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# NORTH CAROLINA CLIMATE OFFICE

## 2016-2017 ANNUAL REPORT

July 28, 2017

The State Climate Office of North Carolina (SCONC) serves as the primary scientific extension resource for weather and climate science focused on North Carolina. Founded in 1976 and chartered as a Public Service Center by the UNC Board of Governors in 1998, SCONC focuses on service to public and private sectors of North Carolina through climate science extension, research, and education.

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## Staff and Students



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Ashley Hiatt



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Geneva Gray



Shar Siddiqui



Kelley DePolt



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# Executive Summary

- The State Climate Office (SCONC) employed 13 scientists and staff, two graduate students, and seven undergraduate students during the past year.
- In addition to daily climate service activities, 24 collaborative research and applied projects were conducted across many sectors including health, agriculture, transportation, and ecology.
- These projects and collaborations yielded 10 publications authored by staff scientists and students. The SCONC continues to provide enhanced climate services via contracts and grants with 10 contract and grant proposals submitted (5 funded; 5 pending).

## Extension: Environmental Monitoring

- Products provided by ECONet enhance our public service mission and support agricultural research and operations, Cooperative Extension, and educational outreach.
- More than 493 million observations were recorded at NC Environment and Climate Observing Network (ECONet) stations, which are maintained and operated by the SCONC.
- There were 179 ECONet site visits made to perform routine or emergency maintenance covering 25,262 vehicle miles, with 327 sensors serviced or replaced.

## Extension: Data / Web Services

- More than 1.7 million visits to the SCONC website last year, an increase of 15% over the previous year. Since 2009, web traffic has increased 621%. Almost 70% of all webpage visits were to online educational content created by SCONC staff and students (<http://climate.ncsu.edu/edu/k12>).
- Users submitted more than 3.4 million data queries through the online data retrieval system – an increase of 21% as compared to last year. More than 6.3 million data queries were made through the application programming interface, which is an advanced, customizable data retrieval service.
- Over the past year, the SCONC has increased its data capacity with access to 85 terabytes of gridded data for partners and end users. The SCONC averages over 6 terabytes of internal climate data transfers each month with about 3.2 billion data records selected, updated, or inserted each month.

## Research and Extension Partnerships

- The partnership between the SCONC and Dr. Barbara Shew in NCSU Plant Pathology is in its 13<sup>th</sup> year providing routine advisories for two peanut foliar diseases.
- For more than a decade, the SCONC has partnered with NC Department of Transportation to provide an operational rainfall alert system to meet their water quality permitting and storm water control requirements. This effort has been estimated to save more than 113,000 work hours each year.
- For more than 10 years, the SCONC has been an integral member of the NC Drought Management Advisory Council, which is an interagency coordination and information exchange body. We participate in weekly drought monitoring conference calls and provide public presentations and media interviews on drought in NC.

- The SCONC contributed to engagement activities of the Carolinas Integrated Sciences and Assessments, a NOAA Regional Integrated Sciences and Assessments (RISA), which is piloting a project to collect narrative reports describing on-the-ground conditions for use in drought monitoring.
- UNC-Chapel Hill and NCSU have partnered together on the NOAA Southeast Regional Climate Center (SERCC) since 2007. As part of this collaboration, the SCONC develops and maintains the technological infrastructure, web services, and online climate tools for SERCC.
- Through a USDA cooperative agreement, the SCONC provides technical, scientific, and extension expertise for Southeast Regional Climate Hub extending climate science to support informed decision making on southeastern US forests, rangelands, and croplands.
- The USDA-funded PINEMAP project ([pinemapdss.com](http://pinemapdss.com)) studied loblolly pine genetics, management, and climate sensitivities for 6 years with a team of over 40 principal investigators at 13 institutions across the Southeast US, including NC State University and the State Climate Office.
- Since 2012, the SCONC has been part of a team of scientists headed by RTI International in the Defense Coastal/Estuarine Research Program (DCERP), which conducts monitoring and research to understand coastal and estuarine ecosystems within the context of a military training environment.
- Our scientists serve as the climate focal point on the Spatial Analytic Framework for Advanced Risk Information Systems (SAFARIS) project, which is a collaboration with colleagues at NCSU's Center for Integrated Pest Management (CIPM) and USDA Animal and Plant Health Inspection Service (APHIS) working to estimate global risk to trade of agricultural products.

## **Outreach and Education**

- The SCONC regularly leads and attends educational outreach events across the state of North Carolina. In 2016-17, staff and students participated in 22 outreach events, 5 of which were large events including NCSU's Packapalooza and the 2017 SciTech Expo.
- More than 40 presentations on NC's climate, weather, and ongoing research projects were given to community groups, professional groups, and conference attendees.
- The SCONC staff and students wrote 45 posts for its Climate Blog, receiving 46,361 total views.
- In the past year, more than 30 media interviews were given on evolving drought conditions, snowfall events, and seasonal outlooks.
- Two State Climate Office students graduated with PhDs, and one scientist was accepted into a PhD program.
- Funded by the Burroughs Wellcome Fund as a Student Science Enrichment Program grant, the SCONC is hosting program for rising 7<sup>th</sup> graders in rural northeastern NC. Through this program, SCONC is developing curriculum and introducing weather and climate concepts through data collection.
- One of the SCONC undergraduate researchers, Kieran Riban, won 3<sup>rd</sup> place in the Undergraduate Research Project Competition (USRESP) for her work on the SAFARIS project. Kieran was also one of the nine College of Sciences (COS) awardees (out of 116 total COS entries) for top presentation at NCSU's 26<sup>th</sup> Annual Spring Undergraduate Research Symposium.

# MISSION

*As approved by the UNC Board of Governors, October 8, 1998*

## Extension

- Provide the most accurate climate information to the citizens of North Carolina.
- Assist North Carolina state agencies in climate-environment interaction issues and related applications.
- Establish, operate, and maintain an extensive meteorological network across North Carolina and archive and disseminate this data to the public in a timely fashion.
- Assist other extension scientists by integrating climate information into applications such as agricultural and environmental models.
- Increase public awareness of variations in North Carolina's climate and environment.

## Research

- Study North Carolina's climate and its interaction with the environment.
- Investigate the effects of climatic variations on agriculture, air pollution, and natural resources and develop forecasts that assist in resource management.

## Education

- Interact with K-12, community college teachers and students, and with other community organizations on different aspects of North Carolina's climate and environment.

# CLIMATE EXTENSION SERVICES

*Extension efforts focus on providing climate services through direct contact, online databases and analysis tools, environmental monitoring, and routine climate summaries. SCONC partners closely with other scientists in agriculture, natural resources, public health, and water resource management to develop and deliver sector-focused climate services. SCONC maintains a network of weather sensors and support regional climate services in partnership with the NOAA Southeast Regional Climate Center.*

*Online visits increased over 15% over the previous year, while direct requests for services decreased by 16%. SCONC's climate database also continues to see heavy traffic, with 6 terabytes of internal database transfers and over 3.2 billion data records selected, updated, or inserted each month, and more than 3.4 million queries made through the website over the past year (a 21% increase).*

*SCONC operates and maintains an extensive monitoring network, the Environment and Climate Observing Network (ECONet) that provides high-quality, real-time observations and supports numerous projects and services. The ECONet uses research-grade sensors to deliver unique, highly valued observations to state, local, and federal agencies. In the past year, SCONC continued to deliver agriculture disease and forecast services, and provide service to the forestry and natural resource sectors. SCONC has continued to develop decision support systems and information portals for multiple sectors including forestry, fire weather, and water resources. SCONC has also sustained engagement and service to the public health community in North Carolina.*

## **Climate Service Highlights by the Numbers:**

- 1.7 million web visits (sessions), an increase of 15% over the previous year
- 6.3 million application programming interface (API) queries to online climate database
- 6 terabytes of internal data transfers
- 3.2 billion climate data records selected, updated, or inserted
- 25,262 vehicle miles that supported 179 ECONet weather station visits
- 99.4% of ECONet data passed the highest level of data quality control

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## **Climate and Information Services**

**Climate Services:** The State Climate Office provides many climate science services to clients and partners. Climate Services is a broad concept, but fundamentally involves interaction between a client who needs climate information and SCONC scientists who are experts in climate data and climate science. Many users are not sure what data or information is best for their needs, and often need guidance on how to properly use and interpret climate information. SCONC staff and students interact directly with users to ensure responsive and reliable climate information services.

**Website Access of Services:** The SCONC website is often the first point of contact with clients who need climate information. Effort continues to focus on developing web products and tools based on weather and climate data to provide dynamic products and services.

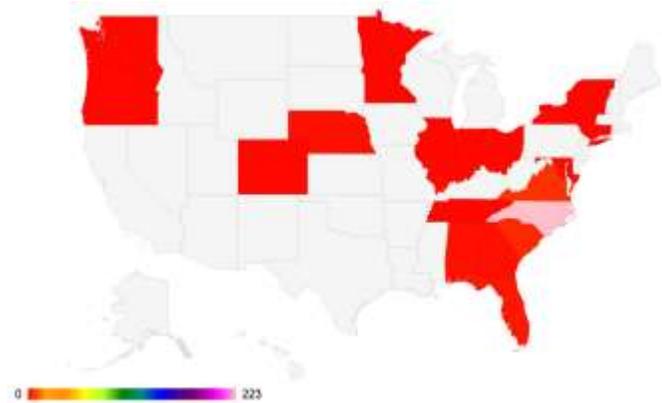
**Web Services Usage:** The number of website visits (sessions, shown in graphic below) was 1,726,792 million visits, an increase of 14.8% over the previous year (1,504,523 million). Of these visits, 81.7% were from new visitors (1,410,161), an increase from 1,232,866 over the previous year. Since 2009, web traffic has increased 621%.



- **Web Traffic Summary:** How are visitors getting to SCONC’s website?
  - 81.2% of website visits came from a search engine (e.g., Google), a 15.2% increase over last year
  - 14% of website visits came from direct sources (e.g., bookmarks, direct URL), an increase of 13.6% since last year
  - 0.9% of website visits came from social media, a 4.2% decrease from last year
  - 4.1% of website visits came from non-search engine referring sites such as news articles, which is a 15.4% increase from last year
  
- **Most visits in a single day:** 17,868 on April 9th, 2017
  - 66.7% of all traffic came from Flipboard, a web portal that aggregates content based on subject
  - K-12 Education page on Climate Change causes had 73.6% of daily traffic (15,053 visits)
  
- **Content Highlight:** What were visitors looking at?
  - 69.0% of all page views were K-12 Education Content
  - 13.8% of all page views were Aspects of NC Climate
  - 7.5% of all page views were data requests
  - Data requests visits by station (5.7% of all page views)
    - 19% for Mount Mitchell ECONet (MITC) (1.1% of all page views)
    - 5.2% for Grandfather Mtn. ECONet (GRANDFATHR)
    - 3.3% for Bald Head Island ECONet (BALD)
    - 1.6% for Bear Wallow Mountain ECONet (BEAR)
    - 1.6% for Goldsboro ECONet (GOLD)
    - 1.5% for Sassafras Mountain ECONet (SASS)
  
- **Visits by Location:** Where are website visitors from?
  - US State Visits (62.7%)
    - 18.7% of all visits came from North Carolina (202,110)
      - CA (9.7%), TX (6.1%), FL (5.7%), NY (5.7%), GA (4.0%)
      - 10,000+ visits from 24 states and over 1,380 from each state

- Global Visits (37.3%)
  - India (6.2%), Philippines (4.0%), Canada (3.7%), UK (3.5%)
  - 1,000+ visits from 64 countries; 100+ visits from 148 countries

**Locations of Clients Requesting Data:** Most clients requesting data were from North Carolina (73.6%), while roughly 14.5% of clients did not specify their location when submitting a request. The remaining requests were put in by clients from 18 other states across the country (1-3 requests per state), as well as one request from a client in British Columbia. The previous year had roughly the same breakdown in client locations.



**Direct Requests for Services:** Due to increased content and availability of online resources, there was a ~16% decrease in direct requests from clients via email and phone, as well as a ~12% decrease in time spent directly responding to requests for services from clients than for the previous year. As with most years, a large percentage of time was devoted to supporting educational requests (64%), while remaining effort went largely to support government (19%) and private industry (13%). Formal public interest requests accounted for 4% of effort. A detailed breakdown of request-driven climate services is provided in Appendix A.

**Data Request Form Statistics:** The number of unique sessions (page views, time series pictured below) for the online data request form from May 1, 2016 through April 30, 2017 was 1,217. The average user spent roughly 2 minutes and 14 seconds on the page, while the page itself had a bounce rate of 58.2%, which suggests just over 40% of the users who visit the page fill out the request form. These numbers were slightly less compared to the previous year, which had more data requests submitted overall.



*Team: John McGuire, Ashley Hiatt, with support from all staff and students*

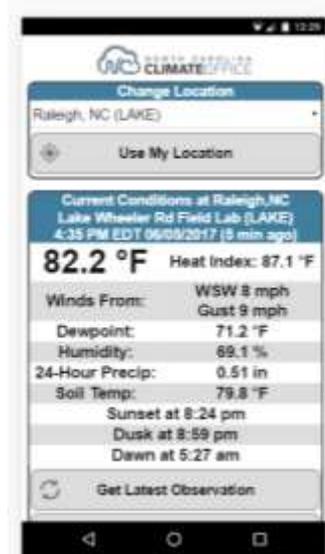
## Climate Data Access and Management

**Data Usage:** Users submitted more than 3.4 million data queries through the CRONOS website interface – an increase of 21% compared to last year. More than 6.3 million queries were requested through the web services API. Over the past year, the SCONC has increased its data capacity with access to 85 terabytes of gridded data to partners and end users. Network and data support for CRONOS users has shown a significant increase in the amount of internal data ingest, management, and transfer. The SCONC now averages more than 6 terabytes of internal climate data transferred each month with about 3.2 billion data records selected, updated, or inserted each month.

**Data Access:** Data accessibility for mobile devices has been improved, a mobile website allows visitors to directly scan QR codes at ECONet stations across the state to access the latest weather conditions. Airport weather stations are also included on the mobile site allowing users to also view recent conditions at these locations.

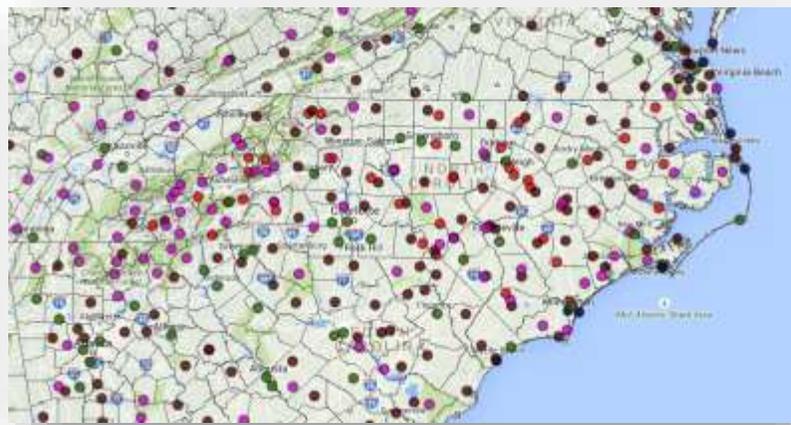
In addition, a new Application Program Interface (API) is in beta release, incorporating many features important such as data aggregation, variable calculation, and unit conversion. This API will enhance data accessibility for advanced users and automated applications. Upcoming features will include a nearest station lookup and an option for "best-estimate" data calculated from gridded data.

API work over the past year improved both the server-side and client-side uses. On the server-side, the focus has been on updating and adding new dataset sources, linking variables to different data tables, network types, and formula calculation. For the client-side, an API builder interface is being designed to allow API clients easier access to data streams.



The API will also incorporate variable metadata such as units, sensor information, and date of first observation of the variable. This information will allow the API to generate a best estimate based on other parameters, using surrogate data such as gridded observations or forecasts in areas where data is unavailable or missing. The API is being written to use a variety of universal output formats, such as JavaScript Object Notation (JSON), and will have the ability to be called from various programming languages such as Python and Perl.

**Data Visualization:** A customizable weather display system has been developed to show current conditions, forecast conditions, weather graphics, and other relevant information. Displays have been tailored for the SCONC office and for groups at NC State (Jordan Hall and Research III Lobby), Isothermal Community College, Bald Head Island Conservancy, and the Department of Natural Resources, South Carolina. This display provides specific details on current and past weather nearest each location, and custom content for each site, with the goal of enabling viewers to quickly put current conditions into a historical climate context.



Sample map of sub-daily stations.

**Data Management:** Improvements in data management are increasing data reliability, providing more robust handling of errors and security, and increasing access to data storage structures and formats. These improvements will provide a more efficient way to find, update, and quality control missing datasets. In addition, new data sources are being added and will allow for a more complete record of existing stations and networks.

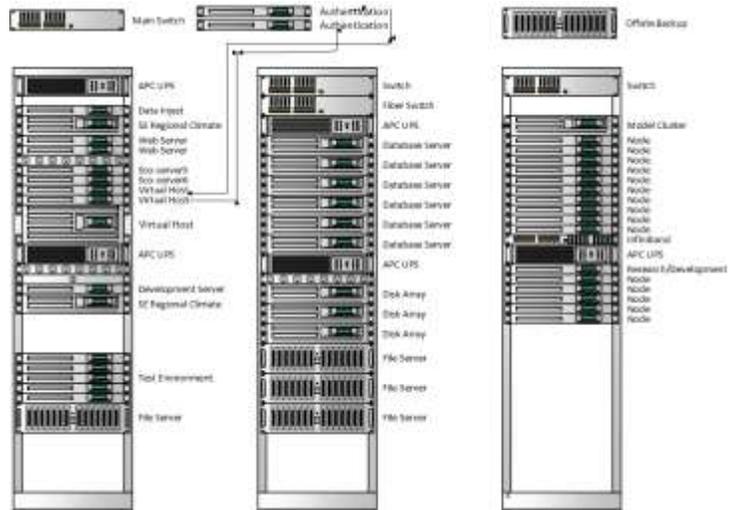
The rollout of the new database infrastructure is ongoing, with new data ingest scripts complete for weather networks. Current and planned work involves the improving access to water resources related datasets. These new database servers each store over 900 gigabytes of point-based weather and climate data, ensuring backwards compatibility during development.

Changes over Past Year:

- Continued migration into a virtualized services environment
- Added faster fiber switching to servers
- New database structure implemented
- Added more versatile iSCSI storage

Performance Statistics over Past Year:

- Web Services Uptime - 99.976%
- Average Database (DB) Availability Uptime (across all DB servers) - 99.987%
- Primary Database Availability Uptime - 99.99%
- Storage Uptime - 99.988%
- Computational Uptime - 99.983%



Schematic of SCONC computing infrastructure.

Team: John McGuire, Nathan Parker, Aaron Sims

**NC Environment and Climate Observing Network (ECONet)**

The ECONet is a network of real-time research-grade monitoring stations that provide observational data on atmospheric and soil conditions. Base funding for the ECONet is provided by NC Agricultural Research Service, which supports the maintenance of sensors at Agriculture Research Stations. Additional support is provided by the National Mesonet Program and individual partners. The ECONet is unique in North Carolina, and provides information that is sparsely collected by other sensors in the state such as solar radiation, soil temperature, and soil moisture.

**Station Maintenance:** Stations were visited several times per year for routine maintenance. These visits help keep the stations operating efficiently, providing the highest quality data. In total, **179** site visits were made to perform routine or emergency maintenance covering **25,262 vehicle miles** – a **67% increase in site visits** and a **28% increase in vehicle miles**. Sensor maintenance activities include:

- 38 wind monitors serviced; 1 wind monitor replaced
- 37 all season precipitation gauge sensors serviced; 2 sensors replaced
- 34 radiation sensors serviced for calibration
- 32 leaf wetness sensors serviced; 18 leaf wetness sensors replaced
- 27 soil temperature sensors serviced; 20 soil temperature sensors installed or replaced



Multi-level soil temperature probe that was installed at all ECONet stations in the past year.

- 22 soil moisture sensors serviced; 8 soil moisture sensors replaced
- 20 integrated wind/temperature/humidity/pressure/precipitation probes serviced; 1 probe replaced
- 18 data loggers replaced and recalibrated
- 18 stations upgraded from landline telephone to cellular communications
- 17 temperature/relative humidity sensors serviced; 14 sensors installed/replaced

*Team: Sean Heuser, Jim Epps, Aaron Sims with assistance from all staff and students*

**Upgraded Communication Protocol:** Over the past two years, station communications have been converted from landline telephones to cellular communications. This effort reduces the costs of communication per station and also allows data to be retrieved at 5-minute intervals.

*Team: Sean Heuser, Jim Epps, and Aaron Sims*

**New Sensor Deployment:** In-house designed multi-level soil temperature measurements have been collected at a handful of ECONet stations for the past few years. Last year, these multi-level sensors – which report soil temperature at 10 cm, 20 cm, 30 cm, and 40 cm below the surface at 1-minute intervals – were deployed at all remaining stations. These sensors have been evaluated and verified against a separate ECONet instrument that records soil temperature at 10 cm. This dataset provides future research opportunities related to environmental monitoring and modeling.

*Team: Sean Heuser and Jim Epps*

**Quality Assurance Quality Control (QAQC):** QAQC routines are run twice per hour and assist scientists with spotting erroneous values and failed sensors across the ECONet network. Over the past year, ECONet data passed automated and manual quality control routines **99.4% of the time**, while **only 0.23% of all data failed** at the highest level of QC.

Most of the QC checks were enhanced this year to account for new sensor deployments. Ongoing QC development is focusing on inter-sensor comparisons – especially between soil temperature probes and between the temperature/humidity probes. In addition, available gridded datasets (which have serially complete data) are being compared to observations at weather stations across the state. For example, SCONC scientists are investigating the relationship between satellite-based soil moisture readings and on-site soil moisture values.

Undergraduate students continue to assist scientists with the daily examination of ECONet data using the QC interface. This manual QAQC has led to improved data quality and earlier detection of sensor failures.

*Team: Sean Heuser, Jim Epps, Aaron Sims with support from staff and students*

**National Mesonet Program:** ECONet observational data files are sent to the NOAA Meteorological Assimilation Data Ingest System (MADIS) gateway for national dissemination to research groups. In addition, monthly reports summarizing the networks' availability are provided to MADIS. As a courtesy, alerts were sent to MADIS if the data became unavailable for an extended period.

As part of this program, all ECONet stations have been upgraded to transmit data back to the office every five minutes. From there, the data are relayed to partners at MADIS. Over the past year, ECONet data availability (defined as within one hour of the original observation time) is **96.13%**, which is **an increase of 0.64%** from the previous year.

*Team: Sean Heuser, Jim Epps, John McGuire, Aaron Sims*

## Climate Support for Agriculture

**Peanut Disease Advisories:** This is the 13<sup>th</sup> year of the State Climate Office's partnership with Dr. Barbara Shew (NCSU Plant Pathology) to provide routine advisories for two peanut foliar diseases: peanut leaf spot and peanut sclerotinia. Daily email alerts are sent from June through September for review by Dr. Shew, who then passes along guidance to her constituents across eastern NC and southeastern VA. Analysis from past years suggests these advisories can save 2-3 fungicide applications per year, with a value to growers of at least \$1 to 3 million per year.

*Team: Aaron Sims, John McGuire, Ashley Hiatt*

**Cucurbit Downy Mildew Forecasts** (<http://cdm.ipmPIPE.org>): In an ongoing collaboration with NCSU Plant Pathology. The SCONC provides operational, national integrated pest management (IPM) forecasts for downy mildew affecting cucurbits (cucumbers, melons, squash). The SCONC provides weather information, technology support, and dispersion forecast guidance. SCONC continues to work with partners in NCSU Plant Pathology to maintain the website and forecasting tools. In addition to operational system updates, the website was migrated to a new server with increased security options last year.

There were 162 confirmed reports of cucurbit downy mildew (CDM) this year, which is a decrease from the 272 reports during the previous year. These reports triggered 15,129 alerts sent to 357 unique phone or email addresses. During the year, 52 new alert sites were added to bring the total number of active sites to 389 (as of May 1, 2017).



*Cucurbit Downy Mildew Risk Maps are prepared with daily*

*Team: John McGuire, Aaron Sims*

*Collaborators: Dr. Peter Ojiambo, Mr. Thomas Keever, and Ms. Wendy Britton*

**Late Blight for Potatoes and Tomatoes:** In collaboration with Dr. Jean Ristaino (NCSU Plant Pathology), the SCONC continues to provide technology support and website administration for monitoring and alerts of Late Blight affecting tomatoes and potatoes. In addition to bug fixes and updates, the website was migrated to a new server with increased security options.

Over the past year, there were 52 confirmed reports of late blight, which is a decrease from 115 during the previous year. These reports triggered 1,241 alerts sent out to 285 unique phone or email addresses. In addition, 24 new alert sites were added for a total of 470 active sites as of May 1, 2017.

*Team: John McGuire, Sean Heuser, Aaron Sims*

**Thrips Exposure Guidance for Cotton Growers** (<http://climate.ncsu.edu/CottonTIP>): In collaboration with researchers in the NCSU Entomology Department, SCONC has developed a Cotton Thrips Infestation Predictor tool for use by cotton growers and extension agents in North Carolina and the southeastern US. Gridded temperature estimates from Parameter–Elevation Regressions on Independent Slopes Model (PRISM) were used in conjunction with thrips dispersal models developed by project partners to develop risk estimates for cotton growers. A series of dynamic infographics were developed to convey these risk estimates to users with the ability to save searches and download content. The website went live on April 1, 2017 and has been used throughout the spring 2017 planting season.

*Team: Rebecca Ward, Kelley DePolt*

*Collaborators: Dr. George Kennedy and Dr. Thomas Chappell (NCSU Entomology)*

**Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP):** The USDA-funded PINEMAP project wrapped up in February 2017 after six years of effort from a team of more than 40 primary investigators at 13 institutions across the Southeast US, including NC State University and the SCONC. PINEMAP researchers studied loblolly pine genetics, management, and climate sensitivities, among other topics, and the SCONC provided the climate science expertise and developed the project’s keystone deliverable, the PINEMAP Decision Support System (DSS, <http://pinemapdss.org>).

The DSS is the main platform for displaying future projections from climate, water supply, and ecological models that are relevant to loblolly pine growers. Tools in the DSS use an innovative three-map layout and time series plot to display these projections from a set of 20 downscaled global climate models. By showing the multi-model mean values as well as the spread of modeled outcomes, the DSS enables decision makers to be better informed about the likely climate-based risks and opportunities both now and in the future.



*Projections of the likely change in Gross Ecosystem Productivity -- one output from the Water Supply Stress Index (WaSSI) model -- by the end of the century.*

Since being officially released to the public in December 2015, the DSS has been presented at various forestry meetings and workshops to connect professional foresters and landowners with this new product. In the past year, the DSS was viewed 3,727 times by 1,255 unique users. Approximately one-third of all sessions were from returning visitors, meaning many users that viewed the DSS later came back to use it again. Even after the end of the PINEMAP project, the DSS will remain online to continue to showcase the results of the project and the fruits of its interdisciplinary collaboration.

Efforts from the SCONC in the past year provided continued support for the DSS in partnership with other researchers. These efforts were focused in three areas:

*PINEMAP Extension and Engagement*

SCONC scientists worked with extension foresters on the PINEMAP project to help prepare for and present the DSS at multiple scientific and industry-specific meetings. These included presentations at several Society of American Foresters meetings, the Carolinas Climate Resilience Conference, and the Georgia Climate Conference.

One training event worked with a group of women landowners, many of whom were novice computer users. By the end of the workshop, these users were able to navigate the DSS, find projections for their locations, and discuss the implications for their future planting and stand management decisions. Together with these extension partners, the SCONC also assisted with conducting webinars; reviewing factsheets, presentations, and other reports; and summarizing scientific data and results for non-technical users.



*Women landowner workshop participants navigate the PINEMAP DSS.*

### PINEMAP Data Management and Dissemination

The gridded future climate projections and aggregated outputs for the DSS took up more than 15 terabytes of space the SCNC's gridded data server. Maintaining this server ensured that these datasets remained available for automated requests and machine-to-machine transfer.

These future projections were the basis for three regional ecological models – the Water Supply Stress Index (WaSSI), the Physiological Processes Predicting Growth (3-PG) model, and the Growth & Yield (G&Y) model – that were run by researchers at other institutions. SCNC scientists provided climate projections of nine variables averaged across 12-digit hydrological units (HUC12s) in the appropriate file formats for each model.

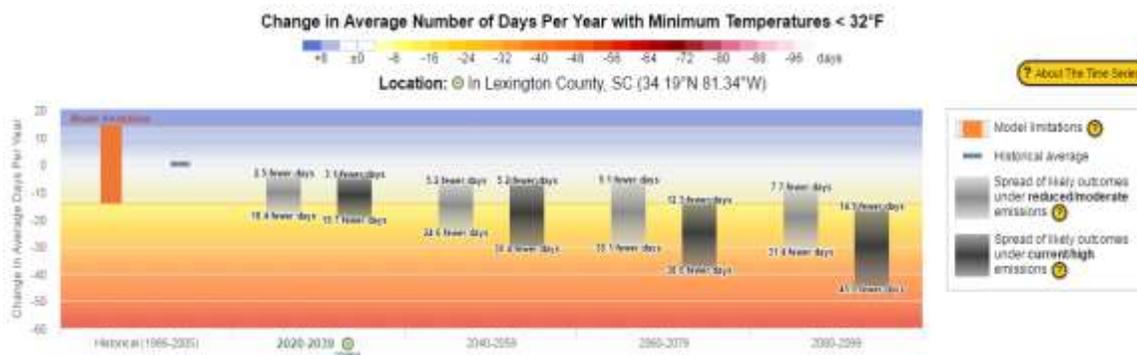
Other PINEMAP researchers needed climate data for approximately 850 different locations plus additional spatial regions. As the keepers of the data, the SCNC completed these requests to help fulfill the needs of these project partners.

### PINEMAP DSS Development

The last year of the PINEMAP project required finalizing the DSS layout, language, and tools based on discussions with the PINEMAP extension team, feedback from professional foresters and other industry experts, and collaboration with other researchers and modelers.

Most of the obvious front-end adjustments focused on making the DSS easier and more intuitive to use. The Introduction page was simplified to provide a more straightforward overview of the DSS, while a more in-depth Frequently Asked Questions page was added to explain features such as the three-map layout, the climate projections in the DSS, and the intricacies of various tools.

To further identify areas for improving the DSS, the SCNC again partnered with the Geocognition and Geoscience Education Research Group in NC State's Department of Marine, Earth, and Atmospheric Sciences. In January 2016, this group conducted an eye tracking study of the DSS with foresters, researchers, and forestry students, which helped inform design changes to the DSS. In March 2017, a second eye tracking study was conducted on non-forestry undergraduate students at NC State to investigate how novice users interacted with the DSS. Results from this study are still pending.



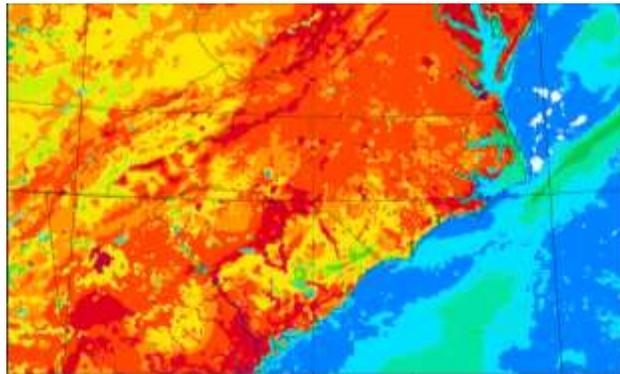
*A time series plot showing likely future changes in the number of days per year with temperatures <32°F near Columbia, SC. Model limitations are highlighted by an orange bar and lines.*

Aimed at more technical users, an experimental method was developed for displaying model error – that is, the difference between historical observations and model projections for a similar baseline period. On the three-map layout and time series plot, locations having a projected value within these model limitations were masked out since those results can be considered non-meaningful for decision-making purposes. This visualization was not incorporated in the final DSS design, but it may be used in the related Climate Voyager tool or other future developments.

Once the PINEMAP modeling teams had completed their ecological model runs, those results were added into the DSS to provide guidance on projected changes in water yield, green weight, Net Primary Productivity, and seven other parameters. Close collaboration with the modeling teams ensured a smooth integration of the model results into the DSS, largely due to impressive multilateral cooperation from all teams to agree on the output format, file and parameter naming conventions, and the visualization of the results within the DSS's unique layout.

*Team: Heather Aldridge, Corey Davis*

**Environmental Modeling:** SCONC continues to produce routine experimental numerical weather and dispersion forecast guidance. These forecasts are distributed to the multiple agencies, including National Weather Service. Model output is included in SCONC's Fire Weather Portal and provides inputs to a series of agricultural products. Additionally, SCONC provides numerical guidance for disease forecasts for cucurbits and efforts with smoke management.



*Model output illustrating heat exchange between the surface and*

*Team: Aaron Sims*

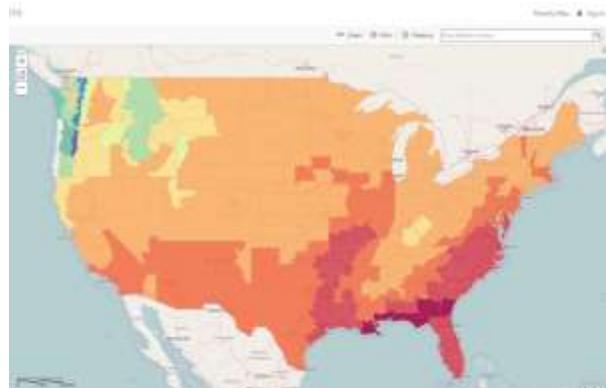
**Support for USDA Southeast Regional Climate Hub (SERCH):** Through a cooperative agreement with USDA, the SCONC is providing technical, scientific, and extension expertise for the Southeast Regional Climate Hub. SERCH is focused on the extension of climate science to support needs and informed decision making on working lands in the southeastern US, including working forests, rangelands, and croplands. Last year the SCONC provided scientific and technical support to:



- 1) Link region-specific climate concerns with Natural Resource Conservation Service resource concerns
- 2) Forecast potential La Niña impacts on agriculture in the southeast US
- 3) Develop an email alert for fire risk.

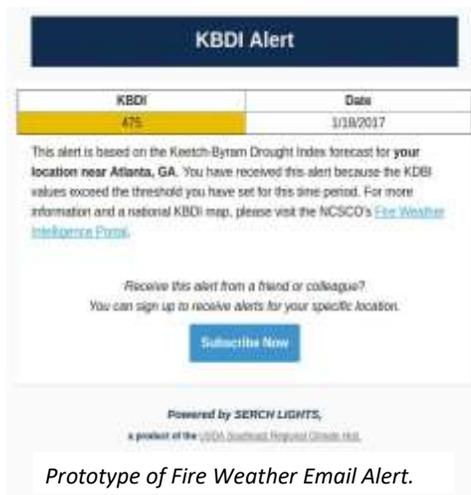
*NRCS Climate Concerns and Adaptation Practices*

*(CCAP):* The Climate Concerns and Adaptation Practices (CCAP) tool is built around an existing suite of NRCS conservation practices and resource concerns, with value added through the development of Climate Connections that describe regional trends in climate variability that are related to resource concerns. SCONC incorporated region-specific climate connections for the Southeast, Northeast and Midwest US into CCAP (<https://nrcs.taccimo.info/menu.php>). Each region includes unique climate connections that define the prominent climate trends and variability that impact the states and resource concerns in that region. The User Guide includes a step-by-step instruction guide as well as a video tutorial. The CCAP tool was demonstrated and presented at the Carolinas Climate Resilience Conference in September of 2016.



*Example map of average precipitation deviation during past La Niña influenced seasons for November, December, and January.*

**Potential La Niña Impacts on Agriculture:** The southeast climate was expected to be impacted by the onset of La Niña in mid to late 2016. Since previous research has illustrated that La Niña tends to influence the climate during the winter months (i.e., November, December, January, February), climatic data was obtained from 1950-2015 to determine how conditions deviated from their respective norm. The resulting temperature and precipitation anomaly data were published on ArcGIS online for users to access the data at their convenience. Users were additionally informed of the risk of climate extremes and impacts on agriculture. The SERCH newsletter system was utilized to distribute this information (<https://content.govdelivery.com/accounts/USDAOCE/bulletins/176413d>).



**Fire Weather Email Alerts:** SERCH is developing email alerts that notify subscribers about wildfire risk and prescribed burning suitability. The alerts are calculated using the Keetch-Byram Drought Index (KBDI) and are being developed in coordination with SCONC’s Fire Weather Intelligence Portal. Early user engagement/sensing with the Southern Regional Forestry Extension group was conducted to inform the subscription parameters. Technical development is wrapping up and user testing and roll out are expected in the near future.

*Team: Aurelia Baca, Aaron Sims, Heather Aldridge, Corey Davis, Rebecca Ward, John McGuire, Nathan Parker*  
*Collaborators: Steven McNulty, Joel Larson, Emrys Treasure, Jennifer Moore-Myers, John Cobb, Sarah Wiener, USDA*

## Climate Support for Water Resources

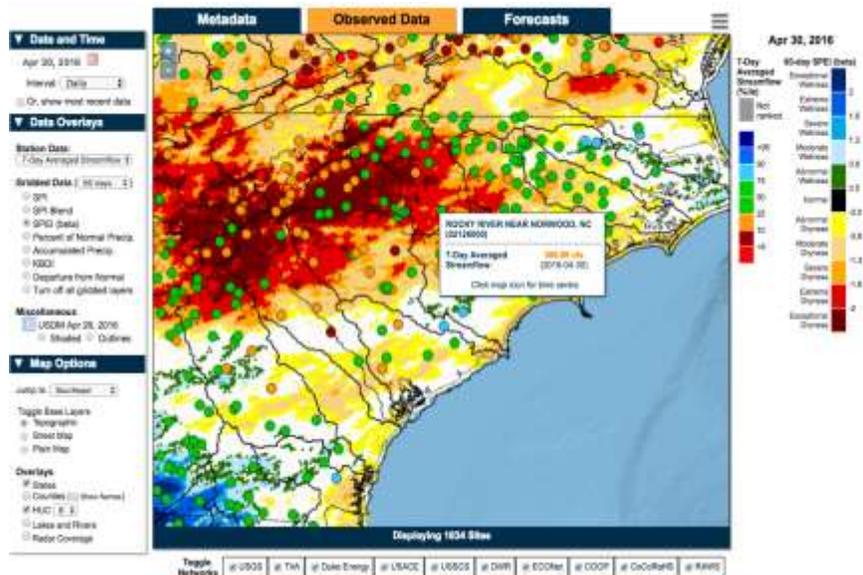
**Drought Monitoring and Response:** SCONC is a member of the NC Drought Management Advisory Council, participating in weekly drought monitoring conference calls and providing public presentations on drought in NC. During the weekly calls, SCONC regularly provides information on recent precipitation placed in historical context as well as the current level of dryness indicated by custom maps of drought indices calculated by SCONC. SCONC has facilitated the weekly process by developing the capacity to draw lines on these custom web maps while overlaying data and frequently communicates the NCDMAC’s consensus to the US Drought Monitor authors.

SCONC provides routine updates on drought conditions and impacts through the Drought Management Advisory Council, monthly climate summaries and blog posts, and provided more than 15 interviews for print and broadcast news media. SCONC additionally gave 9 presentations in the past year to community or professional groups communicating climate drivers of drought, the NC DMAC assessment process, and current drought conditions. Over the past year, NC has seen both exceptional drought and extreme wetness.

*Team: Rebecca Ward, Corey Davis*

**Integrated Water Portal** (<http://climate.ncsu.edu/water/map>): The SCONC has developed an integrated portal that brings together water data from several different agencies into a map-driven data exploration and visualization tool. This site allows users to quickly explore regional and local water conditions with a focus on surface and near surface supplies. This portal incorporates current and historical station-based water and precipitation data with high-resolution gridded products, such as precipitation estimates from the National Weather Service that incorporate radar-estimates of precipitation and drought indices produced by the SCONC.

In addition, point-based streamflow and reservoir forecasts have been added to the portal. Gridded output from NASA LIS has been added to have gridded forecast information as well as streamflow and reservoir forecasts for sites selected based on user engagement. The portal is especially designed to support drought monitoring and forecasting needs and is targeted toward an audience of water supply and natural resource managers at municipal, state, basin, and ecosystem scales. In 2016 a webinar and in-person training session were held with target audiences to teach them how to use the Portal. The Portal was also demonstrated at the 2016 Carolinas



Streamflow and gridded drought severity (SPEI) in the Integrated Water Portal.

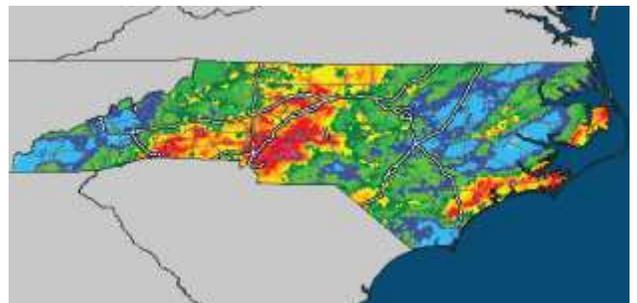
Climate Resilience Conference and the 2017 American Meteorological Society Annual Conference. The portal is additionally used during the weekly NC Drought Management Advisory Council calls. Support for this project was provided by WRI, NC Urban Water Consortium, Tennessee Valley Water Partnership, and DENR Water Resources. Gridded drought products were developed with support from USDA NIFA, NOAA CPO, and NIDIS.

Team: Rebecca Ward

Collaborators: Sankar Arumugam, NCSU Civil, Construction, and Environmental Engineering

### Precipitation Monitoring and Alerts for Storm Water Management (<http://climate.ncsu.edu/dot>):

NC DOT continues to support the SCONC to provide radar-based precipitation alerts and monitoring tools. During the year, Users created 540 individual alert sites and 386 projects for monitoring rainfall. Overall, there are 2,327 active alert sites for 1,602 projects as of May 1st, 2017. The DOT user-base continues to grow as demands for services increase. Over the past year, 181 new DOT user accounts were created, compared to 208 requests for new accounts in the previous year.



Team: John McGuire, Aaron Sims, Ashley Hiatt, Nathan Parker

**Unified Water Data Project:** SCONC scientists are working with the NC Department of Environmental Quality (DEQ) Division of Water Resources (DWR) to unify data from several disparate DEQ datasets that are used to measure and determine the water quality across North Carolina. These data will be combined with SCONC-housed water quantity and weather data in a web-based application programming interface (API) service. This API will give DEQ/DWR staff and stakeholders greater accessibility to weather and water data (both quantity and quality), helping to meet regulatory, planning, and stakeholder needs. During the first year of the project, five in-person meetings were conducted to learn about various DWR datasets, including Lakes, Benthos, Wetlands, and Fish Community datasets.

Team: John McGuire, Rebecca Ward, Aaron Sims, Heather Aldridge

**Support for Carolinas Integrated Sciences and Assessments (CISA):** The SCONC contributed to engagement activities of the Carolinas Integrated Sciences and Assessments (CISA), a NOAA RISA. Namely, CISA is piloting a project to collect narrative reports describing on-the-ground conditions for use in drought monitoring. Volunteers are part of the Community Collaborative Rain, Hail, and Snow Network (CoCoRaHS), a citizen science project that SCONC is actively involved with. Since 2015, SCONC has been using the CoCoRaHS Condition Monitoring reports as part of its weekly assessment process with the NC Drought Management Advisory Council (NCDMAC) and has relayed information between the NCDMAC and CISA on improvements to the visualization of the reports and types of information collected.

In October 2016, the project was expanded to the entire United States and a quantitative scale bar selection was added to the observers' report form. SCONC partnered with CISA to analyze these quantitative, subjective assignments to objective drought indices developed by the SCONC. These include the Standardized Precipitation Index and the Standardized Precipitation Evapotranspiration Index. Analysis began in late spring 2017 and will continue in summer 2017, with a planned presentation at the AMS Applied Climatology Conference in June 2017.



*CISA has developed a web map to view CoCoRaHS Condition Monitoring reports. The map shown is for the week of October 9-15, 2016.*

*Team: Rebecca Ward, Heather Aldridge, Karl Schneider  
Collaborators: Kirsten Lackstrom, Amanda Farris (CISA)*

## Climate Support for Tools and Decision Applications

### Fire Weather Intelligence Portal

(<http://climate.ncsu.edu/fwip>): The Fire Weather Intelligence Portal was developed beginning in 2011 as a real-time monitoring tool for weather and fire risk conditions across North Carolina. Since its release in June 2013, the Portal has been widely used by the NC Forest Service, which funded and helped inform its development, as well as other state and local agencies, along with private landowners.

In the past 12 months, the Portal received 33,802 page views (a 30% increase over the previous year) from 6,023 unique visitors (a 40% increase from the previous year).

A project funded by the USDA Southeast Regional Climate Hub began in July 2016 to expand the Portal across the 13-state US Forest Service southern region, from Virginia through Texas and Oklahoma. This effort includes an overhaul of the Portal's back-end code to make loading data faster and more efficient. Weather and fire risk data from these additional states is also being added. The expansion project is expected to be completed and released in summer 2017.

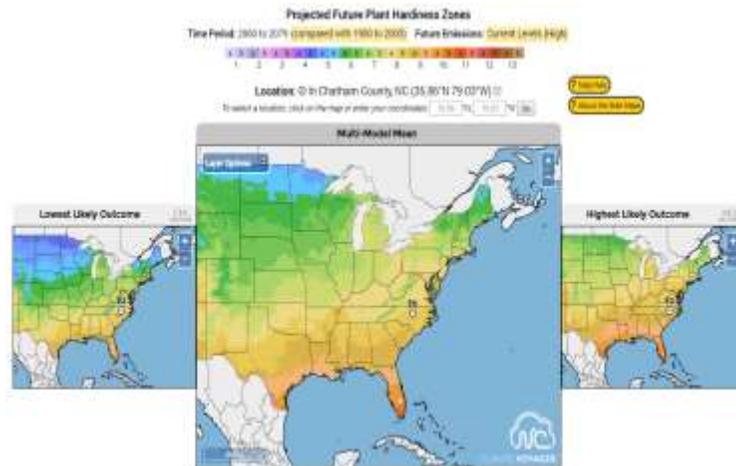


*KBDI data shown within the expanded Fire Weather Intelligence Portal.*

*Team: Corey Davis, Aaron Sims, Rebecca Ward*

**Climate Voyager Decision Support System:** The innovative layout for viewing future forestry-specific climate projections in the PINEMAP Decision Support System has been adapted for general climate data visualizations as part of the Climate Voyager system. Like the PINEMAP DSS, Climate Voyager is a collection of tools designed to assist with future planning based on climate factors, such as changes in extreme cold temperatures or summertime average temperatures and precipitation. One tool designed specifically for Climate Voyager displays the current and projected locations of Plant Hardiness Zones based on downscaled temperature projections.

Although Climate Voyager remains in development, it has already been shared with potential users at a tribal climate workshop for the Oneida Nation, at the American Geophysical Union (AGU) fall 2016 meeting, and at the Water Resources Research Institute (WRI) conference in March 2017. These user engagements will guide the development of future tools within Climate Voyager. Feedback, particularly from tribal groups, has shaped some of the information and options displayed within the tools. Because



*Screenshot from Climate Voyager's Plant Hardiness Zone tool.*

temperatures and precipitation affect key species such as the sugar maple and ramps (wild leeks), the historical locations of these plants have been added as reference layers. New tools could assist tribal groups in their decision-making.

*Team: Corey Davis, Heather Aldridge*

## NOAA Southeast Regional Climate Center

UNC-Chapel Hill and NCSU were awarded the NOAA Southeast Regional Climate Center (SERCC) in 2007. As part of that award, the SCONC supports and maintains the Applied Climate Information System (ACIS), which serves as the climate database for all six NOAA Regional Climate Centers. Additionally, the SCONC is responsible for developing and maintaining the SERCC web services and online climate tools. Partners at UNC-CH include Charles Konrad, William Schmitz, Jordan McLeod, Ashley Ward, and Maggie Kovach.

**SERCC Web Traffic** (<http://www.sercc.com/>): The number of website visits (sessions) was 160,535, a decrease of 6.4% over the previous year (171,536). The largest number of visits in a single day was 1,023 on January 7th, 2016.

- 93.0% of all visits came from the United States
- Top 10 Visits by US State: FL (15.3%), NC (14.0%), GA (12.6%), VA (4.8%), SC (4.6%), CA (4.0%), TX (3.9%), NY (3.6%), TN (2.8%), and AL (2.6%)
- Website Visits by Source:
  - 71%: Search engines (e.g., Google), a 9.1% decrease over the previous year
  - 18.4%: Direct sources (e.g., bookmarks, direct URL), a 4.1% increase over the previous year
  - 8.4%: Non-search engine referral sites (e.g., articles), a 5.0% decrease over the previous year
  - 1.2%: Social Media, a 3.9% increase over the previous year

In addition to bug fixes and updates, the website was migrated to a new server with increased security options.

*Team: John McGuire, Ashley Hiatt*

**Climate and Public Health** (<http://www.sercc.com/hhvt>): Effort over the past year focused on additions and updates to the Climate-Health Toolkit – allowing researchers to explore the relationships between hospital emergency department (ED) admissions data and local climate conditions. These relationships may improve early warning for public health officials. Currently this tool allows users to search for emergency department records based on primary and secondary diagnostics codes, dates and years of interest, and locations. Users can also pull corresponding daily weather records (temperature, maximum heat index, 18 UTC (1PM EDT) heat index, wind chill, precipitation, antecedent weather periods), and generate “reference periods” for ED admissions to help determine when excess morbidity rates occur. After initial data retrieval, the results can be aggregated over different temporal and spatial scales, and narrowed down by demographics, from which summary tables with basic counts and per capita rates can be generated.

Over the past year, new features added to the tool associated with the health dataset include patient ID, patient’s mode of transportation, type of insurance coverage, and disposition. Antecedent weather conditions, including temperature departures from normal and precipitation sums over various time frames leading up to the ED admission, were additionally added. In the upcoming year, UNC researchers will study the relationships between gastrointestinal illnesses and antecedent weather.

In previous years, research stemming from the Climate-Health Toolkit led to the development of the Heat-Health Vulnerability Tool (HHVT). The HHVT displays the expected number of hospital ED admissions (as a percent departure from the baseline) based on the observed and forecast heat indices, as well as on models that were derived from relationships between past admissions associated with heat illnesses across North Carolina. In addition, shaded thresholds give users a general idea of just how severe the number of heat-related hospital admissions is expected to be based on those heat indices.

While previously a standalone tool on the SERCC website, the HHVT has now been embedded in the recently released Convergence website (<http://convergence.unc.edu>). The Convergence website is a product of community engagement supported by the SERCC and Carolinas Integrated Sciences and Assessments (CISA). This website helps identify and address the impact of extreme climate events on communities in the Carolinas. The HHVT was modified to fit into the Convergence site’s responsive design, as well as to address feedback from prior engagement sessions.

The SCONC partnered with the Geocognition and Geoscience Education Research Group in NC State’s Department of Marine, Earth, and Atmospheric Sciences to identify additional areas for HHVT improvement. During a stakeholder engagement session in April 2017, an eye tracking study of HHVT was conducted in collaboration with this research group and the results of this study were used inform design changes to the tool.

*Team: Ashley Hiatt, John McGuire, Heather Aldridge*



*Screenshot of the Heat-Health Vulnerability Tool embedded within the Convergence website.*

**Climate Perspective Updates** (<http://www.sercc.com/perspectives>): Weekly US Drought Monitor authors and contributors from across the country are using Climate Perspectives in national drought assessments. Additionally, SCONC frequently cites the Climate Perspectives tool in monthly or seasonal summaries in its Climate Blog.

*Team: John McGuire, Ashley Hiatt*

# APPLIED RESEARCH

Research efforts build on SCONC's large climate data resources and strengths in connecting climate data and climate science to the decision needs of resource managers. This past year's efforts focused on drought monitoring, coastal fire risk metrics, improvements to short-term weather forecasting, and developing usable climate projections connected to stakeholder needs. SCONC's actionable science feeds into improved extension services and education and outreach programs.

## Applied Research Highlights by the Numbers

- 10 manuscripts were accepted in peer-reviewed journals
- 14 manuscripts are in development or currently in submission
- 51 presentations were given at meetings and scientific conferences
- 14 staff and students attended 37 scientific meetings and conferences

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### Comparison of Soil Moisture Sensors

The North Carolina ECONet (NC-ECONet) uses research-grade sensors to monitor weather and soil parameters, but these sensors can be expensive. SCONC explored several different sensors in summer 2016 to determine whether a more cost-effective sensor could be used and still meet the quality standards of the NC-ECONet. Four types of sensors from two different manufacturers were placed in bins having different soil types. Over the course of a season (June – August 2016), SCONC found that, while a less-expensive sensor can be used to monitor soil moisture (average correlation of 0.9 compared to the official sensor used), the type of soil affected how well the less-expensive sensors fared against the standard, research-grade sensors. Further research in 2017 will examine how these sensors perform in similar soils but different land covers.

Team: *Andrew Henderson, Sean Heuser*

### Wind Speed Comparison between Sensors

The NC-ECONet measures wind speed at three levels: 2, 6, and 10 meters above the surface.

While the same sensor is used to measure wind speed at 6 and 10 meters (RM Young 05103 propeller anemometer), the sensor used at 2 meters is different (Vaisala WXT520 sonic anemometer). A study was conducted in the 2016-2017 to compare wind speeds between these two sensors at the same height. Preliminary results show that the WXT520, on average, is roughly 0.24 m/s faster than the RM Young 05103.

Moving forward, SCONC plans to develop log wind profiles to quantify differences in wind speed at several ECONet stations that have ideal exposure. We hope that these can eventually be used to quality control the wind speeds at 2m, or to provide estimates when the sensor reports incorrect values.

Team: *Jim Epps, Sean Heuser*



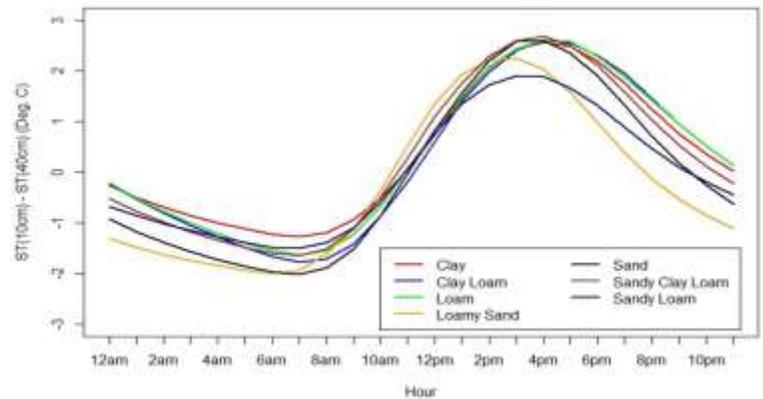
Soil Moisture Experiment with Sand (background) and Topsoil (foreground)

### Comparison of Soil Temperature by Soil Type

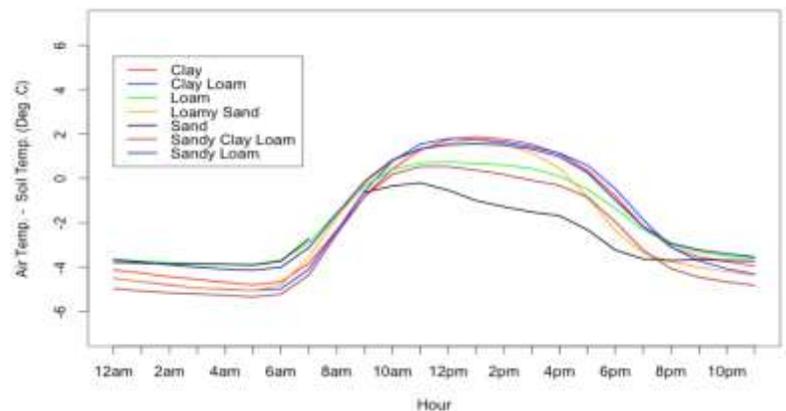
Soil temperature plays a vital role for numerous applications, such as: environmental modeling, agricultural modeling, and transportation safety. While the data collected are beneficial for these applications, performing quality control on the data is challenging. The heterogeneous soil types in North Carolina do not fit a generic quality control algorithm. Therefore, soil classifications (obtained by NC State University's Soil Science department at ECONet stations), air temperature, and multi-level soil temperature values were collected to determine the role of soil type in diurnal temperature trends. Conclusions obtained through this study include:

- 1) Differences between soil temperature and air temperature are more attributed to topography than soil type, though daily differences between air and soil temperature are more pronounced with clay-based soils than sand-based soils.
- 2) The maximum differences between soil temperatures at varying depths occur in the early afternoon. Daily maximum soil temperature differences occur at approximately 3pm local standard time (LST) between 10cm and 20cm, while deeper soil depths have later times of maximum difference. This was found to be the case regardless of the soil type.
- 3) The greatest differences in minimum soil temperature occur in the early morning hours, at roughly 7am LST, regardless of soil type. The magnitude of these differences is much smaller than with the maximum soil temperatures.

Mean Differences in Soil Temperature between 10cm and 40cm by Soil Type



Mean Differences in Air Temperature and Soil Temperature by Soil Type



*Differences soil temperature at different levels by soil type (top); Differences between soil temperature and air temperature by soil type (bottom)*

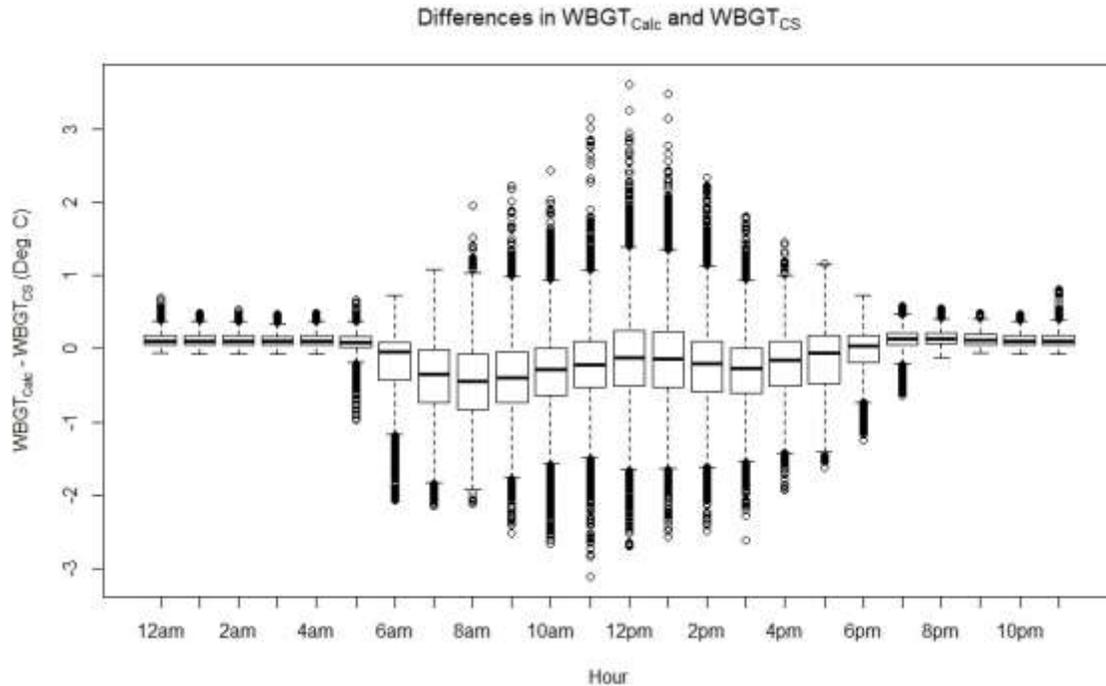
These findings suggest a single quality control routine could be developed by taking into account the differences in soil types between stations. More research exploring the effects of radiation, wind speed, and precipitation to the differences in soil temperature at varying depths could improve quality control routines.

Team: Sean Heuser

### Black Globe Temperature

Heat index is a way to measure how a person feels given current air temperature and relative humidity values. While useful in its simplicity, it may not be the best metric to calculate heat stress on individuals. The US military uses a metric called Wet Bulb Globe Temperature (WBGT) to determine how stressful the atmospheric environment is on humans. This metric uses 3 parameters: wet bulb temperature, dry bulb temperature, and black globe temperature.

Team: Sean Heuser



Differences in Calculated WBGT and the Measured WBGT by hour for study period.

While black globe thermometers are available on the market, they are expensive. However, researchers at the National Weather Service in Tulsa, OK, developed an algorithm that uses basic atmospheric parameters to calculate black globe temperature. These parameters include: air temperature, relative humidity, dew point, station pressure, wind speed, and solar radiation. These six measurements are taken every minute at all ECONet stations. In summer 2016, SCONC compared calculated black globe temperature readings from these metrics to a commercial black globe thermometer. Preliminary results include:

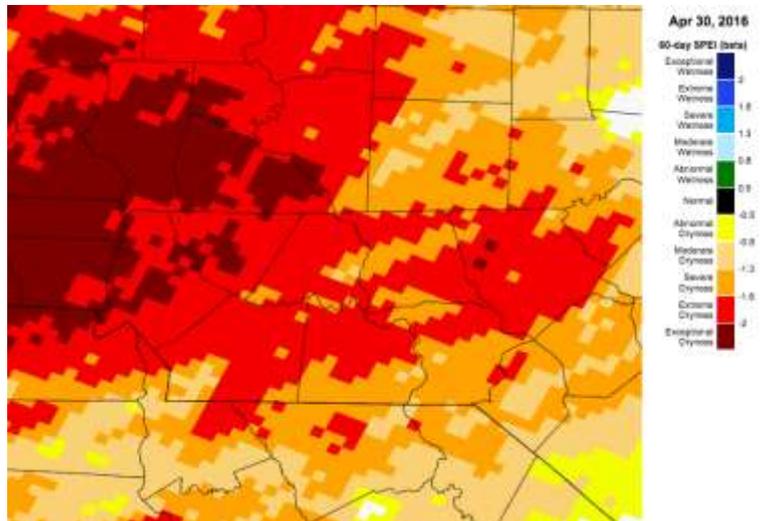
- 1) Calculated black globe temperature was consistently within 1°C of the commercial black globe temperature
- 2) The greatest differences between the observed and calculated values occur during peak sunlight hours, which could be due variations in the calculated solar radiation values.
- 3) Calculations are closest to observed when wind speeds are light (< 2 m/s) and humidity is high (>90%). However, these conditions occur more often at night, when black globe temperature is not as essential.

In the next year, SCONC plans to further evaluate the equations and develop a web-based product that will display WBGT for all ECONet stations and provide valuable information to those who have frequent outdoor exposure.

Team: *Sean Heuser*

**High-Resolution Drought Indices:** The Standardized Precipitation Evapotranspiration Index, or SPEI, is a drought index based on the climate balance between precipitation and potential evapotranspiration. SCONC developed an algorithm for this index based on previous work to calculate a high-resolution Standardized Precipitation Index.

The SPEI calculation utilizes historical distributions calculated from NWS Cooperative Observer Network (COOP) site data and 1981-2010 PRISM normals grids. SPEI additionally uses precipitation accumulations from the AHPS precipitation product, which incorporates gauge-calibrated radar-estimates of precipitation, with potential evapotranspiration accumulations determined using daily PRISM temperature estimates. The SPEI has a spatial resolution of approximately 4.6 km and is generated over the contiguous US for timescales ranging from one month to 3 years.



In addition to an evaluation of the gridded SPEI, drought index values were compared to on-the-ground indicators of drought, including soil moisture, streamflow, and groundwater. A poster was presented at the American Meteorological Society's annual meeting on this research. SPEI has been incorporated into two online GIS tools: (1) the High Resolution Drought Trigger Tool (<http://climate.ncsu.edu/drought>) which is used by several agencies and researchers across the country, and (2) the Integrated Water Portal (<http://climate.ncsu.edu/water/map>) which is used in the weekly NC Drought Management Advisory Council calls.

*Team: Rebecca Ward, Karl Schneider*  
*Collaborators: John Nielson-Gammon (TAMU)*

**Spatial Analytic Framework for Advanced Risk Information Systems (SAFARIS) project:** SCONC scientists serve as the climate focal point on the SAFARIS project, – a collaboration between the Center for Integrated Pest Management (CIPM) at NC State University and the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS). The goal of SAFARIS is to contribute forecasts of the behavior of potentially harmful pests to APHIS' Plant Protection and Quarantine (PPQ) program. These pest forecasts inform risk assessment and management for the United States and the entire globe.

Evaluation of global climate data consisted of quantitatively analyzing minimum and maximum temperature as well as precipitation data for two global climate datasets – Climate Forecast System Reanalysis (CFSR) and Climate Forecast System Version 2 (CFSv2) – to determine the level of accuracy as compared to Global Historical Climatology Network-Monthly (GHCN-M) data. Global error and bias of the two Climate Forecast System datasets were calculated using ground-station – grid-point pairs all over the world. In addition, a regional scale analysis was performed for each continent and sub-region within the continental United States.

*Team: Heather Aldridge, Kieran Riban, Kelley DePolt*  
*Collaborators: Yulu Xia & Yu Takeuchi, NCSU Center for Integrated Pest Management/USDA APHIS*

**Climatological Influence of ENSO and Hurricane Frequency in North Carolina:** El-Niño-Southern Oscillation (ENSO) and variability in tropical cyclone activity are known to induce significant seasonal-to-interannual fluctuations in precipitation. This project focused evaluating the effects that ENSO and hurricane events have on North Carolina's precipitation patterns and distributions. Preliminary results indicate non-linear precipitation trends for individual events and a shift in seasonal and annual precipitation amounts based on event type. Future work will focus on spatial distributions of precipitation during these events.

*Team: Lexia Williams, Geneva Gray, Aaron Sims, Heather Aldridge*

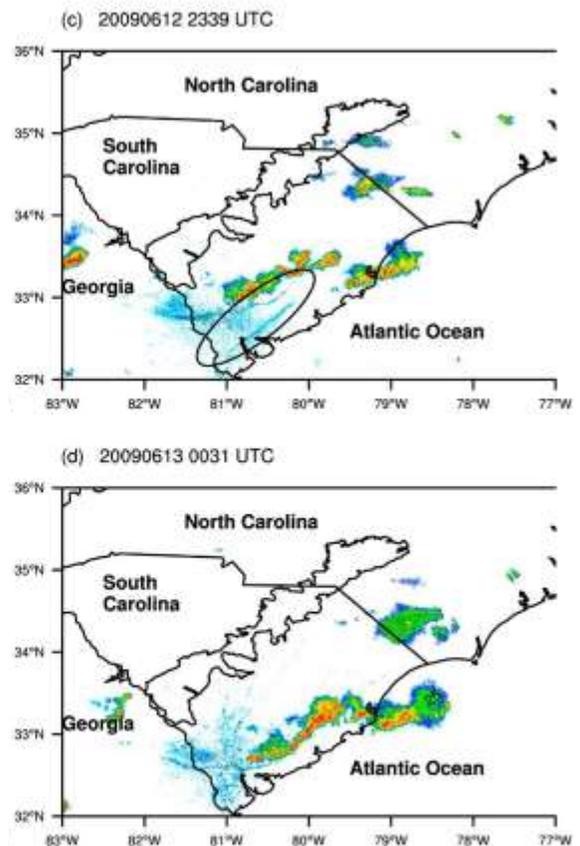
**Observational Analysis of the Interaction Sea-Breeze and Sandhills Front:** The interaction between the Sandhills convection and the sea-breeze front was evaluated to identify its characteristics and investigate the frequency of occurrence for the month of June during the years of 2004 to 2015. Winds speeds and directions were observed to impact the propagation of these frontal features, the development of convection, and precipitation distributions. Southwesterly flow has the highest total average precipitation and the highest maximum amounts per event.

Moderate wind speeds accounted for the highest totals of average precipitation for southwesterly flow. In contrast, light wind speeds produced the highest totals of average precipitation for offshore flow.

Precipitation estimates indicate that the area between the Sandhills and the coastline has the highest total average precipitation. However, the maximum precipitation amounts tend to occur over the Sandhills.

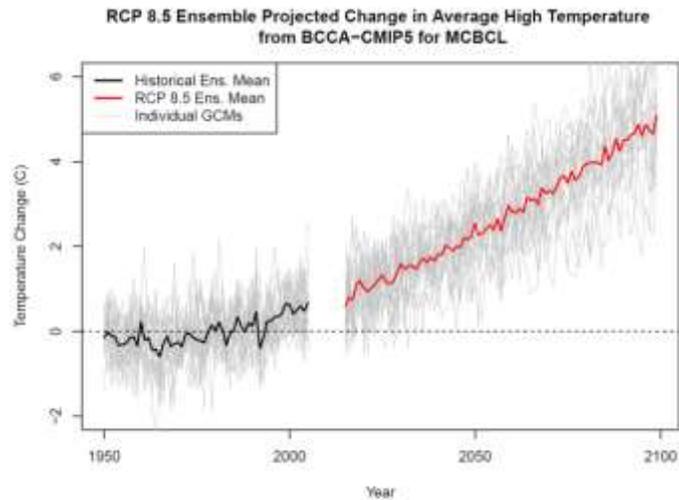
These interactions occur, on average, approximately 24 to 36% of the days in June. Approximately 40% to 70% of the mesoscale driven precipitation occurs in this region when these interactions occur.

*Team: Aaron Sims*



**Defense Coastal / Estuarine Research Program (DCERP):** In summer 2012, SCONC joined a team of scientists headed by RTI International in the second phase of the Defense Coastal/Estuarine Research Program. As DCERP enters its fifth year, SCONC has completed an assessment of the needs of the ecosystem models and research teams. Using the information gleaned from all team scientists, SCONC is beginning research to assess the usefulness of different historical and future projection datasets for the DCERP ecosystem modules. Formal research connected with DCERP began in spring 2015 and continues through fall 2017. More information and partners is available at <http://dcerp.rti.org>.

**Propagation of Uncertainty in Downscaled Climate Projections:** Numerous downscaled climate projections are publicly available for use in impact assessment and by decision makers. The uncertainty from global climate models (GCMs) propagates through the downscaled climate projections, and differences between downscaling techniques adds another important source of uncertainty. Work began in early 2015 to develop an approach to characterize the contribution from each source of uncertainty from GCMs and downscaling techniques from publicly available downscaled data. The methodology was included as part of the Ph.D. dissertation of Adrienne Wootten, and the manuscript version is currently in revision with the Journal of Applied Meteorology and Climatology (reference included below). Results for the Southeast United States suggest that downscaling is a significant source of uncertainty, particularly for precipitation and extremes of temperature.

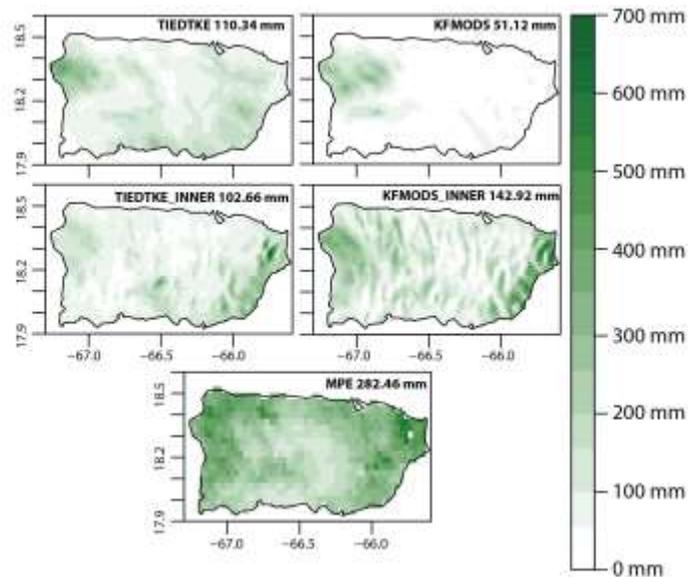


Wootten, A., A. Terando, B. Reich, R. Boyles, and F. Semazzi, in revision. Characterizing Sources of Uncertainty from Global Climate Models and Downscaling Techniques. J. Appl. Meteor. Climatol

*Team: Adrienne Wootten, Ryan Boyles*

*Collaborators: Adam Terando (USGS SECSC), Brian Reich (NC State Statistics).*

**High-Resolution Projections of Climate Change in Puerto Rico:** Ecosystem scientists focused on how climate impacts species distribution and habitat in Puerto Rico. The SCONC worked with USGS and the Department of Interior Southeast Climate Science Center, to produce high-resolution projections for Puerto Rico with an emphasis on the needs of ecosystems scientists in the region. These projections were created using the Weather Research and Forecasting Model (WRF) over Puerto Rico and have been provided to the USGS CIDA GeoData Portal for dissemination to USGS connected interests. In addition, at least 2 manuscripts have been published or submitted for publication (references are included below). Parts of the research from this project were also published as part of Adrienne Wootten’s Ph.D. dissertation at NCSU in 2016.



Bhardwaj, A., V. Misra, A. Mishra, A. Wootten, R. P. Boyles, J.H. Bowden, and A. Terando, in revision: Downscaling Future Climate Change Projections over Puerto Rico using a Non-Hydrostatic Atmospheric Model. Climatic Change

Wootten, A., J. H. Bowden, R. Boyles, and A. Terando, 2016: The Sensitivity of WRF downscaled precipitation in Puerto Rico to Cumulus Parameterization and Interior Grid Nudging. J. Applied Meteor. Climatol., 55, 2263-2281, DOI: 10.1175/JAMC-D-16-0121.1

Wootten, A., 2016: Uncertainty in Climate Projections: An Investigation of the Contribution from Downscaling. Ph.D. dissertation, Dept. of Marine, Earth, and Atmospheric Sciences, North Carolina State University, 160 pp. <https://repository.lib.ncsu.edu/handle/1840.20/33265>

*Team: Adrienne Wootten, Ryan Boyles*

*Collaborators: Adam Terando (USGS SECSC), Jared Bowden (UNC-CH), Lydia Stefanova & Vasu Misra (FSU).*

# Education and Outreach

As North Carolina's primary statewide resource for informal climate education, outreach programming is a substantial focus for SCONC staff and students with more than 38,000 direct educational outreach contact hours. SCONC scientists and students provide direct outreach for dozens of school and community groups; participate in large educational events, such as the NC SciTech Expo at the North Carolina Museum of Natural Sciences; and supply a range climate news and information to the public using social media and the SCONC's Climate Blog. SCONC additionally engages citizens, school groups, and NC teachers through the CoCoRaHS citizen science network.

## **Educational Outreach Highlights by the Numbers:**

- 9 students research assistants trained and financially supported
- 17 school and community groups hosted for outreach
- Participated in 5 large community events including Farm Animal Days, SciTech Expo, and NCSU's Packapalooza
- Over 40 invited presentations to community groups
- 288 new CoCoRaHS observers recruited
- 45 blog posts with 46,361 views
- 931 Twitter followers with 126,117 views
- 38,460 direct educational outreach contact hours

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## **Public Scientific Communication**

**SCONC Blog:** (<http://climate.ncsu.edu/climateblog>)

Since December 2012, the SCONC's Climate Blog has provided timely and user-friendly summaries of weather events, monthly and seasonal conditions and outlooks, student-written posts about summer projects, and behind-the-scenes insight about monitoring and tracking North Carolina's weather conditions.

Over the past year, blog posts included contributions from partners with the North Carolina Forest Service and Carolinas Integrated Sciences and Assessments, and as part of a Hurricane Fran series, the blog featured stories from those who were affected by the storm.



*Staff and students are ready for visitors at NCSU's Packapalooza in August 2016.*

From May 2016 through April 2017, 45 blog posts were published that received 46,361 total views, or an average of 1,030 views each. This is a 13% decrease from the previous 12-month period. A total of 643 individuals and group listservs receive email notifications when new blog posts are released, which is an increase of 6.6% from the previous 12-month period. Blog posts are also shared on Twitter and via an RSS feed.

*Team: Corey Davis with contributions by staff and students.*

**SCONC Twitter:** SCONC’s primary social media platform is on our Twitter account @NCSCO, where weekly content is posted, including blog posts, videos, blurbs about recent weather, infographics, and updates from outreach events and weather station maintenance visits. SCONC’s account has 931 followers – a 20% increase from May 2016. From May 2016 to April 2017, SCONC posted 136 original tweets. These tweets received 126,117 views with 4,225 engagements, which includes link clicks, replies, retweets, and mentions by other accounts.

**Media Interactions:**

- 10 radio interviews on the Southern Farm Network, a syndicated radio program in eastern North Carolina, South Carolina, and Virginia.
- Newspaper interviews with the Associated Press about the Mount Mitchell snow event review from January 2016, with the News & Observer about January 2017 snowfall, and with the Greenville Daily Reflector about historical March snow events.
- TV interview about the winter outlook with WNCT (Greenville).
- 15 television, print, and radio interviews on the evolving drought conditions across the state.

**Bald Head Island Educational Program:** SCONC is working with local conservancy educators to implement a weather program designed for younger kids as they visit the Bald Head Island Conservancy. SCONC constructed a mobile sensor platform that they can use for experiments around the island and compare with the permanent ECONet station.

**Educational Outreach Programs: Focus on Outreach**

**Capacity** SCONC continued to focus on developing more activities for office educational outreach, large engagement events, and building partnerships with Raleigh institutions such as the NC Museum of Natural Sciences. Below are example activities from this effort.

*Defining Normal*

SCONC created a hands-on activity to teach students how climatologists define “normal” by simplifying complex statistical concepts. Students are given index cards with the annual precipitation for a given year written on them. They are then walked through a series of definitions and scenarios and tasked to describe which cards are “normal” or “extreme” based on their prior knowledge and what they have learned. A written version of this lab will be made available in the 2017-2018 year following feedback with additional school and community groups.

*Wind and Pressure*

One of the major questions SCONC receives from school and community groups is about different pressure systems. To teach this concept, SCONC created an activity where students are placed into two boxes drawn on the ground. The number of students in each box is intentionally different and the boxes are small enough so that there is higher "pressure" in the box with more students. The object of the activity is to get the students to balance themselves out until the same number of students are in each box. Students accomplish this by moving from one box to the other. This activity demonstrates how the earth seeks to achieve pressure balance and that the speed the students move from box to box is considered "wind". This activity is also used to help explain why wind speeds are higher when the difference between the numbers of students in each box is greater (or a strong pressure gradient).



Staff and students teach the public about rainfall and clouds at Farm Animal Days in April 2017.

### Tracking Hurricanes

In July 2016, the Duke Talent Identification Program (TIP) middle school summer program visited the SCONC to learn about hurricanes and how they are monitored by surface observations, by radar and satellites, and by reconnaissance aircraft. This included an activity where the students followed the progression of Hurricane Arthur (2014) and plotted its advisories on tracking charts.

### ECONet Videos

(<https://www.youtube.com/user/NCSCO>):

For groups that could not make a tour this year, SCONC released a new ECONet tower tour video to its YouTube channel. This video shows the viewer what a standard ECONet weather tower measures and how important the sensors are to the applied climate community.



A series of tutorial videos were created as part of an initiative with Isothermal Community College to create a certification program for performing ECONet maintenance. These videos teach students how to perform maintenance on SCONC weather towers, including how to operate sensors, wire instruments to a datalogger, and troubleshoot. The videos have been added to an ECONet Certification Page where students' progress can be recorded. Feasibility tests of the certification program will be undertaken in the 2017-2018 year.

**RAIN (Raising Achievement through Inquiry and Networking) Across the River:** Funded by the Burroughs Wellcome Fund as a Student Science Enrichment Program grant, SCONC is hosting a STEM program for rising 7th graders in rural northeastern NC. Through this program, SCONC is developing curriculum and introducing weather and climate concepts through precipitation data collection. This program consists of a year-round after school curriculum, Saturday field trips, and a special week-long summer camp experience.

**Community Collaborative Rain, Hail & Snow Network (CoCoRaHS):** Through CoCoRaHS, thousands of volunteers, young and old, document the size, intensity, duration, and patterns of rain, hail and snow by taking simple measurements in their own backyards. These reports help supplement existing observations from local weather stations and fill in gaps where there are no nearby stations. The SCONC led the establishment of CoCoRaHS in North Carolina in 2007 and over the past year has worked to recruit new volunteers for the program, especially encouraging participation from local schools and areas with data gaps. SCONC has also helped promote the CoCoRaHS Condition Monitoring program, which is an effort spearheaded by the Carolinas Integrated Sciences and Assessments (CISA) to collect drought impacts information from CoCoRaHS volunteers. SCONC recruiting efforts in the past year include:



- A series of five teaser videos to promote CoCoRaHS March Madness, an annual volunteer recruitment effort (<https://www.youtube.com/user/NCSCO>)
  - CoCoRaHS Basketball
  - CoCoRaHS for Breakfast
  - Golfing with CoCoRaHS
  - CoCoRaHS Phone Call
  - SCONC CoCoRaHS Screening

- Introduction to CoCoRaHS during invited presentations and visitor programs including a guessing game using the CoCoRaHS gauge
- Agreement with more than ten local NC school and civic group participants to provide a rain gauge in exchange for their observational commitment, reporting as often as possible
- Engagement with volunteers participating in the program
- Utilization of a CoCoRaHS Rain Game where participants race each other to fill up CoCoRaHS rain gauges and then perform precipitation readings following training by SCONC scientists



*Still shot from SCONC's "CoCoRaHS Phone Call" teaser video*

Every year, a friendly recruiting contest called "CoCoRaHS March Madness" takes place between all 50 states to see who can recruit the most new volunteers during the days of March. North Carolina has won the contest for the past several years, taking home the CoCoRaHS Cup. In the past year, North Carolina placed second, helping recruit 288 new observers – 124 of which signed up during March Madness.

*Team: Heather Aldridge and Rebecca Ward with contributions from all SCONC staff and students*

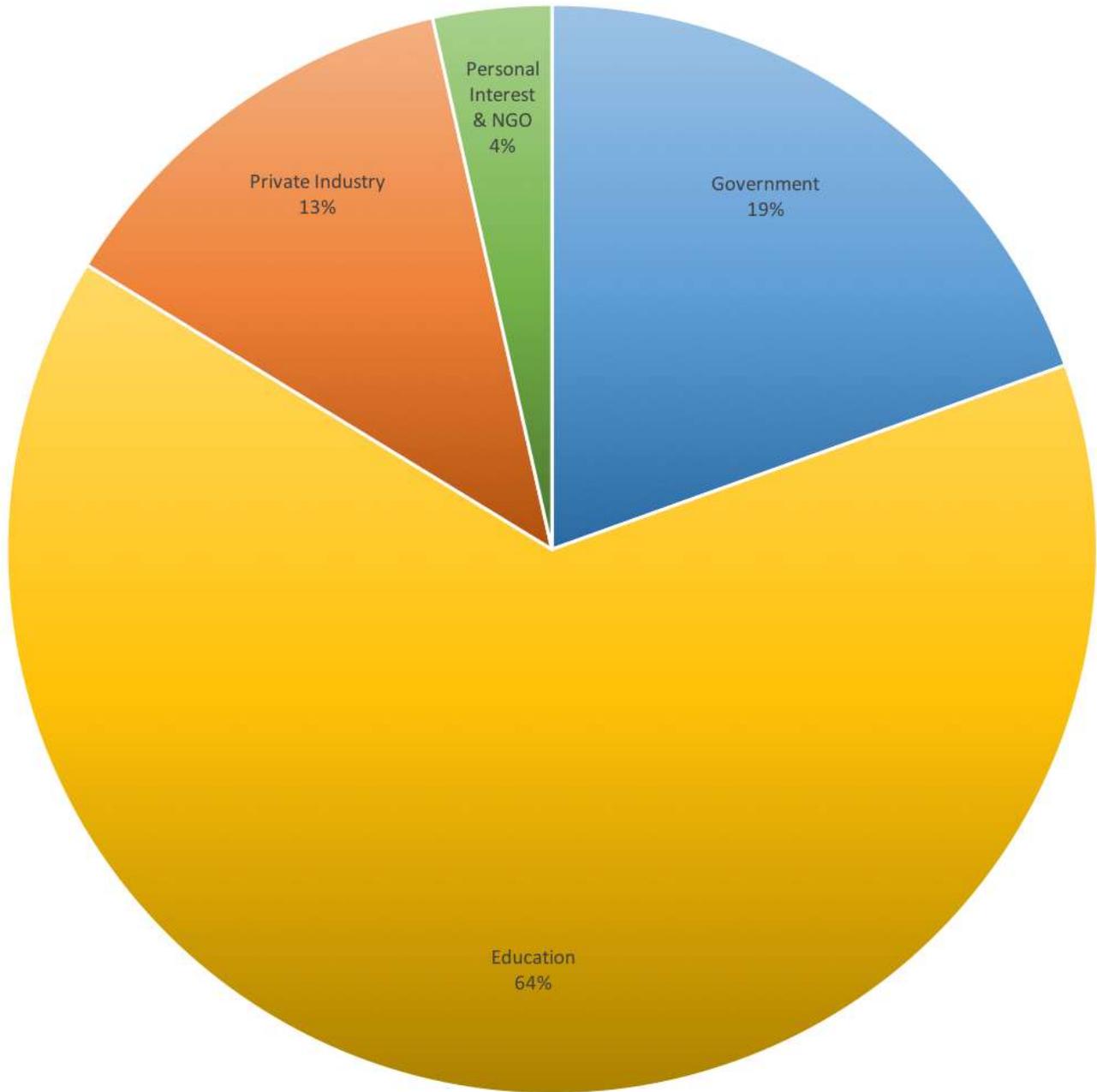
*Collaborators: David Glenn, National Weather Service; the national CoCoRaHS program at Colorado St. U., and Carolinas Integrated Sciences & Assessments (CISA)*

# Appendix A: Climate Services

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## Climate Information Services Effort by Client Sector

*May 1, 2016 through April 30, 2017*



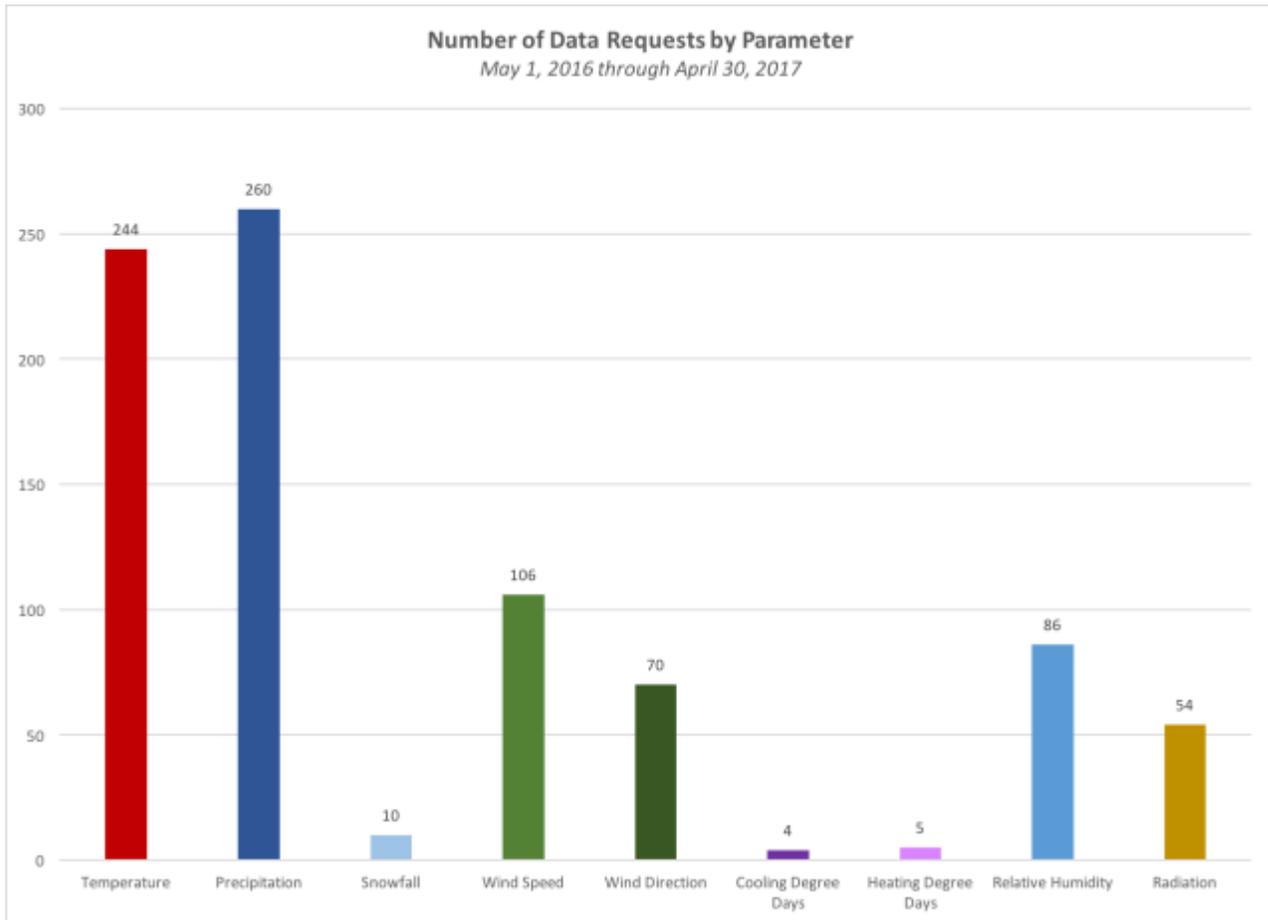
## Climate Information Services by Client Sector – Details

*May 1, 2016 through April 30, 2017*

Classification	Number of Requests	Hours Worked
Government: Federal-Agriculture	11	14
Government: Federal-Education: college, university	1	1
Government: Federal-Engineering	1	1
Government: Federal-Other	12	15
Government: Local-Economic development	1	1
Government: Local-Education: K-12	1	1
Government: Local-Health	1	1
Government: Local-Other	8	9
Government: Local-Water	4	4
Government: State-Agriculture	3	3
Government: State-Construction	2	2
Government: State-Education: college, university	227	253
Government: State-Education: K-12	1	1
Government: State-Energy	1	1
Government: State-Health	3	6
Government: State-Other	18	21
Government: State-Water	7	7
NGO-Water	1	1
Private entity-Agriculture	5	5
Private entity-Construction	4	4
Private entity-Education: college, university	5	7
Private entity-Education: K-12	2	2
Private entity-Energy	2	3
Private entity-Engineering	14	15
Private entity-Legal/insurance	4	5
Private entity-Media	8	9
Private entity-Other	9	10
Private entity-Personal interest	12	12
Private entity-Water	1	1
<b>Totals</b>	<b>369</b>	<b>415</b>
<b>Percent Change from Previous Year</b>	<b>-15.8%</b>	<b>-11.5%</b>

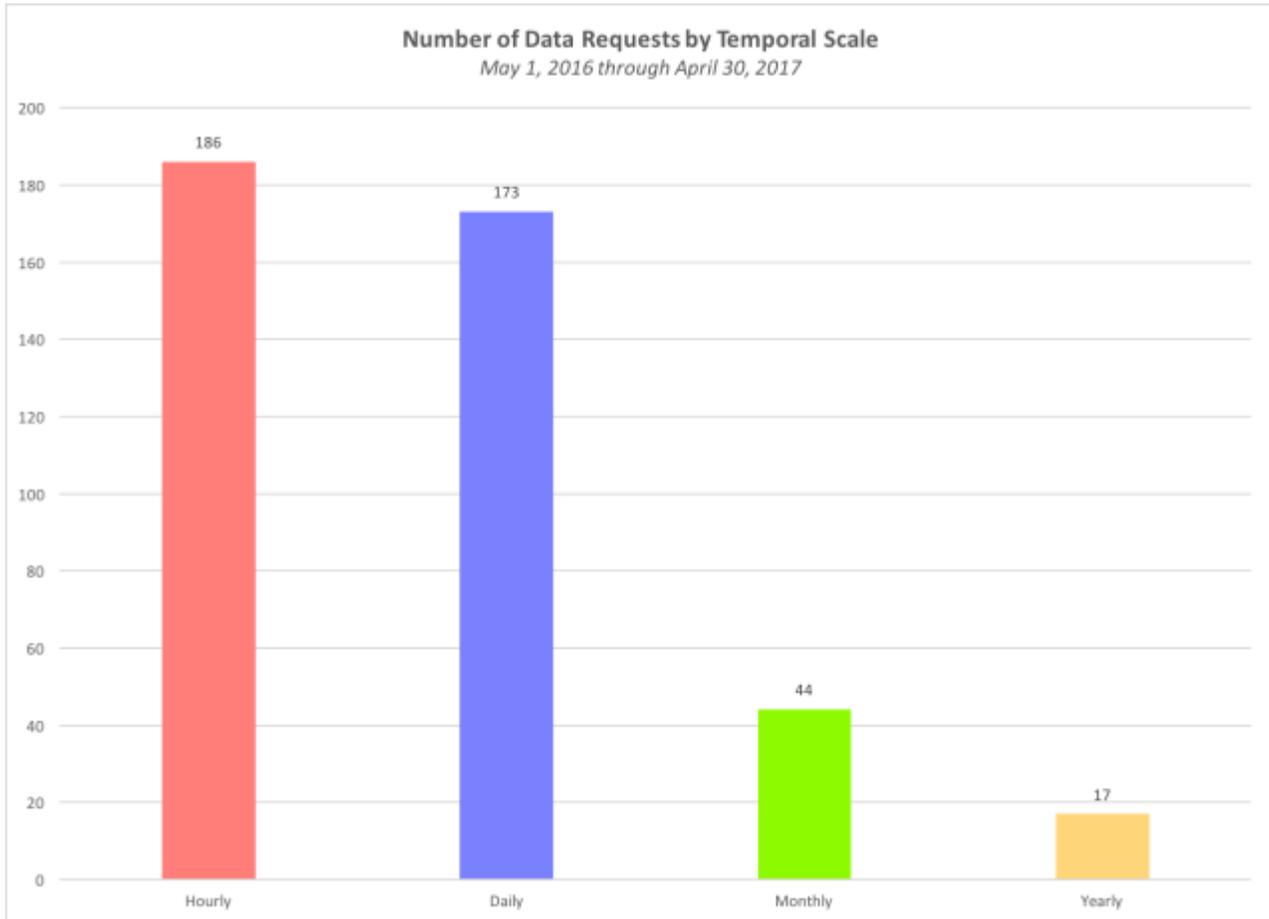
# Climate Information Services by Parameter – Details

May 1, 2016 through April 30, 2017



# Climate Information Services by Temporal Scale – Details

May 1, 2016 through April 30, 2017



## **Appendix B: Impact Statement**

**State Climate Office of North Carolina**

**NC State University**

### **The Need**

Weather and climate affects many aspects of our daily lives - agriculture, environment, transportation, tourism, and natural disasters to name a few. Nearly one-third of our nation's economic activity is estimated to be sensitive to weather and climate. Scientific discovery and understanding of weather and climate begins with environmental data collection, research and education.

### **Serving the Need**

The State Climate Office of North Carolina (SCONC) is a public-service center for climate-environment interactions in North Carolina. The SCONC is housed at NC State University in the College of Sciences with support from the NC Agricultural Research Service. The SCONC is the primary source for North Carolina weather and climate information and is involved in all aspects of climate research, education, and extension services. Activities include:

- Operating and collecting high-resolution weather data from a growing network of 40 research quality weather stations called the Environment and Climate Observing Network (ECONet).
- Disseminating climate information to the citizens, businesses, and agencies of North Carolina through its environmental database infrastructure. Data are accessible through an intuitive interface making climate data available from over 20,000 surface weather and water resource stations in and around North Carolina.
- Assisting state government agencies in activities influenced by weather and climate, reducing costs and conserving resources.
- Collaborating with extension scientists to provide agricultural guidance to growers for disease management and irrigation, which lead to crop loss mitigation and better production decisions. Involved with drought monitoring and management at community, statewide, and national scales.
- Studying climate variations and impacts on North Carolina, including sensor and model evaluation, severe weather patterns, drought and water resource management, and economic impacts.
- Providing numerous community presentations, science fairs, and other interactions with K-12, college students and teachers.

### **Impact beyond North Carolina**

Involved in regional and national partnerships to facilitate the understanding of climate science and the develop climate science applications. Undergraduate and graduate students working at the SCONC gain a genuinely multi-disciplinary experience that contributes to career growth and lifelong learning. Many successes of the SCONC are often heralded as a model for other states' climate offices.