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2015-2016 ANNUAL REPORT

June 2, 2016

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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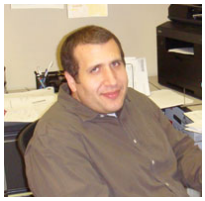
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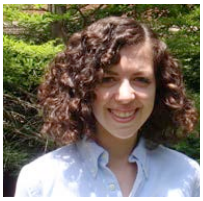
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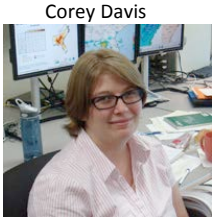
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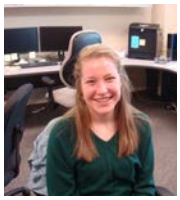
Jessica Miller

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Executive Summary

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

Direct requests for services increased 6% over the previous year, while online visits increased over 13%. Our climate database also continues to see heavy traffic, with 5TB of internal database transfers each month, over 2.8 billion data records selected, updated, or inserted each month, and more than 2.8 million queries made through the website over the past year (an 11% increase).

We operate and maintain the NC Environment and Climate Observing Network (ECONet) that provides high-quality, real-time observations from 40 locations and supports numerous products and services. ECONet uses research-grade sensors to deliver unique, highly valued observations to state, local, and federal agencies. In the past year, we continued to deliver agriculture disease and forecast services, and provide service to the forestry and natural resource sectors. We have continued to develop decision support systems and information portals for multiple sectors including forestry, fire weather, and water resources. We also have sustained engagement and service to the public health community in North Carolina.

Research efforts build on our 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. Our actionable science feeds into improved extension services and our education and outreach programs. Highlights include:

- 6 manuscripts accepted in peer-reviewed journals
- 6 manuscripts in development or currently in submission
- 17 presentations given at 12 scientific conferences
- 9 staff and students attended 15 scientific meetings and conferences

As North Carolina's primary statewide resource for informal climate education, outreach programming is a substantial focus for SCO staff and students with more than 32,000 direct educational outreach contact hours. We provide direct outreach for dozens of school and community groups; participate in large educational events, such as the NC Science & Technology Expo; and push climate information to the public via our blog and social media. Highlights include:

- 9 students research assistants trained and financially supported
- 18 school groups hosted for outreach, and participated in 5 large community events including the Aurora Fossil Festival, NCSU's Packapalooza, Citizen Science Day, and the Wilmington StormFest
- 50 invited presentations to community groups
- 57 blog posts with 67,448 views
- 778 Twitter followers with 160,129 views
- 32,067 direct educational outreach contact hours

Funding from College of Sciences, the NC Agriculture Research Service, and external contracts and grants supported these activities.

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 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 NC 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. We partner closely with other scientists in agriculture, natural resources, public health, and water resource management to develop and deliver sector-focused climate services. We maintain a network of weather sensors and support regional climate services in partnership with the NOAA Southeast Regional Climate Center.

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Climate Service Highlights by the Numbers:

- *1.5 million web visits (sessions), an increase of 12% over the previous year*
- *2.8 million web queries to online climate database*
- *60 terabytes of internal data transfers*
- *33.6 billion climate data records selected, updated, or inserted*
- *19,668 vehicle miles that supported 107 ECONet weather station visits*
- *99.10% of ECONet data passed the highest level of data quality control*

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 SCO 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. SCO staff and students interact directly with users to ensure responsive and reliable climate information services.*

Requests for Services: Direct requests from clients via email and phone during 2015-2016 resulted in a ~6% increase

in requests, as well as an ~8% increase in time spent directly responding to requests for services from clients as compared with the previous year. As with most years, a large percentage of time was devoted to supporting educational requests (59%), while remaining effort went largely to support government (18%) and private industry (15%). Formal public interest requests accounted for 8% of effort. A detailed breakdown of request-driven climate services is provided in Appendix A.

Website Access of Services: *The SCO 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 the weather and climate datasets to provide dynamical products and services.*

Web Services Usage: The number of website visits/sessions was 1,504,523 million (an increase of 11.57% over the previous year). Of these visits, 81.9% from new visitors representing an increase of 13.21% over the previous year. Since 2009, web traffic has increased 621%.

- Most visits in a single day: 8,591 on February 2nd, 2015.
    - 6.45% of all traffic came from the Washington Post (65% of referrals)

- Visits by Location:
    - US State Visits
        - 20.5% of all visits came from North Carolina
            - Other states with many visits: CA (9.5%), TX (6.2%), FL (5.6%), NY (5.5%)
            - Only Wyoming (1,043) failed to have more than 1,250 visits
- Traffic Summary:
    - 80.9% of website visits came from a search engine (e.g. Google), a 11.1% increase over last year
    - 14% of website visits came from direct sources (e.g. bookmarks, direct URL), an increase of 32.7% since last year
    - 0.9% of website visits came from social media, a 13.2% increase over last year
    - 4.1% of website visits came from non-search engine referring sites, such as news articles, which is a 24.6% decrease from last year

- Content Highlights:
    - 64.6% of all page views were the K-12 Education Modules
    - 16.3% of all page views were the Aspects of NC Climate section
    - 9.5% of all page views were CRONOS Database station requests:
        - Page Visits by Station:
            - 24% for Mount Mitchell ECONet (MITC) (2% of all page views)

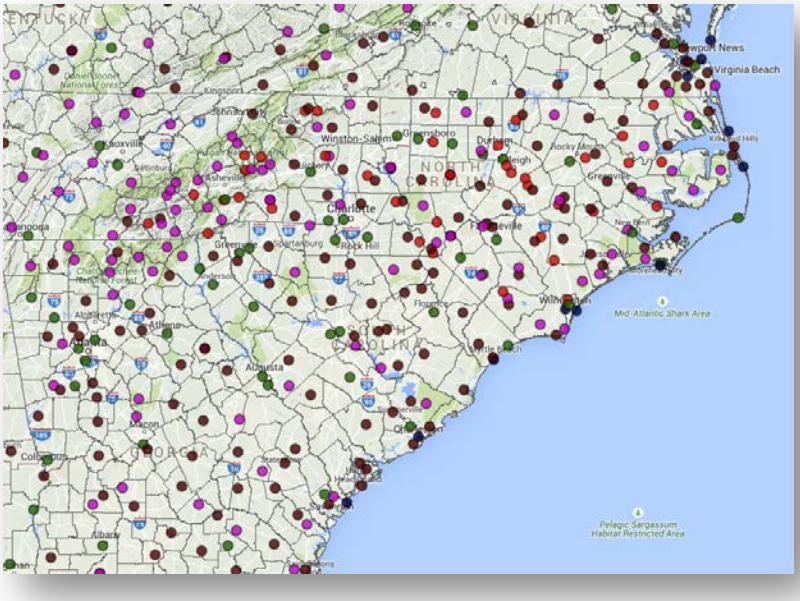
- 4.2% for Grandfather Mtn. ECONet (GRANDFATHR)
- 2.3% for Bald Head Island ECONet (BALD)
- 1.4% for Bear Wallow Mountain ECONet (BEAR)
- 1.3% for Goldsboro ECONet (GOLD)
- 1.2% for Sassafras Mountain ECONet (SASS)

Team: John McGuire, Ashley Hiatt

Climate Data Access and Management

Data Usage: Users requested more than 2.8 million data queries through the website interface – an increase of 11% as compared to previous year. In the past year SCO has more than doubled its data capacity with access to 60 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. SCO now averages about 5 terabytes of internal climate data transfer each month with about 2.8 billion data records selected, updated, or inserted each month.

Data Access: A new Application Program Interface (API) is in beta release, incorporating many features important for users such as data aggregation, variable calculation, and unit conversion. In the future, this will include a nearest station lookup and an option for "best-estimate" data calculated from gridded data. Work over the past year has focused on both server-side and client-side uses. Server-side efforts targeted new dataset sources, linking variables to different data tables, network types, and formula calculation. On the client-side, an API builder interface has been refined to allow API clients easier access to data streams. The API also incorporates variable metadata (such as units, sensor information, and date of first observation of the variable). The API is being written to use a variety of universal output formats, such as JavaScript Object Notation (JSON), which allows for interaction with various programming languages such as Python and Perl.



Sample map of sub-daily stations available across the southeast US.

Data Visualization: A customizable display system has been created to show current conditions, forecast conditions, weather graphics, and other relevant environmental information. Displays have been tailored for our office and for groups at NC State (Jordan Hall and Research III Lobby), Isothermal Community College, and South Carolina Dept of Natural Resources. This tool allows for specific details on current and past information closest to each location, as well as custom content for each site, with the goal of enabling viewers to quickly put current conditions in a historical climate context.

Data Management: Enhancements to the existing datasets within CRONOS are underway that provide improved data reliability, data storage efficiencies in methods to find, update, and quality control missing datasets in a timely manner. In addition, the incorporation of new data sources allows for a more complete record of existing stations and networks.

Improvements and upgrades to the existing SCO database structure are on-going. By testing all of our products on new hardware with a variety of new software packages and configurations, we are looking to optimize and improve the performance, reliability, and features of our seven databases. Together, these databases each store over 510 gigatbytes of point-based weather and climate data.

Changes Over Past Year

- Continued migration into a virtualized services environment
- Upgraded gridded data server
- New database structure created
- Improved data ingest process
- Inclusion of cloud-based offsite backup storage of essential data

Performance Statistics:

- Web Services Uptime - 99.984% for the past year
- Average Database Availability Uptime (across all servers) - 99.975%
- Primary Database Availability Uptime – 99.99%
- Storage Uptime - 99.932%
- Computational Uptime - 99.771%

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 research-grade information that is not collected by any other sensors in the state such as leaf wetness, solar radiation, soil temperature, and soil moisture.

Station Maintenance: 107 site trips were made throughout the past year to perform routine or emergency maintenance covering 19,668 vehicle miles. These numbers are comparable to last year, which saw 115 site trips and nearly 17,000 vehicle miles travelled. Other highlights include:

- 41 wind monitors serviced
- 21 integrated wind / temperature / humidity / pressure probes repaired (14) or replaced (7)
- 51 radiation sensors recalibrated or replaced as part of annual maintenance
- Five soil temperature sensors replaced due to sensor failures
- Five soil moisture sensors replaced with a newer model
- Seven stations upgraded to cellular or Internet communications from traditional phone lines
- Two phone modems replaced due to failure
- Seven enhanced temperature and humidity probes installed
- Four rain gauges replaced to due to failure
- 23 leaf wetness sensors replaced as their three-year cycle had concluded
- 18 data loggers replaced and recalibrated
- 11 new multi-level soil temperature probes installed

Team: Ameenulla Syed, Sean Heuser, Aaron Sims with assistance from all staff and students

ECONet station at the Bald Head Island Conservancy.

New Station Installation: In cooperation with the Bald Head Island Conservancy, the State Climate Office installed their first station on the Outer Banks at Bald Head Island (Station ID: BALD) on June 29, 2015. Data for this station is transmitted every 5 minutes via cellular communication. This station is part of a broader educational outreach program with the conservancy.

Team: Ameenulla Syed, Aaron Sims, Sean Heuser, Jim Epps

Quality Assurance Quality Control (QAQC): QAQC continues to assist scientists in spotting erroneous and failed sensors across the network. This year, new QC routines were developed for the enhanced air temperature / relative humidity sensor. Static checks for leaf wetness sensors were tweaked to better represent the range of values reported. Radiation checks are being adjusted continuously to help scientists identify issues with those sensors.

QAQC of Remote Automated Weather Stations (RAWS) network was implemented along with email alerts for NC Forest Service. This helps our partners at the Forest Service, who focus on RAWS data, to identify possible issues and expedite sensor replacements for their network.

Visualization and analysis tools continue to be at the forefront of the QAQC process. New visualizations tools in include: a long-term time series to compare soil moisture data to precipitation across a station, an updated station metadata page, a historical QAQC data page that allows the user to see spatial QAQC statistics, and longer-time series plots to highlight possible sensor drift.

Enhancement in the QC routines and visualization has helped QAQC metrics to improve once again this year. In the past year, all ECONet data received the highest quality score 99.10% of the time. Ongoing QC development is focusing on more inter-sensor comparisons – especially between soil temperature probes as well as the two temperature / humidity probes on-site. Additional comparisons are planned between available gridded datasets and point observations (such as satellite soil moisture readings with on-site soil moisture values).

Undergraduate students continue to assist scientists with the daily examination of ECONet data using the QC interface. This effort provides students with extensive data analysis experience, and leads to improved QAQC while maximizing efficiency for all to analyze the data.

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

National Mesonet Program: The North Carolina Climate Office continues to send ECONet observational data files to the NOAA Meteorological Assimilation Data Ingest System (MADIS) gateway for national dissemination to research groups and the National Weather Service. As part of this program, we have begun upgrading ECONet stations to five-minute data transmissions using cellular technology. Last year, our MADIS data feed was upgraded to a new data format providing five-minute data over the most recent hour available. We also introduced a digital checklist to help obtain metadata and upload to our databases.

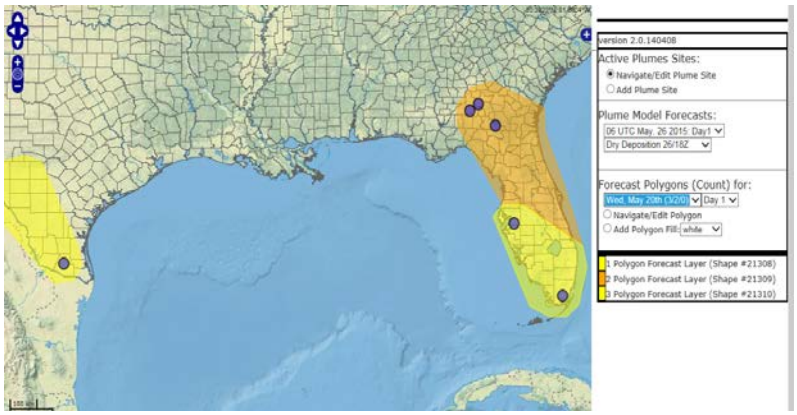
Team: Sean Heuser, Aaron Sims, John McGuire, Jim Epps, Ameenulla Syed

Climate Support for Agriculture

Peanut Disease Advisories: This is the 12th year of our partnership with Dr. Barbara Shew in 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 each year, with a value to growers of at least $1 to 3 million a year.

Team: Aaron Sims, Ashley Hiatt, Ryan Boyles

Cucurbit Downy Mildew Forecasts (*http://cdm.ipmpipe.org*)**:** SCO continues ongoing collaboration with Dr. Peter Ojiambo, Mr. Thomas Keever, and Ms. Wendy Britton (NCSU Plant Pathology) to provide national operational integrated pest management (IPM) forecasts for downy mildew affecting cucurbits (cucumbers, melons, squash). The SCO provides weather information, technology support, and dispersion forecast guidance. We continue to work with our partners in NCSU Plant Pathology to maintain the website and forecasting tools. Over the past year, there were 272 confirmed reports of cucurbit downy mildew (CDM), which is an increase from 151 the previous year. These reports triggered 22,041 alerts sent out to 317 unique phone or email addresses. During the year, 62 new alert sites were added for a total of 339 active sites.



Cucurbit Downy Mildew Risk Maps are prepared with daily SCO dispersion forecasts.

Team: John McGuire, Aaron Sims, Ryan Boyles

Late Blight for Potatoes and Tomatoes (*http://usablight.org*): In collaboration with Dr. Jean Ristaino (NCSU Plant Pathology), the SCO continues to provide technology support and website administration for monitoring and alerts of Late Blight affecting tomatoes and potatoes. There were 114 confirmed reports of late blight this

year, down from 235 the previous year. These reports triggered 7,653 alerts sent out to 346 unique phone or email addresses. During the year 88 new alert sites were added for a total of 450 active sites.

Team: John McGuire, Ryan Boyles, Sean Heuser, Ameenulla Syed, Aaron Sims

Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP): Since 2011, SCO scientists have provided climate support for southern conifer management in collaboration with 42 other investigators from NC State University and almost a dozen other institutions across the southern US. As part of this USDA-funded project, the SCO has served as the conduit to the other State Climatologists, the climate extension resource for all partners, and the developers of a decision support system for professional foresters.

The PINEMAP Decision Support System (DSS) is a comprehensive extension platform and showcase of PINEMAP research. DSS tools help quantify climate-based risks and opportunities, which can be used in decision-making. To visualize the wide range of possible future climatic changes, the DSS uses an innovative three-map layout and time series plot. These show the mean projected outcome from a suite of 20 downscaled global climate models, as well as the spread of outcomes ranging +/-2 standard deviations from the mean. The DSS was officially released to the public in December 2015 (*http://pinemapdss.org*)

Additional efforts in the past year include:

PINEMAP Extension and Engagement

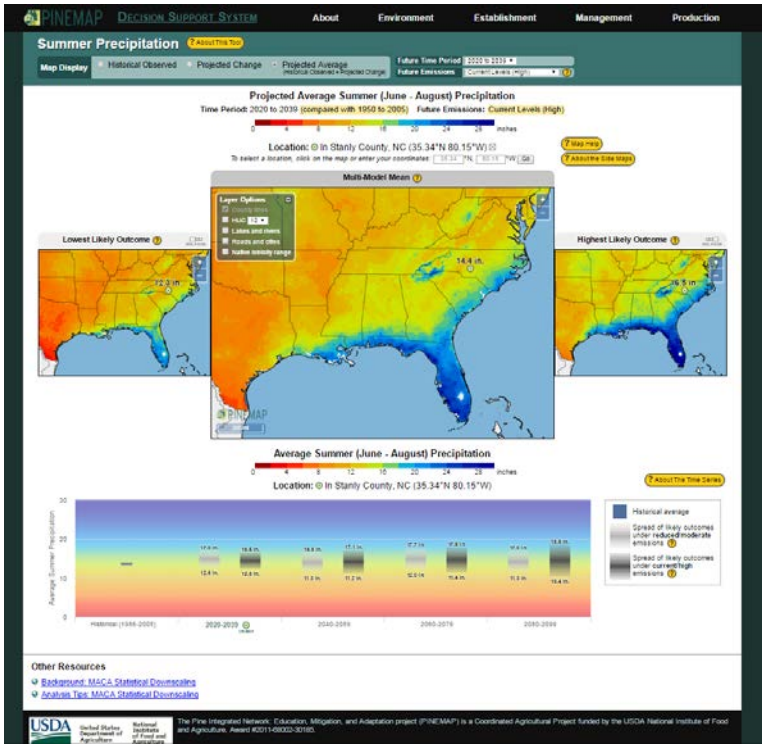
- Connecting forestry extension partners with southern State Climatologists who have served as presenters at regional workshops for natural resource professionals
- Extending climate expertise as part of PINEMAP outreach including:
    - Assisting with several PINEMAP webinars for internal and external users to promote understanding of climate science and collaboration among the interdisciplinary project team
    - Reviewing materials (factsheets, presentations, websites, etc.) for PINEMAP audiences such as private landowners, limited resource landowners, industry/corporate landowners, and state forest agencies
    - Providing guidance to the research sub-groups as to which climate datasets (historical data and future projections) are the most useful for PINEMAP.
- Presenting 24 invited talks about climate and climate change related to forestry -- many of which focused specifically on the DSS

PINEMAP Data

- Hosting the PINEMAP gridded datasets as well as aggregated outputs for the DSS and PINEMAP modelers (~15 terabytes total) on SCO's THREDDS data server, which allows for automated requests and machine-to-machine data manipulation
- Manipulating historical (Univ. of Idaho METDATA) and future downscaled climate projections (MACA) by averaging over HUC12 regions for nine variables required as inputs for three ecological models – the latter of which was generated for the entire US east coast from -98.5 longitude and eastward (~475 gigabytes)
- Performing and storing daily time series extractions at ~850 PINEMAP sites for six standard MACA outputs: min/max temperature, precipitation, wind speed, specific humidity, and solar radiation (~550 gigabytes)
- Completing about a dozen PINEMAP data requests for point or gridded datasets aggregated spatially and/or temporally to meet the needs of PINEMAP researchers
- Creating sample domain-averaged time series plots for the Southeast US for USDA Southeast Regional Climate Hub's Vulnerability Assessment

- Calculating historical average, multi-model mean, and multi-model mean +/- 2 standard deviations grids as well as mean absolute error for all DSS tools (about 75 files total per tool) – the latter of which helps users determine whether future projections are meaningful guidance

PINEMAP DSS Development: Developing and revising several DSS tools including:

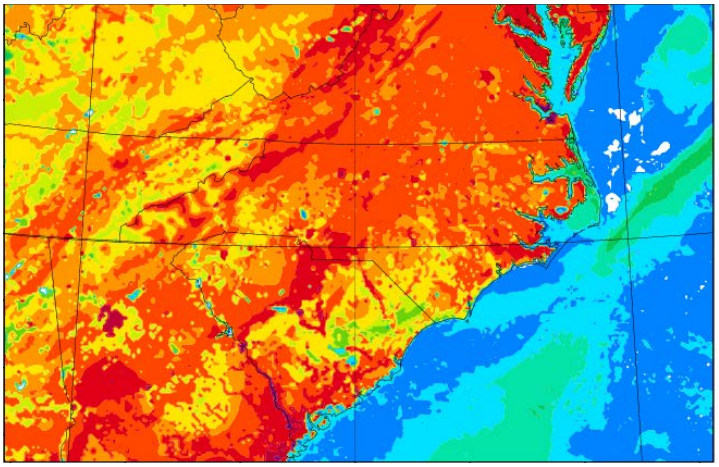


- The **Minimum Temperature Thresholds** tool, which shows the historical and projected occurrence of days with temperatures below certain thresholds, ranging from 32˚F to 15˚F
- The **Summer Temperature** and **Summer Precipitation** tools, which display the historical and projected average summertime temperatures and precipitation amounts
- The **Summer Dryness Index** tool, which shows the historical and projected values of the Summer Dryness Index - a parameter developed specifically for loblolly pine production based on growing degree days and precipitation
- The Seedling Deployment tools - developed last year - have been rebranded as **Dynamic Hardiness Zones**, which indicate the likely movement of 5˚ temperature ranges that can be used by nurseries to assess potential new seedling markets and by landowners to assess potential seedling source regions
- Working with ecological modelers to obtain and test sample data files from regional modeling output to create prototype tools of water yield and green weight
- Collaborating on a review of the DSS - including the layout, colors, wording, and other DSS features - with PINEMAP's extension team, climate modeling experts, and forestry industry professionals and consultants in two rounds of beta testing, which included independent exploration of the DSS and small group discussions
- Coordinating with SCO scientists to evaluate the time series plot display options as part of DSS alpha testing in the summer of 2015 (*N*=20 total for alpha and the previously mentioned beta testing)
- Assisting with an eye tracking study conducted by the Geocognition and Geoscience Education Research Group in Dr. Karen McNeal's lab at NC State University's Department of Marine, Earth, and Atmospheric Sciences, which evaluated the DSS during the Appalachian Society of American Foresters meeting in Durham, NC, on January 28-29, 2016. Thirty-one students, researchers, and professional foresters participated in this study. Results of the study, including heat maps showing areas frequently viewed or ignored on the DSS, informed layout and functionality changes to improve DSS usability.

Team: Heather Dinon Aldridge, Corey Davis, Ryan Boyles

Environmental Modeling: SCO 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 our Fire Weather Portal and provide inputs to a series of agricultural products. Additionally, we provide numerical guidance for disease forecasts for cucurbits and efforts with smoke management.

Team: Aaron Sims



Model output illustrating heat exchange between the surface and air.

Spatial Analytic Framework for Advanced Risk Information Systems (SAFARIS) project: Over the past year, SCO scientists have served as the climate focal point on the 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). SCO is hosting a THREDDS data server that provides access to several gridded climate datasets including historical climate data as well as future climate projections, such as temperature and precipitation. The initial stages of an evaluation are underway to determine statistical measures of error for a minimum temperature dataset, which will be utilized for simulating pest disease guidance on a global scale.

Collaborators: Yulu Xia & Yu Takeuchi, NCSU Center for Integrated Pest Management / USDA APHIS
Team: Heather Dinon Aldridge, Ryan Boyles

Support for USDA Southeast Regional Climate Hub (SERCH): Through a cooperative agreement with USDA, we are providing technical, scientific, and extension expertise for the newly formed SE Regional Climate Hub. SERCH is focused on the extension of climate science to support needs and decisions on working lands in the southeastern US, including working forests, range, and croplands. Last year we provided program coordination support to enhance engagement with cooperative extension programs across the region. We also provide scientific and technical support for SERCH to catalog climate sensitivities and deliver technology tools and alerts to local and regional stakeholders.

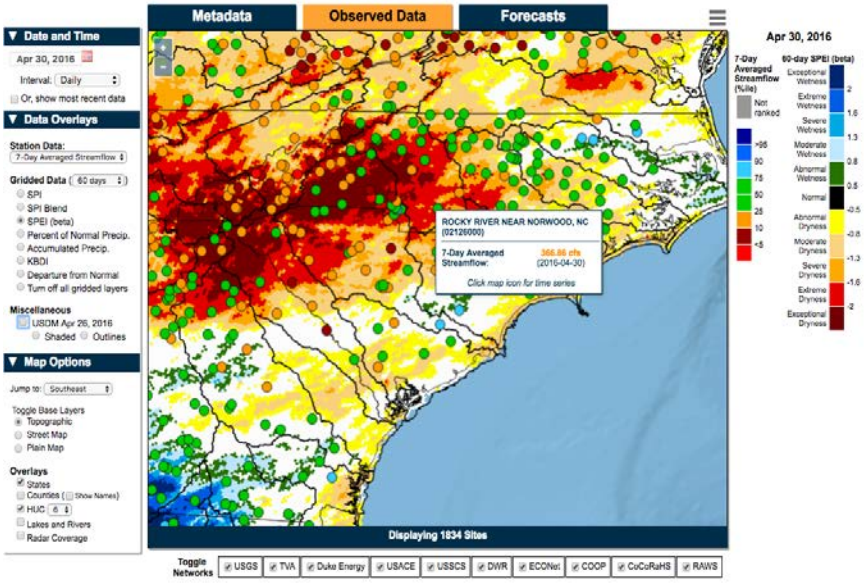
Collaborators: Steven McNulty, Emrys Treasure, Jennifer Moore-Myers, John Cobb, USDA
Team: Sarah Wiener, Aurelia Baca, Aaron Sims, Heather Aldridge, Rebecca Ward, John McGuire, Nathan Parker

Climate Support for Water Resources

Drought Monitoring and Response: SCO 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, SCO 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 SCO. Additionally, SCO has facilitated the weekly process by developing the capacity to draw lines on these custom web maps while overlaying data. SCO provide routine updates on drought conditions and impacts through the Drought Management Advisory Council, monthly climate summaries and blog posts, and more than 15 interviews for print and broadcast news media. Over the past year, NC has seen both severe drought and extreme wetness, with a return of Abnormally Dry conditions in the spring.

Team: Rebecca Ward

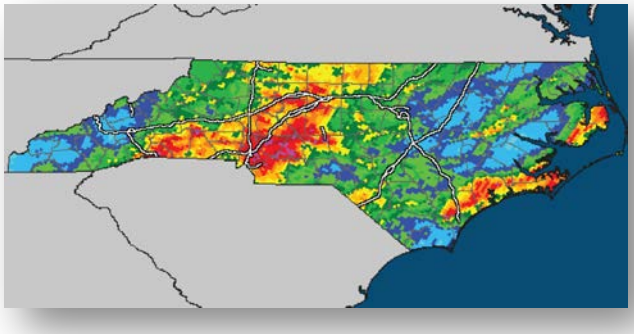
Integrated Water Portal (*http://climate.ncsu.edu/water/map*): The SCO has developed an integrated portal that brings together water data from several different agencies into a map-driven data exploration and visualization tool. This site allows users to quickly explore regional and local water conditions 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 SCO. In addition to this, 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 stream flow 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. The portal was presented at the 2016 WRRI Annual Conference, the 2016 Climate Prediction and Applications Workshop, the December 2015 meeting of the Urban Water Consortium, the 2015 WRRI Freshwater in the NC Coastal Plain meeting, and is used during the weekly NC Drought Management Advisory Council calls. Support for this project was provided by WRRI, 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.



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

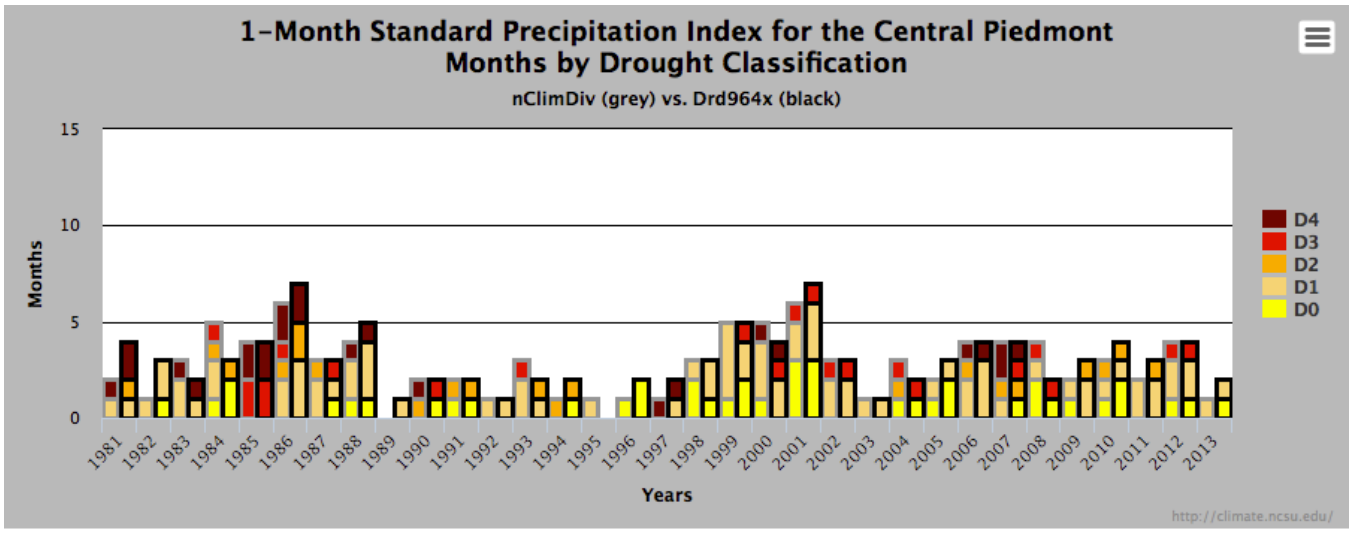
Collaborators: Sankar Arumugam, NCSU Civil, Construction, and Environmental Engineering
Team: Rebecca Ward, Ryan Boyles, Corey Davis, Ashley Hiatt, Aaron Sims, John McGuire

Precipitation Monitoring and Alerts for Storm Water Management (*http://climate.ncsu.edu/dot*): NC DOT continues to support the SCO to provide radar-based precipitation alerts and monitoring tools. During the year, 575 individual alert sites and 406 projects were created. Overall, there are 2,086 active alert sites for 1,936 projects.



Team: John McGuire, Aaron Sims, Ashley Hiatt, Ryan Boyles

New Drought Frequency Tool *(http://climate.ncsu.edu/drought/frequencies*): Drought has been one of the most commonly requested topics for invited presentations since 2002. We created a tool to graphically compare two different climate division datasets in terms of frequency by drought classification. For each NC climate division, users can select a wide array of drought parameters to view how frequently drought occurred on an annual basis from 1895 through 2013, broken down by each of the U.S. Drought Monitor classifications.



Number of months in each year from 1981-2013 where 1-month SPI was categorized as D0, D1, D2, D3 or D4. nClimDiv data outlined in gray; Drd964x data outlined in black.

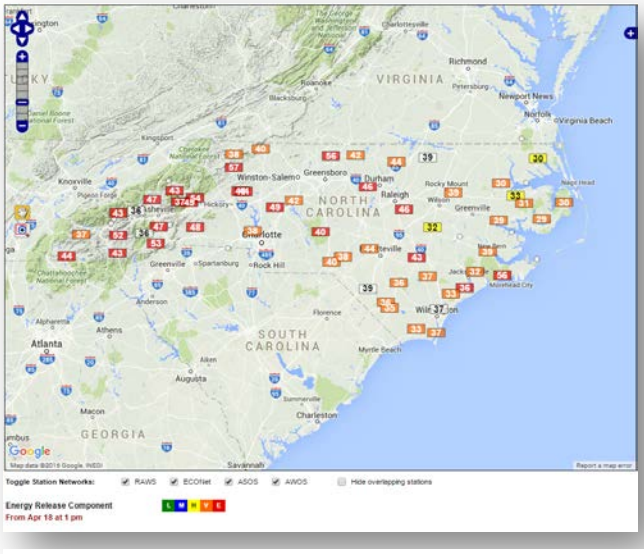
Team: Brandon Black, Ashley Hiatt, Rebecca Ward

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 26,025 page views from 4,314 unique visitors. That's a 17% increase in the number of views and 45% increase in the number of viewers from the previous year.

Ongoing maintenance of the Portal during the past year included the addition of new datasets such as gridded estimates of the Keetch-Byram Drought Index. Our continuing support for the Portal also meant ensuring consistent data availability, and a new source of Remote Automated Weather Station (RAWS) data was identified and implemented to provide up-to-date access to information from those stations. The first formal training for the Portal took place in August 2015. Two hour-long webinars, co-organized by the SCO and the Montgomery Community College Prescribed Fire Training Center, described Portal features and their usage and interpretation, particularly for prescribed burning.



Energy Release Component data from the Fire Weather Portal on April 18, 2016.

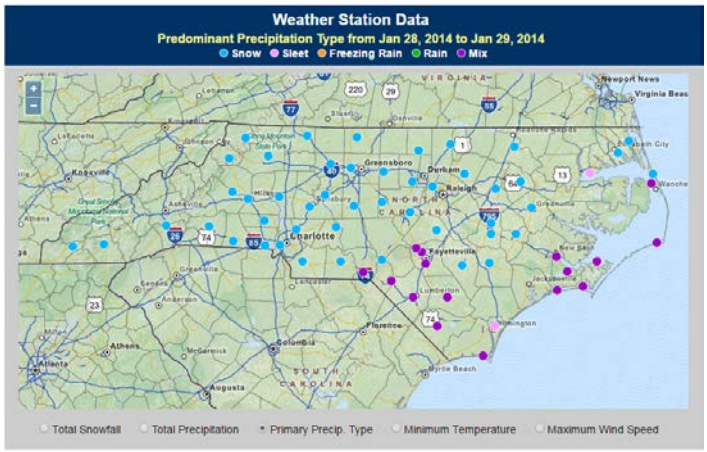
The SCO also continued to establish itself as a local, regional, and national leader in fire weather monitoring and smoke guidance. This included generating smoke plume dispersion models of current and past fires for NC Forest Service and NC Division of Air Quality; discussing historical and future fire and smoke risk guidance with the NC Division of Public Health; and advising groups such as the Texas A&M Forest Service and the Center for Environmental Management of Military Lands at Colorado State about generating fire risk parameters for local weather stations.

Team: Corey Davis, Ryan Boyles, Aaron Sims

Winter Storm Database (*http://climate.ncsu.edu/climate/winter_wx/database.php*): The SCO's searchable archive of wintry events in North Carolina received an upgrade during the past year:

- The search function was optimized to make navigating the archive of more than 400 historical events easier and quicker
- Updated event maps were added featuring storm-total snowfall and precipitation, precipitation type, minimum temperature, and maximum wind speed data
- Additional resources such as SCO blog posts, case studies from the National Weather Service, and large-scale atmospheric maps were linked to individual event summaries

Team: Corey Davis



Predominant precipitation type from the wintry event on January 28-29, 2014.

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 SCO supports and maintains the Applied Climate Information System (ACIS), which serves as the climate database for all six NOAA Regional Climate Centers. Additionally, the SCO is responsible for developing and maintaining the SERCC web services and online climate tools. Partners at UNC-CH include Chip Konrad, William Schmitz, Jordan McLeod, and Maggie Kovach.

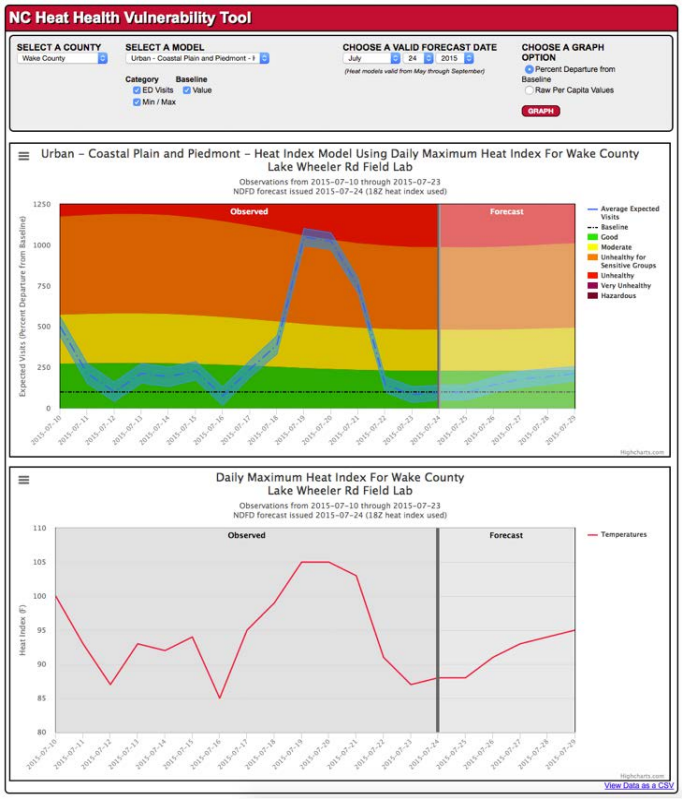
SERCC Web Traffic *(http://www.sercc.com/)*

The number of website visits (sessions) was 171,536, an increase of 27% over the previous year (134,998). The largest number of visits in a single day was 1,813 on January 23, 2016.

- 93.5% of all visits came from the United States
- Top 10 Visits by US State: FL (15%), NC (13.8%), GA (10.7%), VA (5.7%), SC (4.9%), CA (4.5%), TX (4.1%), NY (3.7%), AL (2.7%), IL (2.6%)
- Website Visits by Source:
    - 73.2%: Search engines (e.g. Google), an increase of 21.9% over the previous year
    - 16.5%: Direct sources (e.g. bookmarks, direct URL), a 50% increase over the previous year
    - 9.3%: Non-search engine referral sites (e.g. news articles), a 28.7% increase over the previous year
    - 1.1%: social media, a 121.7% increase over the previous year

Climate and Public Health (*http://www.sercc.com/hhvt*): In 2015, we continued to focus effort on additions to a prototype tool that allows researchers to explore the relationships between hospital emergency department (ED) admissions data and local climate conditions. The hope is that these relationships, if robust, will enable 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, 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.

New features added to the tool over the past year include the 18Z heat index, which better coincides with the timing of NWS forecasts of this particular parameter. UNC and SCO researchers will study the relationships between the daily maximum heat index and 18Z heat index in the upcoming year.



Example of Heat-Health Vulnerability Tool showing predicted heat-related emergency department admissions based on heat index for Wake County in July 2015.

Additional research results from this tool have been used over the past year to further develop the Heat Health Vulnerability Tool (HHVT). The HHVT is geared toward public health officials, NWS personnel, the state

emergency response team, and others who could potentially target messaging of heat warnings to particular groups or areas. While the initial version of the HHVT used models based on daily maximum temperatures, research determined that heat index may give more meaningful guidance. Models based on heat index were generated and made available through the new version of the HHVT, which still allows users to view all models applicable to their location of interest, and graphically displays the model based on observed and forecasted heat indices for a nearby weather station over their selected time period. In addition, the HHVT now depicts shaded thresholds generated to give users a general idea of the severity in how observed and forecast heat indices will affect various populations across NC. Data can be graphically displayed in raw format (expected ED visits per capita) or as a percent departure from the baseline, and is now available in CSV format as well.

Team: Ashley Hiatt, John McGuire, Ryan Boyles

Climate Perspective Updates (*http://www.sercc.com/perspectives*)**:** Updates and enhancements were made to the regional climate information tool known as Climate Perspectives. Updates to Climate Perspectives includes a data feed for the NOAA Southern Region to pull data into their visualization packages. In addition, authors for the weekly US Drought Monitor are using Climate Perspectives to improve national drought assessments.

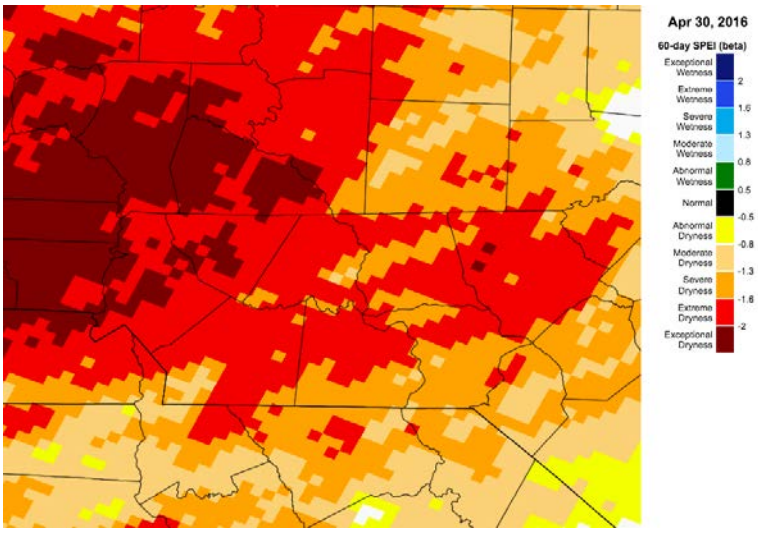
Team: John McGuire, Ashley Hiatt

APPLIED RESEARCH

Research efforts build on our 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. Our actionable science feeds into improved extension services and our education and outreach programs.

Applied Research Highlights by the Numbers

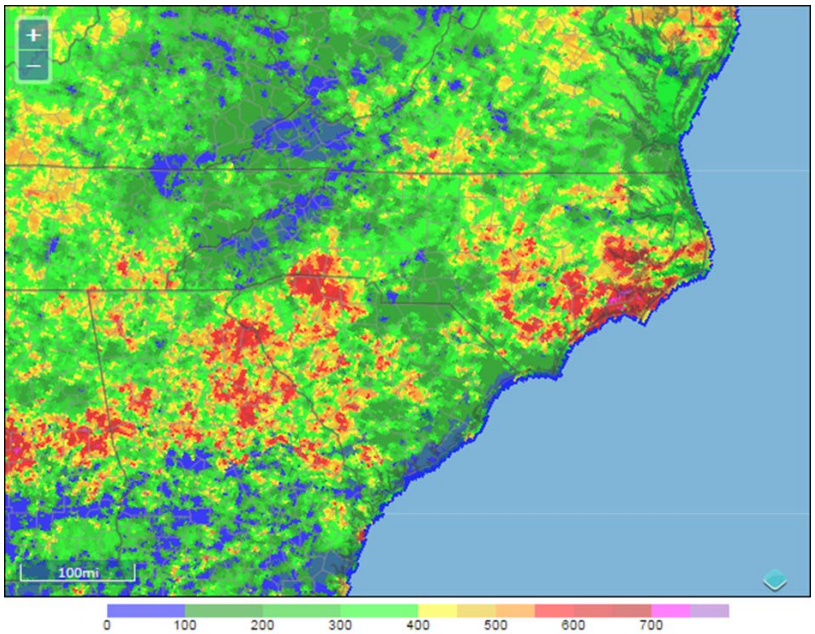
- *6 manuscripts were accepted in peer-reviewed journals*
- *6 manuscripts are in development or currently in submission*
- *17 presentations were given at 12 scientific conferences*
- *9 staff and students attended 15 scientific meetings and conferences*



High-Resolution Drought Indices: The Standardized Precipitation Evapotranspiration Index, or SPEI, is a drought index based on the climate balance of precipitation minus potential evapotranspiration (P-PET). SCO 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. An evaluation of SPEI was conducted in winter 2015-2016, revealing the index agreed well with comparison datasets. SCO has additionally developed a gridded calculation of the Keetch-Byram Drought Index (KBDI). This also incorporates daily AHPS precipitation and PRISM temperatures estimates and has a spatial resolution of approximately 4.6 km. Both SPEI and KBDI are updated daily, allowing for use in active drought monitoring. Additionally, both indices have 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 which is used in the weekly NC Drought Management Advisory Council calls. The SPEI was presented at the 2016 WRRI Annual Conference in Raleigh, NC, and the 2016 Climate Prediction and Applications Workshop in Burlington, VT.

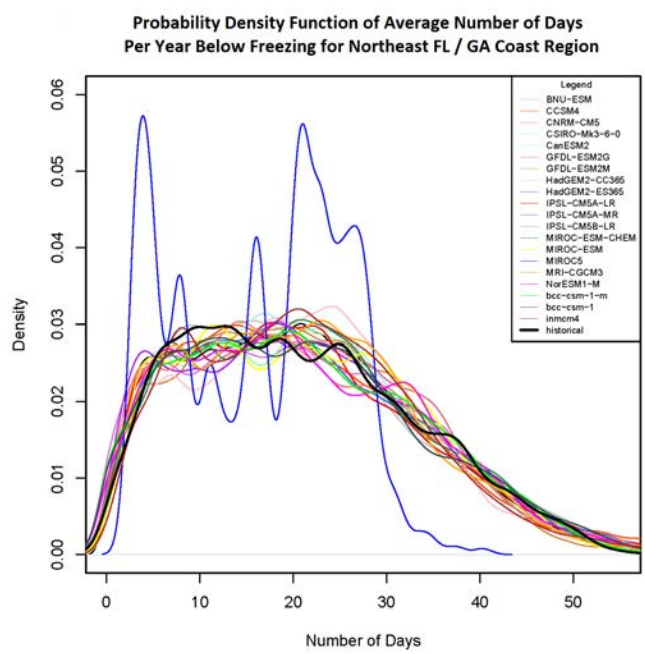
Collaborators: John Nielson-Gammon (TAMU).
Team: Rebecca Ward, Corey Davis, Jessica Miller, John McGuire, Aaron Sims, Ryan Boyles

Coastal Zone Fire Risk: A NIDIS-funded project allowed the SCO to investigate measures of drought and fire risk in the organic soils of eastern North Carolina. One potential risk indicator evaluated was a gridded Keetch-Byram Drought Index dataset developed using National Weather Service radar-based precipitation estimates and daily temperature data from PRISM and NWS Real-Time Mesoscale Analysis (RTMA). This gridded KBDI data, along with gridded precipitation data, gridded Standardized Precipitation Index data, and point-based Energy Release Component data, was compared with Estimated Smoldering Potential data from a suite of experimental coastal sensors. The results agreed with past findings that showed existing fire risk and drought indices, including the gridded KBDI data, are poor proxies for dryness in organic soils. Better and more extensive monitoring of soil moisture in this historically file-vulnerable coastal zone was suggested, and discussions since the project's completion indicate that new sensors have been or will be installed in at least one coastal location.



Team: Corey Davis and Rebecca Ward

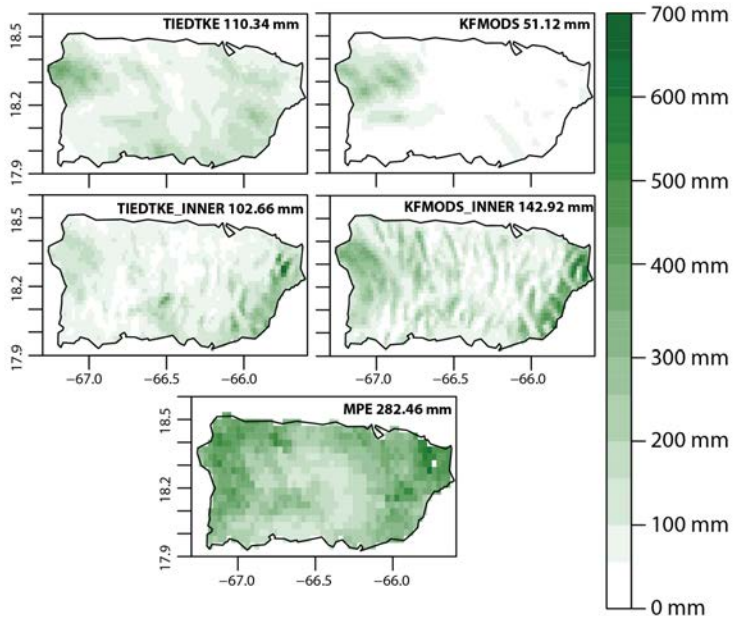
Investigation of error in the MACA downscaled climate model projections: During summer 2015, a preliminary study investigated the error associated with climate projections from 20 downscaled global climate models (GCMs). Probability density functions (PDFs) were created to show the frequency and distribution of the average number of days per year below freezing for the historical period using UofIdaho METDATA observations and for the 20 downscaled climate model baseline periods. For example, the PDF in the figure shown here tells us that most often, the average number of freezing days per year in Northeast FL/Georgia Coast is between 5 and 25 depending on which line you examine on the graph. The PDF can also be used to determine how well the climate model baseline data for all 20 downscaled GCMs (lines with various colors) matches up with what happened historically (black line). If they match up reasonably well, this gives confidence in the future model output. In this case, most of the GCMs show results similar to that of the historical dataset with the exception of the MIROC5 model, which is represented by the blue line. Maps of mean bias were also generated for the average number of days per year below freezing in order to examine spatial patterns in the error. While analysis for this summer project focused on the average



number of days per year below freezing, additional error metrics were generated during spring 2016 for all current tools found within the PINEMAP Decision Support System including minimum temperature thresholds, summer temperature, summer precipitation, summer dryness index, and dynamic hardiness zones.

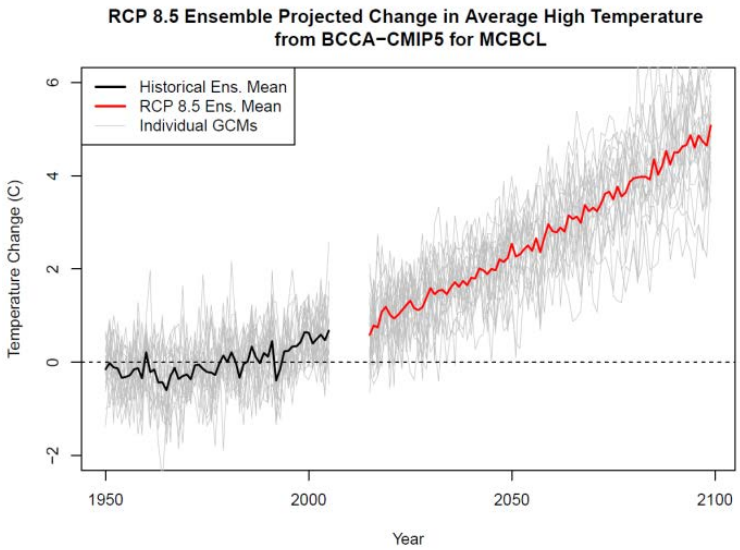
Team: Aurelia Baca, Heather Dinon Aldridge, Ryan Boyles

High-Resolution Projections of Climate Change in Puerto Rico: Ecosystem scientists are working to understand how climate can impact species distribution and habitat. In Puerto Rico, there is also a need for climate projections at a sufficient spatial resolution to assess ecosystem vulnerability. Working with USGS and the Department of Interior Southeast Climate Science Center, SCO is producing high-resolution projections for Puerto Rico with an emphasis on the needs of ecosystems scientists in the region. Production simulations began in early 2015 after an analysis of model sensitivities and accuracy based on the needs of ecosystem scientists in Puerto Rico. For instance, the rainfall pattern on the island is very complex, with dramatic differences over short distances due to the mountains in eastern Puerto Rico. This variation drives changes in the ecology across the island, from rainforest to dry forest. Our projections will help natural scientists understand how precipitation may change in the region and how these ecosystems may react to such changes. Production has been completed for projections using one regional climate model, and production is nearing completion with the other regional climate model being used by our partners at Florida State University.



Collaborators: Adam Terando (USGS SECSC), Jared Bowden (UNC-CH), Lydia Stefanova & Vasu Misra (FSU).
Team: Adrienne Wootten, Ryan Boyles

Defense Coastal / Estuarine Research Program (DCERP): In summer 2012, SCO joined a team of scientists headed by RTI International in the second phase of the Defense Coastal / Estuarine Research Program. As DCERP enters its third year, SCO has completed an assessment of the needs of the ecosystem models and research teams. Using the information gleaned from all team scientists, SCO 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. Progress is summarized below.



Historical Climate Dataset Evaluation: Three different gridded historical climate datasets were evaluated in this region for ecological modeling: the Parameter-elevation Relationships on Independent Slopes Model (PRISM), the University of Idaho Gridded Surface Meteorological Data (METDATA), and the Phase 2 North American Land Data Assimilation System (NLDAS-2). ECONet station observations are used for testing the consistency of the historical datasets. This study uses evaluation metrics, such as bias, probability distribution functions, and annual cycles to assess the historical climate datasets. The results show that temperature and precipitation estimates from the PRISM dataset are the most consistent with ECONet station data. In addition, the results also show the METDATA and NLDAS-2 are very similar in their consistency with the ECONet data for winds and solar radiation. These findings indicate that the PRISM dataset should be used for providing estimates of temperature and precipitation in eastern North Carolina, while the NLDAS-2 and the METDATA have comparable error for estimates of winds and solar radiation. METDATA was recommended for use and provided for the ecosystem modules as it was the most accurate and provided all the required variables for DCERP.

Downscaled Dataset Evaluation: Dynamic, empirical statistical, and constructed analogue-type downscaled global climate models (GCM) were evaluated based against a common gridded observation dataset (METDATA). 83 total models were evaluated on maximum temperature, minimum temperature, precipitation, and six different critical levels. These critical levels (e.g. number of days with temperature over 90°F) were determined by consulting the end users of these downscaled projections. Errors from this evaluation will be used in future steps of the project.

Projection Ensemble Creation: In order to gain a more robust interpretation of future climates, an ensemble of multiple climate models is often used to quantify uncertainty and is assumed to contain the true value of a future climate variables within the ensemble spread. Recent literature has questioned that assumption. True model independence cannot be assumed in an equally weighted ensemble of all GCMs. This may affect calculations of uncertainty. This analysis has yet to be applied to downscaled model ensembles. Downscaled models have added sources of dependence based on the downscaling methodology and training datasets used in statistical models. This study will evaluate downscaled model dependence across multiple GCM generations for both statistically and dynamically downscaled data products in eastern North Carolina. Cluster analysis and model correlation are used to assess model dependence both within a downscaled model ensemble, and across multiple downscaling methods. This project hopes to create a statistically viable ensemble of downscaled climate models across eastern North Carolina for use in several ecological modeling efforts. Future initiatives involve expanding this analysis to the Southeast CONUS.

Climate Projection Datasets for DCERP

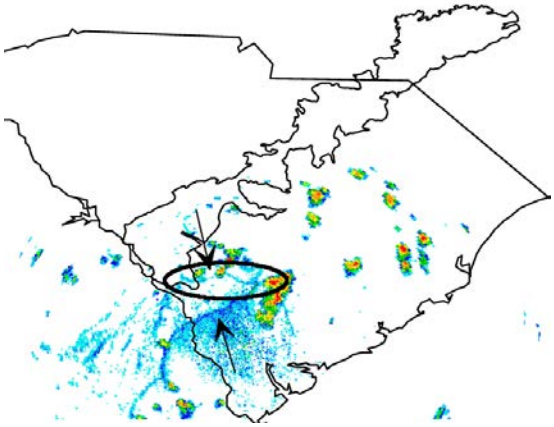
Data Set	Spatial Resolution	Downscaling Method	# of GCMs
BCCA-CMIP5	~12 km	Statistical	20
MACA	4 km	Statistical	19
CLAREnCE10	10 km	Dynamic	3
Hostetler	15 km	Dynamic	3
CCR-WICCI	11 km	Statistical	13
SERAP	12 km	Statistical	16

Team: Adrienne Wootten, Geneva Gray, Michael Brackett, Ryan Boyles

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. Current work and methodological development focus on Eastern North Carolina, but this will be eventually expanded to the Southeast United States.

Collaborators: Adam Terando (USGS SECSC), Brian Reich (NCSU Statistics).
Team: Adrienne Wootten, Ryan Boyles

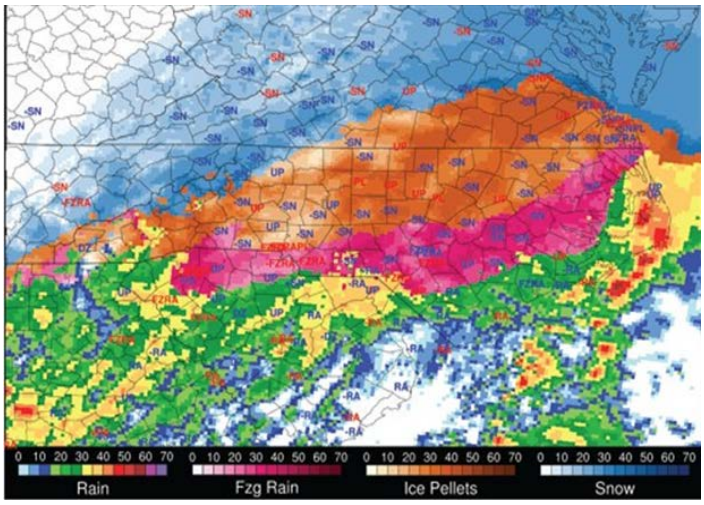
Interaction between Mesoscale Circulations during the Summer in the Coastal Carolinas: Remote sensing, in situ observations, and numerical guidance are used to evaluate locally driven mesoscale precipitation events in summer. Two land surface features in close proximity, the Sandhills and coastline, influence summertime precipitation development in the Coastal Carolinas. A convergence boundary forms along the Sandhills as a result of differential heating, providing a mechanism for triggering convection. This convection forms a shallow cool air mass that propagates as a density current toward the coast, called the Sandhills front. Nearby, the sea breeze circulation, also caused by the differential surface heating, develops along the coast and often migrates inland. The interaction of these two features, the sea breeze front and the Sandhills front, occurs regularly during summer months in the Carolinas. The convergence of these two fronts generate enhanced convection and precipitation in the Coastal Plain.



Base-level radar reflectivity indicating convergence (marked by the black arrows) of the sea breeze front and Sandhills front (circled).

Team: Aaron Sims

Precipitation Type Algorithms and Verification: Central North Carolina often falls within a transition zone of wintry precipitation types, including snow, ice pellets, freezing rain, and rain during winter storms. Predicting the types of precipitation (p-types) over the region can be challenging for these complex events. Two different precipitation type algorithms were evaluated: one using the temperature of warm nose and cold surface layer, and the other using partial thicknesses on the p-type nomogram developed by the National Weather Service. Gridded output from a numerical model (WRF) were used to evaluate the p-type algorithms. For this case, the warm nose temperature method verified better than the partial thicknesses. However, it is important remember that using several precipitation type classification methods and model parameters are useful in creating a forecast. These algorithms are planned to be incorporated into the real-time model at the State Climate Office.



Precipitation types over North Carolina for a winter storm on February 17, 2015.

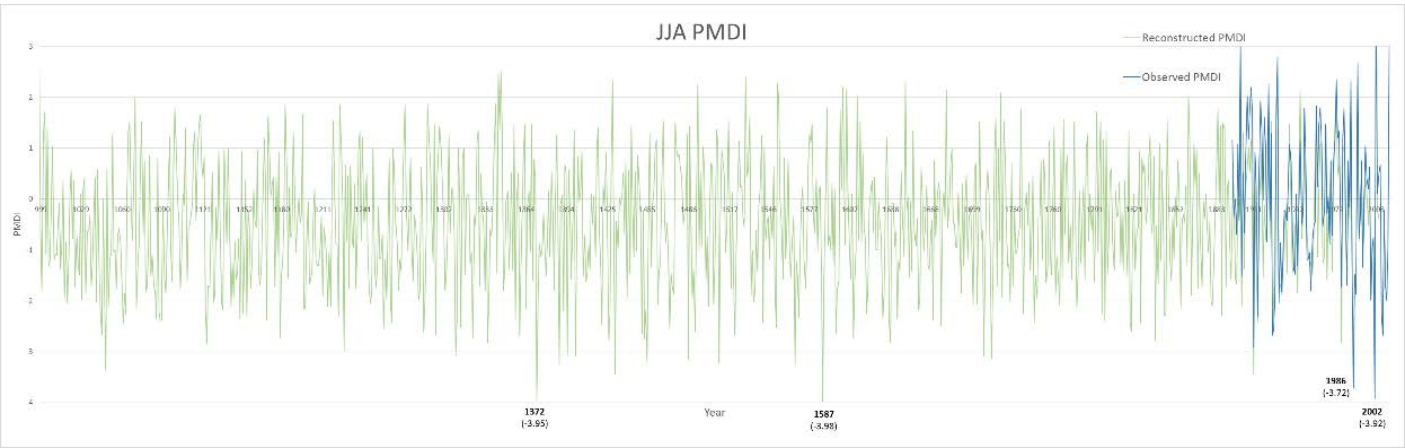
Team: Samuel Roback and Aaron Sims

Sensitivities of Mesoscale Circulations to modifications of numerical model cloud parameterizations: Prediction of the timing, locations, and amounts of convective precipitation is a difficult task, particularly in locally driven events during summer. Numerical models struggle to accurately represent these events. Modifications were made to a physics scheme in a numerical model (WRF) and how clouds are parameterized. This research indicates that utilizing these modifications helps add value to the forecasts at very high resolutions. Simulated cases indicate the skill and bias of the model is improved and the modifications help reduce the over-prediction of daytime precipitation during summer.

Team: Aaron Sims

Summer Drought through the Years: Recent drought events in North Carolina were compared to those over a time period from the year 365 to 2013, in order to determine changes in drought frequency and intensity. A time series of Palmer Modified Drought Index (PMDI) values, reconstructed from tree ring data, was standardized by observed PMDI values provided by the National Centers for Environmental Information (NCEI). These standardized values were analyzed to explore any long-term changes in drought intensity or frequency.

Based on the analysis, the highest magnitude drought occurred in 1587 and had a PMDI value of -3.98. It was also revealed that the longest period with consecutive summer droughts (PMDI <= -1) lasted from 683 – 690 AD. The number of consecutive summer droughts appeared to be decreasing through the period and the average area of North Carolina affected by drought has also been decreasing over the past thousand years. We also found a decline in variance between dry and wet periods. A frequency analysis determined that higher magnitude droughts are less frequent now than they were a thousand years ago, but lower magnitude droughts are slightly more frequent. Overall, drought intensity and frequency has declined over the period. Further work with this data will attempt to determine the forces behind the changes in drought.



Time series of PMDI reconstructed from tree ring data, overlaid with observed PMDI from NCEI

Team: Rachel Bobyak, Rebecca Ward, Heather Dinon Aldridge

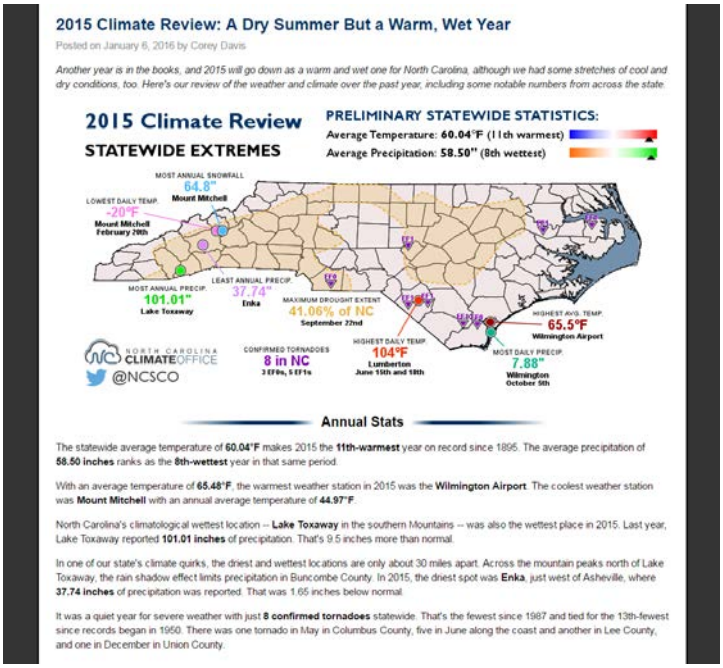
Educational Outreach

As North Carolina's primary statewide resource for informal climate education, outreach programming is a substantial focus for SCO staff and students with more than 32,000 direct educational outreach contact hours. We provide direct outreach for dozens of school and community groups; participate in large educational events, such as The NC Science & Technology Expo; and push a range climate news and information to the public via our blog and social media. We engaged NC teachers through the CoCoRaHS grassroots rainfall network.

Educational Outreach Highlights By the Numbers:

- *9 students research assistants trained and financially supported*
- *18 school groups hosted for outreach, and participated in 5 large community events including Aurora Fossil Festival, NCSU's Packapalooza, Citizen Science Day, and the Wilmington StormFest*
- *50 invited presentations to community groups*
- *250 new CoCoRaHS observers recruited*
- *57 Blog Posts with 67,448 views*
- *778 Twitter followers with 160,129 views*
- *32,067 direct educational outreach contact hours*

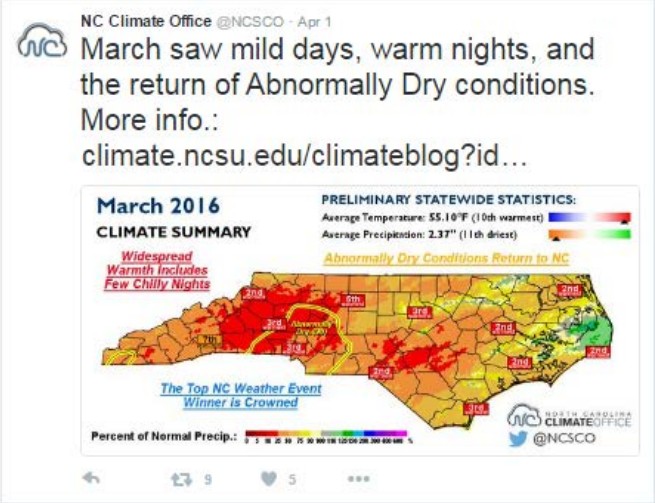
Public Scientific Communication



SCO Blog (*http://climate.ncsu.edu/climateblog*): The SCO's primary and most visible means of science communication is the Climate Blog, which was created in December 2012. Routine blog content includes monthly and seasonal climate summaries and outlooks, recent and historical event recaps, student-written posts about their research, and updates from the ECONet. In 2015, the Climate Blog featured the year-long NC Extremes series of posts about historical extreme weather events. This included an investigation into the state's all-time record high from Fayetteville in 1983, and it uncovered the original documentation about that event. From May 2015 to April 2016, 57 total posts received 67,448 views, averaging 1,183 views each. That marks a 17% increase over the previous 12-month period. A total of 603 individuals and group listservs receive email notifications when new blog posts are released. That is a 12% increase in the number of subscribers over the past year. Blog posts are also shared on Twitter and an RSS feed.

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

SCO Twitter: Our primary social media platform is Twitter @NCSCO where we post weekly content including blog posts, blurbs about recent weather, infographics, and updates from outreach events and weather station maintenance visits. In March 2016, we conducted our first March Madness tournament using Twitter's polling feature to survey our followers about North Carolina's most memorable weather event in the past year. The winner was the February 24, 2016, tornado outbreak. Our account has 778 followers – a 51% increase from May 2015 and a 304% increase from two years ago. From May 2015 to April 2016, we posted 166 original tweets, or an increase of 44% from the previous 12 months. These tweets received 160,129 views with 4,238 engagements, which includes link clicks, replies, retweets, and mentions by other accounts – a 77% increase from the previous year.



Media Interactions: Our blog posts, tweets, and data requests have provided additional opportunities to engage with media across the state. SCO scientists and expertise are routinely featured in newspapers and on radio and television news broadcasts. Notably, blog post content and agriculture-relevant weather updates are regularly included on the syndicated Southern Farm Network's radio program and website.

Bald Head Island Educational Program: SCO is working with local conservancy educators to implement a weather program designed for younger kids as they visit the Bald Head Island Conservancy. SCO 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

Last year we focused on developing more activities for office tours, large engagement events, and building partnerships with Raleigh institutions such as the NC Museum of Natural Sciences and Videri Chocolate Factory. Below are example activities from this effort.

The "CoCoRaHS Rain Gauge Game" is appropriate for all ages, and encourages visitors to use super-soakers and fill CoCoRaHS rain gauges while aiming at a hole in a plywood board painted as a thunderstorm. The hole is connected by pipe to a rain gauge. Visitors are encouraged to get as much water into the rain gauge and to compete with each other. After the competition is over, we teach the visitors how to read rain totals out of the CoCoRaHS gauges and give them information on how to participate in this valuable citizen science program.

"Sensing the Weather" is designed for all ages. Visitors play a matching game and attempt to match the picture of a weather sensor to the meteorological parameter it measures.

"The Wind Around Us" encourages young students to create paper pinwheels and head outside to measure the wind. SCO hosts demonstrate an ECONet propeller anemometer to show the students the difference between their device and what scientists use. This activity is intended for younger elementary students.

"Environmental Influences of the Built and Natural Environments" is intended for middle to high school students. Using handheld temperature and wind speed sensors, students are given a walking tour around Centennial Campus and must measure the temperature and wind speed at different locations. At the end of the tour, students come back together at the climate office and discuss trends and results from their data analysis.

Students (young and old) enjoying trying using super-soakers to fill up rain gauges.

Climate and Chocolate: During September 2015, SCO scientists partnered with Videri Chocolate Factory in downtown Raleigh to deliver an outreach program for 3rd graders from Durham Academy about how climate impacts the chocolate making process. As an example, students learned how the location of the cacao trees - the plant that is used to create chocolate - can influence the taste and smell of the chocolate due to differences in precipitation patterns. They also learned how the humidity level of the factory is an unanticipated yet necessary ingredient in the chocolate making process. This will hopefully be the first of many outreach collaborations that can demonstrate the connections between climate and various sectors in NC.

Team: Greg Deleruyelle, Rebecca Ward, Heather Dinon Aldridge, John McGuire, Geneva Gray, Sean Heuser, Ashley Hiatt with contributions from all staff and student.

Chowan County Green Fair: Hosted by the Chowan Edenton Environmental Group in Edenton, NC in March 2016, the Chowan County Green Fair brings together master gardeners, the local community, the state division of water resources, and others to host an educational event for the community. The event draws numerous visitors from Chowan and other surrounding counties to promote and educate on environmental awareness. The event is held every other year in Chowan County and the SCO had a booth at the event discussing the weather and climate of the area with the community.

Collaborators: Colleen Karl (Chowan Edenton Environmental Group)
Team: Adrienne Wootten and Rachel Bobyak

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. We led the establishment of CoCoRaHS in North Carolina in 2007 and over the past year, we have worked to recruit new volunteers for the program, especially encouraging participation from local schools and areas with data gaps. Our recruiting efforts include:

- introduction to CoCoRaHS during our invited presentations and visitor programs including a guessing game using the CoCoRaHS gauge
- agreement with more than five local NC schools to provide a rain gauge in exchange for their observational commitment, reporting as often as possible
- engagement with many new County Coordinators and other volunteers interested in the program
- creation of a CoCoRaHS Rain Game where participants race each other to fill up a CoCoRaHS rain gauge and then perform a precipitation reading with some training by SCO scientists
- blog post series on CoCoRaHS during March Madness highlighting how CoCoRaHS data is used and the value of the reports including:
    - some of the meteorological applications of CoCoRaHS data -- *http://climate.ncsu.edu/climateblog?id=182* and
    - how CoCoRaHS data is used for condition monitoring and for agricultural purposes -- *http://climate.ncsu.edu/climateblog?id=185.*

Weekly creek pictures submitted by an NC CoCoRaHS observer. Image courtesy of Carolina's CoCoRaHS blog

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, we helped recruit 250 new observers – 105 of which signed up during March Madness.

Collaborators: David Glenn, National Weather Service and the national CoCoRaHS program at Colorado St. U.
Team: Heather Dinon Aldridge and Rebecca Ward with contributions from all SCO staff and students

Environmental Statistics Practicum Course – Mentoring Undergraduate Students in Analysis / Applications of Climate Data: The Environmental Statistics Practicum course in the NCSU Department of Statistics offers an opportunity to train interdisciplinary undergraduate students to analyze environmental data. Students answer real world questions and gain professional skills. Each student team works with a client to gather the data and answer questions posed by the clients. Since the 2013-2014 academic year, the SCO has been serving as one of the clients for this course. For those students working with the SCO, the students receive guidance about the data itself, but perform their analysis independently. The course offers the opportunity for the students to work through the entire process of analysis, from gathering data to presenting their results for a general audience. The presentations themselves are given to the SCO, which offers a medium to provide constructive feedback for the students and at the undergraduate research symposia in North Carolina. This SCO partnership with the instructor, Dr. Brian Eder, allows students the opportunity to work on real world analysis and learn how weather

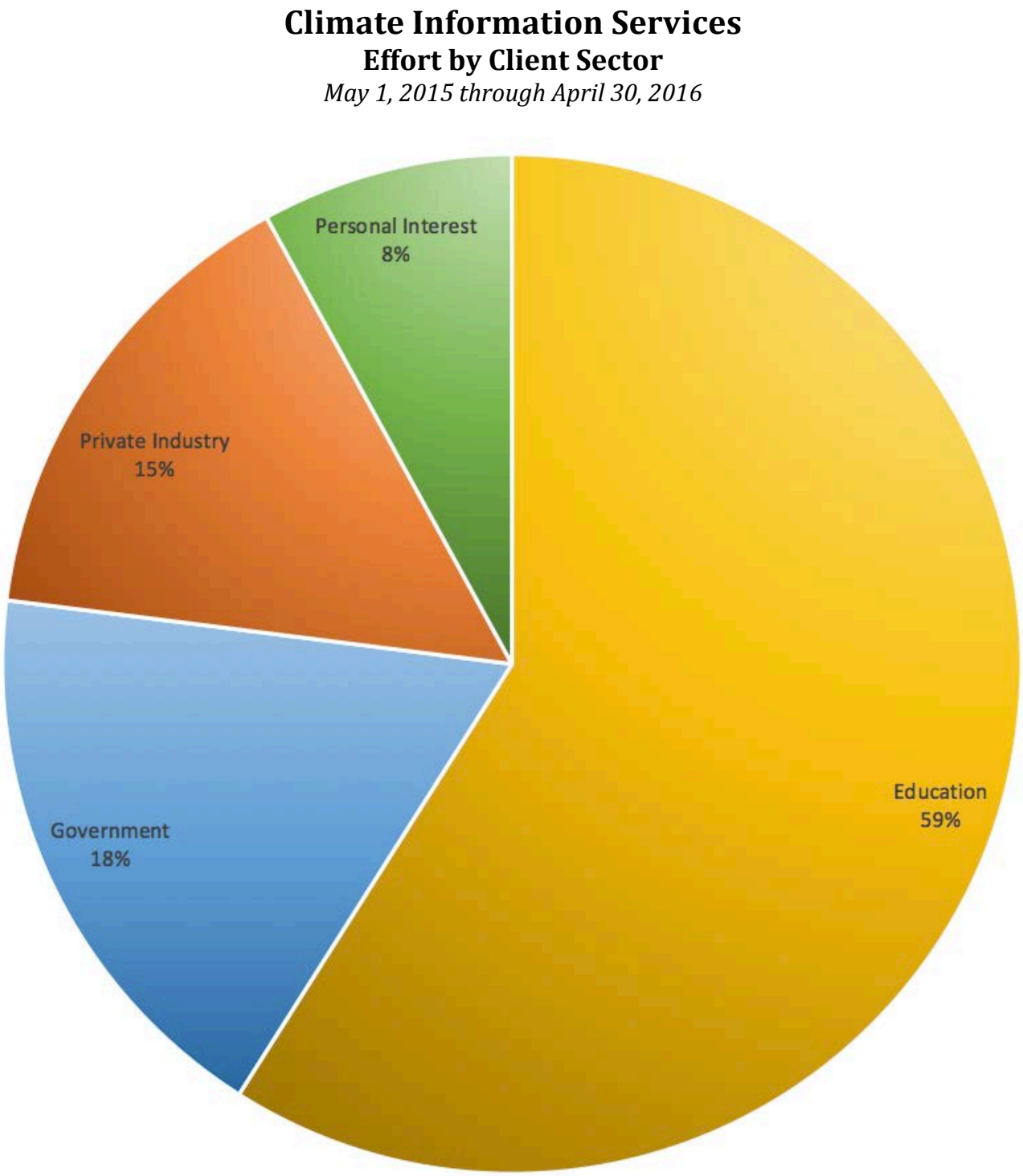
and climate impact multiple sectors in North Carolina. This year the course transitioned to being offered in the Spring semester only. Student projects for the SCO in the 2015-2016 academic year include the following:

- What's the difference between Rain Gauge Sensors? A comparison of tipping bucket and impact sensor precipitation gauges in the NC ECONet.
- Exploring the relationships between soil temperatures, soil type, and different ground cover across North Carolina.

For these two projects, the SCO served a client for 6 students (3 in each project), while clients at the U.S. EPA worked with the other 6 students in the class this year.

Team: Adrienne Wootten with contributions from all SCO staff and graduate students

Appendix A: Climate Services by Client Sector



Climate Information Services by Client Sector – Details

May 1, 2015 through April 30, 2016

Classification	Number of Requests	Hours Worked
Government: Federal-Agriculture	8	8
Government: Federal-Energy	1	1
Government: Federal-Engineering	2	2
Government: Federal-Other	17	17
Government: Local-Education: college, university	3	3
Government: Local-Education: K-12	8	8
Government: Local-Health	1	1
Government: Local-Other	7	7
Government: Local-Water	6	6
Government: State-Agriculture	4	4
Government: State-Construction	3	3
Government: State-Education: college, university	234	243
Government: State-Health	2	2
Government: State-Legal/insurance	1	1
Government: State-Other	23	25
Government: State-Water	3	3
NGO-Tourism/recreation	3	3
Private entity-Agriculture	8	21
Private entity-Construction	5	5
Private entity-Education: college, university	12	13
Private entity-Education: K-12	1	1
Private entity-Engineering	17	18
Private entity-Legal/insurance	5	6
Private entity-Media	12	12
Private entity-Other	18	20
Private entity-Personal interest	33	35
Private entity-Water	1	1
Totals	***438***	***469***
Percent Change from Previous Year	***+6.1%***	***+8.1%***

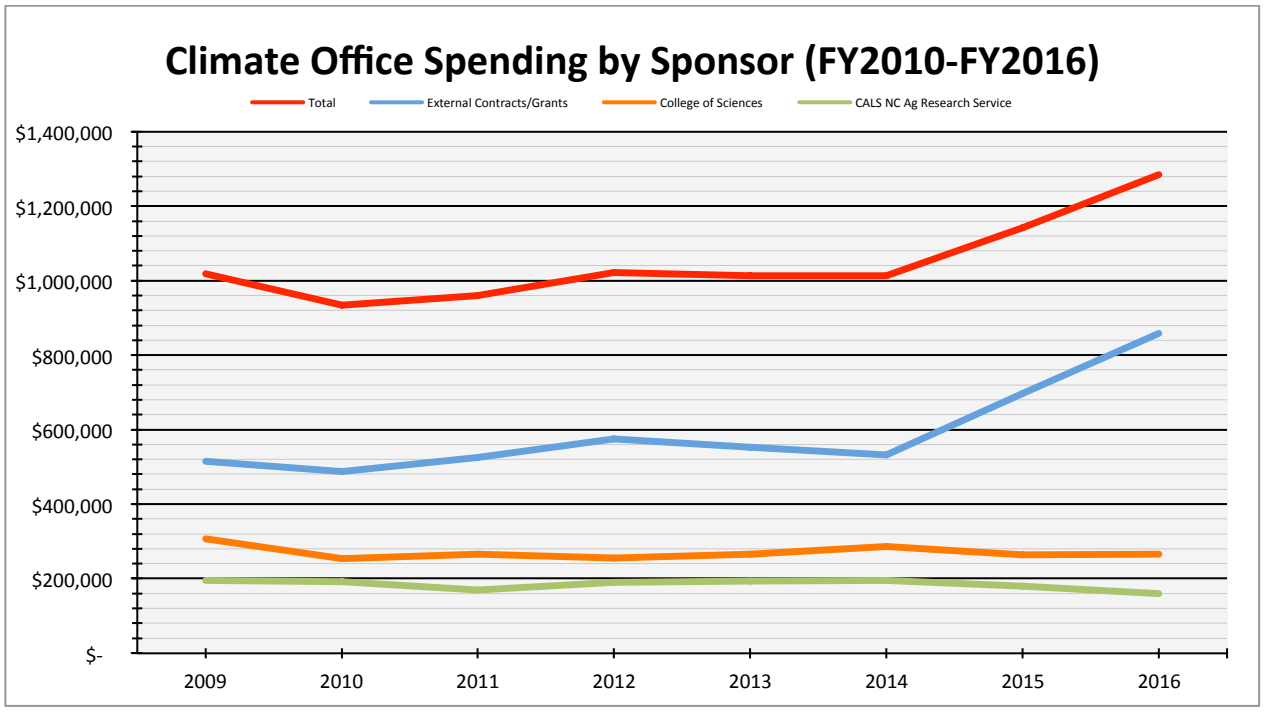
Appendix B: Simplified Budget

FY2016 Proposed Budget (from May 2015 Annual Report)

Source	Personnel	Operating Expenses	Total	Percent
College of Sciences	$269,484	$30,000	$299,484	26%
NC Agriculture Research Service	$135,790	$17,719	$153,509	13%
External Contracts & Grants	$579,007	$115,287	$694,294	60%
Service Center		$15,000	$15,000	1%
Total	**$984,282**	**$178,006**	**$1,162,288**	

FY2016 Expenditures (through May 26, 2016)

Source	Personnel	Operating Expenses	Total	Percent
College of Sciences	$196,633	$69,370	$266,003	21%
NC Agriculture Research Service	$115,664	$44,549	$160,213	12%
External Contracts & Grants	$637,865	$215,299	$853,164	66%
Service Center	$0	$5201	$5201	1%
Total	**$950,162**	**$334,419**	**$1,284,581**	



Appendix C: Impact Statement

State Climate Office of North Carolina

NC State University

The Need

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 (SCO) is a public-service center for climate-environment interactions in North Carolina. The SCO is housed at NC State University in the College of Physical and Mathematical Sciences with support from the NC Agricultural Research Service. The SCO 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:

- Operate and collect high-resolution weather data from a growing network of 38 research quality weather stations called the Environment and Climate Observing Network (ECONet).
- Disseminate climate information to the citizens and businesses of North Carolina through the CRONOS database, an intuitive website making climate data available from over 20,000 surface weather and water resource stations in and around North Carolina.
- Assist state government agencies in climate adaptation activities that reduce costs and conserve resources.
- Collaborate with extension scientists to provide agricultural guidance to growers for disease management and irrigation, which lead to crop loss mitigation and better production decisions. Drought monitoring and management at community, statewide, and national scales.
- Study climate variations and impacts on North Carolina, including sensor and model evaluation, severe weather patterns, drought and water resource management, and economic impacts.
- Numerous community presentations, science fairs, and other interactions with K-12, college students and teachers.

Impact beyond North Carolina

Undergraduate and graduate students working at the SCO gain a genuinely multi-disciplinary experience that contributes to career growth and lifelong learning. Many successes of the SCO are often heralded as a model for other states' climate offices.

Appendix D: Index of Terms and Acronyms

ACIS - Applied Climate Information System
AHPS - Advanced Hydrologic Prediction Service
APHIS - Animal and Plant Health Inspection Service
API - Application Program Interface
CIPM - Center for Integrated Pest Management
CoCoRaHS - Community Collaborative Rain, Hail, and Snow Network
CONUS - Continental United States
COOP - Cooperative Observer Network
CPO - Climate Program Office
CRONOS - North Carolina Climate Retrieval and Observations Network of the Southeast Database
CVS - comma-separated values
DB - database
DCERP - Defense Coastal/Estuarine Research Program
DSS - Decision Support System
DENR - North Carolina Department of Environment and Natural Resources
ECONet - Environment and Climate Observing Network
ED - Emergency Department
FSU - Florida State University
GCM - Global Climate Model/General Circulation Model
GIS - Geographic Information System
HHVT - Heat Health Vulnerability Tool
HUC - Hydrological Unit
IPM - Integrated Pest Management
JSON - JavaScript Object Notation
KBDI - Keetch-Byram Drought Index
LIS - Land Information System
MACA - Multivariate Adaptive Constructed Analogs
MADIS- Meteorological Assimilation Data Ingest System
MEAS - NCSU Department of Marine, Earth, and Atmospheric Sciences
METDATA - University of Idaho Gridded Surface Meteorological Data
NASA - National Aeronautics and Space Administration
NC DOT - North Carolina Department of Transportation
NIDIS - National Integrated Drought Information System
NIFA - National Institute of Food and Agriculture
NLDAS-2 - North American Land Data Assimilation System-Phase 2
NOAA - National Oceanic and Atmospheric Administration
PDF - Probability Distribution Function
PINEMAP - Pine Integrated Network: Education, Mitigation, and Adaptation Project
PRISM - Parameter-elevation Relationships on Independent Slopes Model
QAQC - Quality Assurance Quality Control
QC - Quality Control
RAWS- Remote Automated Weather Stations
RTI - Research Triangle Institute

RTMA - Real-Time Mesoscale Analysis
SAFARIS - Spatial Analytic Framework for Advanced Risk Information Systems
SCO - State Climate Office
SERCC - Southeast Regional Climate Center
SPEI - Standardized Precipitation Evapotranspiration Index
SPI - Standardized Precipitation Index
TAMU - Texas A&M University
USDA - United States Department of Agriculture
USGS - United States Geological Survey
WRF - Weather Research and Forecasting Model
WRRI - Water Resources Research Institute