil water tension (potential) and reported in units of kilopascals (kPa). At the center of each field, a base station receives the data from all nodes at hourly intervals. A base station may support up to 60 nodes. The base station transmits the data via cellular modem hourly to a web-based interface which allow users to visualize their soil moisture data on any Internet enabled device and to make decisions about irrigation. In field tests, the UGA SSA consistently outperformed most other irrigation scheduling methods in terms of amount of water used, yields, and WUE.

Bottom line: SmartIrrigation technologies developed through this work can dramatically improve water use efficiency thus reducing the volume of water used for irrigation, prolonging the availability of limited water supplies used for irrigation, and building resiliency to drought.

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Coupling SimCLIM with Crop Simulation Models to Determine Adaptation Strategies under a Changing Climate

Author: Y. Bao
SECC RISA investigators: G. Hoogenboom and G. Vellidis
Other collaborators: I. Flitcroft, R. McClendon, D. Zierden
Partners: National Climatic Data Center (NCDC)
Leveraged funding sources: USDA NIFA
Focus areas: Decision Support, Agriculture, Climate

Corn (*Zea mays L.*) is one of the world's three most important cereals and contributes the most to the calories that are either directly or indirectly consumed by humans. Thirty-two percent of the world's corn is produced by the United States, with an increasing percentage grown in the Southeast United States (SE US). There is already evidence that climate change is affecting corn yields in some regions of the planet (Bao, 2015; Figure 14). The purpose of this study was to use downscaled general circulation model (GCM) projections and crop simulation models to estimate the impact of climate change on corn production in the SE US in 2050 and 2070. The study also evaluated adaptation strategies that have the potential to help corn producers maintain or increase current yield levels under future conditions.

SimCLIM is a climate model that uses a simple statistical method called "pattern scaling" to downscale climate projections from GCMs. The model can generate climate projections at regional and site-specific scales. Because of this, SimCLIM has been used for climate change impact studies by coupling its projections with other simulation models. For this study, SimCLIM was used to develop downscaled climate change projections from 15 GCMs and 3 gas emission scenarios for a total of 45 different downscaled projections for 2050 and 2070. Two different crop simulation models were used to assess the yield impacts of climate projections and to evaluate adaptation strategies on seven different modern corn cultivars. The first model was the corn simulation model included in the Decision Support System for Agrotechnology Transfer (DSSAT). This corn model is better known as CSM-CERES-Maize (Cropping System Model - Crop-Environment Resource Synthesis - Maize). The second model was the Erosion-Productivity Impact Calculator (EPIC) cropping systems model. The models were applied to 22 locations in Alabama, Florida, and Georgia. Ten different planting dates ranging from mid-February to the end of June were evaluated for each of the 22 locations. Both rainfed and irrigated management practices were considered.

Based on SimCLIM projections, temperature in the future will increase anywhere between 0.9 °C and 6.8 °C, while precipitation may change from -87.6% to 115.7%. (A negative value means a decrease compared to current conditions.) Those changes in both temperature and precipitation are projected to vary with location. Although there were differences between projected yield based on the CSM-CERES-Maize and EPIC models, the models provided similar responses to the projected change in climate conditions. In general, the crop modeling results indicated that changes in corn yields varied with location, planting date, hybrid, climate projection period, climate scenario, and GCM. Projected corn yields were most sensitive to changes in temperature, precipitation, and carbon dioxide concentration. The crop modeling results also showed that the changes in corn yields

for the northern Alabama and Georgia were in general larger than changes in yields for northern Florida and southern Alabama and Georgia.

Both rainfed and irrigated corn yields for the 2050 and 2070 projections were analyzed based on the differences from baseline (current) yields. There were significant differences between the rainfed corn yields projected from the downscaled climate data of individual GCMs. This is because each of the GCMs projected different precipitation patterns and totals for future years. In contrast, there were no significant differences between irrigated corn yields as irrigation accounted for the difference in projected precipitation patterns. Across all 22 locations and the 10 different planting dates, projected changes in yields in 2050 and 2070 compared to the baseline ranged from -100% to 200%. (A negative value means a decrease compared to baseline yields.) Increasing temperatures resulted in yield stability or increased yields for early planting dates. This is because earlier planting avoids periods of high temperatures later in the growing season when the corn is pollinating and filling kernels. In the more northern areas of Alabama and Georgia, large increases in yields were projected for early planting dates compared to the baseline because soil temperatures in these areas is currently usually too cool to plant corn in mid-February or early March.

Bottom line: Possible adaptation strategies to address anticipated climatic changes include planting earlier in the southern areas of the region to avoid the increases in temperature that may cause heat stress during critical periods. For northern areas of the region, anticipated increases in temperature open a longer planting window. Irrigation will likely be a necessary adaptation strategy to counter increased variability in precipitation.

Figure 14. Irrigated corn in Georgia, US.

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Reconciling Seasonal Droughts and Landfalling Tropical Cyclones in the Southeastern US

Authors: V. Misra and S. Bastola
SECC RISA investigators: C. Furman, W. Bartels
Other collaborators: Florida Climate Center, US Geological Survey, North Carolina State University
Leveraged funding sources: National Integrated Drought Information System (NIDIS), National Oceanic and Atmospheric Administration (NOAA) Climate Program Office (CPO) Modeling, Analysis, Predictions, and Projections (MAPP)
Focus Area: Climate

The Southeast United Sates (SE US) is characterized periodically by droughts at various spatial and temporal scales and by landfalling Atlantic Tropical Cyclones (TCs). As a result there is a prevailing perception that landfalling tropical cyclones play an important role in mitigating droughts in the SE US.

To determine if this is actually the case, researchers designed a study in which a specifically defined a Drought Index (DI) was created. The DI is a measure of the moisture level in the watershed based on recent precipitation and temperature. The DI is based on using multiple conceptual rainfall-runoff models to capture the complexity of the soil hydrology. This DI does a better job of capturing the short-term droughts than the two-layer bucket model, which is more commonly used in estimating the Palmer Drought Severity Index (PDSI; Dai et al., 2004). To calculate PDSI, the two-layer bucket model uses a very simple concept of a moisture availability parameter for computing evaporation that avoids the complexity of the surface resistance (Pitman, 2003). The water balance model used in PDSI relies on reliable value of soil moisture capacity, which is a key soil parameter. Direct measurements of soil moisture capacity are expensive and time consuming. Therefore, pseudo-transfer function, based on available soil data such as particle size distribution, soil texture, and density, are used for the estimation of the soil moisture capacity. Therefore, estimation of PDSI is affected both by the uncertainty in model parameter (i.e., soil moisture capacity) and oversimplification used for the representation of a complex hydrological process (Vicente-Serrano et al., 2011). Vicente-Serrano et al. argued that use of more complex hydrological models is suitable for simulating water balance, which is a key variable of PDSI index. However, different model structures result in different soil moisture dynamics (Mo, 2008). To estimate the DI in this study, multiple conceptual, semidistributed, lumped hydrological models were run, which have multiple soil moisture storage tanks at a daily temporal resolution.

Twenty-eight of the most pristine and least managed watersheds across the SE US were used for this study. When the climatological mean DI was computed with and without the rainfall associated with landfalling tropical cyclones for the each of the selected watersheds, they were significantly similar to one other. This indicates that the DI across the watersheds of the SE US were insensitive to rainfall from landfalling tropical cyclones. The total count of drought events over the available period of daily rainfall data (1948–2006) increased by 5% when the rainfall corresponding to landfalling tropical cyclones was disregarded. The researchers found that the sensitivity of the DI to the selection of hydrological model was larger than the sensitivity of rainfall associated with landfalling tropical cyclone (Figure 15). These results suggested that the impact of landfalling tropical cyclones on DI were not significant in the SE US.

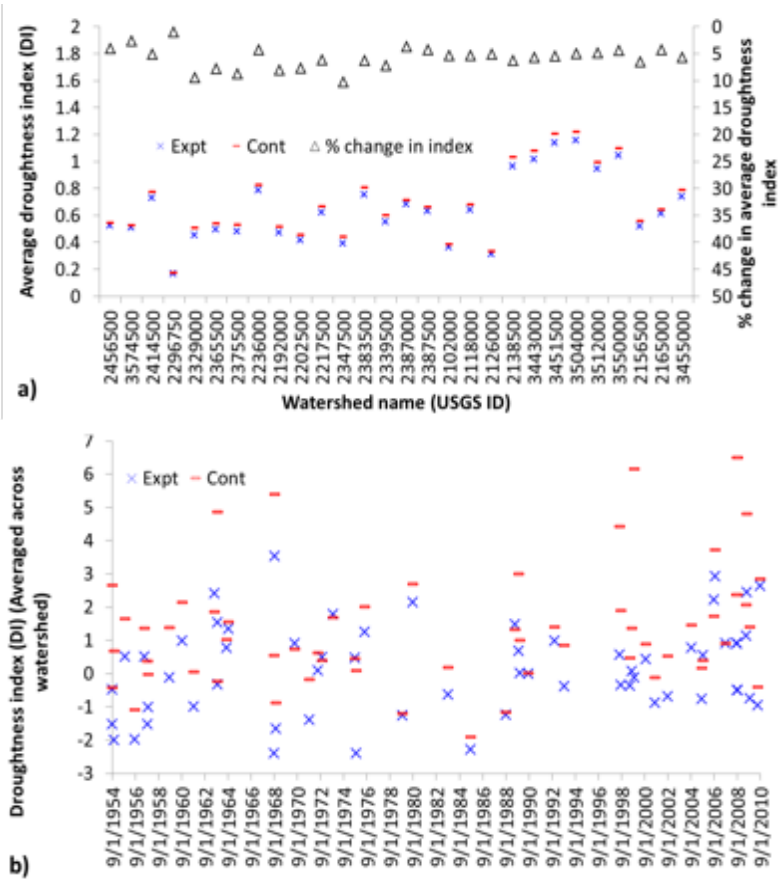

Figure 15. (a) The average drought index for the 28 watersheds spread across the SE US from the control model and experimental model (where the rainfall for five days subsequent to landfall is removed) and the difference in the drought index between control and experiment, showing that the mitigating impact of the landfalling TCs is rather minimal. (b) The drought index averaged across all 28 watersheds for each year from 1954 to 2010 from control and experiment, revealing apparent difference in months when there are multiple landing TCs. (Misra & Bastola, 2015).

On average, the control simulation (which included all landfalling tropical cyclone events in the SE US) showed 123 mild and 39 moderate monthly droughts spread over the 28 watersheds over the 58-year period. In the model, nearly half of the droughts recovered in the subsequent months. However, only 5% of these droughts between 1948 and 2006 actually recovered during the period of landfalling tropical cyclones in the SE US. In other words, the recovery from a drought during a landfalling tropical cyclone event is a rarity in the SE US. The insensitivity of the drought to rainfall from landfalling tropical cyclone on the DI can be attributed to the timing of the event in relation to the overall moisture condition of the watershed and the weakening impact of a landfalling tropical cyclone as it moves inland. It is interesting to note that in the study period of 58 years from 1948 to 2006, an insignificant number of landfalling tropical cyclones in the SE US has affected the monthly DI between June to November.

The result of this study is not surprising following a study by Chan and Misra (2010) that showed that there were no landfalling tropical cyclones during the summer seasonal droughts between 1979 and 2001. This was largely because the large-scale pattern of circulation during the summer droughts seemed to favor the steering of the tropical cyclones away from the SE US (Colbert & Soden, 2012). In years of anomalously wet summers in the SE US, Chan and Misra (2010) showed that there was an excess of moisture drawn from the tropical waters of the Caribbean Sea and northwestern tropical Atlantic Ocean, which was similar to the moisture trajectories of the extreme wet events (e.g., landfalling tropical cyclones) in the SE US. In an observational study using over 100 years of data, Maxwell et al. (2012) found that only about 17.5% of the “drought busting” events in the SE US were a result of landfalling tropical cyclones while the remaining 72.5% were other “drought busting” wet events. The findings of this

study clearly show the popular notion that landfalling tropical cyclones in SE US serve as a drought buster is a myth.

Bottom line: The methods for this study used a very conservative approach to test the hypothesis that landfalling tropical cyclones affect summer droughts in the SE US by assuming that all 71 landfalling tropical cyclones between 1948 and 2006 had identical tracks after making landfall in the SE US. Despite this approach, we found insignificant impact of the tropical cyclone rainfall on droughts over the 28 watersheds in the SE US. Therefore, this study suggested that the irregular tracks of landfalling tropical cyclones, which will likely result in rain falling in different watersheds with each landfalling tropical cyclone in the SE US, is going to further diminish potential influence on the monthly drought anomalies over the SE US despite a comparatively dense population of landfalls along the SE US coast.

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Climate and Agriculture Outreach Efforts

Author: P. Knox
Leveraged funding sources: USDA NIFA Southeast Climate Extension, Animal Agriculture in a Changing Climate USDA NIFA project
Focus areas: Climate, Agriculture, Drought, Coasts

Outreach efforts related to climate impacts on agriculture in the Southeast have been spearheaded through the SECC. P. Knox maintains a daily blog (On the CASE), created an online course on animal agriculture and climate change (Animal Agriculture and Climate Change), and produces monthly climate summaries for Georgia that focus on the impacts of climate variability on agricultural production in the SE US. Many of these have been republished in local newspapers, such as the *Athens Banner Herald*, and in regional newsletters like *Growing Georgia* and *Southeast Farm Press*. Additionally, Knox manages a website for Georgia climate at http://www.gaclimate.org.

Outreach efforts of this program have been presented more than 70 times to groups such as the National Association of County Agricultural Agents, the Society of Environmental Journalists, the Southern Chapter of the International Society of Arborists, and the Southeast Fruit and Vegetable Growers' Conference. Outreach efforts were also made to a number of national and regional workshops, including the Waste to Worth conference in Denver, Colorado in 2013, the Dairy Environmental Systems and Climate Adaptation conference in Ithaca, New York, and the Southern Region Extension Climate Academy. Talks have been presented at many producers' groups, including the Georgia Blueberry Growers, the Georgia Green Industry (landscaping), the Southeast Hay Producers group, and cotton and peanut association meetings. Additionally, the outreach program includes six fact sheets on various aspects of Southeast climate which are available at http://agroclimate.org/fact-sheets-climate.php.

Through the outreach project, Knox has answered 204 technical requests for information on Southeast climate and given 139 media interviews. She has also given 19 professional presentations and posters on SE US climate and agriculture to professional conferences such as those for the American Meteorological Society and the Association of American Geographers. Knox also has testified before the National Academy of Sciences on drought in the SE and its impacts on agriculture. She published an article in *The Southeastern Geographer* on challenges and opportunities for agriculture in the Southeast in the future (Knox, 2014).

Figure 16. Screen capture of the Animal Agriculture & Climate Change course.

The "on the CASE" daily blog began in March 2014 and provides information to a variety of users, including Extension agents, agricultural producers, media outlets, and private citizens, on issues related to climate and agriculture. While it focuses on the Southeast United States (SE US), it also provides articles on global climate impacts, which may affect agricultural interests in the region. The blog highlights research activities of the SECC that are related to climate and agricultural issues.

> "Your blog is great! I use articles from your blog in my newsletters to coastal groups. Thanks for providing this information to us!" --Jill Gambill, Georgia Sea Grant

Since the blog began, it has been visited more than 11,000 times and receives an average of 50 to 60 visits per day. A digest version is also available by email subscription and goes out to about 60 recipients. Articles from the blog have been quoted in the *Southeast Farm Press*, *Growing Georgia* newsletter, and blog posts from a number or Extension agents around the region. Additionally, the monthly climate summary is used in a number of newspapers around Georgia each month.

The Animal Agriculture and Climate Change course is a 15-hour online video-based course that was produced by a team supported by a USDA/NIFA grant on Animal Agriculture and Climate Change (http://www.animalagclimatechange.org; Figure 16). The course was offered monthly starting in September 2014 and is now offered as needed. The course is self-paced and covers the topics of climate trends, impacts of climate on livestock, climate science, mitigation of and adaptation to climate change, and how to communicate these impacts to stakeholders who may be uncertain or dismissive about the impacts of climate change. Continuing education credit through three different groups is available for those who complete the full course.

In the first three months of the project, 217 people signed up for the class, and 46% had completed all course requirements. Since January 2015, an additional 180 people have registered for the course, 82 people have taken at least one module, 21 people have completed all eight modules, and there are a number still in progress. The course participants include Extension agents, federal and state employees, agricultural producers, agro-business workers, and international scientists and producers from 21 different countries.

Bottom line: Knox and others in the SECC-RISA program have provided timely and useful applied climate information to a wide variety of stakeholders in the SE, including agricultural producers of crops, livestock, and wood products. The information has been provided online as blogs, webinars, and online resources like websites as well as in person via talks and workshops.

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Improving Short-Term Urban Water Demand Forecasts with Reforecast Analog Ensembles

Authors: D. Tian, C.J. Martinez, and T. Asefa
SECC RISA investigators: C.J. Martinez and W.D. Graham
Partners: Tampa Bay Water
Leveraged funding sources: NOAA Sectoral Applications Research Program (SARP) Grants: NA10OAR4310171 and NA12OAR4310130
Focus areas: Water resources

Urban water demand forecasting is key to municipal water supply management; however, most forecast approaches are based on recent weather observations and do not use weather or climate forecasts. For this study a Numerical Weather Prediction model was used to improve urban water demand forecasts in the Tampa Bay Area. Municipal water demand models, developed by Tampa Bay Water, were updated to use analog forecasts from the National Weather Service's Global Ensemble Forecast System (GEFS). Demand forecasts were developed for the variables used in demand models, which included total weekly rainfall, number of rainy days in each week, number of hot days in each week (>85°F), and mean temperature of each week at seven main delivery points of water in the Tampa Bay Water service area. All forecasted variables from GEFS were found to be skillful, with the exception of the number of hot days in each week. The forecasted GEFS variables were found to improve the accuracy of the urban water demand forecasts at the seven points of connection in the Tampa Bay Water service area, and the resulting forecasts, expressed as a probability rather than a single value, allow for the quantification of uncertainty of the urban water demand forecasts (Figure 17).

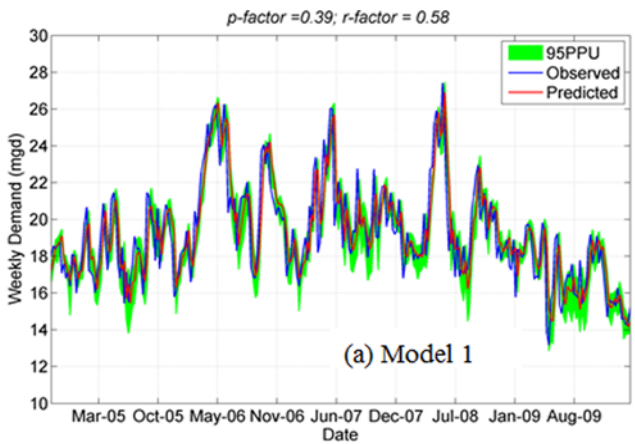

Figure 17. Comparison of observed and predicted (median of the ensemble forecast) weekly water demand for seven water demand models driven by forecasts for 9/23/2004 to 2/25/2010. The 95PPU (95% prediction uncertainty) is the area between the 2.5% and 97.5% percentiles of the ensemble forecast.

Bottom line: Operational Numerical Weather Prediction models can improve municipal water demand forecasts.

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SECC Coastal Collaborations

Authors: M. Risse, J. Gambill, S. Jones
Partners: Sea Grant networks
Leveraged funding sources: Sea Grant networks
Focus areas: Climate, Coasts, Social Sciences

In recent years, the SECC has endeavored to closely integrate coastal challenges into its efforts. Partnering with Sea Grant programs in the Southeast United States (SE US), the SECC engaged experts in law and policy, coastal ecology, public health, and marine science to share information on the current and future impacts of sea level rise, saltwater intrusion, erosion, storm surge, flooding and more. At each SECC meeting, coastal sessions highlighted existing efforts across the SE, exploring lessons learned and where opportunities might exist for future integrated research. At the Southern Region Extension Climate Academy (SRECA), the coastal impacts group developed a list of research and Extension needs for coastal areas, highlighting priorities for future efforts. The group identified the need to better engage small businesses in resilience building to address flooding, and the need to develop K–12 educational materials specifically on the climate-related challenges affecting coastal regions.

Perhaps the greatest successes of the SECC program expansion for coastal areas has been in closing communication gaps between parallel efforts, on a regional scale throughout the Southeast. This included engaging representatives from four state Sea Grant programs, the Southeast and Caribbean Climate Community of Practice (CoP), Carolinas Integrated Sciences and Assessments (CISA), and the Southern Regional Climate Hub. At SRECA, an ongoing regional coastal climate team of Extension professionals was established that continues communicates regularly; members include J. Gambill, K. Spratt, S. Pippin, S. Jones, L. Carnahan, as well as others. This group presented together in Charleston at the Social Coast Forum 2016. This team and other partners also hosted a workshop at the National Adaptation Forum in Louisville in May 2015, called “Joint Meeting of the Sea Grant Sustainable Coastal Communities and Sea Grant Climate Networks: Building Sea Grant's Resilience Toolbox.”

Figure 18. M. Risse explaining living shorelines in Tybee Island, Georgia at the Southeast and Caribbean Climate Community of Practice meeting in April 2016.

The SECC, with its partners, is also involved in several projects focused on building coastal community resilience, including efforts in Tybee Island, Georgia; St. Mary's, Georgia; Hyde County, North Carolina; and Miami Beach, Florida (see Figure 18). These efforts were implemented mostly through partner programs such as the state Sea Grant networks.

Research

SECC teams have approached coastal research through interdisciplinary methods that incorporate impacts, vulnerability, and response. The group is interested in questions concerning coastal community vulnerability to climate variability and change, progress in climate risk management, and adaptation options.

In the past, the SECC has supported the work of the Southeast and Caribbean Climate Community of Practice (CoP). This group brings together individuals from local, state, and federal governments, academia, nonprofit organizations, and the private sector to apply climate science and assess how coastal communities and ecosystems can adapt to the impacts of climate variability and change. The CoP provides a forum for sharing lessons learned and best practices related to climate communication and adaptation. The CoP also provides education and networking opportunities to its members and their stakeholders to increase knowledge and awareness of climate science and to coordinate and perform outreach, Extension programs, and communication related to climate change and its impacts in the Southeast and Caribbean regions.

Coastal research has also been conducted on coastal property law (http://www.seclimate.org/wp-content/uploads/2014/08/Coastal_Hazards_Disclosure_Law_-_Wozniak_et_al._2012.pdf) in conjunction with the UF Levin College of Law, Florida Sea Grant (https://www.flseagrant.org/), and the Florida Climate Institute (https://floridaclimateinstitute.org/) and by the Georgia Sea Grant legal program working with the Carl Vinson Institute of Government.

Bottom line: The SECC coastal efforts are an integral part of beginning dialog between various state efforts and to enable different disciplines, organizations, and networks to share successes, learn from each other, and connect to climate scientists in order to facilitate mitigation and adaptation programs.

Cracking the Drought Nut: Hitting Droughts from Multiple Angles with Research and Stakeholder Engagement

Author: P. Srivastava
SECC RISA investigators: S. Singh, S. Mitra, V. Sharda, K. Ingram
Other collaborators: P. Knox, C. Martinez, J. Bolson, N. Breuer, M. Chelliah, M. Dunn, J. Dobur, J. Schmidt, and L. Torak
Partners: National Weather Service (NWS) Southeast River Forecast Center, US Geological Survey (USGS) South Atlantic Water Science Center, National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center, City of Auburn, Georgia
Leveraged funding sources: USDA National Institute for Food and Agriculture (NIFA), National Integrated Drought Information System (NIDIS), NOAA Sectoral Application Research Program (SARP)
Focus Areas: Water Resources, Climate, Drought

In the Southeast United States (SE US), large seasonal to interannual climate variability that causes frequent droughts is greatly influenced by El Niño Southern Oscillation (ENSO). The ENSO cycle includes El Niño, neutral, and La Niña years. El Niño years tend to be cool and wet, while La Niña years tend to be warm and dry between October and April. However, despite the clear impact of ENSO in the SE and nearly 20 years of work to understand the climate information needs of stakeholders, recent research has shown that a relatively low number of water managers in the Southeast are aware of or use specific climate information products. This research has identified the need for (a) more effective marketing of climate forecast products and (b) more effective training about the forecasts and information and how to apply these (Bolson et al., 2013). These needs have guided SECC research and outreach programs related to drought in the past several years.

Much of the drought-related research and outreach work is focused in the Apalachicola-Chattahoochee-Flint (ACF) River Basin, a 12-million acre basin stretching from north of Atlanta to the Apalachicola Bay on Florida's Gulf Coast (Figure 19). Recurring droughts and the resulting Tri-State Water Wars between Alabama, Georgia, and Florida led the National Integrated Drought Information System (NIDIS) to select this basin as a pilot for developing a Drought Early Warning System (DEWS) for the Southeast.

The need for more effective training regarding drought forecast information resulted in the initiation of the ACF River Basin Drought Assessment Webinars (https://www.drought.gov/drought/dews/acf-river-basin), which are conducted on a regular basis (monthly) by the SECC and NIDIS. These webinars over the past five years have further engaged the stakeholders of the ACF River Basin in understanding and using climate information in their decision making about water resources.

> "[Alabama] has used information from NIDIS in our push to develop a comprehensive water management plan for [the state]."
> – Alabama State Official

In addition to this long-term outreach effort, the team has also been engaged in a number of research projects related to drought. As a result of a 2007-2008 drought in the Southeast, the team worked with the City of Auburn, Alabama, to see how it dealt with water supply and demand issues during drought. As with many southeastern cities, Auburn has been experiencing significant population growth and urbanization. There has been a

trend of increasing water demand in the city, a demand that is often exacerbated by drought. The research team and M. Dunn, the city of Auburn's watershed division manager, discussed how climate forecasts could be used to reduce the impact of drought on water supply and demand (see Sharda et al., 2012, 2013). As a result, Auburn now actively uses climate information for managing water supply and demand.

Figure 19. Apalachicola-Chattahoochee-Flint (ACF) River Basin in Alabama (AL), Florida (FL), and Georgia (GA). Note that much of the basin lies in GA, the Chattahoochee River forms the boundary between AL and GA, and the Chattahoochee and Flint Rivers meet in Lake Seminole at the GA-FL border to form the Apalachicola River.

A number of drought indicators are used for the webinars, and research has been conducted to improve these indicators. A recent study, using groundwater as an indicator of drought, promises to provide a more complete picture of the severity and spatial extent of drought, and ability to recover (Mitra et al., 2014; Srivastava et al., 2014). Results of this study indicated that shallow and moderately deep groundwater wells respond to ENSO in the periodicity of 3–7 years. Comparison of severe (2000-2001) and average (1988-1989) La Niña phases indicated that groundwater recovery times for a severe La Niña can be significant (22 months vs. 2 months). The results of this study can be used to better manage groundwater resources of this region. In a separate study (Singh et al., 2015a, 2015b), baseflow depletion caused by La Niña, Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO), and North Atlantic Oscillation (NAO) was researched. One of the primary issues related to the Tri-State Water Wars is the reduction in baseflow levels in the Flint River during droughts. This affects the availability of freshwater resources to support endangered mussel species in the Flint and Apalachicola Rivers and shellfish industry in the Apalachicola Bay. The study showed that La Niña greatly affects baseflow levels in the Flint River. In addition, interactive effects of the phases of ENSO-PDO and ENSO-AMO on baseflow were found to be highly significant. The study indicated that positive phases of PDO and AMO intensify the effect of La Niña in the ACF River Basin (Figure 20) and cause severe droughts.

Other research studies in the last phase of SECC work have quantified the following: (1) the effect of irrigation and ENSO on water quality of coastal watersheds (Mirhosseini & Srivastava, 2016); (2) the effect of ENSO on water quality of public water supply reservoirs (Elias et al., 2016); (3) the effect of irrigation pumpage during drought on karst aquifer system of the ACF River Basin (Mitra et al., 2016); and (4) the effect of ENSO on point-source discharge permitting (Sharma et al., 2012). The researchers also developed an ecologically sustainable surface

water withdrawal prescription for cropland irrigation using ENSO forecasts (Mondal et al., 2011).

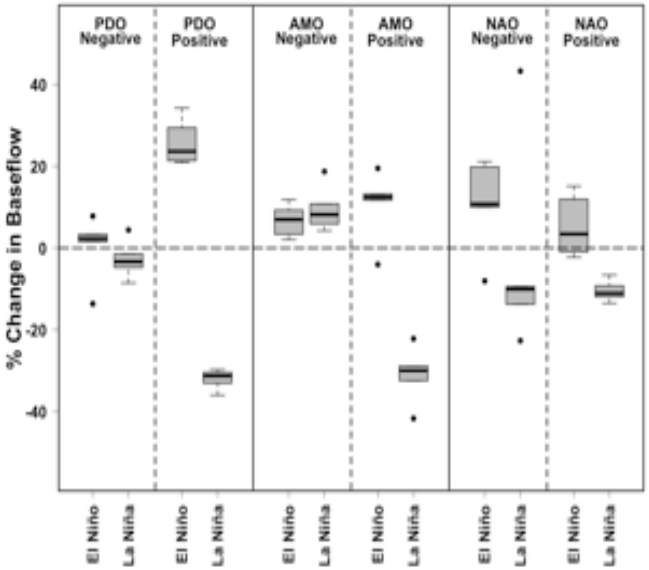

Figure 20: Box and whisker plots of the percent increase/decrease in baseflows for all six USGS streamflow gaging stations evaluated in this study. The boundaries of the box represent the first (Q1) and third (Q3) quartiles and the whiskers extend from the boundaries of the box to the extreme data points, which are no more than 1.5 times the interquartile range (Q3–Q1). The figure shows that positive phases of the Atlantic Multidecadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO) interact with La Niña and bring severe droughts in the Apalachicola-Chattahoochee-Flint (ACF) River Basin.

Bottom line: Water resources in the SE US are greatly affected by ENSO and other climate variability phenomena. With recent advancements in climate science, ENSO can now be forecasted with a high degree of certainty. Results of more than a decade of research in the SE suggest that the ENSO forecasts can be used to address a variety of water resources issues. The SECC has worked with water stakeholders for many years to establish and maintain relationships and is now considered a trusted and unbiased source of information that the stakeholders find very useful.

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The Southeast Climate Extension Project

Author: C. Fraisse
SECC RISA investigators: W. Bartels, D. Dourte, F. Royce, B.V. Ortiz, G. Vellidis, P. Knox, J. Payero, S. Templeton
Partners: USDA-NIFA
Leveraged funding sources: USDA-National Institute for Food and Agriculture (NIFA) Southeast Climate Extension project
Focus areas: Agriculture, Decision Support

As part of the USDA-NIFA project, Climate Variability to Climate Change: Extension Challenges and Opportunities in the Southeast USA, SECC researchers have collaborated with a broader group of scientists and Extension specialists to build an effective Climate Extension program in the Southeast United States (SE US) that will contribute to the existence of a vibrant and sustainable agricultural industry that is capable of adapting to and mitigating risks associated with climate variability and change. By using participatory approaches and taking advantage of established partnerships with the agricultural industry already engaged in our existing climate extension program, the project team sought to develop adaptation and mitigation strategies that would increase the chances of adoption by producers in the SE US.

The project, which offered opportunities to develop strategies to better cope with climate variability and understand potential impacts of projected climate change, generated interest from all sectors of the agricultural industry in the SE US. Results from Extension interviews and surveys support our approach to addressing climate change by first addressing variability. The "Climate Adaptation Exchange Fair," developed through this project, is a leading model to address climate issues with farmers, and it is now being noticed by other groups in the country (Figure 3). This project provides an opportunity to continue previous climate exchange efforts, and it takes advantage of an established network of partners, an open-source platform to develop decision aids (AgroClimate.org), and an

Figure 3. A panel of extension agents and farmers at a Southeast Climate Extension Adaptation Exchange meeting.

established mechanism for integrating Extension and research faculty (SECC). The activities conducted under this project are having an impact in the region, and the team is confident that it will increase the climate literacy of Extension faculty and farmers and will help develop climate adaptation strategies with a real chance of implementation. Ultimately, it will significantly contribute to the primary long-term goal of building an effective

Climate Extension program in the SE US that will contribute to the existence of a resilient agricultural industry in the region.

The activities of this project have resulted in improvements in training resources and skills of Extension professionals, technology providers, and crop consultants; these are the stakeholders who will become the primary technology providers and educators for producers beyond the timeframe of this project. The outputs of Southeast Climate Extension are having an impact in the region—both in terms of knowledge gained (climate literacy) and management changed (more climate-resilience strategies being implemented).

Bottom line: The projects' priorities of expanding AgroClimate training opportunities, delivering two Adaptation Exchange workshops, and production of excellent fact sheets and videos have provided and will continue to provide lasting impacts toward improving Climate Extension in the Southeast and around the nation.

Partnerships

Over the past five years, the Southeast Climate Consortium has maintained, strengthened, renewed, and created new partnerships. The following tables and figures represent these connections throughout the SECC's network (Figure 21).

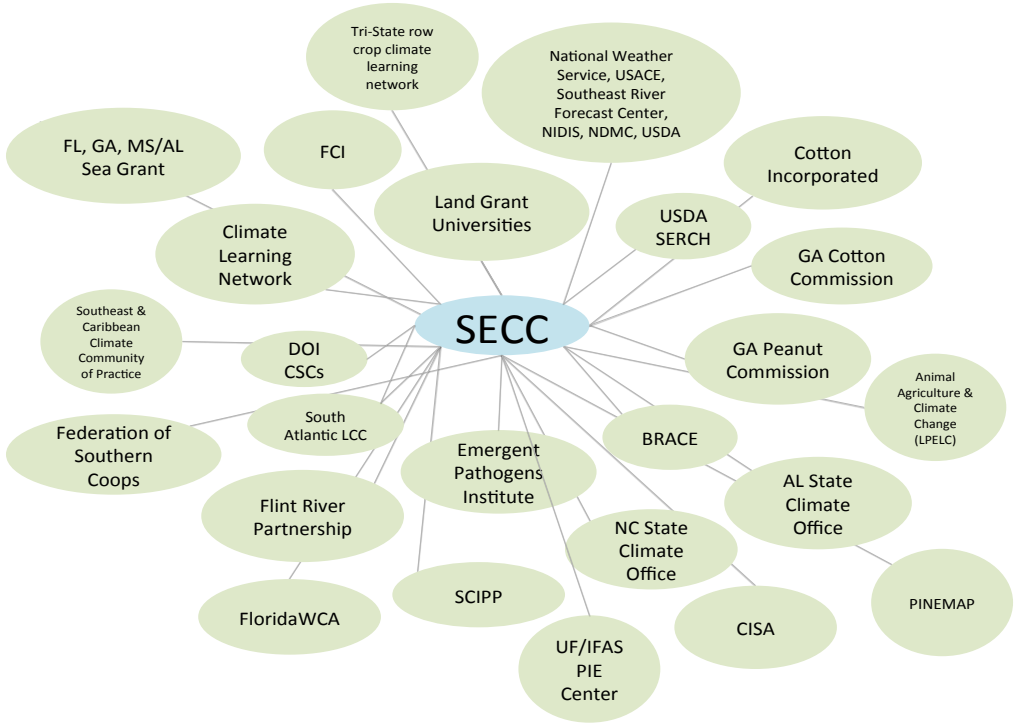

Figure 21. The SECC is situated in the Southeast US region among several partners with whom the organization regularly interacts, exchanging data, resources, and information. These relationships are characterized by multiple connections through the principal investigators and collaborators, which are described in more detail in the following tables.

Table 1. Links with other NOAA Programs

Organization/Agency/Division	Project or Partnership description
NIDIS	SECC researchers work closely with NIDIS in conducting research that improves the ability to forecast drought in the Southeast United States (SE US). The SECC also conducts outreach programs that inform water managers and others in the region of drought conditions and forecasts.
Sea Grant	Florida, Georgia, and Mississippi/Alabama Sea Grant programs; Sea Grant members and directors participate in SECC as executive team members, PIs, and co-PIs.
Southeast Regional Climate Center	Periodic discussions to update teams on relevant programs and to avoid programmatic overlaps and find collaboration opportunities.
Southern RCSD	Periodic discussions to update teams on relevant programs and to seek input.
Other RISAs (SCIPP and CISA)	Collaborated in developing Florida-Atlantic element of the SURGEDAT tool (storm surge database) and NIDIS DEWS pilots (i.e., ACF basin, coastal Carolinas, and Southern Plains)

Table 2. Links with non-NOAA Organizations and Programs

Organization/Agency/Division	Project or Partnership description
EcoAdapt, DOI Southeast Climate Science Center, the USDA Southeast Regional Climate Hub (USDA SERCH), South Atlantic Landscape Conservation Cooperative, etc.	SECC co-chairs working group at the National Adaptation Forum (NAF), which focused on coordination of climate services entities throughout the SE US.
FCI (Florida Climate Institute)	Florida's SECC scientists and Sea Grant have provided expert advice and made data available to many FCI projects.
DOI CSCs (Climate Science Centers)	V. Misra supplied downscaled climate data for joint project in Puerto Rico.
Cotton Incorporated	Partner for smartphone applications developed by Vellidis.
North Carolina State Climate Office	V. Misra supplied downscaled climate data for joint project in Puerto Rico.
Georgia Cotton/Peanut Commissions	G. Vellidis partnered to develop Irrigation Scheduling.

Florida Building Resilience Against Climate Effects (BRACE)	SECC coordinator sits on Technical Advisory Group; M. Griffin and D. Zierden provide climate data for health research projects.
Emergent Pathogens Institute (EPI)	Collaborator A. Kane is an EPI faculty; V. Misra working on joint proposal with EPI in Caribbean.
Flint River Partnership (Soil and Water Conservation District)	G. Vellidis partnered to develop Irrigation Scheduling; SECC committed to supporting Flint River Partnership's USDA-NRCS Regional Conservation Partnership Program.
AL State Climate Office	Exchange climate variability and change data regularly.
Land Grant Universities	Partner universities include University of Georgia, University of Florida, Auburn University, and Florida State University.
National Weather Service, Southeast River Forecast Center, NIDIS, NDMC, USDA, USACE	ACF Drought Assessment webinars are conducted in conjunction with these partners.
USDA SERCH (Southeast Regional Climate Hub)	Regularly interact through phone calls and webinars; SERCH funding AgroClimate expansion work.
George Mason University	Collaborative research development of a global decision support system for agriculture.

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