Climate and Health in North Carolina: Emerging Risks and Opportunities

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Summary

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Key Messages

- North Carolina experiences a wide range of extreme weather events, including hurricanes, floods, droughts, heat waves, winter storms, cold spells, hail, high winds, lightning, and tornadoes. All of these events affect human health and well-being.

- Identifying the underlying risks and vulnerabilities from these events is an essential part of the climate change message. By taking steps to reduce vulnerability to these events through improved monitoring, prediction, education, communication, and planning, North Carolinians can become more resilient to climate change. These steps should be taken as part of our everyday lives, not just in response to an extreme event or disaster.

- Developing tools and products that translate weather and climate information into a form that is useful for public health can also help in managing and reducing vulnerability. There exists a dense network of weather stations in North Carolina, as well as a significant amount of health data from sources such as the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT), CDC, and various research programs. Therefore, there is much potential to link these sources of information to improve surveillance and prediction, particularly for conditions that are not routinely monitored but may have a significant effect on local health.

- Air quality in North Carolina has been improving over the past decade due to state and federal actions and stricter standards to reduce emissions. Air awareness campaigns, which have been launched successfully in several states, may serve as useful models to promote other aspects of public health affected by climate.

- Major outbreaks of waterborne and foodborne disease have been linked to specific weather events and climate patterns. In North Carolina, poor water quality has been linked to periods of drought and heavy precipitation, both of which may increase in frequency with climate change. The development of early warning systems for these diseases should consider their complex ecology and focus on the pathogens and species that pose the greatest risk. Opportunities to link disease surveillance systems with available climate and environmental data should be explored.

- Vulnerability to heat-related illness is not just tied to heat waves. Expanding and improving the surveillance of heat-related illness throughout the warm season can significantly reduce the overall burden on the public health system. Improving education and communication, particularly among at-risk groups and communities, may best be accomplished through collaborative efforts between local meteorologists and public health officials.

- There are numerous sources of information on natural hazards and preparedness plans in North Carolina. However, it is unknown whether this information is being adequately disseminated or communicated. Continued growth in population, along with socioeconomic and environmental change, is placing stress on both natural and man-made systems. It is important to consider whether local governments or other entities should become more proactive in conveying information on natural disasters and their risks.

- Adaptation planning in North Carolina is occurring across various stages of discussion and implementation. Because public health touches all aspects of society, there may be several entry points for public health in adaptation planning. With numerous groups in North Carolina conducting fundamental and applied research on climate and health, with statewide weather monitoring and health surveillance systems in place, and with a strong public health and emergency response infrastructure, North Carolina may serve as an excellent test-bed for building a comprehensive climate change adaptation strategy for public health.

Overview and Objectives

Weather and climate affect human health in a number of ways, from heat stress and respiratory illness during heat waves to outbreaks of gastrointestinal illness following heavy rainfall to injury and trauma resulting from severe storms. North Carolina (NC) is a diverse state with respect to climate, population, and socioeconomic conditions, and this creates unique challenges for public health. On August 19, 2011, a symposium was held on the campus of UNC-Chapel Hill to address issues of climate and health in NC and identify areas where additional research, collaboration, and education are needed. In particular, this symposium was designed to provide a forum for engagement and discussion between climate and health researchers, officials from federal and state agencies, and local health practitioners in NC, who are on the front lines in responding to the health needs of their communities. Recognizing that many of the health impacts from weather and climate are local in scale and are intimately tied to the local environment and public health infrastructure, another goal of this symposium was to address the local health risks associated with weather and climate and the opportunities for managing these risks through adaptation. The symposium was organized topically into four panel discussions led by members of both the climate and public health communities: 1) heat waves and heat-related illness; 2) air quality and respiratory disease; 3) precipitation, drought, and waterborne and foodborne disease; and 4) injuries, mental health, and severe storms. Panel presentations may be downloaded from the workshop website at http://www.sercc.com/ncclimatehealth/. Additional resources on climate and health in North Carolina and across the globe can be found at http://www.sercc.com/climate_health/.

Introductions and Background

The workshop began with introductions from the sponsoring agencies and organizations – the Centers for Disease Control and Prevention (CDC), the NC Association of Local Health Directors, the NC Division of Public Health (DPH), and the Southeast Regional Climate Center – as well as from the North Carolina Interagency Leadership Team for climate change adaptation.

In 2010, the NC Department of Health and Human Services received funding through the CDC's Climate-Ready Cities and States Initiative, led by the Climate and Health Program within the National Center for Environmental Health, to start a climate change program within the DPH. The goal of the program in NC is to develop a strategic plan that addresses the health impacts of climate change across the state. The development of a strategic plan involves a series of assessments focused on vulnerability, health risk, intervention, and gap analysis. A key component to this work is the establishment of partnerships with stakeholders across local, state, and federal agencies, as well as with those in the climate community. Effective collaboration among stakeholders is vital to the success of any strategic plan. This type of interaction often begins with conversations and dialogues in open settings, much like this workshop, where people can begin to share ideas and resources. The creation of the climate change program within DPH may serve as a vehicle to empower these individuals and groups to work together to address what it means to have a healthy and resilient NC in the face of climate change. With numerous groups in NC conducting fundamental and applied research on climate and health, with statewide weather monitoring and health surveillance systems in place, and with a strong public health

and emergency response infrastructure, NC may serve as an excellent test-bed for building a comprehensive climate change adaptation strategy for public health.

The Climate and Health program (formerly the Climate Change Program) within CDC was formally constituted in 2009 and fills three critical roles: 1) to analyze and translate the latest findings in climate science to their public health partners; 2) to apply these findings to decision support tools (e.g. vulnerability maps, surveillance tools, adaptation planning) that will aid in state and local public health response; and 3) to provide leadership to ensure that public health is represented in climate change adaptation and mitigation strategies and create bridges between public health and other sectors. Filling each of these roles involves bridging the gap between climate science and public health. It is critical that a great understanding of the climate change impacts on human health be achieved, as climate change messages are often mistakenly framed as solely environmental or political issues. Climate change is a significant threat to human health.

The Climate and Health program is funding several cities and states through its Climate-Ready Cities and States Initiative to build the capacity of state and local health departments to address the public health consequences of climate change and its effect on human health. The funding period runs from September 2010 to August 2013. North Carolina was provided with Category-1 funding, which involves the creation of a strategic plan and establishment of partnerships with key stakeholders. Workshops such as this one are excellent vehicles for establishing these partnerships and identifying areas where collaboration is needed. Category-2 funding was provided to help strengthen the capacity of cities and states that have already developed a climate change program, particularly through efforts that focus on the most vulnerable populations and communities. More information on the Climate and Health Program can be found at: http://www.cdc.gov/climatechange/. More information on the Climate-Ready Cities and States Initiative can be found at: http://www.cdc.gov/climatechange/climate_ready.htm

The involvement of local health departments is critical in the development of a strategic plan to address the effects of weather and climate on public health. Because they work on the front-lines in protecting the health of their communities, local health departments are often the first to recognize the presence or emergence of environmental health threats, as well as changes in their patterns over time. Additionally, local health departments are a source of health information and guidance within communities. Effectively communicating climate change as a human health issue will involve close partnerships with local health departments.

In NC, the goal of developing a state-level climate change adaptation plan has been spear-headed by a group of federal and state agencies known as the NC Interagency Leadership Team (ILT). Formed in 2004, the ILT is comprised of five federal agencies (Federal Highway Administration, U.S. EPA, U.S. Army Corp of Engineers, U.S. Fish and Wildlife Services, and the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service) and five state agencies (Department of Transportation, Department of Commerce, Wildlife Resources Commission, Department of Environment and Natural Resources, and Department of Cultural Resources). One of the initial goals of the ILT was to enhance mobility and transportation across NC while protecting natural and cultural resources and

creating economic opportunity and development. This involved the formation of partnerships with local governments to integrate transportation and land use planning with cultural and natural resource protection. In 2007, the ILT began discussions on the issues of climate change and sea-level rise in NC. In 2009, the ILT led a major workshop in Raleigh that brought together scientists and members from numerous sectors to begin the process of assessing how climate change may affect our infrastructures and resources in NC and whether we are prepared to address the impacts of climate change in these areas. The workshop focused on adaptation and mitigation strategies, with emphasis on the importance of co-benefits. On-going work, however, has focused primarily on adaptation strategies due to the lack of political support for mitigation strategies. One area of focus has been on the acquisition of datasets that could be integrated into a geographic information system to map and locate areas that are most vulnerable to specific impacts. Identifying risk from natural hazards is an essential part of the climate change message – we may see an increase in natural disasters in the future, and more people may be in harm's way. In addition, the ILT has partnered with various groups funded by NOAA to conduct a series of detailed vulnerability assessments for each sector in NC. These assessments were conducted using a "bottom-up" approach whereby information and data were obtained through engagements and interactions with each sector. More information on the ILT can be found at: http://www.climatechange.nc.gov/

The Southeast Regional Climate Center (SERCC) is one of six regional climate centers and, as part of NOAA's Regional Climate Center Program, serves as the hub for climate services, applications, research, and education in the Southeast. The SERCC provides climate service support and engages in research germane to the states and territories of Alabama, Florida, Georgia, South Carolina, North Carolina, Virginia, the District of Columbia, Puerto Rico, and the American Virgin Islands. Originally established in 1989 at the South Carolina Department of Natural Resources in Columbia, SC, the SERCC relocated to the Department of Geography at the University of North Carolina at Chapel Hill in the spring of 2007. The SERCC provides a variety of climate services to meet sector-specific needs in the Southeast region. These include climate data ingest, quality control, and product development via the Applied Climate Information System (ACIS); monitoring of regional climate patterns and their societal impacts in the context of climate variability and change; education and outreach support; and applied climate research. These services and activities are enhanced through regional support from and collaboration with a variety of entities, including a strong and active network of State Climate Offices, NOAA centers (including NCDC), RISAs, Sea Grant programs, and academic institutions, among others. Currently, the SERCC is focusing its user-engagement and research activities in areas where there is a strong need for expertise in the use of climate information. These areas include public health, planning, tourism, and coastal environments. A number of outreach activities and research projects are presently under various stages of development. These include collaborative research projects on the health impacts of heat waves, heavy rain and drought. The SERCC is also working on behalf of NOAA in support of the upcoming National Climate Assessment. This work involves a series of vulnerability assessments, in partnership with the State Climate Offices, to determine how climate services can be improved and expanded across the Southeast. Additionally, the SERCC has initiated a research program, in collaboration with experts and professionals in other fields, to explore the socioeconomic and human health impacts of extreme weather events in the Southeast. The ultimate goal of this research program

is to provide extended-range weather and climate forecasts that are tailored to specific user groups. These forecasts would provide valuable climatological context and more specificity with respect to the character and probability of extreme events. More information on the SERCC can be found here: http://www.sercc.com/

Keynote Address: North Carolina Weather and Climate

Dr. Ryan Boyles, NC State Climatologist, delivered the keynote address on weather and climate in NC and discussed the role that the climate community can play in addressing issues of climate variability and change with respect to public health. The NC State Climate Office (SCO) operates uniquely as a service center in a university environment (NC State University). This facilitates the development of tools and products that build off of weather and climate datasets and are informed by fundamental research methods. These tools and products are designed to help decision-makers who have climate-sensitive interests. Most funding for projects at the NC SCO comes from the agriculture and transportation sectors, as well as from NOAA. As a result, the NC SCO has invested heavily in these areas, though the long-term plan of the office is to have a dedicated climate specialist for all sectors, including public health. However, it is unlikely that sufficient funding will be available to develop a state-level program that integrates climate science and services into all sectors. Therefore, there is a need to rely on existing partnerships and funding streams to create opportunities and find creative ways to thread climate into those activities. For example, the placement of the SERCC at UNC-Chapel Hill made it easier for other sectors and academic units, such as public health and city and regional planning, to interact with the climate community.

The heritage of SCOs goes back to the early 1900s when it was a federal position within the National Weather Service (NWS). At that time, the primary role the SCOs was to be a public resource for weather and climate data and provide agricultural forecasts. When the NWS was restructured in the 1960s, the SCO position was eliminated and responsibility for maintaining an office was relegated to individual states. The NC SCO began operations at UNC-Chapel Hill in 1976 and was later moved to NC State University in 1980. In the late 1990s, a large investment was made by the state of NC and NC State University to develop a core infrastructure that would sustain a strong SCO focused on providing climate services to the citizens of NC. The concept of climate service is predicated on the notion that good decisions can only be made with quality data backed by quality science. Moreover, this information needs to be used to develop tools and products that help people make good decisions, not used for studies whose results sit in a publication on a shelf. This concept of climate service has taken on particular importance over the last several years, as there has been a marked increase in the demand for climate information across virtually all facets of society.

North Carolina has perhaps the most diverse and complex climate in the eastern US. In fact, there are very few places in the world that experience the wide range of weather events that are experienced in NC. What is important to understand is that these events can be extreme, dangerous, and pose a serious threat to human life. Effectively communicating the threat from extreme weather

events is critical so people can take the necessary measures to protect themselves and better understand how these events may change in the future.

The weather and climate of NC is influenced by its latitude (sits at the intersection of cold and warm air masses with much day-to-day variability), topography (the influence of the mountains complicates weather forecasting, particularly in the winter season), and proximity to water (without the Gulf of Mexico and Atlantic Ocean nearby, our climate would be significantly drier). The juxtaposition of the Gulf Stream and Labrador currents off the NC coast creates a favorable region for the development of Nor'easters that can contribute to beach erosion on the coast.

Weather in NC is also influenced by the position of the jet stream, a fast-moving river of air located over 20,000 feet up in the atmosphere. During the winter season, the jet stream dips across the southern tier of the U.S., carrying storm systems through the region. These storms can produce winter precipitation if enough cold air is available. Winter storms that move up the Southeast coast contribute significantly to coastal erosion as well. In the summer, the jet stream moves northward and our weather becomes dominated by the Bermuda High. This leads to localized storms and warm, humid conditions across NC. When the Bermuda High shifts to the west and becomes situated over the Southeast U.S., the winds shift from the northwest and bring in warm, dry air from the interior of the U.S., which can lead to drought conditions over NC. Unfortunately, the position of the Bermuda High can only be predicted a few days in advance. Predictability during the winter season is much greater (weeks to months in advance) because of the influence of the El Nino-Southern Oscillation (ENSO), a coupled ocean-atmosphere circulation over the tropical Pacific Ocean. When the ENSO is in a positive phase (El Nino), winters in NC tend to be wetter and cooler. Conversely, when the ENSO is in a negative phase (La Nina), winters in NC tend to be drier and warmer. Other large-scale circulation patterns that influence our weather, such as the Arctic Oscillation, are only predictable several days in advance.

While most climate change and global warming arguments focus on long-term trends in average temperature and precipitation, it is the extreme events that have the greatest impact on society. These include tornadoes, lightning, high winds, floods, hurricanes, winter storms, and droughts. Tornadoes occur most frequently in central and eastern NC, but can occur in the mountains. Though most tornadoes are weak, it is the few intense tornadoes that kill and injure the most people. Many of these deaths occur in mobile homes. Future research is needed to identify the populations and communities most vulnerable to tornadoes in NC and use this information to better communicate the risks associated with tornadoes and improve warnings. In addition to tornadoes, there is a high risk associated with thunderstorm winds and high winds from winter season storms. Though these types of wind events occur more frequently than tornadoes, they are generally not perceived as a high risk. Lightning is also a major hazard in NC. Over the last 5 years, NC ranks #5 in the U.S. in terms of lightning-related deaths. NC is also prone to flooding from thunderstorms, coastal storms, and hurricanes. In fact, flooding kills more people in a given year than tornadoes and most other forms of extreme weather. Droughts are difficult to define because multiple systems and sectors can be affected in different ways. Drought can have short-term implications for farmers, as well as long-term implications for water managers.

Perhaps the greatest and most visible threat comes from hurricanes. Fortunately, hurricanes are noticeable several days in advance, allowing residents to prepare. However, the population in NC is largely unprepared for hurricanes. Better communication and education are needed. Because hurricanes can track across the Atlantic Ocean and Gulf of Mexico, every county in NC is at risk. A striking example is the series of hurricanes that made landfall along the Gulf Coast in 2004, causing extraordinary flooding and hundreds of landslides in western NC. Indeed, flooding is the #1 hazard associated with hurricanes.

The key to addressing vulnerabilities to weather and climate extremes in NC is improving the ability to monitor and predict these events so that individuals can make both short-term and long-term decisions. Developing tools and products that allow weather and climate information to be translated into a form that is useful to individuals, businesses, and decision-makers can also help in managing and reducing vulnerability. There is a dense network of weather stations in NC that provide real-time data. This information is extremely valuable before and during an event, as it may help save lives. Obtaining this information at increasingly local scales is important. The next step in improving short-term and long-term forecasts is addressing the societal impacts. For example, if a location is expected to receive 5 inches of rain over the next several days, what would the likely impacts be and how can people prepare for them? Good planning can increase resiliency to the wide range of extreme events that occur across NC. This is particularly important in the context of climate change. In NC, climate change may mean more variability in the types of extreme events that NC already experiences. Therefore, by taking steps to reduce vulnerability to known hazards associated with these events (e.g. better communication, education, and planning), NC can increase its resiliency to climate change.

Several points were made during the Q&A portion of the presentation. It was suggested that broadcast meteorologists could play a lead role in disseminating climate change information to the public, particularly since they are already seen as a trusted source of weather information. Two important limitations are that most broadcast meteorologists are not trained in climate science and that their short weather pitch is controlled by interests of the news director. Finding ways to integrate climate information into the 3-5 minute weather segment is a challenge, but also a real possibility.

The recent occurrence of hot summers and bitterly cold winters has led some people to mistake short-term climate variability for long-term climate change. The occurrence of one cold winter or one particularly hot summer does not automatically signal a long-term trend; they are manifestations of short-term variability that can be tied to patterns such as ENSO or the Arctic Oscillation. It is important to find more effective ways to communicate this difference, beginning with the removal of scientific jargon and concepts and developing words, phrases, and concepts that people can understand and use to make decisions. Better education and communication will allow people to better understand the difference between short-term variability and long-term climate change, allowing them to make smarter and more informed decisions.

The overarching question resulting from this discussion was: What message should the public health community deliver about climate change? It was made clear that the public health community should not be educating people on the climate science. Instead, they should be talking about the health

impacts and how people can decrease their risk. This begs the question: At what level does the public health community need to understand the science behind climate change to be able to deliver this message? Since there is a portion of society that will dismiss any message regarding climate change, it was suggested that the public health message should not focus on the impacts from climate change. Alternatively, the message should revolve around the fact that the weather and climate we currently face have implications for public health, and that addressing these vulnerabilities and risks can improve human health regardless of what the climate may be in the future.

Panel Summary: Heat Waves

Meteorology and climatology of heat waves:

- There is no universal definition of a heat wave, though the term is typically used when discussing periods of exceptionally hot (and sometimes humid) temperatures that can lead to public health and other societal impacts (e.g. power grid failure)
- During the summer, extended periods of exceptionally hot temperatures can cover large geographic areas (e.g. the eastern half of the U.S. in July 2011); however, there is much regional to local scale variability in the pattern of heat and humidity
- While the Bermuda High dominates the weather pattern in NC during the warm season, periods of exceptionally hot weather require additional ingredients. When the surface is particularly dry, as is the case during drought, the rate of cooling due to evaporation of water and transpiration of plants decreases and more of the sun's energy goes into directly heating the surface. A similar phenomenon occurs in cities due to the urban heat island effect. In particular, the urban landscape disturbs the processes that help cool the surface at night, leading to warmer nighttime temperatures in cities compared to surrounding rural areas. Exceptionally warm temperatures along the NC coast appear to be associated with strong west and northwesterly winds that blow hot, dry air from the land into the coastal plain. These offshore winds prevent the inland penetration of the sea breeze, which helps to moderate daytime temperatures on the coast.
- Long-term trends in extreme heat also vary considerably across NC are driven primarily by local conditions. The NC Mountains experienced several major heat waves in the 1950s that have not been matched since. Hot summers have been more frequent in the Piedmont in the last decade or so, but this does not appear to be part of a long-term trend. And along the coast, there is no discernable trend in the frequency of extreme heat over time. One trend that is consistent across NC is an increase in the number of exceptionally warm overnight temperatures since about the 1970s. This is likely due to urban development in the vicinity of many weather stations across the state.
- Several NOAA offices (the National Weather Service, Hydrometeorological Prediction Center, Climate Prediction Center) are tasked with issuing excessive heat forecasts. These range from short-term forecasts (12-48 hours) to weekly forecasts. These forecasts are based on the heat index, which is a measure of the combined influence of temperature and humidity on the human body.

Educating the public about these forecasts and communicating the public health impacts are priorities and NOAA is working with the CDC to address them.

Epidemiology of heat waves

- Heat waves often capture our imagination and attention, but are they really our concern as public health officials and researchers? Are heat waves really defined by their impacts? If so, it shifts attention to aberrations, or deviations from what is typically experienced. What is typical may be of greater concern to the public health community.
- Research conducted in NC shows that while the emergency department (ED) visit rates for heat-related illness are highest at the tail of the temperature distribution, the total number of ED visits throughout the year is actually highest near the middle of the distribution. What this implies is that while the greatest risk occurs with the highest temperatures, the true public health impact occurs at lower temperatures because more patients are visiting the ER for heat-related illness over the course of the year when the temperature is at these less deviant levels. Moreover, the rate of ED visits for heat-related illness does not dramatically increase above a certain threshold as is often implied in the literature. Instead, in NC, the rate increases exponentially throughout the temperature distribution beginning around 70°F. What might these results mean in the context of assessing risk and susceptibility? How might these effect public health interventions?
- Future work may wish to examine the role of humidity on these days with lower temperatures (but high public health impact) as well as the effect of using maximum, minimum, and apparent temperature (e.g. heat index) to examine temperature-health relationships .
- In most epidemiological studies and surveillance practices, heat waves are defined as multiple days above a given temperature threshold (either an absolute or relative threshold). To assess the impact of the heat wave on mortality or morbidity, the question is asked "How many people died (went to the ED) on these heat wave days compared to non-heat wave days?" However, the future does not hold predictive power. In this case, if a heat wave is defined as three consecutive days above a threshold, did the people who died on the second day die during the heat wave? How could they if the heat wave, as defined here, has not been realized yet? In fact, mortality or morbidity due to temperature effects are based on what a person experiences on that day and perhaps what they experience in the day(s) prior. Instead, the deaths or ER visits that are "heat-wave related" are those that occur following a heat wave event, and therefore control for deaths and ED visits that could have been attributed to temperature in the absence of the heat wave.
- In NC, the public health response to heat is led through a coordinated effort between the Epidemiological branch of DPH and the Public Health Preparedness branch. The goal is to monitor and communicate the occurrence of heat-related injuries. The heat wave of 2007 gained much media attention and prompted greater surveillance. In 2010, the Injury Prevention branch began posting their weekly surveillance activities using data from NC DETECT. They use various key words from the chief complaints, E-codes, and sometimes triage notes to identify heat-related injuries. Collaborations with other groups will be necessary to expand or improve upon the surveillance of heat-related injuries, as DHHS currently has limited resources to devote to this task. One group that

may be able to help is the National Weather Service. Could their forecasts include more information and discussion regarding the public health impacts of extreme heat?

- Communicating the effect of temperature on human health is an important task that is made difficult because so much of the focus is placed on heat waves and deviant events. In fact, heat waves explain very little of the variance in ED visits in NC. Therefore, it may not be useful to focus the climate change discussion solely on heat waves. Instead, the climate change discussion, from a public health perspective, should focus on the likelihood of experiencing more persistently warm days and shift the public health response away from the more extreme, deviant events.

Panel Summary: Air Quality

Monitoring

- The amount of air pollution over NC has decreased over the past 30-40 years. At the same time, air quality monitoring has improved across the state and across the country.
- The EPA sets primary and secondary standards for six criteria pollutants (i.e. the National Ambient Air Quality Standards, or NAAQS). The primary standards focus on ozone and small particulate matter (PM2.5) because they have the greatest impact on human health, particularly respiratory and, in the case of PM2.5, cardiovascular health.
- There is a stronger seasonal pattern to ozone (April-October) then there is to PM2.5 because ozone production depends on the presence of sunlight and heat (though ozone produced upwind can be transported into the state). PM2.5 is more complicated than ozone in terms of source, which includes dust, dirt, soot, and smoke. Most PM are primary (i.e. directly emitted through burning fires, vehicle emissions, etc.), but some are secondary. NAAQS standards are rarely exceeded in NC except in situations where there are large or numerous wildfires. Unfortunately, PM is underreported in these areas due to the lack of monitoring stations.
- The NAAQS for ozone was reduced from 80 ppb to 75 ppb in 2008, which is about 30 ppb above the background concentration. In NC, four counties exceeded the new standard from 2008 to 2010. As a result, most monitoring activities take place within these counties; there are fewer monitors elsewhere since air quality is less of a problem in rural areas.
- Despite an increase in the frequency of warm temperatures, the number of days in NC exceeding the NAAQS has been dropping significantly in the past decade. This may be due to more state and federal actions and stricter standards to reduce ozone-forming emissions from power plants, vehicles, and other sources. There has also been a decrease in nitrous oxides due to stricter vehicle emissions testing.
- The NAAQS is translated into an Air Quality Index (AQI) for public communication. The index ranges from 0 to 500; an AQI of 100 corresponds to the primary standard and anything above this is considered “unhealthy”. The AQI categories include subjective descriptions that range from good to unhealthy to hazardous, as well as response recommendations.
- Air quality information is disseminated though a variety of sources. AIRNow is a collaborative effort to provide the public with easy access to national air quality information. The EPA has established a

subscription service called EnviroFlash that provides air quality information from state and local agencies. NC DENR also provides air quality information for NC. Additionally, the NWS and EPA have produced a gridded, deterministic air quality forecast product, which is particularly useful in areas that are not covered by a monitoring site.

Air quality and human/public health

- Who is going to be most susceptible to the health effects of climate change? Those most likely to be affected are children, the elderly, those with asthma, COPD, cardiovascular disease, allergies, those that are resource-poor, and those in vulnerable locations and environments.
- Asthma rates among children and adults have been increasing over time. Between 10-25% of the population has been diagnosed with asthma. Wildfires are a significant and often underappreciated source of poor air quality that can lead to negative health outcomes, particularly for people with pre-existing medical conditions
- The air mass conditions that are most strongly related to high rates of asthma incidence (i.e. tropical air masses and transition periods between air mass types) are likely to increase in the future based on long-range climate models. This suggests that asthma prevalence will increase in the future, placing additional burdens on public health. However, it is important to consider the potential benefits of climate change (possible reductions in ozone) and how they may affect air quality and human health.
- In NC, there is a significant amount of data on respiratory health at the state and county levels. This includes information from CDC as well as from NC DETECT. Coupled with the dense network of weather stations across the state and data collected by the NC Division of Air Quality, there is much potential to link these data sources in a meaningful way to improve surveillance and prediction. This is particularly important in cases that are not routinely monitored, but may have a significant effect on local health (e.g. factory hog farming and the production of hydrogen sulfites in eastern NC). Interoperable systems may be necessary, such as linking NC DETECT with the AIRNow system.
- Education and outreach should be the top priorities in responding to the health effects of climate change. Do we need experts on how to influence public opinion to counter the misinformation on climate change? National surveys indicate that most people in the US are actually concerned about climate change, while relatively few remain dismissive. Reaching out to concerned citizens and learning about their specific concerns is an important step. Our response and our message need to be relevant to what people are actually concerned about. Air awareness campaigns, which are active in several states, may serve as useful models to promote other aspects of public health affected by climate change. More generally, we need to empower the public health community to increase their monitoring capabilities and education (i.e. how can people protect themselves?). Close collaboration with public affairs in DPH and the media is needed to improve the public health message and make sure it reaches all communities and at-risk groups in NC.

Panel Summary: Waterborne and Foodborne Disease

Precipitation and drought

- The connections between precipitation and disease are complex; there is a fine line between receiving too much or too little precipitation. Heavy precipitation is considered the biggest forecast challenge. Will it be over a broad area or will it be localized? Predicting where it will rain and how much remains a real challenge.
- Heavy precipitation can lead to flooding, which can degrade water quality. Flash flooding refers to flooding that beings and ends quickly in response to locally heavy precipitation over a small area (e.g. the downtown area of a city). River flooding occurs in response to a prolonged period of heavy rainfall over the scale of a river basin or watershed. River flooding associated with tropical storms and hurricanes is particularly problematic in the coastal plain of NC where streams move slowly compared to the Piedmont, causing broad areas to be inundated with flood waters for long periods of time. Conversely, in heavier terrain, water moves more swiftly and therefore river flooding is less of a threat. River flooding can also occur when frontal boundaries stall over an area, leading to long periods of moisture transport. When these frontal boundaries interact with tropical cyclones, prodigious flooding can occur (e.g. Hurricane Floyd in 1999).
- Tropical cyclones and hurricanes contribute significantly to heavy precipitation and flooding in NC. Large, slow-moving tropical cyclones that interact with frontal boundaries are typically associated with the heaviest precipitation; storm strength is only weakly correlated with precipitation.
- The frequency of tropical cyclones in the western Atlantic basin is greatest off the NC coast. Averaged over several decades, a tropical cyclone will pass within 125 km of the NC coast about once a year; in the mountains, the frequency is once every three years.
- Tropical cyclones affecting NC tend to cluster in time; in other words, if a tropical cyclone makes landfall in NC, there is a high probability that another tropical cyclone will make landfall within several days or weeks. Examples include Hurricanes Dennis and Floyd in 1999 and Hurricanes Frances, Ivan, and Jeanne in 2004.
- Droughts can be divided into two main types: agricultural and hydrological. Agricultural droughts are short-lived (i.e. several weeks), respond quickly to changes in precipitation, and affect crop growth. Hydrological droughts are longer-lived (i.e. months to years) and are associated with decreases in groundwater levels and low river flows, which can lead to increased concentrations of contaminants and degraded water quality. Hydrological droughts respond less quickly to changes in precipitation (except with tropical cyclones); extended periods of above normal precipitation are therefore required to alleviate a hydrological drought.
- Agricultural droughts are influenced primarily by seasonal changes in evapotranspiration (typically occur in late summer in conjunction with warm temperatures and dry conditions; “flash droughts” can occur when conditions are especially hot and dry and evapotranspiration rates accelerate, such as in August 2007). Hydrological droughts are influenced by annual variability in precipitation and municipal water use.
- According to several state-wide drought indicators, NC experienced several major droughts in the early 20th century. However, the frequency of drought appears to be increasing, particularly over

the past 10-15 years. This may be the result of long-term reforestation of lands which used to be farms, resulting in more water being drawn out of the ground.

Foodborne disease

- Catastrophic weather events, such as Hurricane Katrina, have led to changes in population dynamics and agricultural production. Loss of infrastructure and population displacement places more people at risk for disease.
- Water and food are intimately connected (98% of the food we eat is water), and because climate change will have an effect on water supplies and water quality, it will also affect food production, distribution, and consumption.
- Clean and abundant water is essential to food production, processing, and preparation. It is also essential for personal hygiene. Approximately 70% of foodborne diseases in the U.S. are tied to poor personal hygiene. On the other hand, too much water can increase the risk of fecal contamination from sewage runoff and bacterial agents such as E. Coli and Salmonella.
- The major manifestations of climate change in foodborne disease incidence are temperature and nutrient overload, which impact food safety and security. Changes in nutrient overloads lead to changes in the ecology of people, animals, pests, and microbes, all with unintended consequences and risks to human health.
- Many enteric diseases have a seasonality that appears to be associated with temperature. For example, Salmonella and Campylobacter tend to peak about two weeks after the annual peak in temperature
- One of the best examples of an organism that responds uniquely to climate are various pathogenic vibrio species, which are ubiquitous in most marine waters. Outbreaks in these vibrio species in the 1990s were associated with unusually warm waters in Alaska and other northern regions including Europe (where they had never been seen before). These species are important to monitor because of their high mortality rates (50% in some cases). Cholera has long been linked to water temperature and precipitation patterns, which are driven primarily by ENSO cycles.
- Zoonotic diseases, such as Chagas, are likely to increase with climate change (particularly with higher temperatures) due to increases in susceptibility of animals to disease, increases in the range and abundance of vectors, and an increase in the length of the transmission cycle.
- Mycotoxins, which are produced by mold in warm, humid conditions, may become more prevalent with increased hydroclimatic and temperature variability, as plants are generally more susceptible during periods of drought.

Coastal ecosystems and health

- Research being conducted in the Neuse River Estuary is focused on understanding the impact of excessive nutrient inputs and extreme storm/weather events on estuarine health. This work includes humans as part of the marine ecosystem (the drivers and recipients of these effects).
- The microbiology of the estuarine system affects the health of communities along the Neuse River and new instrumentation allows researchers to examine various characteristics of the estuary that affect microbial activity (e.g. temperature, salinity, oxygen, chlorophyll, turbidity).

- There is a strong link between freshwater and oceanic inputs and the wind (tides are not as much of an issue in the estuaries). Since wind plays an important role, extreme storms with high winds are key drivers of ecosystem health. Even winds that are not particularly strong (less than 20 mph), particularly if they are unidirectional, can result in water column re-suspension. These events tend to occur most often in late summer and early fall, coincident with the Atlantic hurricane season.
- This research has shown that freshwater influx from precipitation and runoff from big coastal storms (nor'easters) severely disrupts the growth of phytoplankton blooms. Additionally, the best predictors of vibrio concentrations in the estuary are salinity and water temperature.
- The public health community has much experience in detecting and dealing with outbreaks, but how can they better detect water washed and water contact diseases that do not always occur in outbreaks? Two options are FoodNet and PulseNet. FoodNet is a passive surveillance system that focuses on many common foodborne diseases, but it may not be appropriate for epidemiological research. The larger foodborne outbreaks have been identified primarily through PulseNet, which covers NC, but it is threatened by budget cuts. There is adequate reporting of water contact diseases (e.g. infected cuts and wounds) but it is largely understudied. Various forms of vibrio are common and people are aware of them, but they are largely unreported as few people seek treatment in hospitals or urgent care centers. Pathogenic vibrios, such as Vulnificus, are routinely monitored by the CDC in the Gulf of Mexico because of their prevalence there.
- Can we begin building early warning systems that incorporate all the observational datasets and monitoring platforms that are currently available? Or, do we need more fundamental research before we can begin thinking of an early warning system? Most of the vibrio species along the coasts are not a threat to human health, so there is a risk of overprotecting or desensitizing the public. Focusing on those species with the greatest risk is a logical step, but the ecology is extremely complex. Foodborne illnesses may offer a greater opportunity to begin linking with available climate and environmental data. Big outbreaks appear to be associated with specific weather events and climate patterns (e.g. major flood, unusually wet summer).

Severe Storms

Overview

- Severe weather can occur in any season in NC. In the winter we can experience heavy snow, ice storms, and bitter cold. In the spring and summer we can experience tornadoes, damaging wind from thunderstorms, and hail. Summer also brings heat waves, and in the summer and fall we can experience hurricanes and tropical storms.
- Snow can occur anywhere in NC, even along the Outer Banks. Snowstorms can be widespread, covering much of the state, but heavy snow is often localized. Because of the tremendous variability in temperatures during the winter season, snow that accumulates on the ground often melts within a day or so, but in some big events the snow can stay on the ground for several weeks. Even small amounts of snow can cause major disruptions on roadways, leading to gridlock and accidents. In fact, most deaths and injuries from winter storms occur in traffic-related accidents. Power outages

can occur during snowstorms, but are generally not widespread because snow does not weigh down on power lines.

- Freezing rain occurs most frequently in the Piedmont region of NC. During major events there can be a broad swath of ice across a large portion of the state with some locations experiencing significant ice accumulations. Determining if and where significant freezing rain will occur is a big forecast challenge in the region. Power outages are a major problem with ice storms. Loss of power can lead people to riskier behavior. Most notably, emergency room admissions for carbon monoxide poisoning tend to increase following ice storms. Injuries can also occur from slips and falls on icy surfaces.
- Despite the fact that lightning is a major hazard in NC, it is not a factor in issuing a severe thunderstorm warning. Only large hail and high winds are considered when issuing a warning. Meteorologists should broadcast special statements that include the threat from excessive lightning, especially if a warning is not issued.
- Tornadoes are rare events compared to other types of severe weather, but they contribute to a significant number of deaths (particularly the most severe tornadoes). Thunderstorm winds tend to cause more damage overall than tornadoes.
- Flooding due to heavy rain is a major problem in urban and low-lying areas. Deaths due to drowning from people trying to cross flood waters either by foot or by vehicle are unfortunately not uncommon. Flooding from hurricanes causes more deaths and damage than wind and can occur anywhere in the state. The greatest threats from hurricanes along the coast are storm surge flooding and flying debris.

Public health response

- From a public health perspective, a disaster is an event that reveals the weaknesses in man-made systems. Reducing vulnerability to disasters involves fixing or adjusting those systems in ways that protect people. Doing this effectively may require building or improving systems for dual uses. However, reducing vulnerability may also involve changing everyday practices and behaviors: can the things we do during and following a disaster be done every day?
- Our vulnerability to disasters has increased over time. One reason is our dependence on mobility (i.e. a “just-in-time” society). When we are unable to relocate, seek shelter, or contact other people, we become more vulnerable and less resilient. Another reason is the shift in medical care to mostly out-patient service. As much as 80% of the most medically frail individuals are living outside of hospitals and other care centers. Not only do these individuals require more mobility, but they rely on other systems that are also vulnerable to limited mobility. In addition, our built infrastructure is not currently meeting the demands placed on it by our growing population. This includes our water supplies, roadways, and power grids. In terms of our public health infrastructure, many of our medical facilities may not be available when a disaster occurs because of changes in surge capacity (e.g. reduction in the number of hospital beds).
- The public health response is the same for all types of disasters. Mobilizing resources requires looking into the toolbox and determining what tools can be used to prepare and respond. Detailed plans at the state level have been created that outline the major functions of all groups and entities

involved and when they are to be implemented in relation to the disaster. Two systems in NC, CASPER and NC DETECT, provide the public health community and other disaster responders with information that allow them to assess the health status and basic needs of communities across the state during and following a disaster. This is a great example of learning through experience.

Disasters and mental health

- Many people experience disasters, but very few people actually have a disaster plan. Preparedness is the key in protecting ourselves from disasters. Information on developing a personal disaster plan is available through the Red Cross. Communication is an important part of any plan. How can you assure that you will be able to contact someone after a disaster? Addressing the psychological impacts from disasters requires that people have someone to talk to and be in contact with. To ensure that a communications strategy is in place following a disaster, it may be best to consider community-based plans so that more resources are available to contact people who may be isolated.
- A disaster can cause us to feel as though our safety and security have been violated. This can result from having to evacuate or relocate, not having a home to return to, and having to adapt to a new location and social structure. Our sense of safety and security can also be violated when we consider loss of unemployment, health care, and housing following a disaster. Disasters can also take away our identity and self-esteem (e.g. a farming family in eastern NC whose fields are destroyed by flooding from a hurricane).
- It is important to recognize that after a disaster, most people affected will suffer from some acute stress disorder. During this time it is important to engage with these people and offer "psychological first aid". Acute stress disorder can lead to thoughts of suicide, substance abuse, and domestic abuse, so offering assistance and companionship is important. Post-traumatic stress disorder is a condition that forms over time and may be alleviated through short-term intervention of the acute stress.
- There are numerous sources of information in NC on natural disasters and preparedness plans. Is this information reaching the public? Are we doing an adequate job of getting the message out? Is there sufficient communication and warning ahead of time (how many people own and use a NOAA weather radio)? Instead, it may be that people are encouraged to be more proactive in receiving information on natural hazards in the state. Does this structure need to change? Who should be responsible for conveying this information? These are important questions to consider, because a large portion of the population is not originally from NC and the state's growth rate continues to rise each year. Could more information be included in new property rental leases? Because NC is largely a decentralized state, the task of communicating risk from natural hazards and disasters falls largely on local governments.

Adaptation Strategies for Public Health in North Carolina

Amy Morsch from Duke University's Southeast Climate Resource Center discussed how public health can be incorporated into climate change adaptation plans. Her work at Duke has involved an

assessment of climate change adaptation activities across several cities in the Southeast. Of the 44 cities examined, about 40% indicated that they were looking at or addressing climate change adaptation. This is not an insignificant number, though the scope of adaptation work in the region is still lagging behind that of cities like Chicago and New York. Instead, adaptation planning in the Southeast is occurring across various stages of discussion and implementation.

Adaptation planning begins with an assessment of vulnerabilities, needs, and strengths. This is followed by an assessment of projected impacts based on how these vulnerabilities might change in the future. Lastly, a sound adaptation plan must consider a response to these impacts and a strategy for monitoring them. Adaptation plans should be iterative in that assessments and responses are continuous so that vulnerabilities are reduced over time. The keys to developing a sound adaptation plan include collaboration (breaking down silos and developing a common vocabulary), an honest assessment about our values and what we consider to be acceptable risk, and managing costs by integrating existing resources and infrastructures. Conversely, focusing on the uncertainties surrounding future impacts can impede adaptation. Because public health touches virtually every major aspect of society, there may be numerous entry points for public health in adaptation planning. Examples include the assignment of building codes to prevent various health hazards, the risk of waterborne disease due to floodplain development, and employee guidelines for emergency personnel such as police officers and firefighters during periods of extreme heat.

Pre-Workshop Survey

To understand how the workshop participants are viewing and responding to weather and climate as a public health issue, a short survey was conducted as part of the workshop registration. The response rate was 90% (76 out of 84 registrants). A break-down of the questions and responses is provided below.

- Over 80% of the participants either agree or strongly agree that preparing for the health effects of weather and climate is a priority, and over 90% feel that weather and climate are serious threats to public health now. These results echo surveys of local health directors that have taken place nationally[1] and in specific states (e.g. California[2]), as well as among the general public in several countries[3].
- Over 70% of the participants identified either severe weather (including floods and hurricanes) and/or heat waves as health issues affecting their organization or community. Nearly 60% of the

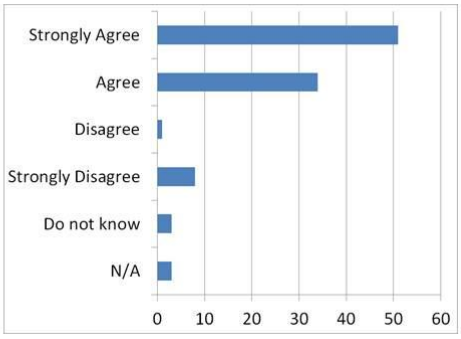
[1] Maibach, E.W. and Co-authors, 2008: Climate change and local public health in the United States: Preparedness, programs and perceptions of local public health department directors. PLoS, 3(7), e2838.
[2] Bedsworth, L., 2009: Preparing for climate change: A perspective from local public health officers in California. Environmental Health Perspectives, 117, 617-623.
[3] Akerlof, K., and Co-authors, 2010: Public perceptions of climate change as a human health risk: Surveys of the United States, Canada, and Malta. International Journal of Environmental Research and Public Health, 7, 2559-2606.

participants identified severe weather as the greatest risk, followed by air quality (20%), and heat waves (8%).

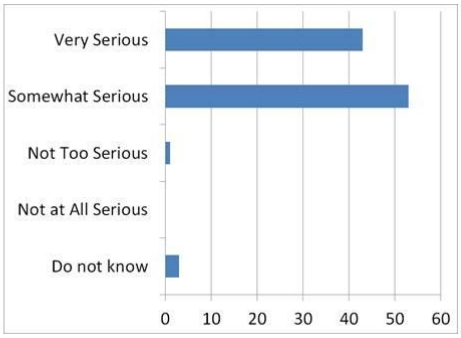
- When asked whether their organization or community has adequate information to respond to current weather and climate emergencies, participants were split between those that agree (32%) and those that disagree (40%). By contrast, in a survey of local health directors in California[2], 70% felt that they had adequate information.
- With regards to adaptation, about 35% of participants are either currently incorporating or planning to incorporate adaptation into their planning activities and strategies, while 30% either did not know or adaptation is not applicable in their planning. When asked whether their community or organization has ample expertise to create an effective adaptation plan, participants were split between those that agree (25%) and those that disagree (30%). About 20% were unsure. In comparison, about 16% of local health directors in the U.S. feel as though they have ample expertise to create an effective climate change adaptation plan[1]. These disparities may be due to the diversity of the workshop participants and the more recent development of public health adaptation strategies and climate change awareness in North Carolina.

Pre-Workshop Survey Results

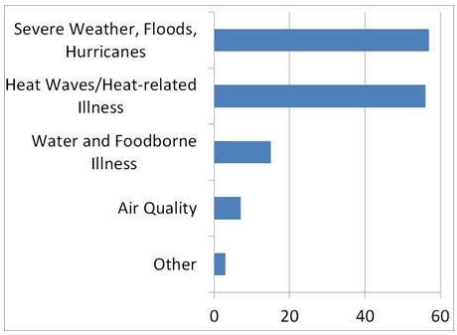
Preparing for the health effects of weather and climate is an important priority for you and your organization/community



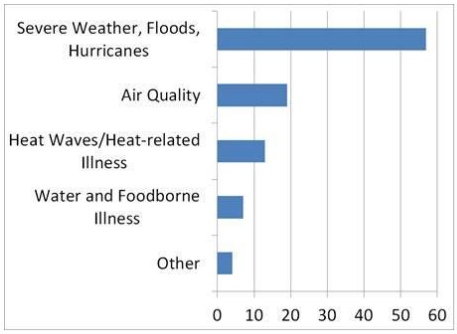
How large of a threat do you think weather and climate are to public health now?



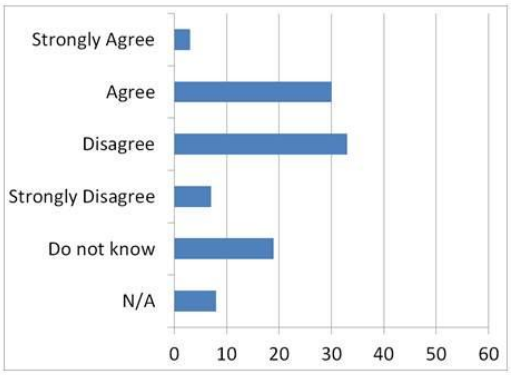
Which of these health issues affects your organization/community?



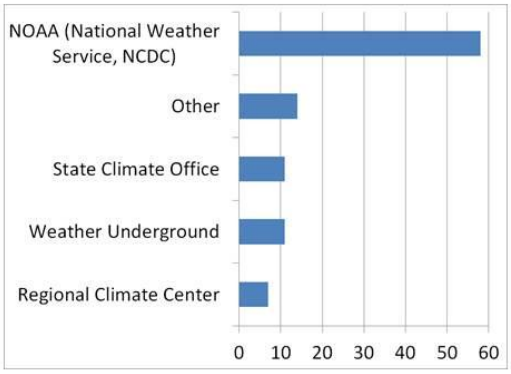
Which of the above would you identify as the greatest risk?



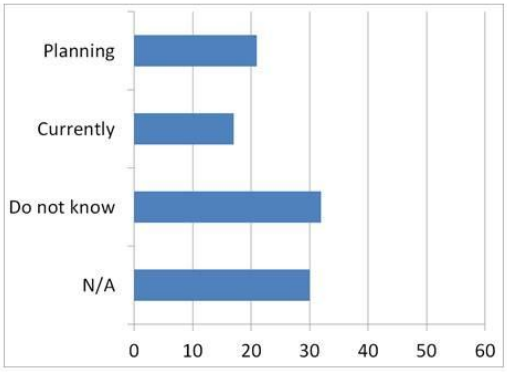
Your organization/community has adequate information to respond to current climate-related health emergencies



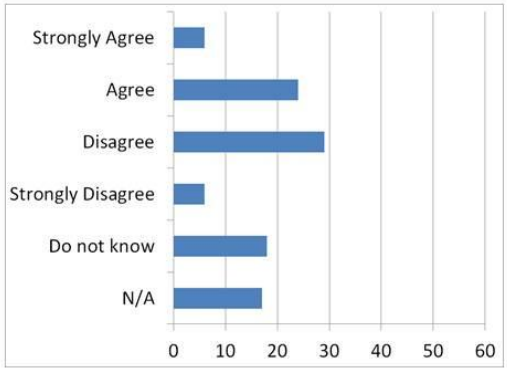
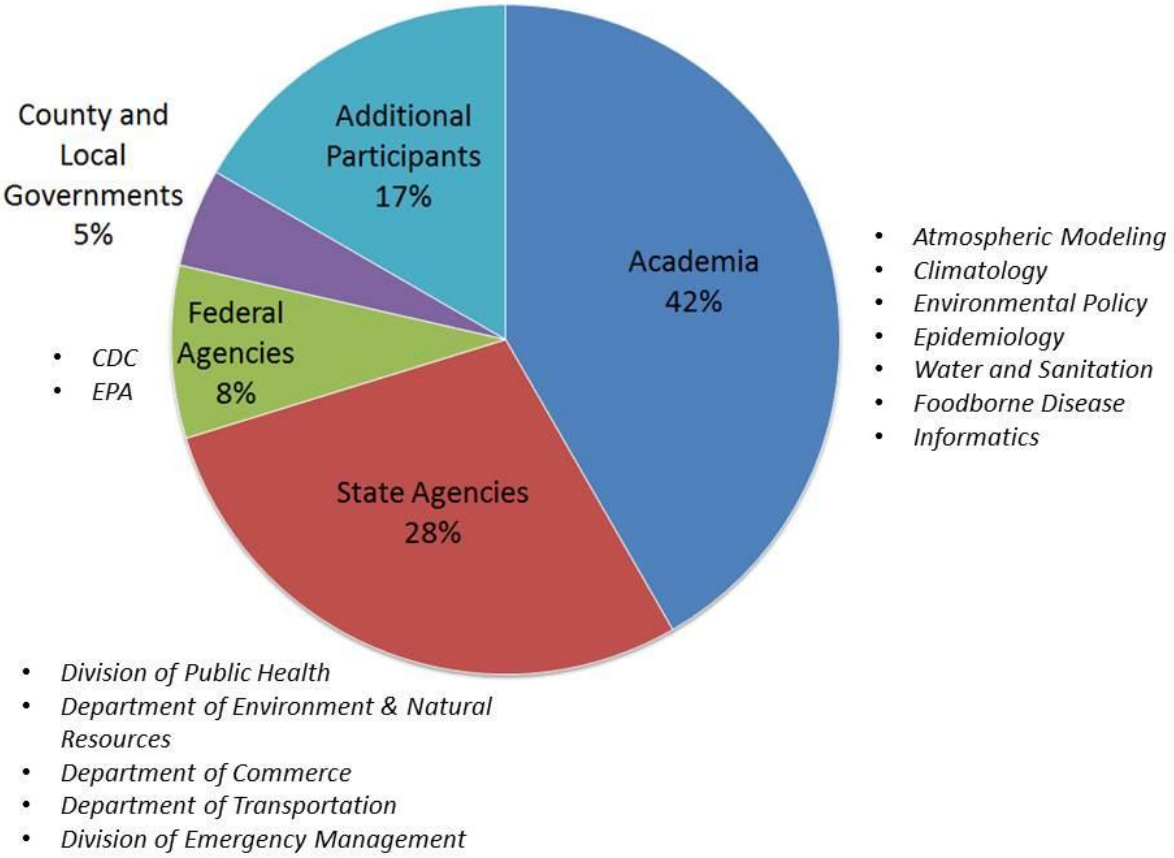
Where do you go to obtain weather and climate information?



Do you currently or are you planning to incorporate adaptation into your planning?



My organization/community currently has ample expertise to create an effective climate change adaptation plan



Workshop Participants: Groups Represented