CITIZEN SCIENCE CONDITION MONITORING

Phase 3: January 2018 through August 2020

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RISA Regional Integrated Sciences and Assessments

CISA A NOAA RISA TEAM

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Executive Summary

The Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network is a well-regarded, trusted source of precipitation data. In addition to their daily precipitation measurements, CoCoRaHS volunteers also provide weather and climate observations through weekly Condition Monitoring reports which describe how recent weather conditions affect local environmental, social, and economic systems. The Condition Monitoring program was created and piloted in the Carolinas by the Carolinas Integrated Sciences & Assessments (CISA) team to meet a need for local information about drought events and associated impacts. In contrast to drought impact reports, submitted only when notable changes caused by a lack of precipitation are observed, Condition Monitoring reports describe normal conditions and changes during periods of less or more rainfall, to create a baseline for comparison over time. This process provides more information about the onset, intensification, and recovery of drought impacts in contrast to traditional drought impacts reporting.

Phase 3 of the program (January 2018 to August 2020), outlined in this report, built on the successes of the previous phases. The project team created additional resources for CoCoRaHS volunteers and drought decision makers and explored the wealth of information provided by the 447 observers in North Carolina and South Carolina. These observers have submitted over 7,000 Condition Monitoring reports since October 2016.

Recommendations for Future Work

Encourage consistent (weekly to biweekly) Condition Monitoring reporting.

- Consistent reporting remains a key component of Condition Monitoring. For drought events and impacts, consistent reporting helps to improve understanding and identification of onset, intensification, and recovery. During wetter periods, consistent observations capture antecedent wet conditions that can lead to more extensive flooding during thunderstorms, tropical storms, or hurricanes.

Develop new and update existing instructional resources to educate observers about what types of information to submit in the different CoCoRaHS reports and how the information is used.

- Findings suggest that consistent Condition Monitoring may not be as important when reporting on the direct impacts of other severe weather events, such as hurricanes or winter weather. Additionally, for some events, CoCoRaHS Significant Weather reports may be a more appropriate place for observers to submit their observations instead of a Condition Monitoring report. Regular reminders about what to report in Condition Monitoring reports, versus other reports, might be helpful for some volunteers.
- While agencies are generally interested in whatever information the observers provide, guidance that clarifies and details the most useful types of information will help volunteers submit more usable content. The "Helpful Reporting Hints" document is a start; some volunteers may benefit from, or be interested in, more explicit instructions, as in a training slideshow.

Engage with decision makers about the wealth of information contained in Condition Monitoring reports and how that information is or could be applied.

- Condition Monitoring reports are used by a variety of agencies for drought monitoring, which is a notable accomplishment for this project. However, the reports seem to be underutilized for other purposes. Identifying and documenting a variety of applications may motivate other agencies and users to explore the reports. Obtaining agency feedback about how they use the reports, or what content they would like to see in the reports, can then be communicated to observers and used to continually improve the Condition Monitoring program.

Phase 3 Accomplishments

Project Components	Accomplishments and Deliverables
Support for the National Condition Monitoring Program	
Invest in Technological Improvements to Enhance Report Access and Use	• Created the "consistent stations" layer for the Condition Monitoring web map to allow users to easily view reports from observers who submit regularly • Increased web map functionality with improved search features for report content and observer locations and an enhanced time slider • Circulated information about web map enhancements to the volunteer network and drought decision makers
Develop and Produce Regional Condition Monitoring Guidance Documents	• Developed regional guidance documents for six regions within the continental U.S. as well as Alaska, Hawaii, and Puerto Rico and the U.S. Virgin Islands, for which a Spanish language version is also available • Created communications and outreach materials to support dissemination of the guidance documents to regional CoCoRaHS coordinators and the national network of volunteers
Support for Condition Monitoring in the Carolinas	
Promote Consistent Monitoring and Observer Recognition	• Produced the monthly CoCoRaHS Condition Monitoring in the Carolinas newsletter for over 2,000 volunteers in NC and SC • Recognized individual observers through the monthly "Observer Spotlight" in the newsletter • Recognized consistent observers (at least 20 reports submitted in the past 12 months) from April 2019 to April 2020 • Issued certificates of appreciation to 26 NC and SC volunteers who consistently submitted Condition Monitoring reports for a full year (April 2019-April 2020)
Explore New Applications for Condition Monitoring Reports	• Analyzed weather and climate reports from four agencies in the Carolinas and Condition Monitoring report content to assess how Condition Monitoring reports might serve to inform agency activities and responsibilities • Conducted webinars and an online survey to gather feedback from agency representatives • Developed the Helpful Reporting Hints infographic to further support CoCoRaHS observers in providing weather and climate observations • Created the "More than Drought: Condition Monitoring for All Types of Weather" story map to disseminate project findings

Introduction

Project History (2013-2017)

The Citizen Science Condition Monitoring project was created and piloted (2013-2017) in the Carolinas by the Carolinas Integrated Sciences & Assessments (CISA) team. Born out of stakeholder needs for more on-the-ground information about the societal and environmental impacts of drought, the program was designed to address drought impact monitoring needs, inform broader efforts to develop more effective approaches to drought monitoring, and facilitate the integration of impacts information into decision making. The project team utilized existing tools developed by the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network to pilot a new method of drought impacts reporting. Unlike drought impact reports, which are often submitted only once drought conditions become severe, Condition Monitoring documents the evolution of impacts over time by asking volunteers to submit weekly reports that describe how recent weather conditions affected environmental, social, and economic systems in their communities. This process provides more information about the onset, intensification, and recovery of drought in contrast to more traditional, "one off", drought impacts reporting.

CISA initiated the Carolinas Condition Monitoring project in September 2013. Working with CoCoRaHS headquarters, the team recruited a group of volunteers in North Carolina and South Carolina to submit weekly to bi-weekly reports about how the precipitation they had, or had not, received affected their local environment and community. Volunteers submit their reports through the CoCoRaHS website where they are publicly available. Feedback interviews with those responsible for drought designations in the Carolinas and via the US Drought Monitor map indicated that information in the reports was useful for their decision making process, but could be improved through increased accessibility.

Following the success of the Carolinas pilot, CISA worked with CoCoRaHS headquarters to expand the effort to a national program. Building on findings from the pilot program evaluation, several new resources were developed to improve the reporting process, training for observers, and accessibility of reports for the end user. This included the "Condition Monitoring scale bar" which provides a quantitative metric for reporting, the "Condition Monitoring web map" to improve usability of the reports, online summary report charts to help capture changing conditions over time, and communications and training materials, including a training animation, to promote volunteer participation.

Phase 3 (2018-2020)

During Phase 3 of the project (January 2018 - August 2020), the CISA team improved access to the reports for end users, developed additional training materials for volunteers throughout the U.S., maintained communications and outreach with Carolinas CoCoRaHS observers, and explored new applications for report information. This report details these final efforts of the CISA team to continue to improve the Condition Monitoring program and ensure it remains a viable means of documenting the occurrence of drought conditions across the country and the effects of this highly impactful phenomenon to our environment and society.

Project Timeline

Activities		2012	2013	2014	2015	2016	2017	2018	2019	2020
Scoping	Coastal Carolinas DEWS Stakeholder Workshop									
	Drought Impacts Monitoring Workshop; "The Missing Piece Report"									
Tool and Resource Development	"Condition Monitoring" checkbox added to CoCoRaHS Drought Impact Report Form									
	Scale Bar Development and Report Revisions									
	Condition Monitoring Web Map									
	"Consistent Stations" Layer and other web map updates									
Volunteer Engagement	Pilot Project Education and Training Materials									
	Volunteer Recruitment and Trainings									
	Communications: Newsletter, Blog, Conference Calls									
	Training Animation									
	Volunteer Feedback Surveys									
	Regional Guidance Documents									
	Helpful Reporting Hints Infographic									
Condition Monitoring Report Analysis	Report Coding and Analysis									
	Scale Bar Analysis									
	Report Content and Case Study Analysis									
	Comparative Analysis of Agency and Condition Monitoring Reports									
Decision Maker Feedback	Communications and Outreach									
	Feedback Webinars, Interviews, and Online Surveys									

CoCoRaHS Condition Monitoring Observers

From October 2016 through August 2020, 5,109 observers across the United States submitted 63,241 Condition Monitoring reports. Of these reports, 7,559 (~12% of the total) were submitted by 447 observers (~9% of the total) in North Carolina and South Carolina.

Table 1: Condition Monitoring observers and reports, October 2016 - August 2020

	# of Observers	# of Reports
All CoCoRaHS Observers	5,109	63,204
North Carolina	287	5,200
South Carolina	160	2,359

Figure 1 shows the locations of the CoCoRaHS observers in the Carolinas who submitted Condition Monitoring reports during this time period. A majority of the participants (374 observers, 84% of the total) contributed fewer than 20 reports per participant, accounting for 1,235 reports (16% of the total). The remaining reports (6,324) were submitted by 73 observers. Of these, 54 observers reported consistently, i.e., they submitted at least 20 reports over any given calendar year (Table 2). Almost half of these 54 observers reported for at least 3 years. Eighteen of them reported throughout the entire time period, accounting for 2,972 reports, or 39% of the total reports submitted from the Carolinas.

Table 2: Number of observers who submitted at least 20 reports per calendar year, from 2017-2020.

	2017		2018		2019		2020	
	# of Observers	Report Total	# of Observers	Report Total	# of Observers	Report Total	# of Observers	Report Total
NC	29	1,010	20	791	23	1,006	22	685
SC	8	337	9	380	13	528	11	320
Total	37	1,438	29	1,171	36	1,534	33	1,005

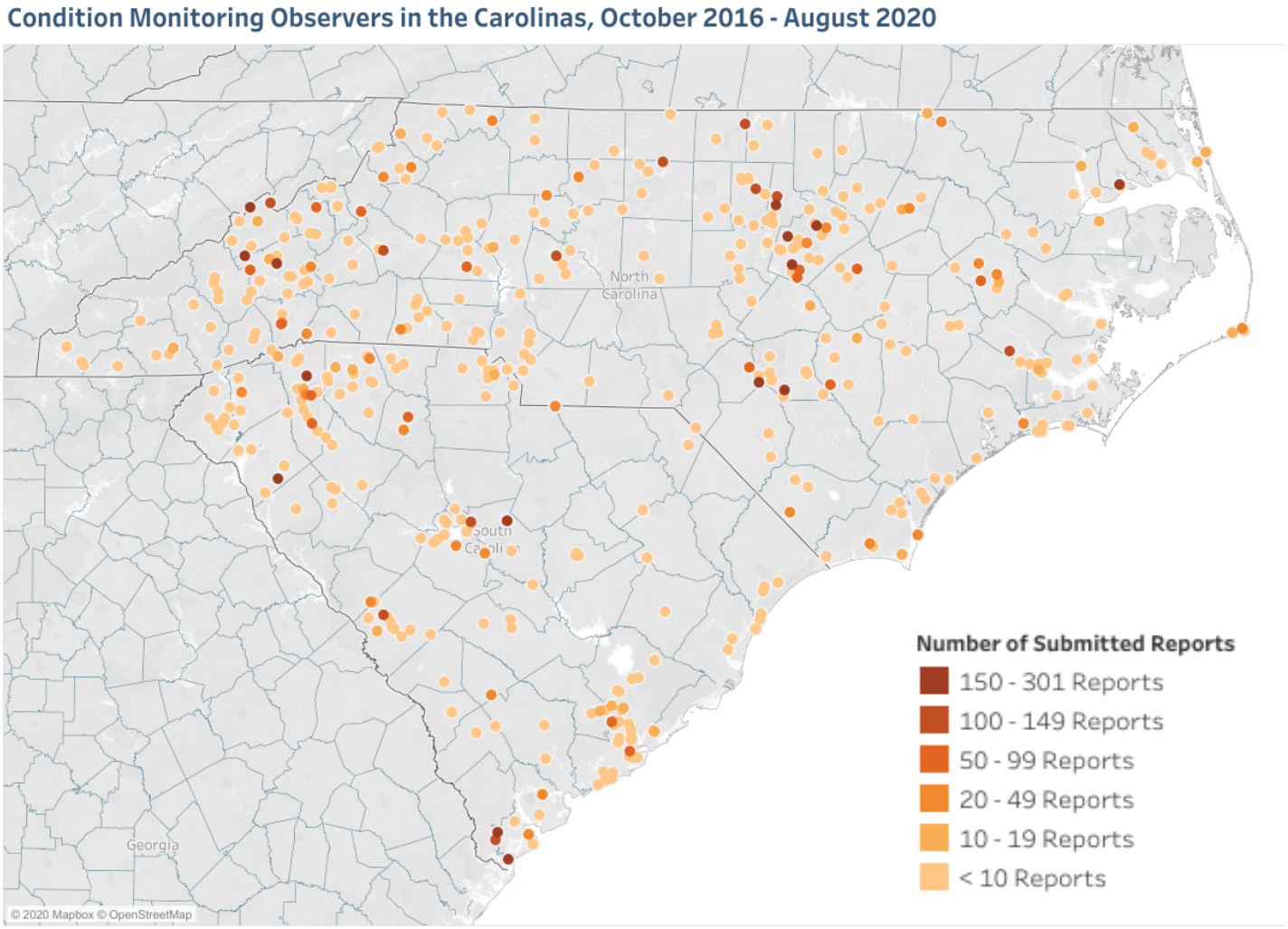


Figure 1: Locations of CoCoRaHS observers who submitted Condition Monitoring reports, October 2016 - August 2020. Colors indicate the number of reports submitted by the observer. View an interactive version of the map here.

Figure 2 (below) shows the number of reports submitted each month (right y-axis). The average number of Condition Monitoring reports submitted per month equaled 161. Report submissions ranged from a high of 260 (November 2016) to a low of 92 (October 2018, January 2019). In general, reporting peaks coincided with dry or drought periods, shown by the percentage of land area designated as D0-D4 by the US Drought Monitor (left y-axis). Examples include Fall 2016 and Fall 2017 and the flash drought events of Spring and Fall 2019. This is not unsurprising, given that "Condition Monitoring" was initially developed and promoted to inform drought monitoring and related decision making processes.

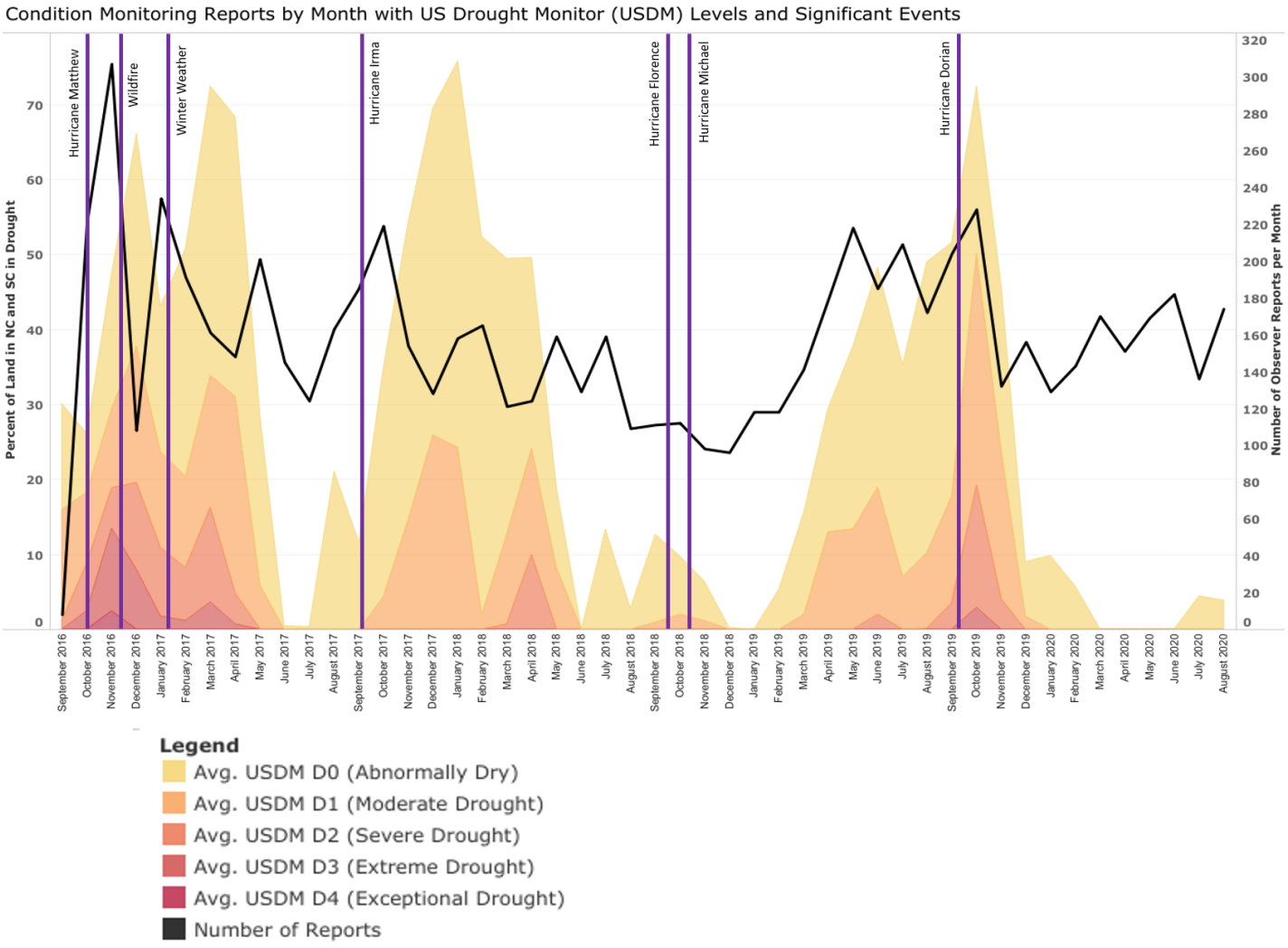


Figure 2: This graphic represents the number of Condition Monitoring reports submitted in the Carolinas from October 2016 to August 2020 in conjunction with information about major weather and climate events. The black line represents the number of Condition Monitoring reports (right y-axis). The percentage of the Carolinas' land area in drought status (left y-axis) is depicted by the US Drought Monitor drought intensity levels (shown in legend). Other significant weather events are labeled and identified by the purple vertical lines.

Data Source: US Drought Monitor https://droughtmonitor.unl.edu/Data/DataDownload.aspx

Support for National Condition Monitoring

Technological Improvements to Enhance Report Access and Use

Motivation

Feedback from decision makers regarding the Condition Monitoring web map was very positive during the Phase 2 evaluation. Report users noted that it is very useful in identifying areas that might need more investigation based on an observer's scale bar selection represented on the map. During Phase 3, CISA made improvements to the web map based on decision maker recommendations during the Phase 2 evaluation.

Activities

A "Consistent Stations" layer was added to the Condition Monitoring web map, which filters reports to display only those from observers who have submitted at least 20 reports in the last twelve months (about once every two weeks). The layer allows users to view consistent stations on a rolling basis, based on the week selected. The expectation is that these observers may be better able to document change over time because they monitor their local environment on a more regular basis. Because these observers consistently submit reports about local conditions, web map users gain a better understanding of the timescale of these changes by referring to observers' regular reports.

Other functionality improvements included:

- Updates to the geolocation features for the location search to make finding a specific station easier.
- Improvements to the search options to allow map viewers to search specific reports in the current map view. This allows users to easily filter specific types of information such as soil moisture levels, fire risk, or to view reports from a specific station.
- Improvements to the time slider function to allow users to view reports from any desired day since the launch of the national web map in October 2016.

Accomplishments and Final Deliverables

These updates were launched in December 2018. CoCoRaHS maintains the web map, which is accessible via their website at: https://www.cocorahs.org/Maps/conditionmonitoring/. Information about these updated map features was distributed to our list of decision makers via e-mail and an informational flyer in February 2019.

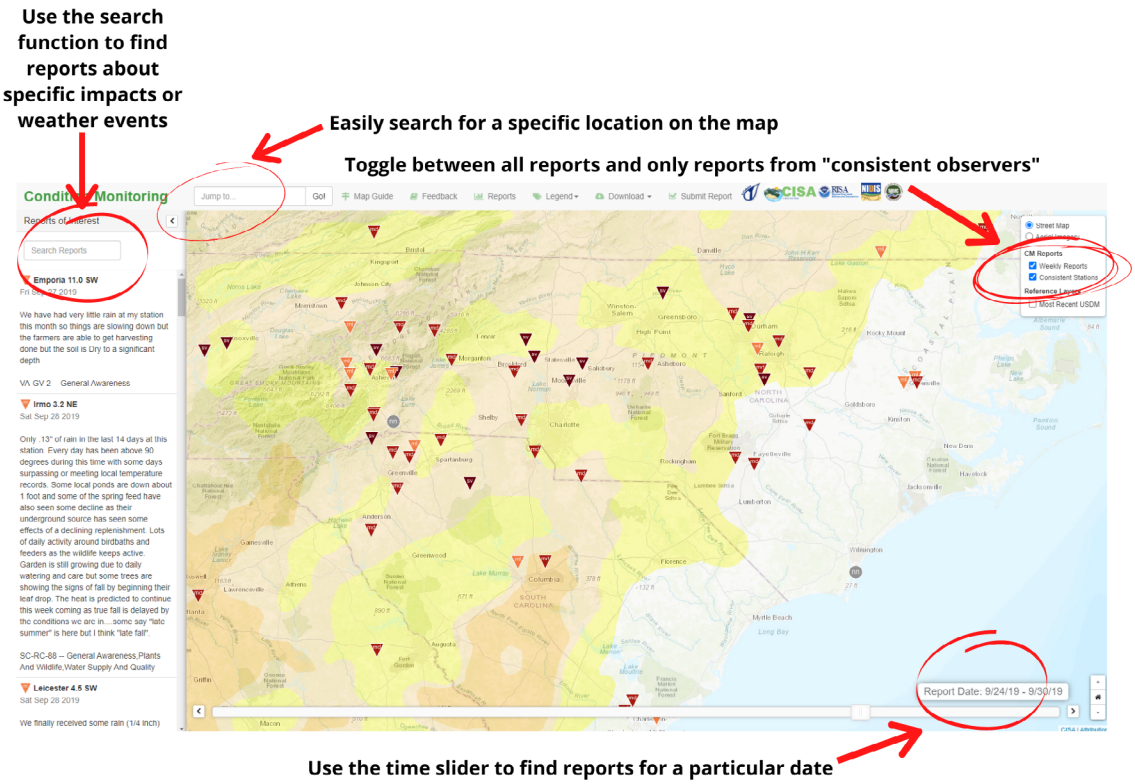


Figure 3: Several improvements were made to the functionality and features on the Condition Monitoring web map based on decision maker feedback during the Phase 2 evaluation.

Develop and Produce Regional Guidance for Condition Monitoring

Motivation

During the Phase 2 evaluation, both observers and report users asked how to account for regional variations in dry or wet conditions when observers throughout the U.S. use the same seven-point Condition Monitoring scale bar. For example, what is considered dry would be very different in the arid Southwest versus the more temperate Southeast. Moreover, even within a given region such as the Southeast, dry conditions can vary greatly from the mountains to the coast. Seasonal changes can also have a significant impact. How to account for temporal aspects in the guidance was also raised. In order to address these concerns, regionally specific guidance was developed to demystify the process of qualitative observation and provide CoCoRaHS members with a sense of direction for their particular region in the country.

Activities

CISA developed regional Condition Monitoring guidance documents for six regions within the continental U.S. as well as guidance for Alaska, Hawaii, and Puerto Rico/US Virgin Islands. The Puerto Rico/US Virgin Islands guidance document was translated to Spanish to improve accessibility for CoCoRaHS observers in this region. Each guidance document includes:

- Summary climate information including mean annual precipitation for the region and temperature and precipitation climographs for representative cities (Figure 4)
- Reporting reminders that encourage observers to compare current conditions to climate normals for the region and to think long-term to assess seasonal change or trends
- Guidance on selecting a representative wet, dry, or normal category from the Condition Monitoring scale bar
- Examples of different types of wet and dry impacts drawn from previously submitted reports and the National Drought Mitigation Center's Drought Impact Reporter

Through tailored suggestions and baseline information, differences in climate and geography are better accounted for, making information from across locations easier to evaluate and compare for report users. Appendix A provides additional detail about the development of the regional guidance documents.

Accomplishments and Final Deliverables

The final guidance documents are available via the Condition Monitoring webpage on the CoCoRaHS website (https://www.cocorahs.org/Content.aspx?page=condition). CISA developed an editable PowerPoint version of the documents which was sent to CoCoRaHS regional coordinators to allow them to customize the guidance further to their specific locations (e.g., state level). CISA also drafted outreach materials for CoCoRaHS observers to include "Messages of the Day," language for the CoCoRaHS director's monthly e-mail, and social media messaging. CoCoRaHS personnel shared these products with their coordinators and volunteers.

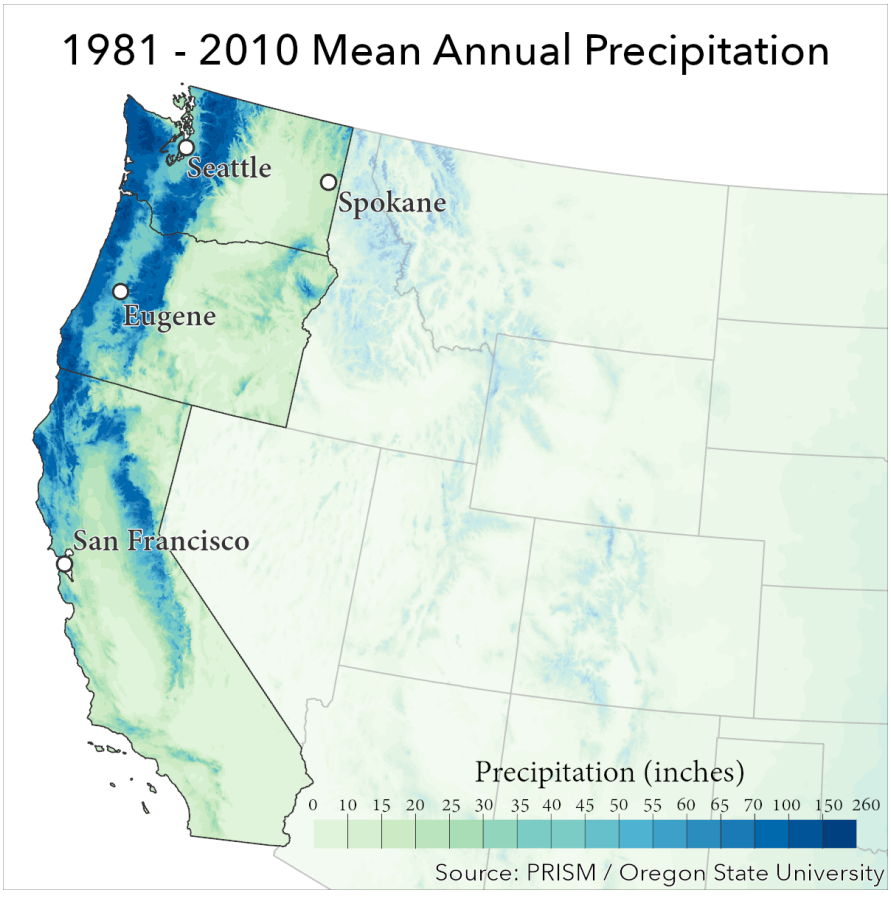


Figure 4: This map of mean annual precipitation is included in the Regional Guidance document for the Pacific Northwest. An image of the full Regional Guidance document is available in Appendix A.

Support for Condition Monitoring in the Carolinas

Promote Consistent Reporting and Recognizing Observers

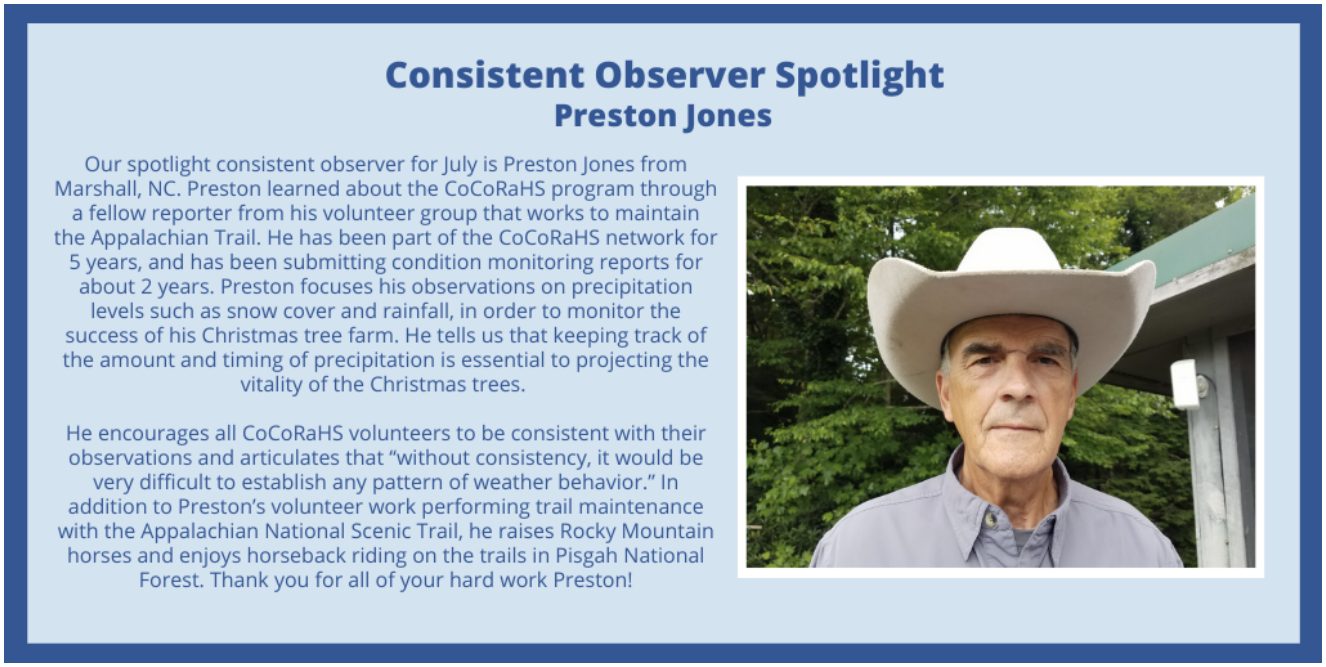
Motivation

Volunteer engagement has been integral to the success of the Condition Monitoring program. In feedback surveys conducted in Phases 1 and 2, observers repeatedly indicated that regular communications, education and training materials, and opportunities to learn about other volunteers helped to empower them and foster their sense of community. Through outreach and communications efforts, information is provided to volunteers about how their reports are utilized by decision makers, another key motivation for participants.

Activities

CISA began producing monthly newsletters to CoCoRaHS volunteers in the Carolinas in December 2013 and continued doing so through Phase 3. In October 2017 a monthly "Consistent Observer Spotlight" was added to recognize the efforts of individual volunteers. Each month an observer was notified of their selection and asked a series of questions about their motivation for submitting Condition Monitoring reports and their most interesting observation. Responses were summarized and included in the newsletter with the observer's photo (Figure 5).

Between April 2019 and April 2020, the monthly newsletter included a list of stations consistently submitting Condition Monitoring reports to encourage participation. This effort followed the launch of the "consistent stations" layer on the web map in 2018 and decision maker recommendations that consistency in reporting increases the credibility and reliability of information in the reports.



Consistent Observer Spotlight

Preston Jones

Our spotlight consistent observer for July is Preston Jones from Marshall, NC. Preston learned about the CoCoRaHS program through a fellow reporter from his volunteer group that works to maintain the Appalachian Trail. He has been part of the CoCoRaHS network for 5 years, and has been submitting condition monitoring reports for about 2 years. Preston focuses his observations on precipitation levels such as snow cover and rainfall, in order to monitor the success of his Christmas tree farm. He tells us that keeping track of the amount and timing of precipitation is essential to projecting the vitality of the Christmas trees.

He encourages all CoCoRaHS volunteers to be consistent with their observations and articulates that "without consistency, it would be very difficult to establish any pattern of weather behavior." In addition to Preston's volunteer work performing trail maintenance with the Appalachian National Scenic Trail, he raises Rocky Mountain horses and enjoys horseback riding on the trails in Pisgah National Forest. Thank you for all of your hard work Preston!

Figure 5: Example of Consistent Observer Spotlight from the July 2020 Newsletter

Accomplishments and Final Deliverables

Monthly newsletters were emailed to over 2,000 CoCoRaHS volunteers in North Carolina and South Carolina. The newsletter is also posted to the CoCoRaHS Condition Monitoring project page of the CISA website. In May 2020 certificates of appreciation were sent to 26 observers who consistently submitted Condition Monitoring reports between April 2019 and April 2020 (Figure 6).

Figure 6: Certificates of appreciation were sent to Carolina's Condition Monitoring reporters for their dedication to the program in May 2020.

Explore New Applications for Condition Monitoring Reports

Motivation

Condition Monitoring reports contain a wealth of information about local conditions and the impacts of weather events, well beyond dry and drought conditions alone. For this component of Phase 3, the CISA team examined how Condition Monitoring might be used for other monitoring, reporting, and communications efforts undertaken by agencies such as the National Weather Service (NWS) forecast offices, the Southeast Regional Climate Center (SERCC), and state climate offices (SCOs) - groups who already support CoCoRaHS and use CoCoRaHS data.

Activities

The CISA team undertook three interrelated activities (Figure 7). As a first step, the team reviewed the content of Condition Monitoring reports from observers in the Carolinas, for the October 1, 2016, to December, 31, 2019, time period, to document the different types of weather events, climate patterns, and related impacts they included. A similar process was conducted using reports developed by NWS offices, SERCC, and SCOs, for the same time period and region (i.e., North Carolina, South Carolina). Second, the team created a series of maps, timelines, and graphs to summarize and compare results from the report reviews. The objective was to explore if the content, spatial scale and location, and timing of Condition Monitoring reports fit the agencies' needs for information. Appendix B provides additional detail about the methods used to collect, review, and compare the Condition Monitoring and agency reports. Third, CISA conducted two webinars and an online survey with agency representatives. The purpose was to share findings from the report analyses, obtain feedback about the potential usefulness of Condition Monitoring reports for non-drought events, and ask for reporting recommendations that could be conveyed to CoCoRaHS volunteers.

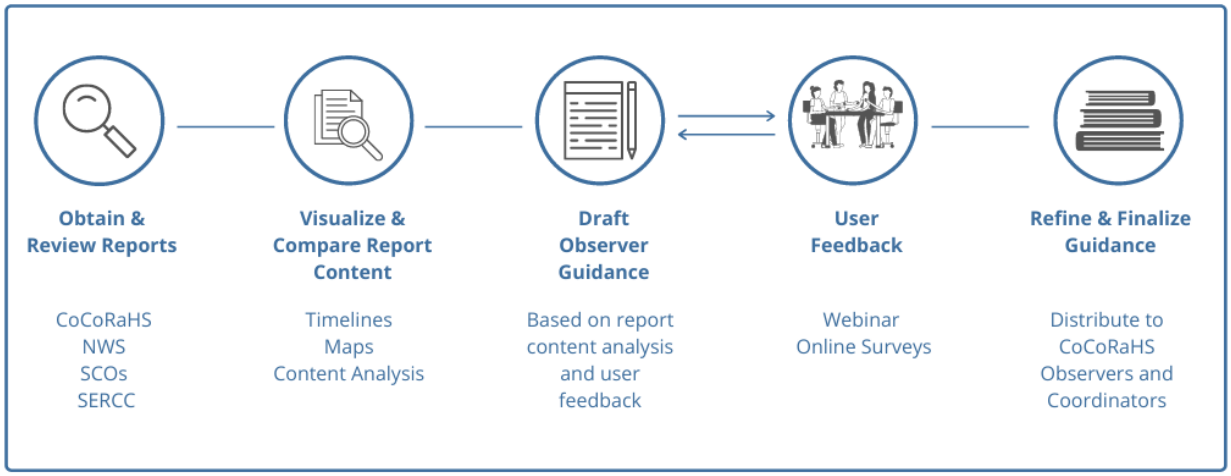


Figure 7: Steps in the research and engagement process

Accomplishments and Final Deliverables

This analysis of Condition Monitoring reports, comparison to agency reports, and feedback from NWS, SERCC, and SCO personnel revealed important insights about the value of CoCoRaHS data and its potential to inform and validate many types of weather and climate event reports.

Feedback confirmed that CoCoRaHS volunteers' data and observations are valued and used by agencies in the Carolinas. However, how and the extent to which different observations (e.g., precipitation data, significant weather reports, Condition Monitoring reports) are used seems to vary considerably, depending on individual office's principal activities and interests, roles and responsibilities of individual staff members in those offices or agencies, the weather or climate event, and the type of CoCoRaHS observation or report.

Condition Monitoring is considered very useful for monitoring environmental conditions and changes. The reports are not widely used beyond their initial purpose for drought monitoring. This is likely due to the initial design and "marketing" of Condition Monitoring for this purpose. Although, some agencies and individuals did report using them for monitoring flood conditions and documenting the impacts of severe events. This suggests that there could be ongoing opportunities to promote Condition Monitoring reports for a variety of applications, such as monitoring, post-event reports, verifying warnings.

While participants generally report that any information that CoCoRaHS volunteers provide through their different reports is welcome and potentially useful, more detailed and consistent content could enhance the usability of Condition Monitoring reports.

The report analysis reinforced the idea that different offices and agencies have different focal interests and responsibilities, which affects both the perceived and actual relevance and use of different CoCoRaHS reports for their activities. To that end, a Helpful Reporting Hints for CoCoRaHS Observers (Figure 8) was developed to support volunteers in providing relevant weather event information through three different CoCoRaHS report types: significant weather reports, daily comments with precipitation measurements, and Condition Monitoring reports. The CISA team also developed a story map that documents the project's methods, results, and final products.

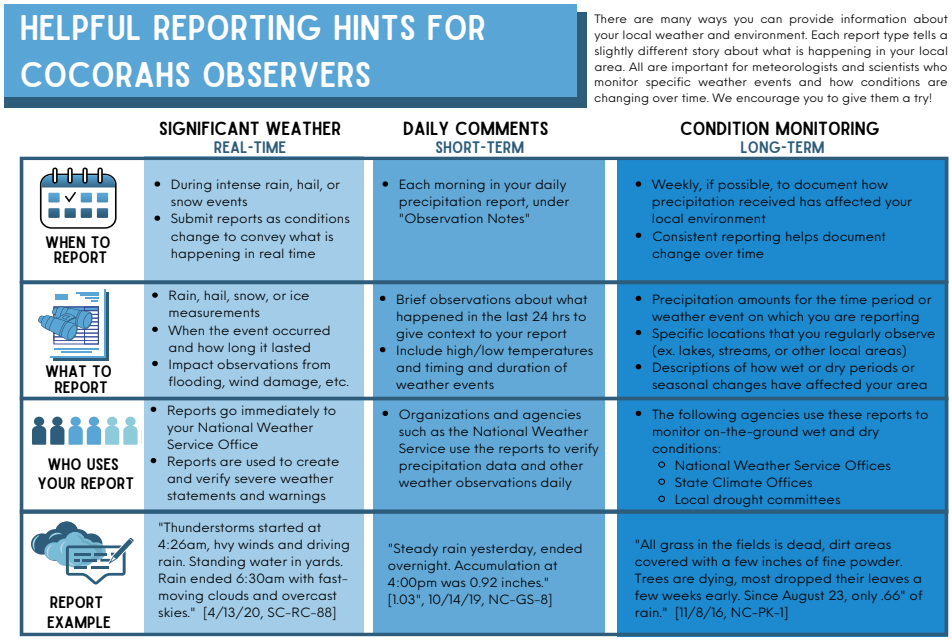


Figure 8: Feedback from agency representatives received during Phase 3 was used to develop this "Helpful Reporting Hints" document for the national network of CoCoRaHS observers.

Appendix A: Developing the Regional Guidance Documents

Each of the Condition Monitoring Regional Guidance Documents contains similar elements to provide regionally relevant information to volunteers. The development process for each of the document sections is described below. The first page of the guidance document includes information about each regions climate and additional resources (see Figure A-1). The second page provides examples of observations and impacts that correspond to the different wet and dry categories (see Figure A-2).

Regions

States were originally divided into regions as defined by the US Drought Monitor, but were then readjusted to prioritize the demarcation of areas with similar Köppen climate types, landscapes, and weather drivers. The inclusion of the precipitation maps and climographs in the documents synopsizes the climates of each region, giving CoCoRaHS observers a better understanding of baseline conditions in their area. Maps for the continental U.S. and Alaska were created using thirty-year annual precipitation normals (1981-2010) from the Oregon State University PRISM Climate Group (see Figure A-1). Precipitation normals for this same time period from the NOAA National Centers for Environmental Information were used for the Puerto Rico and US Virgin Islands maps. For Hawaii, mean annual precipitation data from 1978-2007 from the Climate Atlas of Hawaii were used.

Representative cities were identified on each regional map with corresponding climographs of mean annual temperatures and precipitation. Selected cities are intended to provide a sample of measurements by which observers can extrapolate reasonable baselines for their own locations. City selection was guided by latitude, elevation, climate type, and proximity to major bodies of water, rather than the sizes or populations of the city.

The documents also include links to supplemental, layperson-friendly climate resources from NOAA, the Regional Climate Centers, the National Drought Mitigation Center, the American Association of State Climatologists, and region-specific resources, such as the Alaska Climate Research Center.

Reporting Reminders

The "Reporting Reminders" included in each document were designed to achieve three general goals:

- Improve the consistency in the qualitative categorization of precipitation conditions,
- Foster greater applicability of Condition Monitoring reports by encouraging more detailed and appropriate content, and
- Better support new CoCoRaHS volunteers by providing them instructions with a higher degree of direction and clarity.

Impact Tables

Tables guiding volunteers on the appropriate Condition Monitoring scale bar selections are intended to improve the consistency of reports and minimize the overuse of the extreme wet and dry categories. The recommendations in these tables are based on those laid out in the CoCoRaHS Condition Monitoring Reporting Guide.

Drought impacts information was gathered through a state-by-state analysis of reports submitted to the National Drought Mitigation Center's Drought Impacts Reporter. Impacts caused by wet conditions were synthesized directly from previous Condition Monitoring reports submitted with scale bar selections of mildly to severely wet. Content is representative of unique characteristics in each region. The impact tables are non-exhaustive and should serve only as a guide by which observers may learn to better recognize potential impacts of precipitation or a lack thereof.

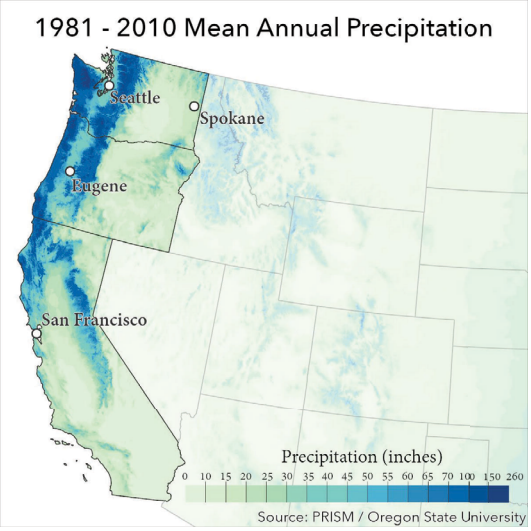
Iterative Evaluation and Document Design

Regional guidance documents were sent to CoCoRaHS headquarters and regional coordinators, the National Drought Mitigation Center, regional climate centers, state climate offices, and National Weather Service offices for review. Feedback requests were circulated via a Google form with specific questions about the different elements of the documents (i.e., regional division of the continental U.S., representative city selection, and customization of impacts information). Revisions were made to the documents based on this feedback and recirculated for final review.

Condition Monitoring Reporting Guide: Pacific Northwest

Regional Background

Along the coast, the Pacific Northwest is famously rainy. Summer is relatively dry, but rainfall is frequent throughout the rest of the year. Temperatures are relatively moderate along the coast in all seasons, meaning that most winter precipitation at lower elevations falls as rain rather than snow. The eastern interior of the region is a rain shadow with very little precipitation. The interior is characterized by hot summers and cold winters, though the lack of humidity keeps night-time temperatures cool all year. (CoCoRaHS observers in Southern California should consult the Southwest Reporting Guide.)



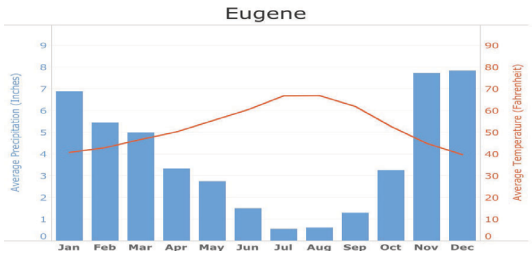
Reporting Reminders

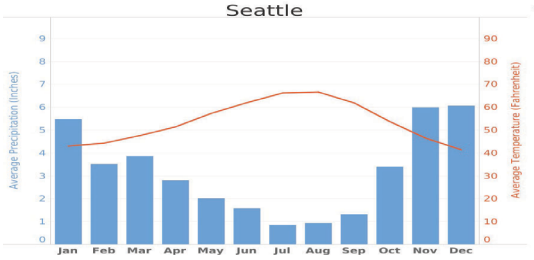
- Use "Severe" categories sparingly: overuse of these labels can make it hard for researchers to identify the hardest hit areas.
- Sometimes, minor events may still have major human impacts, or vice versa. Don't worry if your precipitation measurements seem to conflict with the severity reflected in your reports: differentiating between magnitude and human impact is valuable to researchers and decision makers!
- While heat and drought often go together, be careful to note that impacts of heat (e.g., wilting plants) are not necessarily indicative of drought conditions.
- Droughts don't end instantly. Rain after long droughts may mean *less dry* conditions, but not necessarily a reset to "Near Normal" conditions. Think *long term*.
- In addition to rain measurements, notes on a storm's duration, power outages, road closures, and other such impacts are helpful to include.

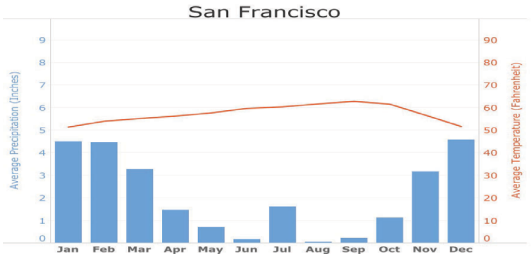
Average Monthly Climate Data

These sample climate charts represent normal monthly precipitation and temperature in your region. Pick a city near you and use the data below as a baseline for your "near normal" conditions. Explore these resources for climate data in other locations:

- National Drought Mitigation Center
- NOAA National Centers for Environmental Information
- NOAA Regional Climate Centers
- American Association of State Climatologists







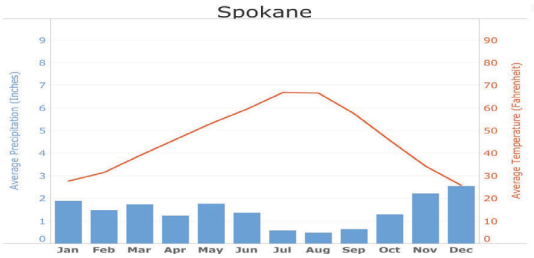


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Figure A-1 : Page 1 of the Condition Monitoring Reporting Guide for the Pacific Northwest

What to Look For

The following tables provide examples of the types of conditions you might observe during different wet or dry periods. **These lists are designed as an aid.** The first table shows the condition monitoring scale bar categories and the types of conditions that correspond to those categories. The second table organizes different types of conditions and impacts by sectors and areas of interest. Be sure to note any other observations that you think may relate to dry or wet conditions.

SEVERELY WET	MODERATELY WET	MILDLY WET	NEAR NORMAL	MILDLY DRY	MODERATELY DRY	SEVERELY DRY
• **Use this category sparingly** • Wet conditions have persisted for several weeks • Major flooding • Soil is saturated	• Wet conditions have persisted for a few weeks, or there has been a major rainfall event • Standing water and minor flooding • Soil is very damp	• Frequent precipitation for several days • Standing water is common • Soil moisture is above normal	• Observed conditions normal for this time of year • **This should be your default entry**	• Dry conditions have persisted for a few weeks • Soil is somewhat dry	• Dry conditions have persisted for several weeks • Lakes and rivers are low • Water use restrictions start • Soil is very dry	• **Use this category sparingly** • Dy conditions have persisted for months • Soil is completely dry • Water is scarce • State of Emergency

	WET	DRY
Agriculture	Crops and grazing pastures will likely be green and in healthy conditions. Even with moderately wet conditions, need for irrigation may drop off noticeably. Orchard fruits and berries will likely yield larger and more plentiful fruit.	Without enough water, crops may develop late, show stunted growth, or yield smaller harvests. Irrigation systems in the interior may be strained. Livestock may be smaller or require supplemental water and feed, especially where the growth of pastureland is stunted. Ranchers may reduce their herd sizes.
Business	Rainy and muddy conditions may delay construction and infrastructure projects. Flooding or snow may result in school closures or lost work hours, particularly in rural areas where alternative routes may not be available.	Landscaping and similar businesses are likely to lose revenue as urban areas are pressured to reduce their water consumption. Algal blooms and diminished water quality may contribute to a decline in shellfish harvests.
Energy	Hydropower output may benefit from increased snowmelt. Periods of heavy rain or snow may create the risk of power outages due to wind, ice, or falling limbs.	Dying tree limbs, heat, and subsiding soil are threats to electrical infrastructure and may increase the likelihood of power outages. Utility bills may increase, especially in areas reliant on hydroelectric, coal, or nuclear plants. Increases in solar energy production are possible.
Fire	Fire danger declarations at or near minimum. Fire crews will often wait for wet conditions to perform prescribed burns to minimize the danger of unwanted spreading.	Wildfires will be larger and more common, as reflected by increases in Fire Danger ratings from the U.S. Forest Service. Firefighting groups may be strained and put out calls for volunteer firefighters. Fire season may begin earlier or last later into the season with dry conditions.
Plant &Wildlife	Rainy seasons may improve conditions for fish and shellfish. Increased growth of mosses can also be expected. Heavier-than-usual snowfall at high elevations may push animal populations farther down the mountain to forage, potentially resulting in more encounters with humans.	Scarcity of resources may push bears into residential areas. Fish migration may be impeded by low flows and populations of fish and shellfish may show signs of stress. Fish hatcheries may be forced to close. Damage to native tree populations may increase risk for outbreaks of pine beetles. Visible signs of disease may appear in bird populations.
Relief & Response	Restrictions on water use and outdoor burning are likely to be lifted or relaxed as weather shifts from dry to wet. Highway safety measures are possible on routes likely to be affected by fog, flooding, ice, or landslides.	Governments and other agencies may issue statements encouraging voluntary conservation of water and energy. These will often become mandatory if drought worsens. Regulations on outdoor burning and the use of fireworks are common, even at low levels of drought. Rangelands under the Conservation Reserve Program may be opened for emergency grazing.
Safety & Health	Heavy, saturated soil creates a risk of landslides and flooding in the region. In mountainous areas, weather can be highly variable throughout the year, making driving conditions dangerous. Pooling water can cause increases in mosquito populations following wet periods.	Areas of the Northwest's interior may experience dust storms as topsoil dries out. The shallowing of wetlands may increase the presence of stagnant water and contribute to higher mosquito levels. Pollen and diminished air quality may exacerbate allergies and asthma symptoms.
Tourism & Recreation	Relatively wet seasons may often work to the benefit of ski and rafting seasons. While the region is characterized by frequent rain, extended wet periods may still discourage hiking, camping, and other outdoor activities.	Ski seasons may be delayed or postponed, and there is likely to be decreased turnout to resorts. Boating and fishing may be harmed by warmer, shallower waters.
Water	Rivers and reservoirs may be at normal or above normal levels. Wetter years may experience greater alpine snowpack that lasts later into the season. Mountain streams fed by snowmelt may be at higher levels throughout the spring.	Ponds, small streams, and wells dry completely in severe conditions. Water quality will typically decrease due to increased temperature and decreased volume. There may be less snowpack at higher elevations, in turn resulting in lower springtime stream levels.

Figure A-2: Page 2 of the Condition Monitoring Reporting Guide for the Pacific Northwest

Appendix B: Exploring New Applications for Condition Monitoring Reports - Methods and Summary of Results

Overview

Condition Monitoring reports contain a wealth of information about local conditions and the impacts of weather events, well beyond dry and drought conditions alone. For this component of Phase 3, the CISA team examined how Condition Monitoring might be used for other monitoring, reporting, and communications efforts undertaken by agencies such as the National Weather Service (NWS) Forecast Offices, the Southeast Regional Climate Center (SERCC), the State Climate Office of North Carolina (SCONC), and the South Carolina State Climatology Office (SCSCO) - groups who already support CoCoRaHS and use CoCoRaHS data.

The CISA team undertook three interrelated activities.

1. The team reviewed the content of Condition Monitoring reports from observers in the Carolinas, for the October 1, 2016, to December, 31, 2019, time period, to document the different types of weather events, climate patterns, and related impacts they included. A similar process was conducted using reports developed by NWS offices, SERCC, and SCOs, for the same time period and region (i.e., North Carolina, South Carolina). All reports are publicly accessible.
2. The team created a series of maps, timelines, and graphs to summarize and compare results from the report reviews. The objective was to explore if the content, spatial scale and location, and timing of Condition Monitoring reports fit the agencies' needs for information.
3. CISA conducted two webinars and an online survey with agency representatives. The purpose was to share findings from the report analyses, obtain feedback about the potential usefulness of Condition Monitoring reports for non-drought events, and ask for reporting recommendations that could be conveyed to CoCoRaHS volunteers.

This Appendix provides additional detail about the methods used to collect, review, and analyze the Condition Monitoring and agency reports (steps 1 and 2, above). The CISA team also developed a story map that documents the project.

Identifying Weather and Climate Events

One aim of this study was to identify the types of weather and impacts information that Condition Monitoring observers currently report and which would also be useful for agency personnel. The team drew from the 54 storm event types used in the NWS Storm Reports to develop a list of categories with which to review and compare report content related to significant weather events (Table B-1)[1]. The climate categories correspond to the conditions and patterns monitored by State Climate Offices and Regional Climate Centers.

Table B-1: Weather and Climate Event Categories

Weather Events (<1 week)	Climate Conditions & Trends (>1 week)
Flood: Includes flash flood, storm surge, and tidal flooding	**Drought:** Includes references to drought declarations made by monitoring groups such as the US Drought Monitor
Frost/Freeze: Includes first frost/freeze of the season and other occurrences	**Precipitation Above Normal:** In comparison to the reported time period (month, season, year)
Heavy Precipitation: Includes all events noted for the intensity of rainfall received during a specified time period	**Precipitation Below Normal:** In comparison to the reported time period (month, season, year)
Hurricane/Tropical Storm: Includes associated information related to heavy precipitation, thunderstorms, tornados, wind, and flooding	**Temperature Above Normal:** In comparison to the reported time period (month, season, year)
Temperature Above/Below Normal: Includes references to short-term, abnormally cool or warm temperatures for a given season	**Temperature Below Normal:** In comparison to the reported time period (month, season, year)
Thunderstorm: Includes hail, wind	
Tornado: Often associated with thunderstorms, tropical storms	
Wildfire: Often associated with drought, wind, below-normal precipitation	
Winter Precipitation: Includes snow, sleet, freezing rain	

1 National Weather Service Instruction 10-1605. March 23, 2016. Operations and Services Performance, NWSPD 10-16. Storm Data Preparation. https://www.ncdc.noaa.gov/stormevents/pd01016005curr.pdf

Key Findings and Highlights

- Condition Monitoring was originally designed to promote the weekly to biweekly reporting of local conditions with the goal of supporting drought monitoring. This study found that 1,054 (17%) of the 6,270 reports included observations of significant weather events and their impacts. 183 different observers contributed these reports, representing almost half of all Condition Monitoring observers who submitted reports during the study period. This suggests an opportunity to encourage other Condition Monitoring volunteers to include significant weather information in their reports.
- It is difficult to make direct comparisons between the Condition Monitoring and agency reports because they focus on different geographies and timescales and have different purposes and audiences. In general, agency reports primarily focus on weather phenomena, climate patterns and anomalies, and their direct effects on human life (fatalities, injuries), property, infrastructure, or water levels (in flooding events); whereas, most Condition Monitoring reports tend to describe local conditions and changes occurring over weeks to months.
- However, when viewed together, the reports collectively underscore the region's climate variability and wide range of weather and climate events the region has experienced during this relatively short time period. It is also clear that no one agency or report type is able to capture both the short-term damages and lingering effects of any given event.
- Many Condition Monitoring volunteers write comprehensive narratives to document their "on-the-ground" observations. Content may include references to how weather and climate affects their own gardens and yards, nearby rivers and lakes, and events happening in their communities ranging from tourism to burn bans to wildlife activity. Descriptions of long-lasting effects of weather and climate contrast with the agency reports which are more restrictive in the time scales they cover.
- Some Condition Monitoring reports contain a high level of specificity regarding the location, timing, and duration of weather and climate events; precipitation amounts; and the weather phenomena associated with any given event. However, most reports do not detail all variables that might be of interest to the agencies using the reports. This presents another opportunity to educate volunteers about the types of information that would be most useful to inform agency reports.

Condition Monitoring (CM) and Agency Report Examples

Thunderstorm Report Examples

CM report: "1.12" of rain for the week at this station. Some of that rain coming in as little as 10 minutes as it accompanies the fast moving thunderstorms that seemed to fly by this past week. Lots of wildlife signs on my walks with damp undergrowth. Lush vibrant green everywhere as nature revels in the current rain cycle. [SC-RC-88; 6/23/2019]

SCSCO report: "Afternoon heating, surface moisture and a sharp upper level short wave trough combined to force a powerful line of thunderstorms that swept across the Midlands, Lowcountry and Pee Dee. Wind gust downed power lines and knocked out power to thousands of utility customers. A falling tree in Columbia was responsible for the storm's single fatality. The Orangeburg Municipal Airport recorded a 63 m.p.h. wind gust and 0.67 inches of heavy rain." [SCSCO Weekly Report; 6/24/2019]

Flood Report Examples

CM report: "Steady, heavy rainfall for the last 2 to 3 days has caused ponding in roadways and flooding. Roads and interstate highways are beginning to close sections to travel due to flooding. Standing water in fields and pastures that look like small ponds. Raleigh, NC Emergency Management has issued a flash flood emergency for the city of Raleigh at this time. Rain has stopped for now and the sun is out and skies look to be clearing." [NC-FK-18, 4/25/2017]

SERCC: "From April 23rd–25th, Raleigh, NC observed its highest 1-day (4.51 inches), 2-day (6.68 inches), and 3-day (7.45 inches) precipitation totals on record for meteorological spring, leading to widespread flooding and several water rescues." [SERCC, Quarterly Outlook, 4/23-25/2017]

Winter Precipitation Report Examples

CM report: "We received 2.44 inches of precipitation this past week; almost all with the 9.5 inches of a combination of rain, sleet and snow. The ground is covered with slushy snow and the ground itself is muddy. All the leaves except for a few are gone from the Shagbark Hickory. The bushes are bowed by the weight of the wet snow." [NC-DH-48, 12/10/18]

SCONC report: " A low pressure system developing along the Gulf coast on Saturday morning brought in ample moisture as it tracked off the Atlantic coast. Liquid precipitation totals across the state generally ranged from 1.5 to 3 inches, with 4.16 inches reported at Cape Hatteras. In the Mountains and Foothills, that liquid fell as almost all snow, yielding widespread accumulations of more than ten inches. Mount Mitchell reported 32 inches, Jefferson received 20 inches, and Boone picked up 15 inches of snow. Many sites in the northern and western parts of the state received more than a foot of snow, which is at or above their annual average snowfall." [SCONC Rapid Reaction Report, 12/11/2018]

Frost/Freeze Report Examples

CM report: "Our nice snow of the 12th and 4 days of light rain in the last 6 days has put us just a little below normal for the year in precipitation. Things are looking up but the 7 hard frosts of the last 2 weeks have ruined our peach growers, hurt the vineyards extensively and cut the strawberry crop by an unknown %, so far. With the warm Feb. much damage has been done by our cold March- a record low of 15 on the 16th following 19 on the 15th was the worst. Wildfires are way down after the last 8 days of moist conditions." [NC-RW-17, 3/19/2017]

SCSCO report: "A heavy frost was observed on the morning March 13. Ninety Nine Islands reported a low temperature of 23 degrees. On March 15, Sassafras Mountain recorded a 12.4 degree low temperature. A hard freeze on March 16 was noted from a line north of and including Allendale, Walterboro, Manning, Kingstree and Conway. It was 17 degrees in Greenwood, and 21 degrees in Calhoun Falls. Preliminary inspections of berry and peach acreage indicated damage not seen since the late-season cold of April 8, 2007." [SCSCO, Annual Report, 3/13-16/2017]

Condition Monitoring Reports

Approach

Condition Monitoring reports were downloaded from the online web map as a CSV file. During the study period, 404 individual observers in North Carolina and South Carolina submitted 6,270 reports. When submitting Condition Monitoring reports, CoCoRaHS volunteers provide two types of observations: 1) They rate conditions on a scale ranging from severely dry to near normal to severely wet. 2) They write narratives to describe how recent weather and climate events affect their local environments and communities. The review of Condition Monitoring reports focused primarily on identifying the volunteers' significant weather event observations from their narratives.

Key word searches were used to narrow down the original set of 6,270 reports for the following significant weather events: flood, frost/freeze, heavy precipitation, thunderstorm, tornado, and winter precipitation. Only fourteen Condition Monitoring Reports mentioned tornadoes, primarily in regards to receiving watches or warnings. As none provided direct observations of tornadoes or their impacts, these reports were not included in subsequent reviews.

A project team member read each set of event-specific reports, first, to determine whether a report was relevant to the study and second, to ascertain additional information such as the timing and duration of the observed event. Reports were eliminated if they did not provide an observation of an event and/or its effects at the observers' location. For example, some reporters described events occurring in other areas of the state or discussed anticipated conditions ("chance of snow this week"). Others used a keyword but in a different context ("snowbirds", "snow peas", "leaves are falling like snow"). The report content was also reviewed with the purpose of classifying the reports according to sub-categories that reflect the nuanced information contained in the reports. A second, and sometimes third, team member reviewed the spreadsheet entries. Any questions or discrepancies were discussed and resolved during team meetings.

A different approach was used to identify hurricane observations. The Carolinas experienced five major hurricanes during the study period: Matthew (October 2016), Irma (September 2017), Florence (September 2018), Michael (October 2018), and Dorian (September 2019). Many hurricane-related reports only referenced the hurricane by its name (e.g., "Matthew") or mentioned the hurricane because it "missed" their location, so a "hurricane" keyword search was not the most effective method to identify hurricane observations. To capture a larger set of relevant hurricane reports, all reports for the 1-month period beginning on the date the hurricane or tropical storm made landfall in, or otherwise began to affect, either of the two states, were pulled from the full dataset. Reports were reviewed to document the various types of information that observers provided regarding hurricane events, including precipitation amounts, direct impacts such as downed trees or flooded waterways, and broader-scale effects on communities, vegetation, and wildlife. Reports were also reviewed in association with their scale bar categories (ranging from extremely wet to extremely dry), to discern how and where hurricane events may have ameliorated previously dry conditions and to identify the recovery from extremely wet conditions over time.

Summary of Results

The keyword searches and subsequent review of the report content resulted in 1,054 reports (17% of all Condition Monitoring reports) with significant weather observations. 183 different observers contributed to this total, representing 45% of all Condition Monitoring observers who submitted reports during the study period.

Reports often contained information about multiple events. In these instances, the reports were classified according to those different event types. A total of 1,162 events were identified within the 1,054 reports (Table B-2). In some instances, observers reported on several events experienced over a several-week period, particularly if they submit reports every 2-3 weeks. Some observers wrote very comprehensive narratives and included substantial detail about related events, for example winter weather when they experienced both freezing temperatures and precipitation (snow, sleet, and/or freezing rain).

Table B-2: The number of significant events identified in the Condition Monitoring reports and the types of information included for each event type.

Event Type	# of Events	Types of Information Included in Reports	
Flood	168	• Localized, flash floods • Riverine, tidal, and coastal floods	• Impacts to roads, buildings, fields, yards • Recovery, improving conditions
Frost/ Freeze	228	• Significant events and impacts • First frost/freeze of the season	• Ice on water bodies, vegetation, roads • Related conditions, impacts, recovery from freezes
Heavy Precipitation	114	• Rain amounts and impacts from previous week's significant event	• Lingering effects and/or recovery from past events (>1 week)
Hurricane/ Tropical Storm	277	• Rain amounts • Direct impacts (wind damage, flood)	• Broad-scale observations of power outages, infrastructure damage, school and business closures, effects on vegetation and wildlife
Thunderstorm	143	• Rain amounts from thunderstorms • Descriptions of weather patterns	• Effects from recent storms, including excessive wetness or relief from dryness
Winter Precipitation	232	• Snow events, with specific amounts and impacts • Trace amounts of winter precipitation	• Multi-precipitation events (snow, sleet, freezing rain, rain), with specific amounts and impacts

Figure B-1 shows the station locations of those observers who submitted Condition Monitoring reports with significant weather observations. The pie charts represent the number and types of events reported by each observer. The event type categories in the map correspond to the summary information provided in Table B-2 (above). In the spirit of the "condition monitoring" approach, any one Condition Monitoring report may include a wide array of information about the conditions and impacts associated with an event. In addition, reports often include updates on how local areas are recovering or "returning to normal" after significant events.

- The **Flood** category includes observations of flash floods due to heavy precipitation events, flooding associated with high tides, and broad-scale flooding and inundation from hurricane and tropical storm activity. "Flood" reports were also categorized as heavy precipitation, hurricane/tropical storm, or thunderstorm events, if the report provided in-depth information about rainfall amounts and other, non-flood effects associated with a storm.
- The **Frost/Freeze** and **Winter Precipitation** events are grouped as "Winter Conditions" in Figure B-1. Observers often noted both types of events in the same report, when they co-occurred. The Frost/Freeze reports primarily included observations of the first frost or freeze of the winter season, significant freezes during the winter, and late freezes and their impacts on vegetation that linger well past the actual event. Winter Precipitation reports include references to snow, sleet, and freezing rain events, periods when trace amounts of snow or other frozen precipitation were recorded, and any associated effects on local conditions.
- The **Heavy Precipitation** category includes observations of precipitation events notable for the intensity and amount of rainfall received over a specified time period but were not specifically discussed in a "Thunderstorm" or "Hurricane" report. Some of these observations were made in conjunction with volunteers' more general synopses of precipitation patterns and amounts received over the reporting time period (i.e., in a weekly or biweekly report).
- **Hurricane/Tropical Storm** reports describe rainfall amounts, and direct damages associated with wind, excessive rain, and floods, as well as impacts such as power outages and school and business closures.
- The **Thunderstorm** events include references to associated wind, hail, and flooding. Reports frequently provided detailed information about how these events affected local environmental conditions, such as improvements to dry conditions if rain was received, continued dry conditions if a location did not receive sufficient rainfall, or excessively wet vegetation or saturated soils if a location received a large amount of precipitation.

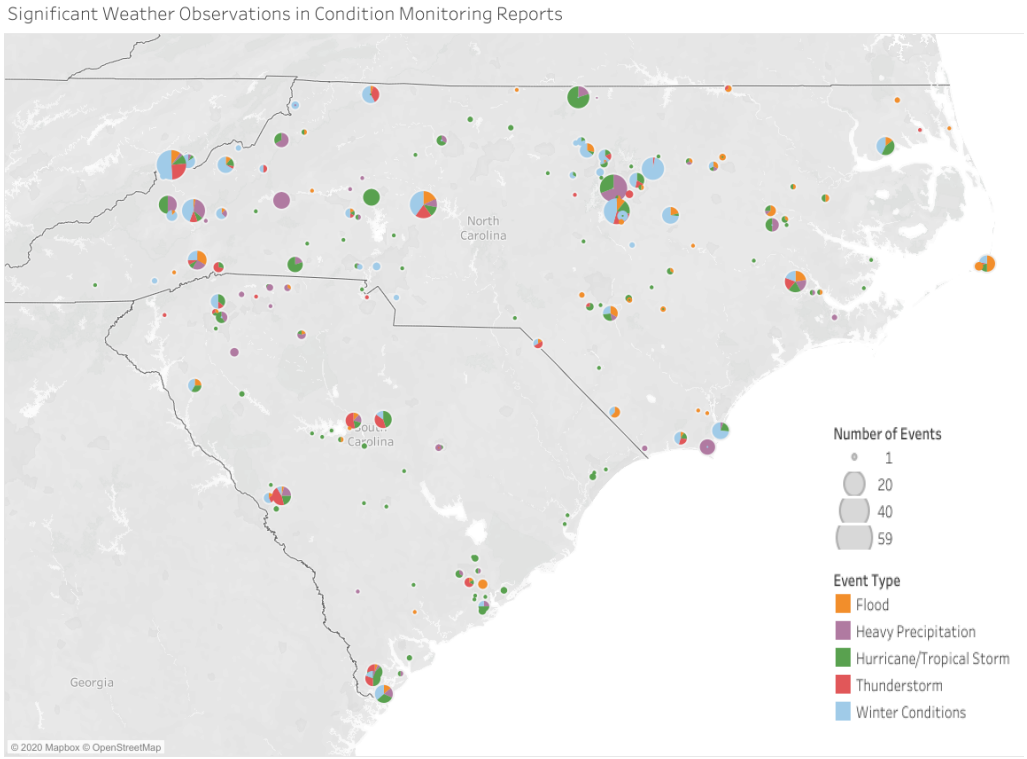


Figure B-1 : Station locations of volunteers submitting significant weather observations. The size of the pie charts represent the total number of events reported by that station. The wedges represent the types of events about which the observer reported. The "Frost/Freeze" and "Winter Precipitation" event types are shown here as a combined "Winter Conditions" category. View the interactive map here.

Each of the maps, timelines, and bar graphs in Appendix B was created using Tableau software and features interactive elements. Click on the figure or the hyperlink in the caption to view the interactive version of the image online.

Agency Reports

Approach

Agency reports were selected based on their location in the project study area and assumptions that 1) these reports represented the primary weather and climate events of interest for those agencies and 2) the agencies could potentially use or consult Condition Monitoring reports when writing these reports. The agencies have slightly different focuses and purposes, and cover different temporal and spatial scales, when writing these reports. Table B-3 provides a brief description of each report type and the website urls where the reports were accessed. Figure B-2 shows the geographic coverage of each agency. The following sections provide further explanation.

Table B-3: Agency documents used in the study

Agency	Reports URL	Frequency	Focus	Geographic Scope
NWS	Storm Reports https://www.ncdc.noaa.gov/stormevents/	Event-driven	Location, duration, severity, and impacts of significant weather phenomena	County Warning Area locations
SCONC	North Carolina Climate Blog Posts http://climate.ncsu.edu/climateblog	Monthly	Climate patterns and anomalies Climate context and impacts of significant events	North Carolina
SCSCO	Weekly Weather Reports https://www.dnr.sc.gov/climate/sco/	Weekly	Weather patterns and events Significant events and impacts	South Carolina
SERCC	Quarterly Climate Impacts and Outlook Reports https://sercc.com/seasonalsummary	Quarterly	Seasonal climate trends, patterns, anomalies Significant events and impacts	Six southeastern states, plus Puerto Rico and the U.S. Virgin Islands

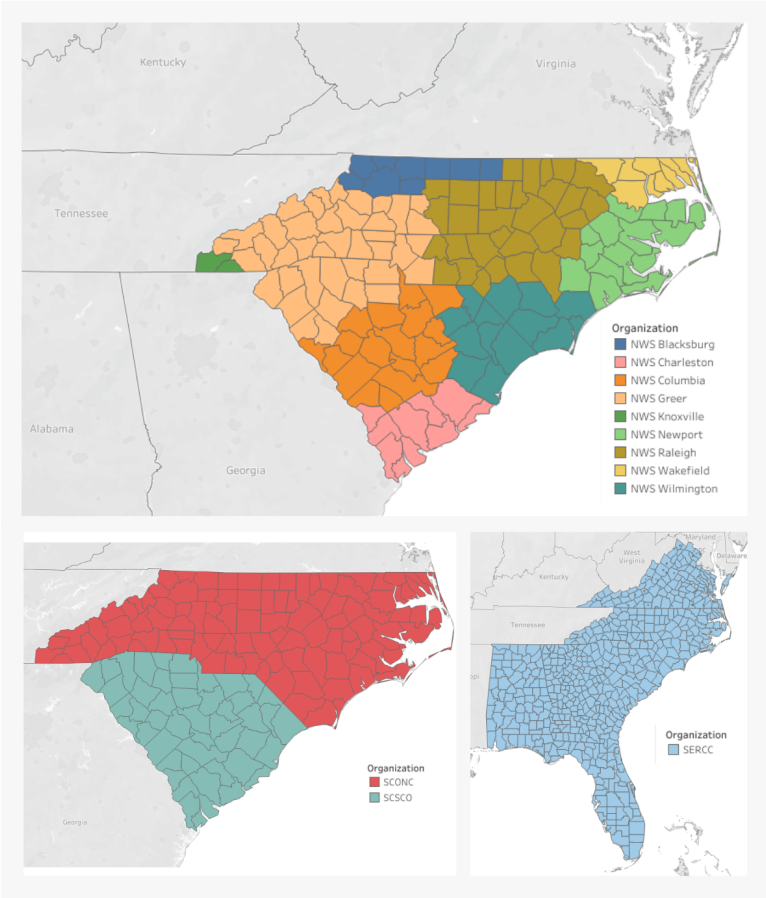


Figure B-2: Geographic coverage of each agency and the reports reviewed in the study. The maps show county and state boundaries. The top map shows the NWS Weather Forecast Offices' coverage of the Carolinas. The bottom left map shows the statewide coverage of the State Climate Offices. The bottom right map shows the SERCC's regional coverage. Note: Puerto Rico and the US Virgin Islands are also part of the SERCC region but are not shown on this map. View the interactive map here.

Reviewing Agency Reports and Identifying Events

Due to the differences in the focus, geographies, and timescales of interest in the reports, two different approaches were used to identify events as this project defined those events. Table B-4 shows the number of reports downloaded for each agency and the number of events identified from those reports.

Table B-4: Agency Reports, With Number of Events Identified with Each Report Type

Agency	Report Source	# and Type of Reports	# of Events
NWS	Storm Reports, Storm Events Database	NC: 794 episode narratives; 4,773 event narratives SC: 484 episode narratives; 2,846 event narratives	545
SCONC	North Carolina Climate Blog Posts	39 monthly summaries; 14 significant event reports	142
SCSCO	Weekly Weather Reports	3 annual reports (2016-2018); 53 weekly reports (2019)	348
SERCC	Quarterly Climate Impacts and Outlook Reports	14 quarterly reports	78

Identifying National Weather Service Storm Reports Database Events

NOAA's National Centers for Environmental Information (NCEI) hosts the Storm Events Database, which comprises reports submitted by National Weather Service Forecast Office personnel based on their County Warning Areas (CWA). See Figure B-2 for the Forecast Offices covering counties in North Carolina and South Carolina. The purpose of the Storm Reports is to document severe storms and weather phenomena, their impacts , and notable events such as record temperature or precipitation values. The reports also serve as input into processes to verify NWS forecasts, warnings, and other products.[2]

The Storm Events Database includes two types of narratives. The **episode narrative** briefly describes the weather phenomenon or atmospheric conditions that contributed to an event (or events). The **event narrative** provides detailed information about an event's significance and/or its localized impacts, such as fatalities, injuries, or damages to property, roads, bridges, power lines, crops, and trees. Events are categorized according to 54 event types which attempt to describe all weather phenomena with sufficient intensity to cause injury or damage. Each event is associated with an episode; a single episode may have one or more events associated with it. Multiple episode narratives may describe the same weather phenomenon.

A total of 1,278 episode narratives and 7,619 event narratives for North Carolina and South Carolina were accessed from the Storm Events Database for the study period (October 1, 2016 to December 31, 2019) and downloaded into an Excel spreadsheet. The dataset included 794 episode narratives and 4,773 event narratives for North Carolina and 484 episode narratives and 2,846 event narratives for South Carolina. This vast number of narratives, and thirty-two different event types represented in the dataset, made it difficult to compare the NWS narratives with Condition Monitoring reports and other agencies' documents. To make the NWS dataset more useful and manageable for the report review, the Storm Reports were consolidated and reduced as follows:

- Episode and event narratives associated with a single weather phenomenon, such as a hurricane or frontal system were recorded as a single event. For example, Hurricane Matthew was associated with 15 different episode narratives and 358 event narratives.
- Event types about which CoCoRaHS observers were less likely to report, such as high surf and funnel clouds, were removed.
- Similar event types were combined into one, overarching category. For example, the "Winter Precipitation" category used in this project included NWS event types such as blizzard, heavy snow, ice storm, winter storm, and winter weather.
- Event narratives that appeared to duplicate other types of events were removed. For example, the "heavy rain" event narratives were usually associated with thunderstorm or tropical activity and otherwise captured by those events.

Identifying Events from the State Climate Office and Southeast Regional Climate Center Reports

For each agency, a project team member read and reviewed each report to identify specific events, their event type, and additional information such as the timing, duration, and location of those events. This information was manually entered into an Excel spreadsheet, along with the relevant report content. A second, and sometimes a third, team member would review the spreadsheet entries. Any questions or discrepancies were discussed and resolved during team meetings. Additional information about these reports is provided below.

The ***North Carolina Climate Blog***, published by the **State Climate Office of North Carolina** (SCONC), covers a wide range of topics, including monthly and seasonal climate summaries, "rapid reaction" posts about significant weather events (e.g., hurricanes), seasonal articles of interest,

2 National Weather Service Instruction 10-1605. March 23, 2016. Operations and Services Performance, NWSPD 10-16. Storm Data Preparation. https://www.ncdc.noaa.gov/stormevents/pd01016005curr.pdf

and SCONC news. The posts are specific to North Carolina. Ninety-four blog posts were published during the study period. The dataset was narrowed by removing posts about historical weather events, SCONC news, and topics of less relevance to this study (e.g., monitoring air quality). Events documented in both a monthly summary and rapid reaction post were entered as a single event in the project spreadsheet.

The **South Carolina State Climatology Office** (SCSCO) writes ***Weekly Weather Reports*** to document weather patterns and extreme events across the State and then uses the weekly reports to develop an annual ***Weather in Review***. The annual reports from 2016, 2017, and 2018 were used in this study. However, beginning in 2019, the SCSCO initiated a new public-facing ***Weather in Review*** that included narratives, historical context, quotes, charts, and other visuals and slightly different content compared to previous annual reports. Consequently, the ***Weekly Weather Reports*** were used to identify 2019 weather and climate events.

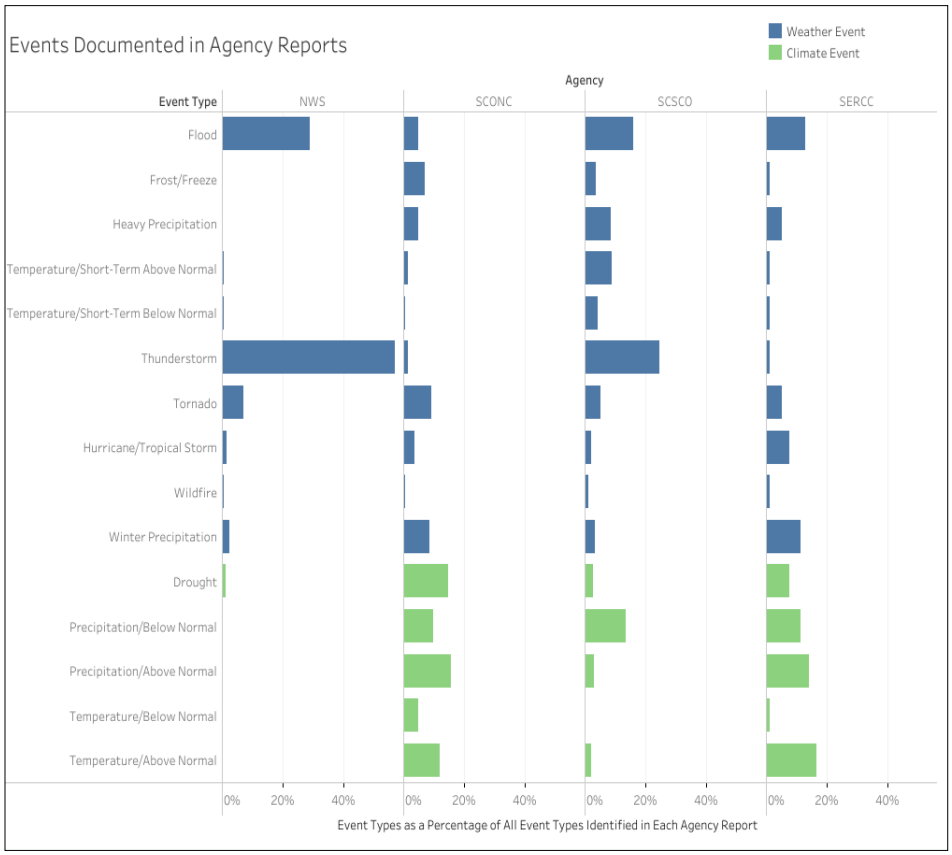
The **Southeast Regional Climate Center** (SERCC) issues the ***Quarterly Climate Impacts and Outlook***, a 2-page document, for each climatological season. The reports typically describe seasonal weather patterns, significant weather events, temperature and precipitation anomalies, and drought conditions and provide longer summaries of major events (e.g., hurricanes, tornado outbreaks, wildfire) and related impacts. The reports cover the entire SERCC region: Alabama, Florida, Georgia, North Carolina, South Carolina, Virginia, Puerto Rico, and the US Virgin Islands. For this study, only events or impacts that occurred in or affected either North Carolina or South Carolina were included.

Summary of Results

The individual NWS, SCO, and SERCC spreadsheets with lists of events and associated information (e.g., dates, location, event type, report content) were combined into a master spreadsheet. The project team conducted a final review to ensure that the report coding was consistent between the agencies and then used the compiled data to develop descriptive statistics and charts.

Figure B-3 summarizes the results of the report review and highlights the specific events of most (and least) interest for each agency, as documented in the reports selected for this study. Figure B-4 shows the categorized events in chronological order which also illustrates the time scales most closely monitored by the different agencies. These results are not unexpected, due to the agencies' varying focuses (Table B-3).

- The NWS Storm Reports, and to a lesser extent the SCSCO reports, primarily focus on short-term weather phenomena and their impacts, as demonstrated by the relatively high percentage of thunderstorm and flood reports.
- The SCONC and SERCC documents tend to emphasize climate trends and anomalies, although they also report on weather events that are impactful due to the extreme nature of the phenomena and/or the impacts caused.
- Due to how specific events were counted and classified, hurricane events are not prevalent in either figure, although the Carolinas experienced five major hurricanes during this time period.



- Across all agencies, short-term temperature events and anomalies (abnormally warm or cool periods) appear to receive the least attention. The SCONC and SERCC reports document seasonal temperature trends and anomalies, with above-normal temperatures prevailing throughout most of the study period. Click on the timeline (Figure B-4) to access the interactive Tableau map to further explore these trends.
- Drought is the only climate event that appears in the NWS reports, with the majority of these referencing the severe drought that affected the western part of the region in fall 2016. The State Climate Offices' and SERRC reports are more likely to document drought and associated climate patterns such as below-normal precipitation and above-normal temperature.
- All agencies documented the most impactful wildfire event (fall 2016) occurring in the region. The only other wildfire event in the timeline occurred in conjunction with the spring 2019 flash drought in South Carolinas and was noted by NWS offices in South Carolina and the SCSCO.

Figure B-3: Events Documented in Agency Reports. The bars represent each event type as a percentage of events identified in each agency's reports. The blue bars represent weather (<1 week) events, and the green bars represent climate (>1 week) events, as defined for the study. View the interactive bar graph here.

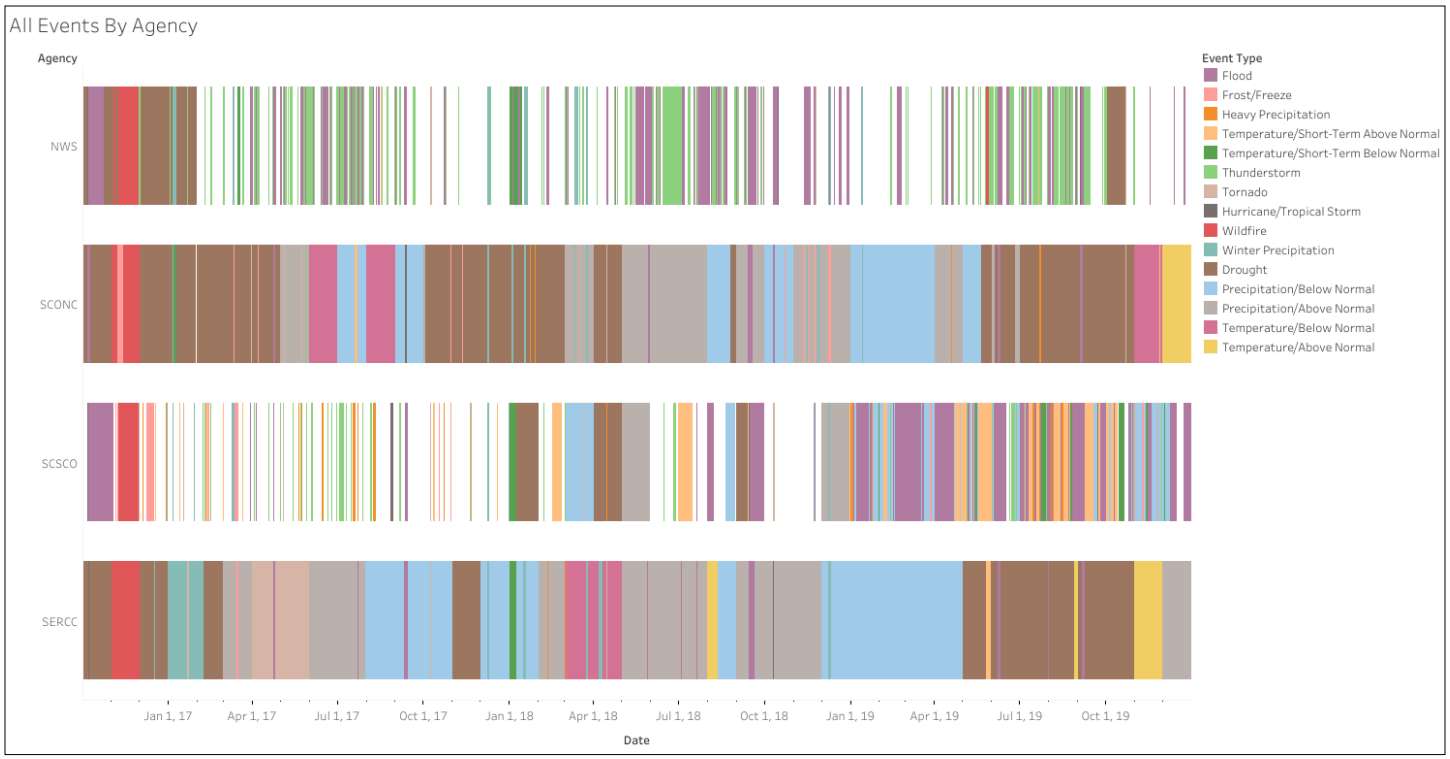


Figure B-4: Timeline Showing Weather Events Documented in Agency Reports. View the interactive timeline here.

What Makes a Condition Monitoring Report Useful?

Expectations about what makes a useful and usable Condition Monitoring report were based on evaluations and feedback from users during earlier phases of the Condition Monitoring project. Key elements include:

1. Information about weather and climate events that are of fundamental interest to the user
2. Information that is delivered in a timely and accessible manner
3. Data that helps to fill geographic gaps in coverage of other monitoring networks
4. Report content is relevant to the user, for example comparison of conditions for a single location, such as a water body or land area, over time

As earlier feedback focused on the applicability of Condition Monitoring reports for **drought monitoring**, this study sought to explore how those elements might pertain to the use of Condition Monitoring reports for other significant events. The results suggest that Condition Monitoring reports could be useful for agencies monitoring and reporting on the same events as well as gaps that could be addressed through education and outreach to volunteers and to the agency users of these reports.

1. Some Condition Monitoring volunteers provide very detailed and comprehensive observations about weather events and their impacts, which could be of use and interest to agency users. Others provide more general information and may not contain the level of specificity that agency reports typically contain.
2. Many of the events described by Condition Monitoring volunteers generally align with those documented by the agencies in their reports. However, because the volunteers typically report weekly- to biweekly, and oftentimes on an irregular basis, their reports may not be written or available in a timeframe that is most useful for the agencies.
3. There appears to be a core group of volunteers who provide regular Condition Monitoring reports, including those that document significant weather events and their impacts. While a few of these observers are located in rural areas or areas with limited monitoring from other networks, most are located near population centers where other monitoring networks likely exist. Overall, the spatial extent of these reports is somewhat limited and more could possibly be done to encourage CoCoRaHS volunteers in rural areas and where other monitoring is limited to submit "weather observations" through their Condition Monitoring reports or other mechanisms available through CoCoRaHS.
4. Regular, consistent observers tend to document conditions and changes occurring at their specific location or at nearby features, such as lakes, ponds, creeks, and rivers as well as agricultural fields and natural areas. These detailed accounts could help agencies monitor and anticipate the severity or extent of impacts due to the antecedent conditions in place at the time of a significant event. Additional guidance to observers to help them consider broader, community-wide impacts could also provide useful details for agency reports.

Heavy Precipitation, Floods, and Related Events

The Carolinas frequently experience extreme rainfall events caused by frontal systems, tropical storms and hurricanes, and pop-up thunderstorms, especially in warmer months. These events can contribute to flooding and other hazards. Monitoring and improving understanding of these events is particularly important for developing warnings and communicating with the public.

The timeline below (Figure B-5) illustrates the events documented by CoCoRaHS observers, many of which align with events documented in the agency reports. Thunderstorms or heavy precipitation events are included more regularly in SCSCO and NWS reports, which report on a weekly and event-specific basis, respectively; while, the SCONC and SERCC report on seasonal conditions through monthly and quarterly climate reports as well as significant events such as hurricanes and tropical storms. The agency reports, in general, focus on the amount and intensity of precipitation, the meteorological context of the event, and direct damages caused by the event.

Figure B-5: Heavy Precipitation, Thunderstorm, Hurricane, and Flood Events in All Reports. View the interactive timeline here.

This study found that Condition Monitoring observers' reports provide details about specific rain events, such as rainfall totals and intensity, suggesting these reports could help to validate other meteorological data sources, and associated impacts, such as flash flooding in their locale. In addition, consistent Condition Monitoring can help to track longer-term trends for both wet and dry periods. During wetter periods, consistent observations capture antecedent conditions that can lead to more extensive flooding during thunderstorms, tropical storms, and hurricanes. Their reports also discuss lingering effects of storm and rain events days to weeks after the event and the status of conditions when a storm misses a location.

For example, the report analysis identified the following sub-categories of information contained in the Condition Monitoring observers' **thunderstorm** reports:

- **Heavy Rain:** Recap of a specific event with significant rainfall totals in a short time period (usually <1 day), includes precipitation amounts and event duration.
- **Precipitation Patterns:** Information about precipitation patterns and amounts for the preceding week to month; may include mention of soil and vegetation conditions affected by recent precipitation patterns and watering or irrigation requirements.
- **Improving Conditions:** References to dry conditions that are improving due to thunderstorms.
- **Dry Conditions:** Reports of thunderstorm activity, but lack of substantial precipitation amounts to alleviate dry conditions; cumulative precipitation amounts that are below normal.
- **General Conditions:** References to thunderstorm activity but no specific dates or precipitation amounts; may include discussion of conditions (soil moisture, vegetation, irrigation needs).

This study also reviewed all reports with flood information to further compare the content in the Condition Monitoring and agency reports. Similar to other events, CoCoRaHS observers' reports provide wide-ranging details about the effects of floods on local water levels, roads, homes, and yards. Such information could potentially contribute to post-event assessments and tracking of recovering or improving conditions. The flood sub-categories identified in this review are shown in Figure B-6 and include the following:

- **Flood:** Includes high flows, overflows, and inundation of water; may include reference to riverine flooding, river stages, or effects of major storms and heavy rain events; includes reports with insufficient detail to categorize as "coastal" or "flash" floods.
- **Flood-Coastal:** References to flooding specific to coastal areas due to a combination of storms, storm surge, tides, rain, and/or wind.
- **Flood-Flash:** Indicates a rapid rise of water, beginning within minutes to hours of an event (intense rainfall or storm, for example); may include references to flooding in smaller creeks and streams, urban areas, roads, or dam/levee failures.

- **Flood-Recovery:** Refers to post-flood impacts, "drying out" conditions, and clean-up efforts; most are in reference to tropical storm or hurricane events.
- **Flood-Tidal:** References to flooding associated with high tides, including King Tides.

Figure B-6 shows the extent to which the flood events documented in Condition Monitoring and agency reports align with one another chronologically. Some major flood events appear in all timelines, such as those associated with hurricanes or impactful frontal systems (for example, April 23-24, 2017). However, the events and timelines do not align in many other places, suggesting that no one agency, or observer, captures all "minor" flood events and localized impacts.

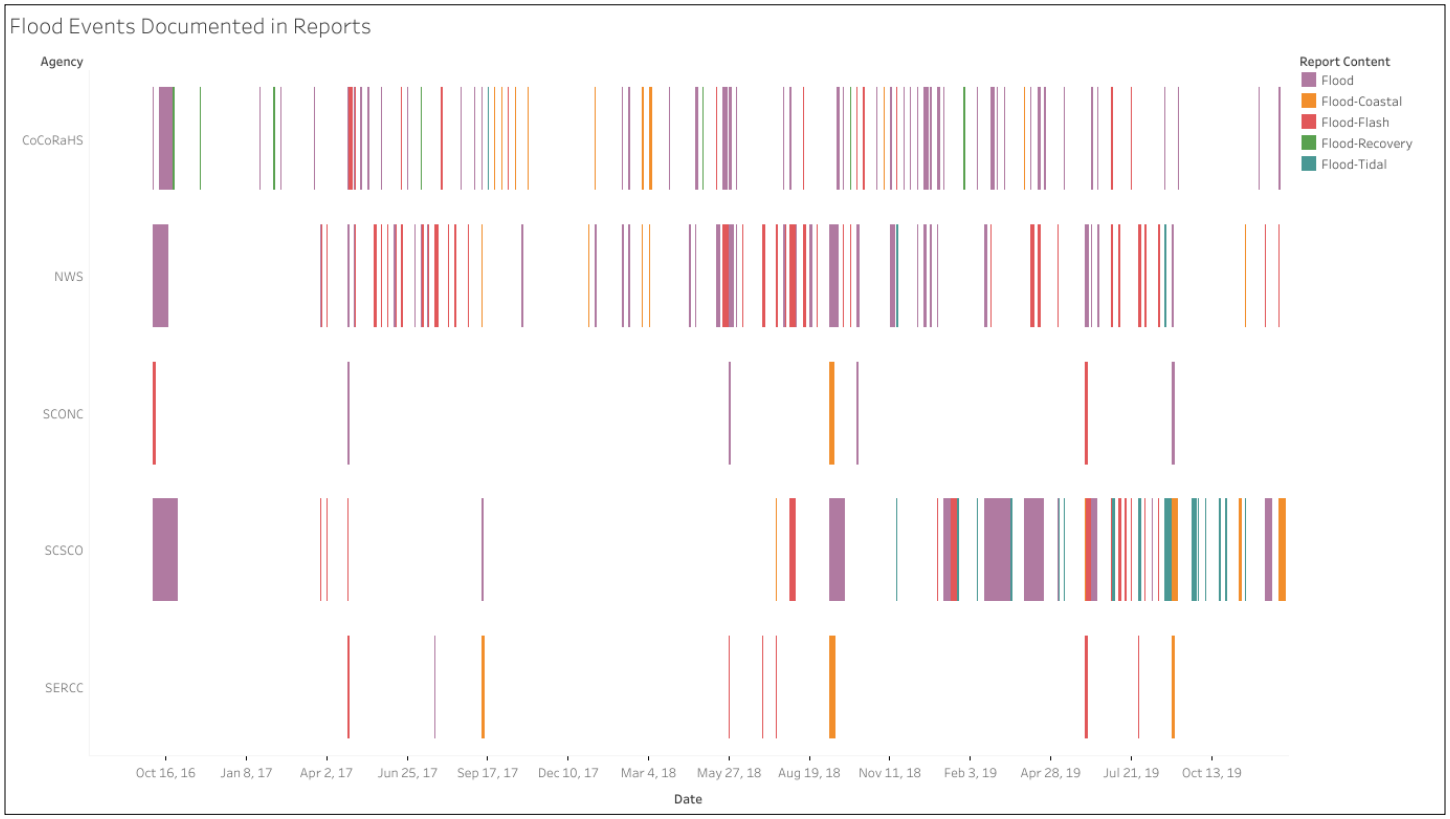
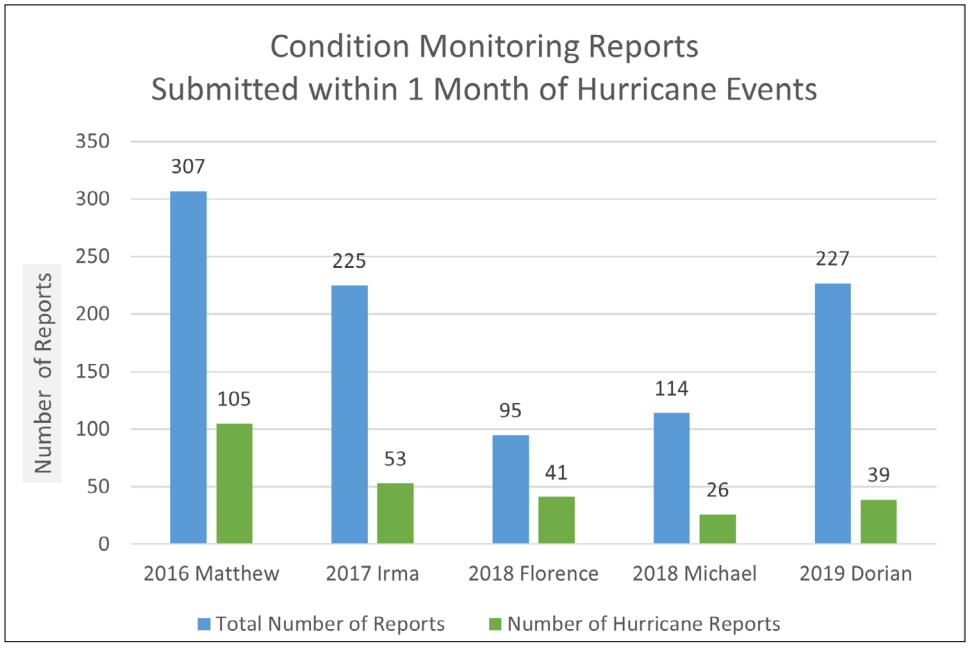


Figure B-6: Flood Events Documented in All Reports. View the interactive timeline here.

Hurricane Reports



All reports for the one-month period beginning on the date a hurricane or tropical storm made landfall in or began to affect the Carolinas were pulled from the full dataset to facilitate the more in-depth exploration of the report content. Figure B-7 shows the total number of reports submitted for each one-month period, compared to the number of reports ("hurricane reports") that contained observations of the immediate and direct effects of the hurricane event. Figure B-8 shows the various content (categories shown on the y-axis) included in the "hurricane reports." The percentages (x-axis) represent the extent to which the "hurricane reports" included each type of information. Table B-5 describes the impacts depicted in Figure B-8.

Figure B-7: This bar chart shows the number of all reports submitted within the one month period after each hurricane and the percentage which were designated as "hurricane reports." Note: There was a brief period (October 12-14, 2018) when Florence and Michael reports overlapped. Reports submitted during this time were deleted from the Florence group as they primarily focused on Michael.

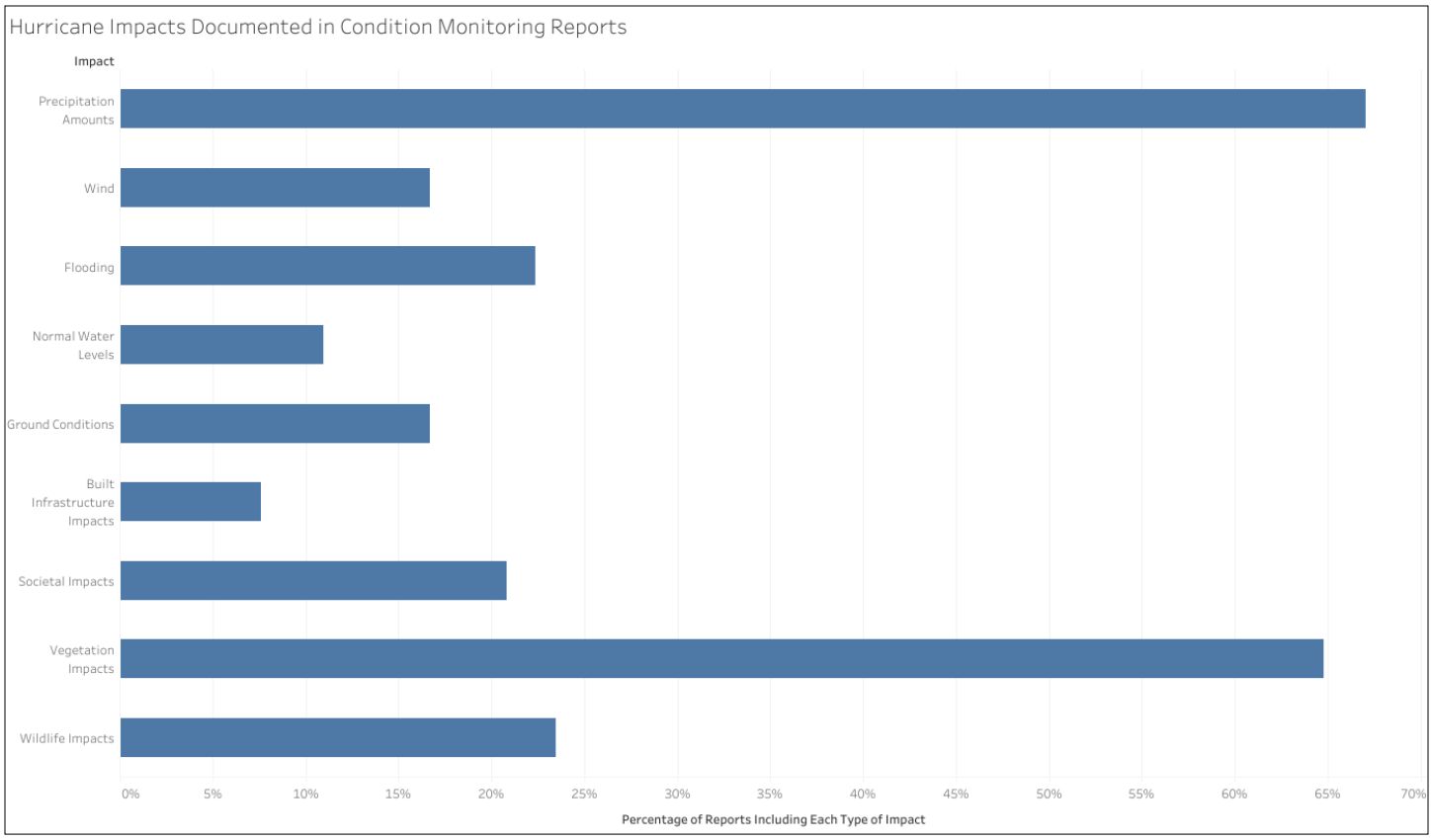


Figure B-8: This bar graph shows the types of hurricane impacts documented in the Condition Monitoring reports. View the interactive bar graph here.

Table B-5: Hurricane Impact Categories

Precipitation Amounts: Observer reports the amount of rain received at their location during the hurricane .	**Built Infrastructure Impacts**: Report notes damages to built infrastructure such as houses, buildings, docks, piers, roads, and bridges.
Wind: Report references wind conditions during the event and wind-associated damages.	**Societal Impacts:** Report contains information about effects on individuals (deaths, injuries), public safety (flood alerts and warnings, evacuations, power outages), and socioeconomic conditions (business or school closures).
Flooding: Report references flooded roads, fields, and yards and/or water bodies that are overflowing, overtopping, or at flood levels.	**Vegetation Impacts**: Report describes effects on any type of vegetation (trees, gardens, grass) and landscaping (yards, lawns, plantings), as well as storm debris.
Normal Water Levels: Report describes reservoir and stream levels as normal or as would be expected for the time of year.	**Wildlife Impacts:** Report describes observations of wildlife activity during or in the aftermath of the storm event, including insect (primarily mosquito) activity.
Ground Conditions: Report contains an assessment of soil moisture conditions, such as references to saturated ground or standing water.	

In addition to the direct impact categories shown in Figure B-8, the report narratives were also reviewed to identify and categorize observations of dry, drought, or recovering conditions and grouped according to their scale bar categories (extremely wet to extremely dry). The purpose was to explore if and how the Condition Monitoring observations might help agencies track the recovery from extremely wet conditions or discern where hurricane events may have ameliorated previously dry conditions. Results for Hurricanes Matthew, Florence, and Dorian are shown here. For these maps, the dry category combines the three dry scale bar categories (severely, moderately, and mildly dry) from the Condition Monitoring web map. Likewise, the wet category consists of the three wet scale bar categories (severely, moderately, and mildly wet). The line charts show the percentage of reports that discuss different types of hydrological conditions and post-hurricane recovery, during the month following the hurricane's initial impact (Table B-6).

Table B-6: Post-Hurricane Conditions Documented in Condition Monitoring Reports

Flood	Above-normal water levels in reservoirs, rivers, streams; flooded roads, fields, yards
Normal Water Levels	Normal or expected hydrological conditions, reservoir levels or stream flows
Below Normal Water Levels	Low or declining water levels; dry creek beds, ditches, and natural areas such as marshes that are normally wet
Recovery	Conditions are improving, drying out if wet, or otherwise getting back to normal
Dry & Drought	Changing or intensification of dry or drought conditions

Hurricane Matthew made landfall near McClellanville, SC, as a Category 1 storm on October 16, 2016. Rainfall amounts ranged from 10 to 17 inches along the coastline, where ground was already saturated from previous rain events. Hurricane Matthew led to extensive flooding on the coast, but it did little to relieve drought conditions in the western Carolinas. The map shows the delineation between wet conditions in the coastal areas and dry conditions in the Piedmont and mountains, as indicated by Condition Monitoring observers' scale bar selections (Figure B-9a). The line chart demonstrates how Condition Monitoring reports documented an increase in below-normal hydrological conditions (e.g., low flows in streams and rivers) as well as dry and drought conditions (e.g., drying soils and vegetation) in the weeks following the hurricane (Figure B-9b).

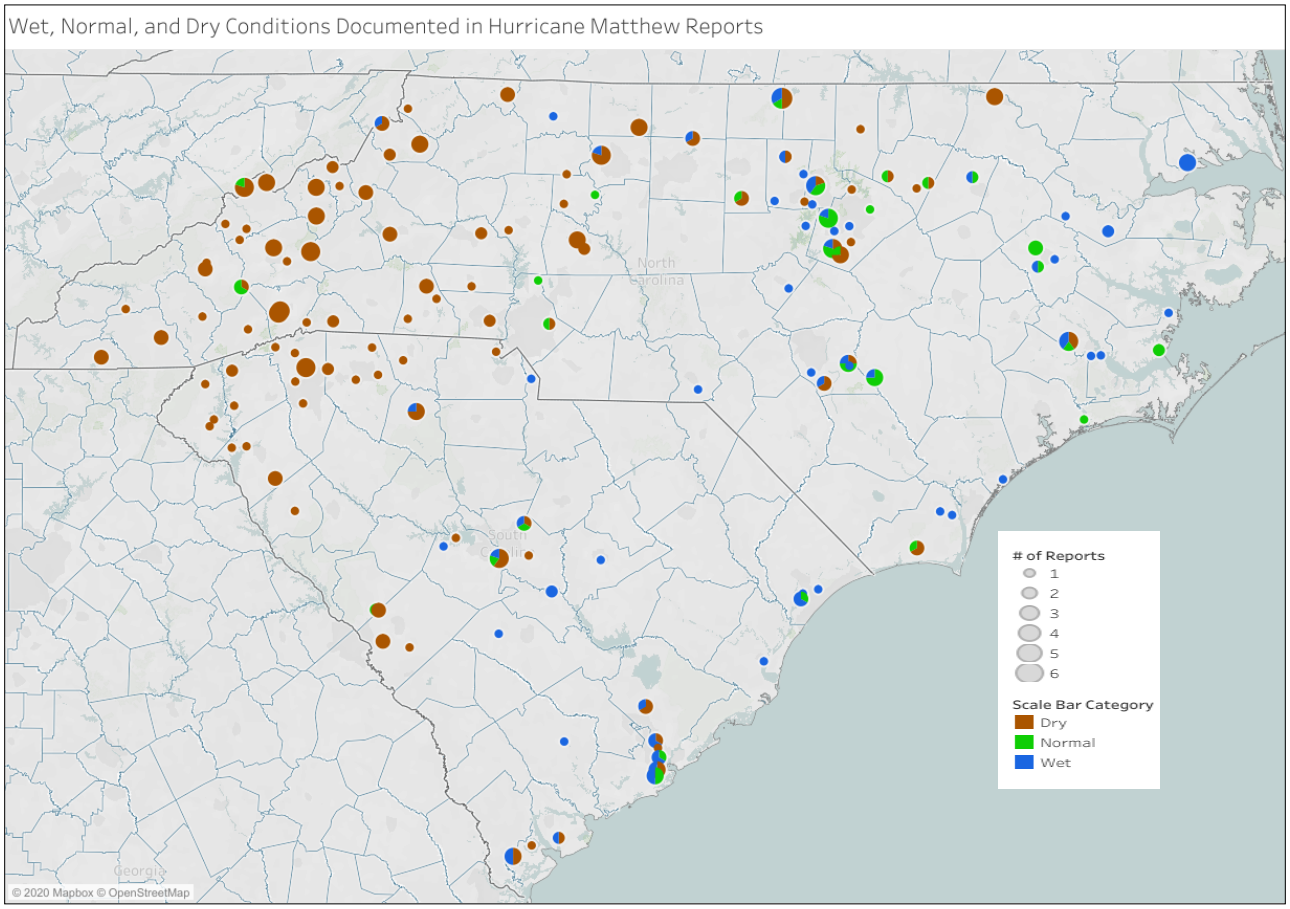


Figure B-9a: Wet, Normal, and Dry Conditions Documented in Hurricane Matthew Reports. View the interactive map here.

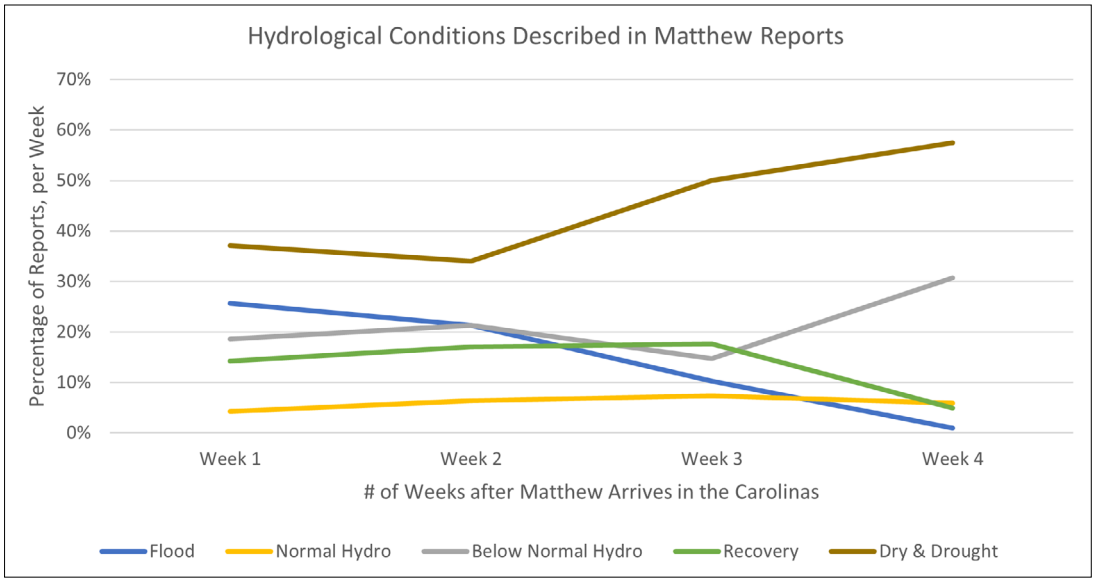


Figure B-9b: Hydrological Conditions Described in Hurricane Matthew Reports

Hurricane Florence made landfall near Wrightsville Beach, NC, as a Category 1 storm on September 14, 2018. The storm's slow movement brought record rainfall, exceeding 30 inches in parts of southeast North Carolina, and extensive flooding to the region. Prior to Hurricane Florence, the US Drought Monitor designated portions of the Carolina Piedmont as Abnormally Dry, but overall the area was not experiencing drought. The map reflects the overall wet conditions in the period following Florence's arrival and an alleviation from previous dryness (Figure B-10a). The line chart shows the percentage of reports documenting flood conditions earlier in the period and a recovery to normal water levels as the weeks progress (Figure B-10b). Fewer CoCoRaHS observers submitted Condition Monitoring reports post-Florence. This could be due to the devastating nature of the event which may have affected some observers' ability to report, and/or the lack of drought conditions may have made reporting appear less urgent.

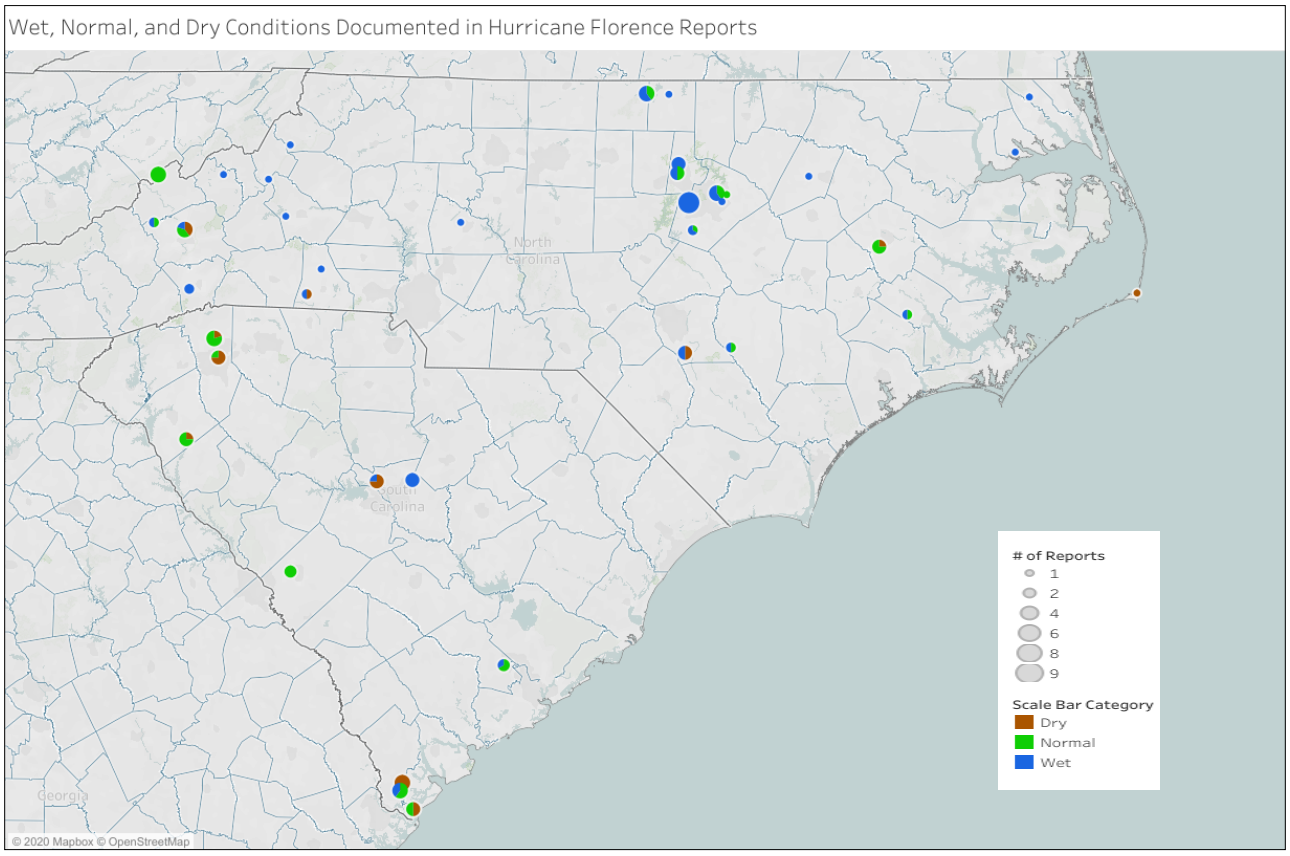


Figure B-10a: Wet, Normal, and Dry Conditions Documented in Hurricane Florence Reports. View the interactive map here.

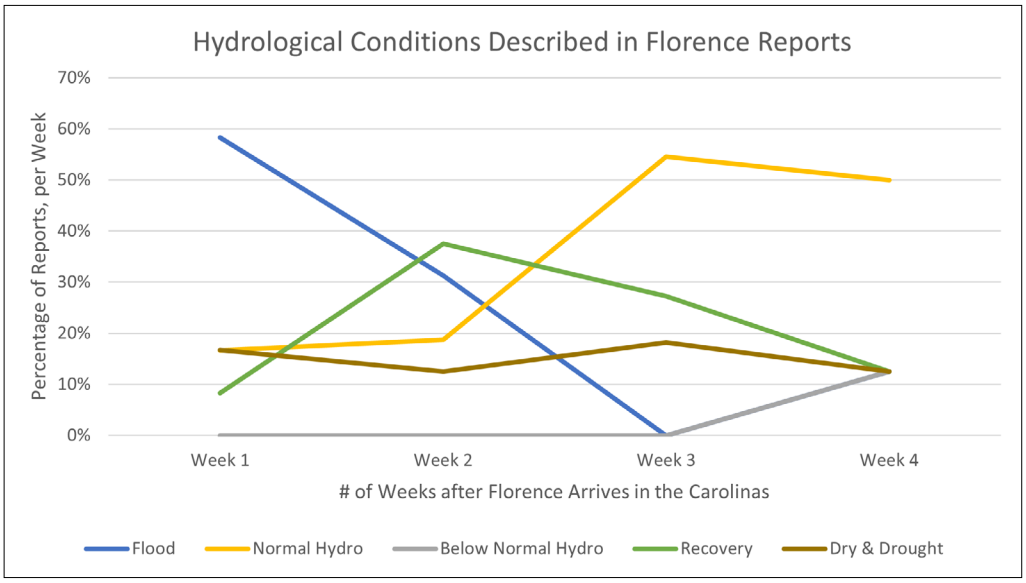


Figure B-10b: Hydrological Conditions Described in Hurricane Florence Reports

Hurricane Dorian made landfall near Cape Hatteras, NC, on September 6, 2019. Rainfall amounts of nearly a foot were recorded in New Hanover County, NC. Flooding along the coast was more localized during Dorian compared to other recent hurricanes. The storm did little to relieve drier conditions inland, where the lack of precipitation from Dorian and high temperatures led to a flash drought across the Southeast in fall 2019. The map shows the extent of dry conditions in fall 2019 as indicated by Condition Monitoring observers' scale bar selections in the weeks following Dorian (Figure B-11a). The line chart shows that Condition Monitoring observers documented declining water levels and the onset of drought in the weeks following the hurricane (Figure B-11b).

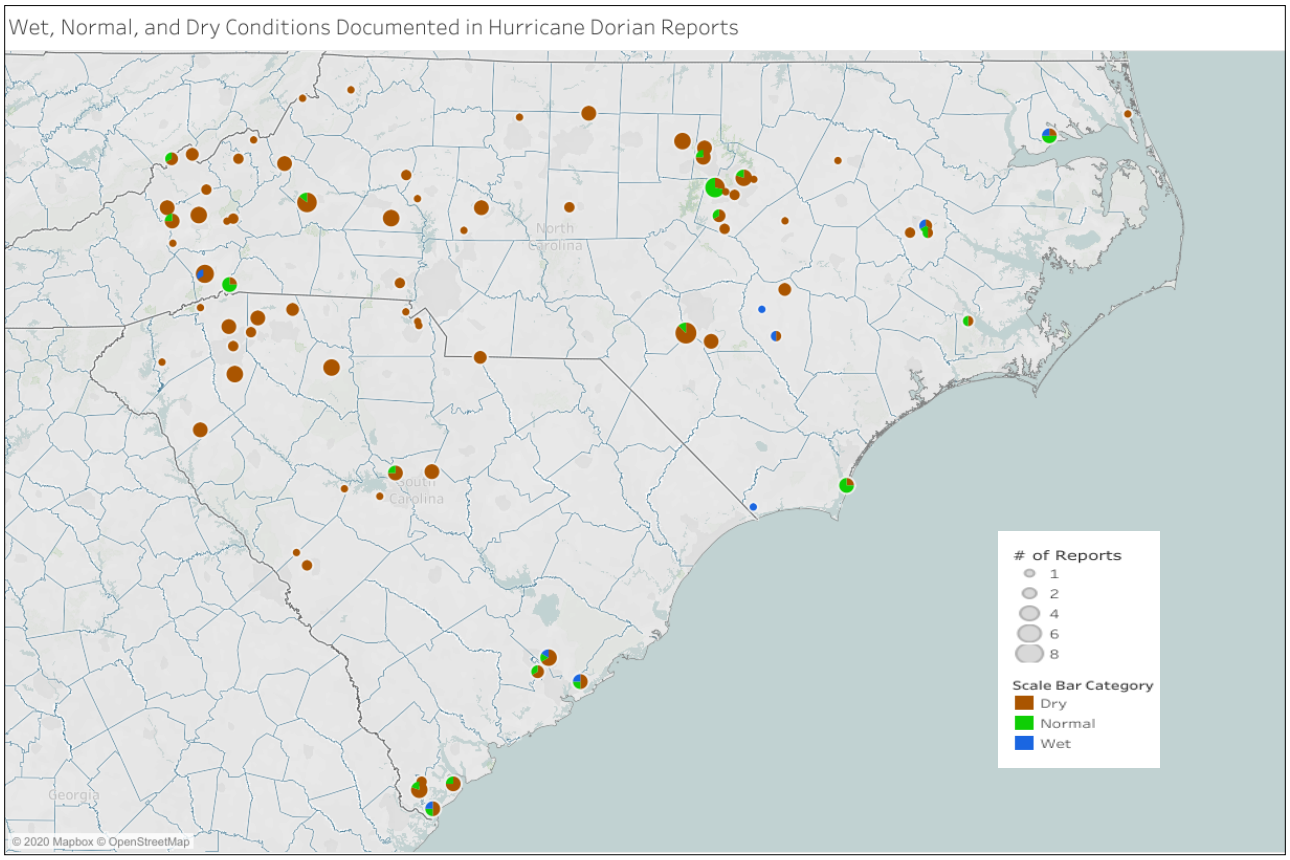


Figure B-11a: Wet, Normal, and Dry Conditions Documented in Hurricane Dorian Reports. View the interactive map here.

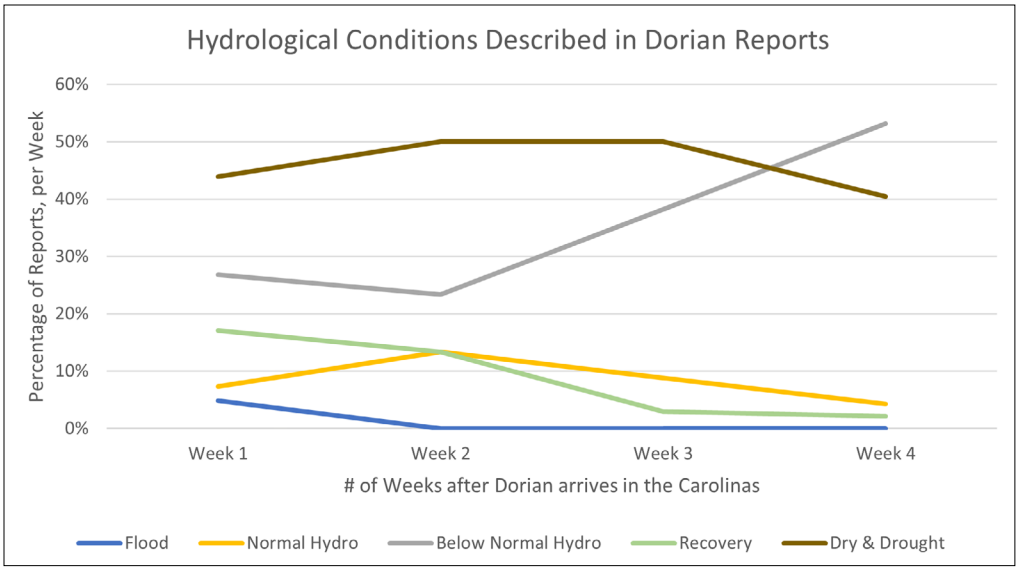


Figure B-11b: Hydrological Conditions Described in Hurricane Dorian Reports

Winter Conditions

This study categorized "Winter Conditions" to include precipitation events such as snow and sleet, freezing temperatures, and impacts associated with these types of events and conditions. Figure B-12 shows the occurrences of these events, as reported by the agencies and Condition Monitoring volunteers.

As the region typically experiences only a few snow events per year, these are easy to identify in the timeline and to see that CoCoRaHS observers and the agencies generally report on the same events. These events also include occurrences of sleet and freezing rain. Condition Monitoring reports tended to include a wider range of information, including occurrences of trace amounts of snow or sleet and the general effects of winter precipitation on ground conditions, water levels, and vegetation (Figure B-13.)

In contrast, agency discussions of frost/freeze events were limited, while CoCoRaHS observers reported extensively on these occurrences (Figure B-12). Observers use the Condition Monitoring reports to document the first and last frost or freeze of the season. They also provide information about associated impacts of frost/freeze events that occur throughout the year, particularly as they relate to plants and wildlife. For example, reports submitted in summer 2017 note the long-lasting impacts from the severe March freeze event after warm weather in February led to an early bloom for some crops.

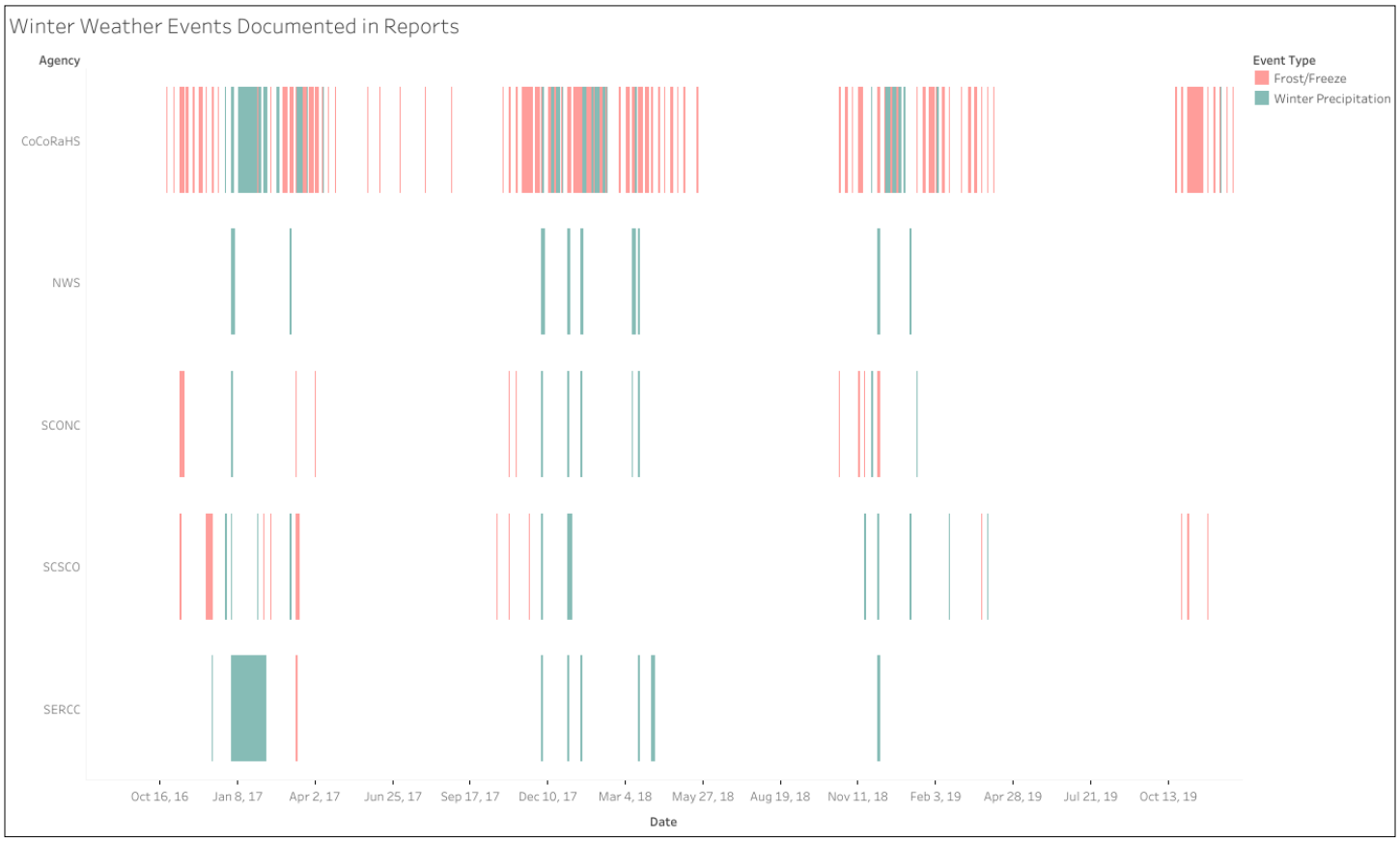


Figure B-12: Winter Weather Events Documented in All Reports. View the interactive timeline here.

Figure B-13 shows the geographic distribution of observers' locations, which corresponds to the areas where winter precipitation is more common. Volunteers provide a wide variety of information beyond the meteorological aspects of the events, such as business and school closings and effects on vegetation and wildlife. The circle size represents the number of events included in an observers' reports. The color of the "pie slices" in the map represents the report content:

- **Multi-Precipitation Event:** Winter precipitation totals, coming from a variety of winter precipitation types (i.e., snow, sleet, freezing rain, and rain).
- **Snow Event:** Snow amounts, such as snow depth and/or liquid water equivalent; accumulated snow for the reporting period; amount of snow on the ground at the time of the report; may also include information about impacts and associated conditions.
- **General Conditions:** Observations about how winter precipitation has affected soil and water body conditions, such as frozen or snow-covered ground, increasing water levels due to snow melt; also includes dry conditions due to limited amounts of rain and winter weather.
- **Trace Event:** Occurrences of winter weather precipitation with trace or negligible amounts; may include description of observed conditions, such as frozen ground or no accumulation

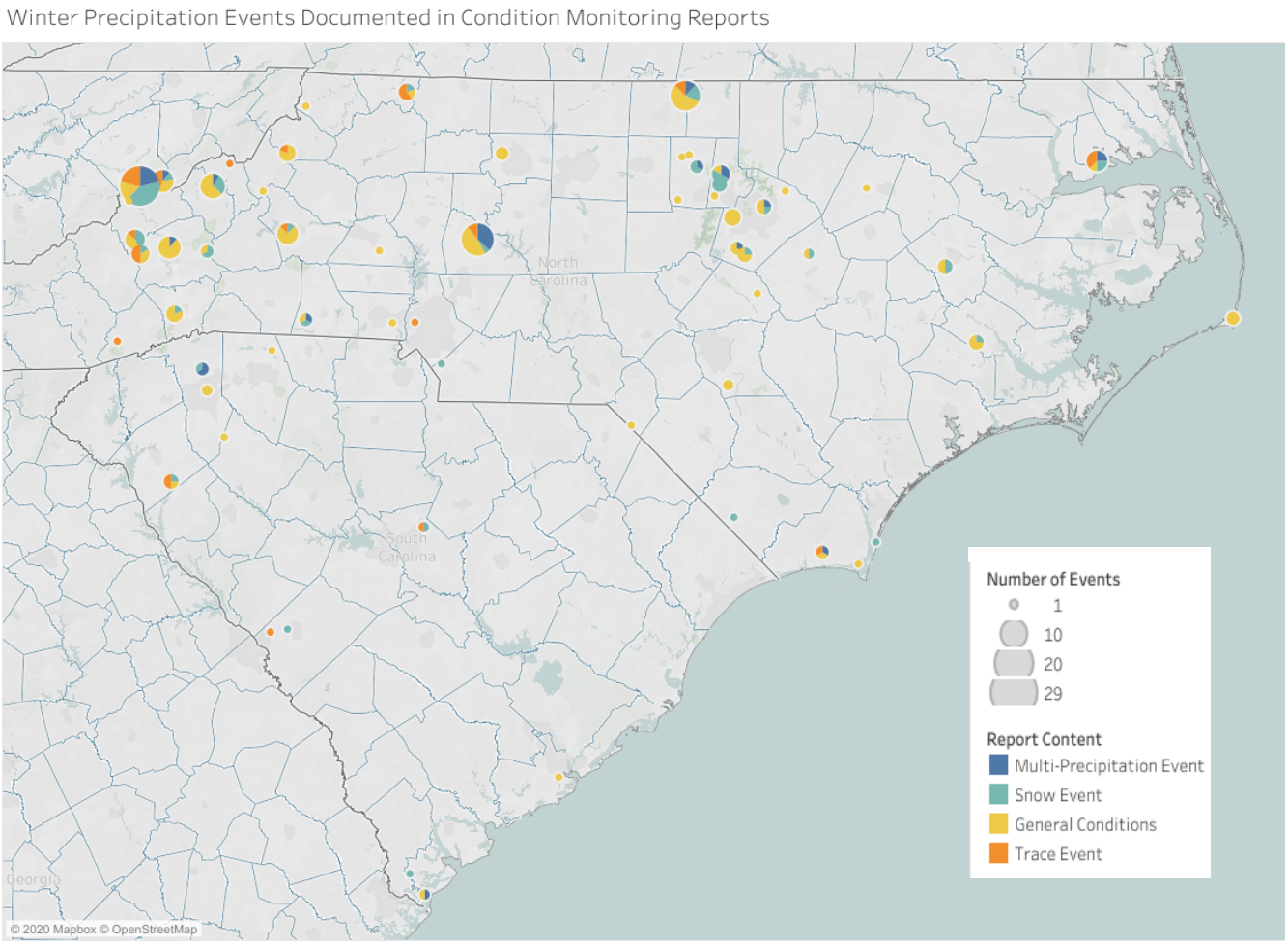


Figure B-13: Winter Precipitation Events Documented in Condition Monitoring Reports. View the interactive map here.

Figure B-14: shows the geographic distribution of observers' locations. Compared to the location of winter precipitation events, frost and freeze events appear throughout the region and are of particular concern to farmers and gardeners who often report extensively on effects to crops, fruits, and yard plantings. The circle size represents the number of events included in an observers' reports. The color of the "pie slices" in the map represents the report content:

- **First Frost/Freeze:** Occurrence of a first frost or first freeze, a specific date or week can be determined from report content.
- **Frost/Freeze Event:** A notable frost or freeze event; reports typically include a date and describe associated impacts and conditions.
- **Ice:** Reference to ice on water bodies, yards, vegetation, or roads due to cold temperatures.
- **Related Conditions & Impacts:** Descriptions of impacts caused by frost and/or freeze events; may not include enough detail to determine an actual event date or week.

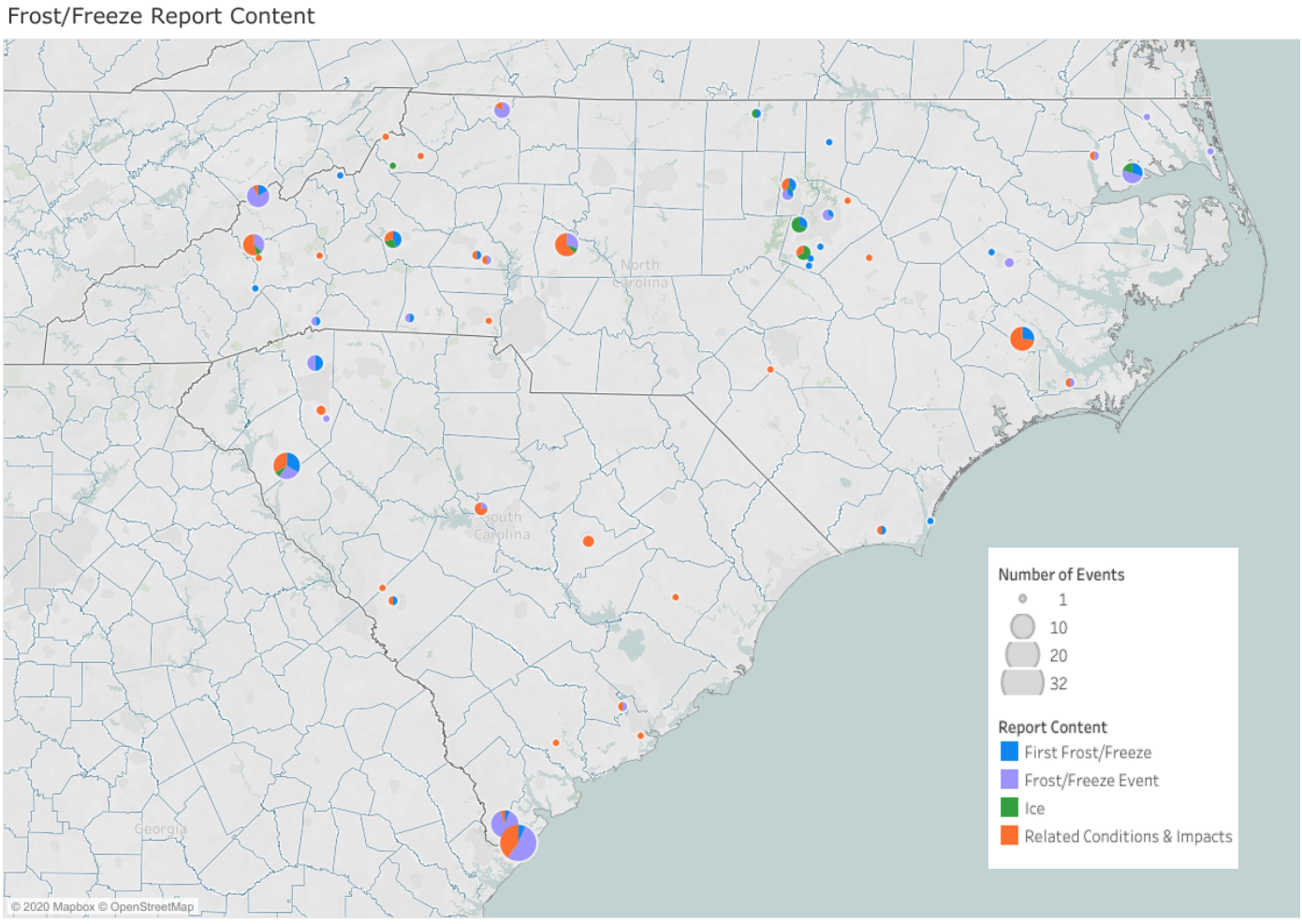


Figure B-14: Frost/Freeze Events Documented in Condition Monitoring Reports. View the interactive map here.