REAUTHORIZING THE WEATHER ACT: USERS OF WEATHER DATA AND AREAS FOR IMPROVEMENT BY SECTOR

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

OF THE

HOUSE OF REPRESENTATIVES

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C O N T E N T S

June 6, 2023

REAUTHORIZING THE WEATHER ACT: USERS OF WEATHER DATA AND AREAS FOR IMPROVEMENT BY SECTOR

TUESDAY, JUNE 6, 2023

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met , pursuant to notice, at 10:03 a.m., in room 2318, Rayburn House Office Building, Hon. Max Miller [Chairman of the Subcommittee] presiding.

COMMITTEE ON
SCIENCE, SPACE
AND TECHNOLOGY
CHAIRMAN FRANK LUCAS

SUBCOMITTEE ON ENVIRONMENT
HEARING CHARTER

"Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector"

Tuesday, June 6, 2023
10:00 a.m.
2318 Rayburn House Office Building

Purpose
The purpose of this hearing is to examine the quality and availability of weather data and how the public understands and utilizes this information. This hearing will be an opportunity for Members to discuss potential areas of improvement related to the collection, distribution, and use of weather data and to better understand the varying needs of each of these communities to enhance the future of federal weather policy.

Witnesses
- **Mr. Gary McManus**, State Climatologist at the Oklahoma Climatological Survey**.**
- **Ms. Jeanine Jones**, Interstate Resources Manager at the California Department of Water Resources. Representing Western States Water Council
- **Mr. Eric Snodgrass**, Senior Fellow Scientist and Principal Atmospheric Scientist at Nutrien.
- **Dr. Kathie Dello,** State Climatologist of North Carolina and Co-Director of NOAA's Carolinas Climate Adaptation Partnership (CAP/RISA).

Overarching Questions
- How well does the weather data currently being collected translate into information that is useful to the communities that rely on it?
- How does public perception impact the usefulness of current weather data to the average household?
- How can weather data be better communicated to the public? For example, what do individuals understand when they hear the term "storm warning" versus "storm watch"?
- How can data be better specialized to cater to industry specific needs, for example the agricultural industry, emergency managers and the meteorological community?

Background

This hearing will include testimony from individuals in the meteorological, water and emergency management, and agricultural communities in order to enhance the sustainability and accuracy of federally-provided weather information as the Committee looks toward reauthorizing the Weather Research and Forecasting Innovation Act of 2017. This conversation will include insight on what data is currently accessible; how people like farmers, emergency managers and the general public understand and use the data; and what gaps need to be filled in the short and long term.

Weather Predictors, Networks and Technologies

Meteorologists analyze current data from a variety of sources to prepare and issue forecasts of approaching weather patterns in the short-term.[1]Climatologists focus on long-term climate trends affecting a certain population's food production, energy usage, species conservation, and public health. [2] State Climatologists currently exist in 47 states and Puerto Rico and aim to provide up to date information, data, and expertise directly from the federal government (NOAA) to state agencies, legislators, and citizens. They are typically either employees of state agencies or staff members of state-supported universities.

One tool that the public uses for weather information is Weather Data Receivers. These are low-cost satellite receiving systems that get data and information directly from federal weather satellites like the NOAA Geostationary Operational Environment Satellite (GOES) and the European Space Agency's Meteosat. Weather Data Receivers are frequently used by independent meteorologists, agribusiness firms, small airports or flying clubs, marine vessels, and small TV stations.[3] Farmers and ranchers also use these receivers to make planting and crop management decisions based on rainfall totals, storm predictions, wind speed, freeze predictions, and other risk factors that have the potential to affect crop yield outcomes.[4]

Another public tool is the National Mesonet Program (NMP), which serves as a "network of networks" to deliver critical information to improve weather predictions and warnings to ensure a weather-ready nation. The NMP is the central repository for real-time collection and dissemination of non-federal surface, boundary layer and tropospheric atmospheric weather observations in the U.S. It is made up of diverse public-private partnerships and acts as a resource to state and local agencies, businesses, researchers, and policy makers. The NMP's 35,000 stations/platforms significantly improve weather prediction, severe weather warnings, and emergency response for all regions of the country.[5]

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[1] National Weather Service, *Careers in Meteorology,* *https://www.weather.gov/careers/meteorology#:~:text=What%20is%20a%20Meteorologist%3F,studies%2C%20or%20forecasts%20the%20weather.*

[2] Mizzell, Hope, *Climatologist,* South Carolina Department of Natural Resources, https://www.dnr.sc.gov/education/pdf/Climatologist.pdf

[3] NASA Spinoff, *Weather Data Receiver (1982),* https://spinoff.nasa.gov/node/9204

[4] Hannan, Joe, *Personal Weather Station for Specialty Crop Management,* Iowa State University Extension and Outreach (2020), https://www.extension.iastate.edu/smallfarms/personal-weather-station-specialty-crop-management

[5] National Mesonet, *The National Mesonet Program,* https://nationalmesonet.us/

Of particular interest to state agencies and local communities are subseasonal to seasonal forecasts. Subseasonal forecasts cover two weeks to three months and seasonal forecasts cover three months to two years. NOAA's Subseasonal to Seasonal (S2S) Prediction Task Force was organized to improve prediction skill and products to close the gap between traditional weather and seasonal lead times. The taskforce invited scientists from universities, research laboratories, and NOAA centers to share datasets, methodologies, and results in reports, journals, and community engagement.

Subseasonal to Seasonal Research continues to be a priority area for NOAA due to its ability to fill emerging forecast needs in various economic sectors. As directed by the Weather Research Act of 2017, the S2S program works to improve the skill of S2S forecasts and enhance the value of S2S products for stakeholders. Accurately predicting weather from 2 weeks to 2 months, commonly referred to as the S2S Timescale, will significantly aid decision support across industries and keep the public informed and prepared for weather phenomena.

Legislative History

The Weather Research and Forecasting Innovation Act of 2017 (Public Law 115-25), known simply as the Weather Act, was signed into law in April 2017, capping a bipartisan, bicameral legislative effort that began in 2013 in the House Science Committee.[6] It was widely viewed as the first comprehensive weather authorization since the National Oceanic and Atmospheric Administration Authorization Act of 1992.[7]

The main goals of the Weather Act were to improve NOAA's weather research through investments in observational, computing, and modeling capabilities; to support improvement in weather forecasting and prediction of high impact weather events; and to expand commercial opportunities for the provision of weather data. Many sections of the bill were inspired by recommendations from reports authored by experts in the U.S. weather enterprise, including a National Academy of Sciences report published in 2012 entitled *Weather Services for the Nation: Becoming Second to None*[8] and a National Academy of Public Administration report published in 2013 entitled *Forecast for the Future: Assuring the Capacity of the National Weather Service*.[9]

Recognizing the immediate and impactful advances in the accuracy and timeliness of weather forecasting that the Weather Act prompted, the National Integrated Drought Information System (NIDIS) Reauthorization Act of 2018 (Public Law 115-423) was signed into law just two years later in January 2019.[10] The bipartisan NIDIS Reauthorization Act extended authorizations and improved several key programs from the Weather Act. Some of the programs, such as the agriculture weather provisions and NOAA's Office of Oceanic and Atmospheric Research, were extended with gradual increases in authorization of appropriations until FY 2023. Other

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[6] P.L. 115-25
[7] P.L. 102-567
[8] National Research Council, *Weather Services for the Nation: Becoming Second to None*, THE NATIONAL ACADEMIES PRESS (2012), https://doi.org/10.17226/13429.
[9] National Academy of Public Administration, *Forecast for the Future: Assuring the Capacity of the National Weather Service*, NAPA (2013), https://www.weather.gov/media/ooe/ForecastfortheFuture-AssuringtheCapacityoftheNationalWeatherService.pdf.
[10] P.L. 115-423

provisions, like NOAA Computing Resources, were simply updated with revised focus based on stakeholder and community feedback since the signing of the Weather Act.

Reauthorizing the Weather Act is an opportunity to modernize U.S. weather policy and better serve American communities. At a hearing on March 23, 2023, entitled "Reauthorizing the Weather Act: Data and Innovation for Predictions" the Committee heard from private companies in the U.S. weather industry that are capable of providing observations and data to NOAA and other federal agencies. This hearing aims to hear the perspective of people and groups who use that data.

Chairman MILLER. The Committee will come to order. Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Welcome to today's hearing entitled "Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector." I recognize myself for 5 minutes for an opening statement.

I want to welcome everyone to this morning's hearing, "Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector." This is the Environment Subcommittee's second hearing this Congress on reauthorizing the *Weather Research and Forecasting Innovation Act of 2017,* an important effort for the Committee at large. Today's hearing continues our examination of U.S. weather policy and how best to update the crucial work started by the *Weather Act* 6 years ago.

In March, we had the privilege of hearing from innovators from the commercial sector on the advancements they have made in collecting weather data. Today, we will hear from witnesses who utilize all of this raw weather data to inform the public about imminent storms, what the weather is going to be like days from now, and what conditions we can expect over the course of an entire season. So it's easy to see that weather data doesn't just help determine the day's clothing. It enhances our national economy by assisting long-term decisionmaking, and it helps protect lives and property.

It should go without saying there are serious economic and humanitarian implications to not only being able to predict weather correctly or precisely, and we cannot afford to let the United States be in such a position. From my conversations with farmers back home in Ohio, I know that seasonal weather predictions are vital to American agriculture. Without accurate predictions in this sector, seasonal planting and harvesting is put at major risk.

As we will hear today, regional data isn't enough for subseasonal to seasonal (S2S) forecasting. Accurate long-term prediction requires knowledge of weather patterns around the world, such as El Niño or La Niña. The purpose of today's hearing is to get an idea of how our witnesses will utilize both Federal and private data to achieve these accurate predictions, and we'll hear how that data improves our short-term forecasting and our ability to protect the public from deadly weather events.

Whether the data comes from NOAA (National Oceanic and Atmospheric Administration), State services, or commercial providers, we must ensure that all tools at our disposal are used to make the public aware of extreme weather conditions. Just last week, the Atlantic hurricane season officially kicked off with NOAA predicting one to four hurricanes will be classified as a major hurricane. And while this prediction is a near normal season, our goal every year should be to prepare the public in a way that no lives are lost as a result of these events.

Though—through innovation to improve the accuracy and timeliness of weather models, as well as public awareness, we can save lives and property. This hearing and ultimately the *Weather Act* reauthorization will identify actionable items NOAA can pursue to build trust and education in weather forecasting products. When an E4 tornado, EF4 tornado, or a category 3 hurricane is bearing

down on the United States citizens, there should be no doubt on what the best course of action is. Additionally, by working together and increasing partnerships between NOAA and the commercial sector, the users of weather data will be better equipped to strengthen both short- and long-term weather predictions, benefiting all Americans across all sectors.

I want to thank all of our witnesses for being here. I look forward to each of your testimonies.

[The prepared statement of Chairman Miller follows:]

I want to welcome everybody to this morning's hearing, Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector. This is the Environment Subcommittee's second hearing this Congress on reauthorizing the *Weather Research and Forecasting Innovation Act of 2017,* an important effort for the Committee at large.

Today's hearing continues our examination of U.S. weather policy and how best to update the crucial work started by the *Weather Act* six years ago. In March, we had the privilege of hearing from innovators from the commercial sector on the advancements they have made in collecting weather data.

Today, we will hear from witnesses who utilize all this raw weather data to inform the public about imminent storms, what the weather is going to be like days from now, and what conditions we can expect over the course of an entire season.

So it's easy to see that weather data doesn't just help determine the day's clothing. It enhances our national economy by assisting long term decision making and it helps protect lives and property. It should go without saying there are serious economic and humanitarian implications to not being able to predict weather correctly or precisely, and we cannot afford to let the United States be in such a position.

From my conversations with farmers back home in Ohio, I know that seasonal weather predictions are vital to American agriculture. Without accurate predictions in this sector, seasonal planting and harvesting is put at major risk.

As we will hear today, regional data isn't enough for subseasonal to seasonal forecasting. Accurate long-term prediction requires knowledge of weather patterns around the world, such as El Nino or La Nina.

The purpose of today's hearing is to get an idea of how our witnesses utilize both federal and private data to achieve these accurate predictions. And we'll hear how that data improves our short-term forecasting and our ability to protect the public from deadly weather events.

Whether the data comes from NOAA, state services, or commercial providers, we must ensure that all tools at our disposal are used to make the public aware of extreme weather conditions.

Just last week, the Atlantic hurricane season officially kicked off, with NOAA predicting one to four hurricanes will be classified as a major hurricane.

And while this prediction is a "near-normal" season, our goal every year should be to prepare the public in a way that no lives are lost as a result of these events.

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This hearing, and ultimately the *Weather Act Reauthorization,* will identify actionable items NOAA can pursue to build trust and education in weather forecasting products. When an EF-4 tornado or a Category 3 hurricane is bearing down on U.S. citizens, there should be no doubt on what the best course of action is.

Additionally, by working together and increasing partnerships between NOAA and the commercial sector, the "users" of weather data will be better equipped to strengthen both short- and long-term weather predictions, benefitting all Americans across all sectors.

I want to thank all of our witnesses for being here. I look forward to each of your testimonies.

Chairman MILLER. I now recognize the Ranking Member, the gentlewoman from North Carolina, for an opening statement.

Ms. ROSS. Thank you, Chairman Miller, for convening this important hearing considering the many users of weather data, and thank you to our witnesses for joining us this morning to share your expertise. I'm especially excited that North Carolina's own State Climatologist, Dr. Kathie Dello, is joining us today, and she's my neighbor, too. We live less than a mile away.

Weather data is critical for informing decisions and protecting American lives and property daily. A wide variety of users benefit from NOAA's weather and climate data. Emergency response agencies inform their decisionmaking by closely following seasonal outlooks and weather forecasts. Weather resource managers rely on accurate forecasts along—across timescales to guide everything from permitting and negotiations to resource distribution and reservoir management.

Directly relevant to my home State of North Carolina and many of those represented by this Committee is the critical application of NOAA's data to the agricultural industry. High quality weather data is paramount for protecting yields and managing water and fertilizer use. Furthermore, global weather and climate data provided by NOAA is used to predict the yields and agricultural market performance of our international partners and our adversaries.

Lastly, but certainly not least, is the critical application of NOAA's weather and climate data to furthering coastal resilience across the United States. At the forefront of providing these data is NOAA's National Weather Service. From generating long-term hurricane season outlooks to short-term weather forecasts, the National Weather Service does it all. Mandated by policy NOAA provides open access weather and climate data services worldwide. In fact, NOAA's products and services are recognized as being some of the most user friendly and accessible of any Federal agency.

Additionally, NOAA promotes and facilitates the flow of these data and services to many users. For example, NOAA's Climate Adaptation Partnership (CAP) Program facilitates collaborative partnerships with extension networks, State and local governments, and other organizations to help improve and disseminate NOAA data and services to users. Key to these efforts is tailoring information to the needs of communities and addressing inequities.

I look forward to hearing about Dr. Dello's experiences giving—given her wealth of knowledge working with constituents and data users across sectors while developing and leading both Oregon's and North Carolina's CAP programs.

In short, NOAA's contribution to providing weather and climate data services worldwide cannot be understated. As each user tackles unique problems that vary in scope and application, it's critical that the vast needs of users of public data are considered. With worsening climate change and weather events looming, ensuring quality data is available to the many users is paramount to protecting the American people.

I'm eager to hear from our witnesses today on their experiences using NOAA's climate and weather data and how Congress can support the improvement of its quality, quantity, and availability.

Thank you, Mr. Chairman, and I yield back.

[The prepared statement of Ms. Ross follows:]

Thank you, Chairman Miller, for convening this important hearing considering the many users of weather data, and thank you to our witnesses for joining us this morning to share your expertise. I am especially excited that North Carolina's own State Climatologist, Dr. Kathie Dello, is joining us today.

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I am eager to hear from our witnesses today on their experiences using NOAA's climate and weather data and how Congress can support the improvement of its quality, quantity, and availability.

Thank you, and I yield back.

Chairman MILLER. Thank you, Ms. Ross.

I now recognize the Chairman of the Committee, the gentleman from Oklahoma, for an opening statement.

Chairman LUCAS. And I want to thank the gentleman from Ohio, Mr. Miller, for holding today's hearing.

As a rancher in Tornado Alley, weather data is vital to me and all Oklahomans. While the *Weather Act* had an immediate positive effect, we still have work to do if we want to be the most accurate, trusted source of forecasting in the world. Since taking over as Chairman of the Committee, I prioritized reauthorizing the *Weather Act,* and this hearing is another step toward finalizing that bill.

A critical component of the *Weather Act* reauthorization will be improving subseasonal and seasonal research and forecasting. This area of weather research is extremely important to farmers and ranchers whose livelihoods are subject to precipitation patterns. Better forecasting means better decisions on planting, managing crops, which translates into more food for America.

I'm pleased to have an Oklahoma representative here to discuss our State's weather and climate services, including the Mesonet system. I take a lot of pride in the fact that this system is the gold standard in the country, and the Committee looks forward to hearing more details about how the data is updated, processed, and communicated to the public.

As we have seen through the years, the impacts of weather are far too important not to strive for the very best tools. Protecting life and property, helping first responders during extreme weather events, and ensuring farmers and ranchers have the best data are

only a few of the reasons we—having the most accurate weather forecast is paramount. It's encouraging to see the progress that NOAA and the private sector have made to help each other since the *Weather Act of 2017.* And don't get me wrong, they are indeed helping each other. It goes both ways. But even as we sit here today, 6 years after the passage of the first *Weather Act,* I believe there's still much more we can do for NOAA to maximize the innovations our country has to offer. So as we look forward to reauthorize the *Weather Act,* I'll push to continue this growth and expand the options and resources NOAA has to improve their long-term weather models and forecasts.

Today's hearing is important because it allows us to examine a wide range of sectors that utilize all different types of weather data. It's a diverse group of the weather community, but they share many of the same needs from NOAA. Their input will help us ensure the direction and the resources we provide to NOAA end up benefiting the most Americans, as intended.

I thank our witnesses for sharing their expertise with us today, and I look forward to a productive discussion. Thank you, and I yield back, Mr. Chairman.

[The prepared statement of Chairman Lucas follows:]

I want to thank the gentleman from Ohio, Mr. Miller, for holding today's hearing. As a rancher in tornado alley, weather data is vital to me and all Oklahomans.

While the *Weather Act* had an immediate positive impact, we still have work to do if we want to be the most accurate and trusted source of forecasting in the world.

Since taking over as Chairman of the Committee, I've prioritized reauthorizing the *Weather Act,* and this hearing is another step towards finalizing that bill.

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I thank our witnesses for sharing their expertise with us and I look forward to a productive discussion. Thank you and I yield back Mr. Chairman.

Chairman MILLER. Thank you, Mr. Lucas.

I now recognize the Ranking Member of the Committee, the gentlewoman from California, for an opening statement.

Ms. LOFGREN. Well, thanks to you, Chairman Miller, and also to Ranking Member Ross for this second in a series of hearings on the *National Weather Act.* Of particular interest to my district in California and especially the rural parts of my district is the subseasonal to seasonal forecasting that enables communities, water resource managers, and farmers to plan ahead. As Ms. Jones notes in her testimony, the West is increasingly experiencing climate change-driven extremes. It seems like we go from historic drought to historic flooding, and both are taking a toll on our communities.

We have to take aggressive steps to ameliorate climate change, but we also need to take steps to adapt to it, and that starts with having the data and the models required to understand how the changing climate is affecting weather patterns beyond the next few days. At stake are both lives and livelihoods, and I look forward to hearing the experts on this panel about that.

Now, where agriculture is particularly important in my district, there isn't a sector of our economy that doesn't use the National Weather Service's data and data products. The National Weather Service is very well-regarded, as the Chairman has just said, and for good reason. However, that doesn't mean there isn't room for improvement, and in addition to learning more about subseasonal or seasonal forecasting, I'm interested in all the recommendations from this panel for improving the National Weather Service's data, models, and communication.

Now, given the witnesses before us, all of whom are quite expert, this hearing is a very good opportunity to discuss Federal climate change services and how they can be strengthened to support States, farmers, those who fish, business owners, infrastructure owners, city planners, and just plain individuals in preparing for a changing climate in the region they reside in.

Even as climate change is accelerating beyond predictions of just a few years ago, we still have a long way to go to build a robust national climate service. While multiple agencies have a role in contributing to a national climate service in whatever form that may take, NOAA's role is certainly central. Fortunately, the Biden Administration is making this a priority. They have released a Federal Framework and National Action Plan for Climate Services, and while I hope this Committee holds hearing specifically on national climate services in the coming months, today's hearing can also help inform us on how NOAA's current climate services are being utilized and about unmet needs for climate services across those sectors.

Again, I want to thank the Chairman and Ranking Member of the Subcommittee, as well as the Chairman of the Committee, for this hearing. I look forward to it, and I yield back.

[The prepared statement of Ms. Lofgren follows:]

Good morning. Thank you to Chairman Miller and Ranking Member Ross for holding this 2nd in a series of hearings exploring issues for reauthorization of the *National Weather Act.* Today's hearing features users of NOAA's weather and climate data with expertise relevant to a range of sectors, from agriculture- to water management- to transportation.

Of particular interest to my district- and especially the rural parts of my district- is the subseasonal to seasonal forecasting that enables communities, water resource

managers, and farmers to plan ahead. As Ms. Jones notes in her testimony, the West is increasingly experiencing climate change driven extremes, from severe drought to catastrophic flooding. In addition to taking aggressive steps to mitigate climate change, we must also take all necessary steps to adapt to the changing climate. That starts with having the data and models required to understand how the changing climate is affecting weather patterns beyond the next few days. At stake are both lives and livelihoods. I look forward to hearing the expert panel's recommendations for improving subseasonal to seasonal forecasting.

While agriculture is particularly important to my district, there isn't a sector of our economy that doesn't use the National Weather Service's data and data products. The National Weather Service is extremely well regarded, and for good reason. However, that does not mean there is no room for improvement. In addition to learning more about subseasonal to seasonal forecasting, I'm interested in all recommendations from this panel for improving the National Weather Service's data, models, and communication.

Given the witnesses before us, this hearing is also a good opportunity to discuss Federal climate services and how they can be strengthened to support states, farmers, fishers, business owners, infrastructure owners, city planners, and individuals in preparing for a changing climate in their region. Even as climate change is accelerating beyond the predictions of just a few years ago, we still have a long way to go to build a robust national climate service. While multiple agencies have a role in contributing to a national climate service, in whatever form that may take, NOAA's role is central.

Fortunately, we have an Administration that is making this a priority. This past March the Biden Administration released a Federal Framework and National Action Plan for Climate Services. While I hope this Committee holds hearings specifically on a national climate service in the coming months, today's hearing can also help inform us how NOAA's current climate services are being utilized, and of the unmet needs for climate services across sectors.

Thank you to the expert panel for being here this morning. I look forward to your testimony and the discussion. I yield back.

Chairman MILLER. Thank you, Ms. Lofgren.

Let me introduce our witnesses. Our first witness today is Mr. Gary McManus. He joined the Oklahoma Climatological Survey in May of 1999 and currently serves as the State Climatologist for Oklahoma. Gary is Editor-in-Chief of Oklahoma's Monthly Climate Summaries and has done extensive research cataloging Oklahoma's weather hazards.

Our second witness is Ms. Jeanine Jones. She is the Interstate Resources Manager for the California Department of Water Resources (DWR). She is a member and past chair of the Western States Water Council, whom she is representing today. She is a designee on the Colorado River Board of California and a registered civil engineer in California and Nevada. She has more than 40 years of experience in water resources management with extensive background in drought preparedness and response.

Our third witness is Mr. Eric Snodgrass. He is the Senior Fellow Scientist and Principal Atmospheric Scientist for Nutrien's retail division, Nutrien Ag Solutions, where he develops predictive and analytical software solutions to manage weather risk for global production agriculture. He is the cofounder of Global Weather and Climate Logistic LLC and Agrible Inc., which were both acquired by Nutrien Ag Solutions in 2018. From 2006 to 2019, Eric was the Director of Undergraduate Studies for the Department of Atmospheric Sciences at the University of Illinois at Urbana-Champaign, where he taught over 20,000 students across a wide range of coursework in atmospheric science.

I now recognize the Ranking Member of the Environment Subcommittee, the gentlewoman from North Carolina, for the introduction of our final witness.

Ms. ROSS. Thank you, Chairman Miller. And it's my honor today to introduce one of my constituents, Dr. Kathie Dello. Dr Dello is North Carolina's own Director and State Climatologist at the North Carolina State Climate Office at North Carolina State University. Go Pack. She is also the codirector of NOAA Carolina's Climate Adaptation Partnership Program. Prior to coming to North Carolina, she was the Associate Director of the Oregon Climate Change Research Institute and Deputy Director of the Oregon Climate Service for nearly 10 years. Dr. Dello earned her Ph.D. in environmental sciences from Oregon State University, a master's in geography, and a bachelor's in atmospheric science both from the State University of New York at Albany.

Throughout her career, Dr. Dello has been a champion in fighting against climate change specifically in the areas of climate resilience, planning, and impacts assessment. Not only does she contribute to research and large-scale climate assessment reports such as the Fifth National Climate Assessment, she is also actively involved in efforts to make science relevant to the broader public.

A proficient science communicator, she often works with local and State—local, State, and national media, State government, NGOs (non-governmental organizations), and climate organizations. Oftentimes, scientific knowledge is lost in translation, and important information goes unused by those who need it most. Bridging the gap between science and the public is critical for ensuring Americans are well-informed and equipped to tackle the challenges of climate change and extreme weather events.

That's why scientists like Dr. Dello who are bridging these gaps are so important for our communities. Given her expertise as a climate—in climate science and passion for making science accessible and informative for a vast array of constituents, I'm eager to hear from her today. Please join me in welcoming Dr. Dello.

And I yield back.

Chairman MILLER. Thank you, Ms. Ross.

Welcome to all the witnesses, and thank you for being here today. It truly is an honor.

I now recognize Mr. Gary McManus for 5 minutes to present his testimony.

TESTIMONY OF MR. GARY MCMANUS,
STATE CLIMATOLOGIST,
OKLAHOMA CLIMATOLOGICAL SURVEY

Mr. MCMANUS. Good morning, Chairman Miller, Ranking Member Ross, Chairman Lucas, and Ranking Member Lofgren and all other Members of the Subcommittee, and thank you for the opportunity to testify today.

I'm a third-generation Okie, born and raised in the high plains of western Oklahoma in the small town of Buffalo just to the north of Chairman Lucas's small town of Cheyenne where he was—his hometown. I work as a State Climatologist at the Oklahoma Climatological Survey and the National Weather Center on the campus of the University of Oklahoma for a State that has had by far more FEMA (Federal Emergency Management Agency)-declared disasters than any other State since the year 2000. It's my job to interpret all manner of weather and climate data—Federal, State,

local, or commercial—and disseminate that to the State's decision-makers and citizens to help protect lives, livelihoods, and property.

Much of that work is accomplished using data from the Oklahoma Mesonet, which is jointly operated by Oklahoma State University (OSU) and the University of Oklahoma. The Mesonet was established 30 years ago both to address the needs for improved severe weather warnings and to improve our ability to research and better understand the weather, especially in Oklahoma. We have one or more stations in each of our 77 counties so that, no matter where you are in Oklahoma, we have local, real-time observations without—within about 10 miles of your location.

The Mesonet's partnership gives us access to a synthesis of world-class meteorological and agricultural expertise from the two universities. In just the past 2 years, the Oklahoma Mesonet's outreach programs have trained users and decisionmakers from 495 agencies across Oklahoma. These groups span the gamut from tribal organizations to public schools, to city and county entities, to State and Federal agencies.

Mesonet data are used to improve production and optimize inputs for crops and livestock and protect them from many pests, diseases, and environmental conditions detrimental to their growth and development. I use the Mesonet weather and soil moisture data weekly as Oklahoma's main contributor to the U.S. Drought Monitor, a vitally important chore due to the agricultural aid triggered by the drought monitors depiction. Drought verification with Mesonet rainfall and soil moisture data has helped bring more than $1 billion in Federal aid to Oklahomans suffering from drought and its impact since the year 2011.

The Mesonet employs an OSU Extension Specialist for direct outreach with the agricultural community, as well as an OSU fire weather expert. Our OK fire outreach program has trained nearly 2,000 wildland fire managers and firefighters on weather's impact on wildfire suppression, prescribed burning, and smoke management. The Oklahoma Mesonet's real-time forecast fire danger products are used by fire departments, emergency managers, State and Federal agencies, private organizations, and private landowners.

The Mesonet's public safety outreach program OK-First has trained over 2,000 emergency managers, police, fire, and public health professionals to use our data to help keep Oklahomans safe. This program provides Oklahoma's public safety community with weather education and access to critical real-time weather data, and not just the Mesonet data, but also the NOAA data as well.

The Oklahoma Mesonet is a proud member of NOAA's National Mesonet Program, along with other universities and State Mesonets and additional partners. The National Mesonet Program has proven to be a successful public-private partnership model in which the Federal Government can leverage tens of thousands of additional real-time weather observations from across the Nation without having to maintain and operate them. This allows forecasters to use these additional data to improve weather models, and thus every community's weather forecast. It's essential that Congress and the Administration support and expand the national Mesonet to ensure that local forecasters have access to these highly localized weather data.

Now, how has the Oklahoma Mesonet and NOAA data impacted me personally? On May 20, 2013, my day began in Moore, Oklahoma, filled with anxiety. A severe weather outbreak the day before spawned several strong tornadoes across central Oklahoma, leaving two dead, 14 injured, and a swath of destruction in their path. More high and severe weather was predicted for that day. Using a combination of NOAA high resolution computer models and Oklahoma Mesonet data, the forecasters at the Norman National Weather Service office managed to pinpoint the location and counties with the highest tornado threat for that day. Now, this enabled me to go get my kids from their elementary school and daycare in Moore and take them home, where we later huddled in our storm shelter as an EF5 monster churned through our neighborhood, our school system, and our hometown. That violent tornado ended up killing 24 people, including seven children at Plaza Towers Elementary School.

I remain eternally grateful for the scale and expertise of the National Weather Service forecasters that day and for the Oklahoma Mesonet data that help guide their abilities, the very same Oklahoma Mesonet that I work for and whose data I turn—I in turn use to help keep people safe.

Thank you, and I welcome any questions you might have for me.

[The prepared statement of Mr. McManus follows:]

Good morning, Chairman Miller, Ranking Member Ross, and all other members of the Subcommittee, and thank you for the opportunity to testify today. I'm a third generation Oklahoman, born and raised in the High Plains of northwestern Oklahoma in the small town of Buffalo. Like many Oklahomans, I've lived through some of the most extreme weather Mother Nature has to offer. Violent tornadoes, softball size hail, 500-year floods, drought, heat waves, wildfires, blizzards, ice storms, and even a strengthening tropical cyclone—Oklahoma has had more FEMA-declared disasters than any other state since the year 2000. That's just a part of the Okie experience. However, out of all that calamitous weather comes skill, innovation, and excellence in weather research and technology.

I work as the State Climatologist at the Oklahoma Climatological Survey in the National Weather Center on the campus of the University of Oklahoma. It's my job to interpret all manner of meteorological and climatological data—federal, state, local, or commercial—and disseminate that to the state's decisionmakers and citizens to help protect lives, livelihoods, and property. Much of that work is accomplished using data from the Oklahoma Mesonet, which is jointly operated by the Oklahoma State University and the University of Oklahoma. The Mesonet was established 30 years ago, both to address the needs for improved severe weather warnings, and to improve our ability to research and better understand the weather. We have one or more stations in each of our 77 counties so that no matter where you are in Oklahoma, you have local, real time observations within about 10 miles of your location.

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Oklahoma. These groups span the gamut from tribal organizations to public schools to city and county entities to state and federal agencies. Mesonet data are used to improve production and optimize inputs for crops and livestock, and protect them from the many pests, diseases, and environmental conditions detrimental to their growth and development. I use the Mesonet weather and soil moisture data weekly as Oklahoma's main contributor to the U.S. Drought Monitor, a vitally important chore due to the agricultural aid triggered by the Drought Monitor's depiction. Drought verification with Mesonet rainfall and soil moisture data has helped bring more than $1 billion in federal aid to Oklahomans suffering from drought and its impacts since 2011.

The Mesonet employs an OSU Extension Specialist for direct Outreach with the agricultural community, as well as an OSU Fire Weather expert. Our OK-FIRE outreach program has trained nearly 2000 wildland fire managers and firefighters on weather's impact on wildfire suppression, prescribed burning, and smoke management. The Oklahoma Mesonet's real-time and forecast fire danger products are used by fire departments, emergency managers, state and federal agencies, private organizations, and private landowners.

The Mesonet's Public Safety Outreach Program, OK-First, has trained over 2000 Emergency Managers, police, fire, and public health professionals to use our data to keep Oklahomans safe. This program provides Oklahoma's public safety community with weather education and access to critical real-time weather data.

Climate services is also an important element of what OCS and the Mesonet provides. As State Climatologist, I use Mesonet and NOAA data and information to provide historical context to

current weather conditions for media, government agencies, private businesses, and the citizens of Oklahoma. I rely heavily upon information from our partners in the National Weather Service to convey weather risks through the Mesonet Ticker, an e-mail blog that reaches an audience of thousands four to five times a week. The real time data of the Oklahoma Mesonet also allows me to provide timely summaries of departures from normal conditions, document interesting local phenomena like heat bursts, and assess dry conditions for input into the U.S. Drought Monitor.

The Oklahoma Mesonet is a proud member of NOAA's National Mesonet Program along with other university and state Mesonets and additional partners. The National Mesonet Program has proven to be a successful public/private partnership model, in which the Federal Government can leverage tens of thousands of additional real time weather observations from across the nation without having to maintain and operate them. This allows forecasters to use these additional data to improve weather models, and thus every community's weather forecast. It's essential that Congress and the administration support and expand the national Mesonet to ensure that local forecasters have access to these highly localized weather data.

How has the Oklahoma Mesonet and NOAA data impacted me personally? On May 20, 2013, my day began in Moore with much trepidation and anxiety. A severe weather outbreak the day before spawned several strong tornadoes across central Oklahoma, leaving two dead, 14 injured, and a swath of destruction in their path. More high-end severe weather was predicted for that day. Using a combination of NOAA high-resolution computer models and Oklahoma Mesonet data, the forecasters at the Norman National Weather Service office managed to pinpoint the location and counties with the highest tornado threat. This enabled me to go get my kids from

their elementary school and daycare in Moore and take them home where we later huddled in our storm shelter as an EF-5 monster churned through our neighborhood, our school system, and our hometown. My 6 year-old son's daycare was obliterated by the storm, and while my wife remained in danger throughout that ordeal as an Assistant Principal at another Moore elementary school, she at least knew her own kids were safe. That violent tornado ended up killing 24 people, including seven children at Plaza Towers Elementary School. I remain eternally grateful for the skill and expertise of the NWS forecasters that day, and for the Oklahoma Mesonet data that helped guide their abilities. The very same Oklahoma Mesonet that I work for, and whose data I in turn use to help keep people safe.

Thank you.

Gary McManus joined the Oklahoma Climatological Survey in May 1999 and currently serves as the State Climatologist for Oklahoma. Gary's tasks are focused on providing the citizens and decision-makers of Oklahoma with vital and timely climate and weather information, as well as assessing the past weather conditions for the state. Gary is editor in chief of Oklahoma's Monthly Climate Summaries and has done extensive research cataloguing Oklahoma's weather hazards. A lifelong Okie and a native of Buffalo, Oklahoma, Gary earned his B.S. and M.S. degrees in Meteorology from the University of Oklahoma. Gary lives in Norman, Oklahoma, and his wife Jennifer serves as a Counselor in the Moore Public Schools. Gary and Jennifer have three kids: 18-year-old identical twin daughters and a 16-year-old son.

Chairman MILLER. Thank you, Mr. McManus.

I now recognize Ms. Jeanine Jones for five minutes to present her testimony.

TESTIMONY OF MS. JEANINE JONES,
INTERSTATE RESOURCES MANAGER,
CALIFORNIA DEPARTMENT OF WATER RESOURCES

Ms. JONES. Mr. Chairman, Ranking Member, Subcommittee Members, thank you for the opportunity to appear today. I'm here on behalf of the Western States Water Council to talk about the importance of subseasonal to seasonal forecasting for water management in the West, where we're characterized by extreme variability in precipitation from year to year, as well as within a year. And, as the Committee Chairman said, we still have much work to do in parts of the *Weather Act,* and this is definitely one of those areas.

Now, from a water management perspective, lead time is very important for us because most of our critical water management decisions aren't made within the span of a 7- to 10-day weather forecast. They're made at much longer lead times. And frankly, the most important, most costly, and some of the most significant decisions are made at lead times of many months. So this is an area that is very important for improving our efficiency in water management and especially for responding to extremes of droughts and floods, which we have seen all too much of in the West recently.

Now, unfortunately, this is an area where the operational outlooks produced by the National Weather Service have very little skill. The example included in my testimony shows a map of the historical skill for the winter months when precipitation is most important for us. And on this map, what it shows is that there is essentially no better skill than predicting average weather conditions for much of the country, including much of the West. And for us these maps are unfortunately rather similar to a horoscope in that they essentially are something that you look at for interest or entertainment, but you can't use it to make a decision. And this is what we really need is the improved ability to make decisions.

And it's been particularly critical that there have been some very significant misses in the outlooks in some of our most extreme years. I refer back to, for example, water year 2016, which was the fifth year of a then ve-year drought in California, when we also had the—what was famously called Godzilla El Niño, one of the strongest El Niño events on record. Much chatter in the news media based on the forecasts being made at the time that southern California, for example, was going to need Noah's Ark because it was going to be so wet. And in fact, what happened, we continued in drought. So, you know, a completely missed forecast.

And as we saw this year in water year 23 in California, we went from what had been our three driest consecutive years of record to one of our wettest years of record, something that was also missed in these seasonal outlooks. And it's these extremes that are very important for water management to allow water agencies, the agricultural producers that we serve, the cities that we serve to make important decisions about managing their assets.

And, you know, we really look forward to opportunities to improve S2S forecasting. And in 2020, pursuant to the *Weather Act,* NOAA submitted a report to Congress with recommendations to do so that included pilot projects to improve forecasting, including a pilot for Western winter precip and for central U.S. summer precip, which is important for agriculture. And we have—we at California DWR have been funding some seed money research toward this effort for a while, including funding NASA (National Aeronautics and Space Administration), NOAA, and academic centers. And this research has shown that there is opportunity for improvement, even from a project that we funded NOAA's Boulder labs to do, which had better skill with a statistical model than their national multimodel ensemble.

So clearly, you know, there is opportunity here. We just need to make the investment in the research that's needed to get there. So we very much encourage the Subcommittee and the Full Committee to consider including NOAA's recommended pilot projects in *Weather Act* reauthorization. This is very important to have something that says, well, here's a pilot project that if you do this with these metrics to improve operational forecasts, we really could have some success here, which will help us as water managers better manage our resources, and it also contributes to climate change adaptation because this is a necessary tool for that.

So with that, I would wrap up, thank the Committee for the opportunity to speak today.

[The prepared statement of Ms. Jones follows:]

WRITTEN STATEMENT

Jeanine Jones

Interstate Resources Manager for the California Department of Water Resources

on behalf of the Western States Water Council

Before the

Subcommittee on Environment

Committee on Science, Space, and Technology

United States House of Representatives

Hearing on

“Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector”

June 6, 2023

Chairman Miller, Ranking Member Ross, and members of the Environment Subcommittee. Thank you for inviting me to testify before you today on the importance of improving subseasonal to seasonal (S2S) forecasting in the upcoming reauthorization of the *Weather Research and Forecasting Innovation Act of 2017* (Public Law 115-25). I am Jeanine Jones, Interstate Resources Manager for the California Department of Water Resources and a member and former Chair of the Western States Water Council. The Western States Water Council is a government entity composed of representatives from eighteen western states that works to promote effective cooperation among western states on conservation, development, and management of water resources.

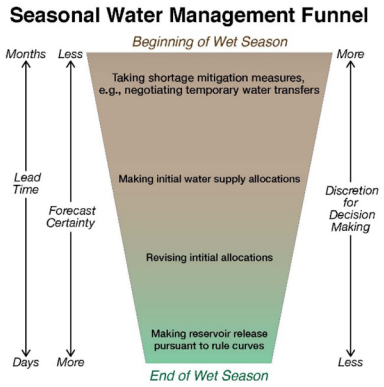
I am a registered civil engineer in California and Nevada and a designee on the Colorado River Board of California. Much of my career has been spent in drought preparedness and management. I have previously served on NOAA's Climate Working Group and on the Water Resources Adaptation to Climate Change Workgroup of the USGS Advisory Committee on Water Information.

Forecasting and Water Management

The western U.S. has high variability in precipitation, both annually and within the water year. As documented by the National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Environmental Information, disasters at both wet and dry extremes (floods and droughts) are responsible for billions of dollars in losses. Being able to predict and plan for extremes and to store water when available benefits local communities, agriculture, energy production, and the environment.

Water management decisions are made at many time scales. Lead time is critical in making water management decisions and few such decisions are made within the time period of a conventional weather forecast (i.e., lead times of up to seven to ten days). These short-lead forecasts can support actions such as near-term reservoir operations, but reservoir operations decisions represent only a small fraction of water management decision-making. Most decisions involve longer timeframes, with the most impactful ones involving resource allocation or hazard mitigation actions made with lead times of months, not days.

Water users, whether they are retail water agencies who contract with a water wholesaler for their supplies or individuals such as agricultural producers, want information about their likely annual water allocations as early as possible to allow them to make operational or business decisions. It is not the forecast of a single storm that influences such decisions, but rather the cumulative results of multiple storms occurring over weeks or months that determines their water supply conditions. For example, about half of the nation's drinking water and most of the drinking water in rural areas comes from groundwater; whether a community or resident needs to drill a new well or deepen an existing one in expectation of potential drought-related shortages is unrelated to the forecast of a single storm but a seasonal forecast would be relevant information.

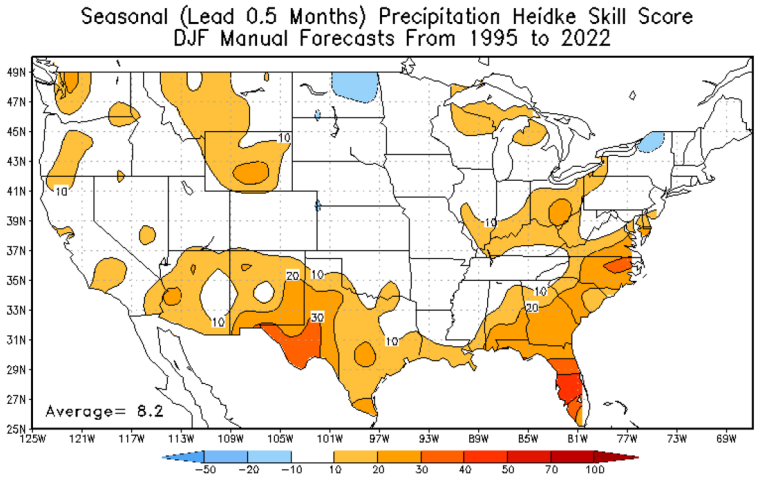


Water agencies' preparation for the extremes of droughts and floods can entail actions such as prepositioning resources, negotiating contracts for water transfers or temporary agricultural land fallowing programs, completing environmental regulatory compliance and permitting, or implementing public outreach campaigns. Such actions do not happen quickly, and they need to be put in place before impacts occur in order to mitigate potential hazards. State water agencies may be able to offer financial or technical assistance to mitigate impacts, but they too need advance warning to secure the resources needed,

including state budget resources. Water agencies have pointed out the importance of skillful seasonal forecasting for drought response, as has NOAA itself.[1]

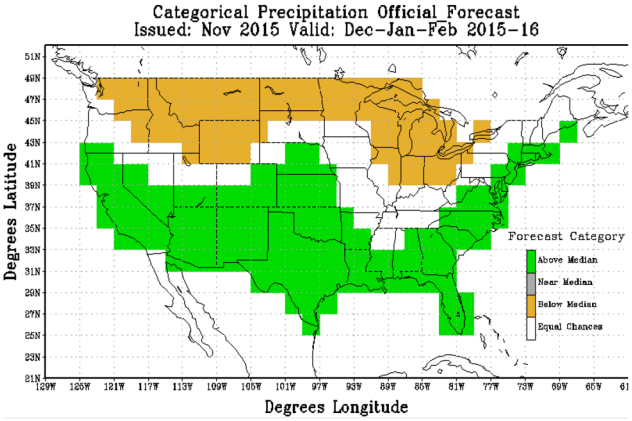
Present S2S Forecast Products Not Adequate

There is significant disparity between water agency needs and applications for S2S precipitation forecasts and the skill of presently available operational products. The National Weather Service's Climate Prediction Center (CPC) has issued S2S precipitation outlooks since the mid-1990s. However, forecast skill for the western U.S. is limited – just slightly better than predicting average weather conditions – and is not adequate to support water management decision-making. The CPC graphic below summarizes the historical skill of its outlooks for the December – February period important for western water supply. The Heidke skill score measures the performance of forecasts. A zero score means no more skill than predicting average historical conditions; a perfect forecast would have a score of one.

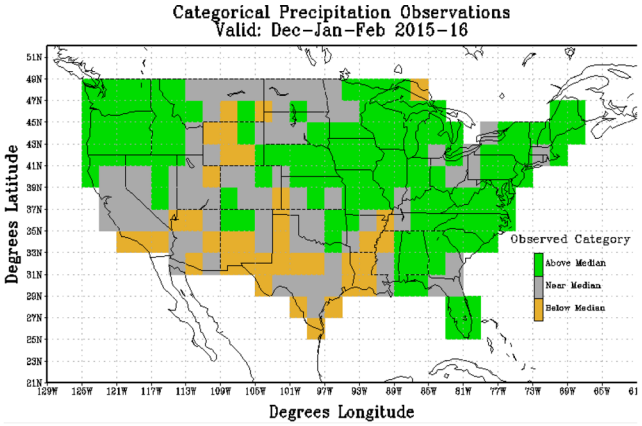


[1] https://www.weather.gov/media/publications/assessments/drought_ca14.pdf

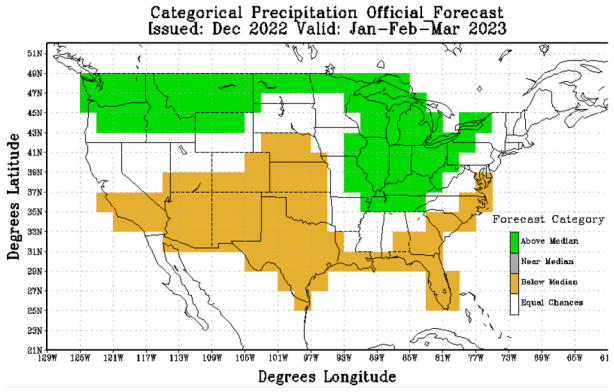
Of particular note for water agencies, NOAA's seasonal outlooks have been dramatically wrong in extreme years when the need for skillful forecasts is the greatest. Shown below is a Water Year 2016 example, when one of the strongest El Niño events of record occurred, comparing NOAA's precipitation outlook with the observed conditions. Water Year 2016 was the fifth year of California's 2012-2016 drought, when urban water agencies were calling for their customers to comply with stringent conservation requirements at the same time as the news media were postulating wide-scale flooding based on the precipitation outlook tied to a strong El Niño event. This example highlights the lack of scientific understanding regarding the actual influence of the El Niño-Southern Oscillation (ENSO) in much of the country. NOAA's precipitation outlooks rely heavily on ENSO conditions as an indicator of precipitation, but research performed by the Western Regional Climate Center[2] and by others[3] shows that ENSO conditions alone are a poor predictor in many western watersheds, including in California and in the Upper Colorado River Basin.

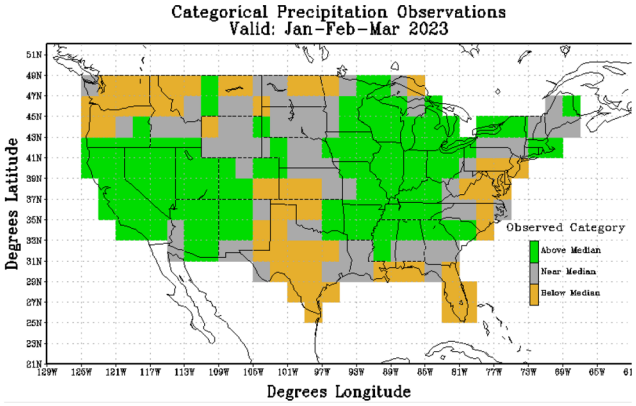


[2] https://wrcc.dri.edu/Climate/soi_precip.php
[3] https://journals.ametsoc.org/view/journals/bams/103/12/BAMS-D-21-0252.1.xml



The present water year, Water Year 2023, is another illustration of a dramatically missed forecast in a critically important water year. Many western watersheds went from severe drought conditions to flooding conditions. California, for example, had just experienced its driest three consecutive years of record and water agencies were preparing for another year of drought emergency response. Instead, one of the wettest years of record occurred, necessitating a rapid shift to flood emergency response and flood fights, and a massive effort to maximize groundwater recharge with temporarily available floodwaters, including issuance of emergency recharge permits and mobilization of rented high-capacity pumps.





Opportunities for Improving Forecasting

The *Weather Research and Forecasting Innovation Act of 2017* directed NOAA to improve its S2S forecasts and to submit a report to Congress with recommendation for doing so. NOAA's 2020 report to Congress[4] pursuant to that requirement recommended four regional pilot projects *chosen based on the existence of major climate phenomena that have huge economic impacts and for which current S2S predictive skill is too low to be effectively used by many stakeholders. They were also chosen because the limited predictive skill of the climate phenomena highlighted for these regions is due to fundamental limitations in our current understanding and models. Therefore, improving predictive skill for these projects would improve skill for other regions as well.*

Two of the pilot projects were for precipitation forecasting, one for winter precipitation in the western U.S. to support water management and the other for spring/summer precipitation in the central U.S. for agriculture. Although recommended in 2020, NOAA has not sought funding for these pilot projects via the President's budget request to Congress. In concept, the pilot projects would be modelled after NOAA's successful Hurricane Forecasting Improvement Program (HFIP), in which specific metrics of performance

[4] https://repository.library.noaa.gov/view/noaa/27408

improvement would be identified for its operational forecasts. Each of the pilot projects would require a level of investment and time commitment similar to that for HFIP.

Western water agencies have demonstrated their support for a winter precipitation pilot project, as evidenced by seed research projects funded by the California Department of Water Resources with NOAA, the National Aeronautics and Space Administration, and the academic community, and by stakeholder support as evidenced by the attached letter for the record.

Reliable S2S forecasts would allow water managers to operate infrastructure more efficiently and allocate resources to mitigate and manage impacts. Improved forecasts would also allow agencies to expand the use of new technologies to maximize efficient use of infrastructure and resources. Forecast-informed reservoir operations (FIRO) and managed aquifer recharge with floodwaters (FloodMAR) are now being successfully piloted at the seven-day weather forecast time scale. Expanding use of forecasts to longer time scales, if reliable S2S forecasts were available, would significantly increase the ability to develop new water supplies at minimal cost to their customers.

Recommendation

The Western States Water Council respectfully recommends that the Weather Act be reauthorized with explicit direction to NOAA to improve S2S precipitation forecasting, including the specific direction to NOAA to implement to two precipitation forecasting pilot projects it recommended in its 2020 report to Congress.

Conclusion

Mr. Chairman, Ranking Member, and Members of the Subcommittee, thank you for the opportunity to testify before you today. I would be pleased to answer any questions you may have.

Short Bio – Jeanine Jones

Jeanine Jones is the Interstate Resources Manager for the California Department of Water Resources. She is a member and past Chair of the Western States Water Council, whom she is representing today. She is a Designee on the Colorado River Board of California and a registered civil engineer in California and Nevada. She has more than 40 years of experience in water resources management, with extensive background in drought preparedness and response.

Chairman MILLER. Thank you, Ms. Jones.

I now recognize Mr. Eric Snodgrass for 5 minutes to present his testimony.

TESTIMONY OF MR. ERIC SNODGRASS,
SENIOR FELLOW SCIENTIST
AND PRINCIPAL ATMOSPHERIC SCIENTIST, NUTRIEN

Mr. SNODGRASS. Chairman Lucas, Ranking Member Lofgren, Chairman Miller, Ranking Miller—excuse me, Ranking Member Ross, and Members of the Subcommittee, thank you for the opportunity to testify today and speak on the use of weather data in agriculture. My name is Eric Snodgrass, and I'm the Senior Science Fellow and Principal Atmospheric Scientist at Nutrien, the world's largest provider of crop inputs and services.

As a global agriculture retailer, our aim is to provide everything the farmer needs at the farm level through our over 1,200 retail locations worldwide—or nationwide. My role in this industry is to provide accurate and timely weather forecast information, which is critically important to every decision our grower customers make. At present, my forecasts are delivered to over 25,000 farmers daily. I maintain an ag weather website with four terabytes of traffic each month and speak at over 120 conferences and grower meetings each year on weather risk and production agriculture. Accurate and timely weather forecasts that our farmer customers rely on and are dependent on and that is accurate and timely weather data is a critical part of them.

Weather risk is ubiquitous in agriculture. In a recent survey published by the University of Illinois' farmdocDAILY, a widely read publication in the agricultural community, weather was identified as the main source of risk for farmers by more than double the next highest category, which was output price.

The United States has nearly 900 million acres of farmland that contributes over $1.26 trillion of the U.S. economy, and it is the uniqueness of the geography of this country that creates the variety of weather that sustains U.S. agriculture. The atmosphere can be unforgiving at times. High impact weather events like the Midwest tornado outbreak on March 31 of this year or the derecho that hit Iowa in 2020 or the drought of fall of 2022 that dropped the Mississippi River to historic levels or the present—or the persistent—excuse me—onshore flow of the atmospheric rivers (ARs) that hit the West Coast this January and March, delivering over 900 inches of snow to some Western mountains, these determine the success of U.S. crops.

We often focus on NOAA's lifesaving efforts in each of these events, which is unmatched at providing, but I see NOAA's utility as something significantly more vital to the U.S. economy. The severe storm outbreak in March also aided in reviving Midwest soil moisture. It was NOAA's radars and rain gauges that captured every move of these storms. NOAA's monitoring of the hydrology of the Mississippi River was strategically used in repositioning barge traffic carrying grain and fertilizer during the drought of last fall. And the incredibly deep Western U.S. snowpack has filled reservoirs this spring, allowing California, which leads the Nation in

the production of over 40 different fruits and vegetables and milk, to precisely and responsibly use water for agriculture.

I prepared a list of all of the resources from NOAA that my team at Nutrien uses daily to provide weather insights to our grower customers, and that list has over 30 products. These data and analyses are compulsively consumed by the agricultural community. Nearly every decision a grower makes is about the future success of their crop and the future success of their business. Weather is uncontrollable, but it is observable and predictable and certain—at certain timescales, and our grower customers consume NOAA's products as a part of every on-farm decision. An average Midwest corn and soybean farmer averages $800 per acre in expenses, resulting in $1-1.5 million of annual cash-flow through their farm. Weather impacts everything from crop type to ideal planting windows to optimal fertilizer application to how vegetative and reproductive crop stages will impact yield, how the market react, and how insurance premiums are set just to name a few examples.

Agriculture is pushing the limits of atmospheric sciences by increasing the demand for subseasonal to seasonal forecasting. Successful farming requires accurate and skillful long-term planning, and long-range weather forecasts provided by NOAA are essential to crop planning and marketing. Just as valuable are NOAA's incredibly rich historical weather and climate records. Farmers study and examine historical weather records and climate data to understand climatic shifts that could impact their farming decisions. These same data are used to compile sustainability metrics of which are of high demand in food production in the United States.

I want to conclude by thanking the Subcommittee for inviting me here today to share with you the importance of weather data in agriculture. In summary, the United States is a global powerhouse in agricultural productivity, and we are an integral part to the food security of this Nation and to the world. NOAA's data and forecasting are mission-critical to the success of U.S. agriculture, investment and computing infrastructure, data assimilation, increased capacity for observation, and industry partnerships are vital to the continued success of NOAA.

So thank you, and I look forward to questions.

[The prepared statement of Mr. Snodgrass follows:]

Written Testimony of
Eric Snodgrass, Senior Science Fellow and Principal Atmospheric Scientist
Nutrien

Before the
House Committee on Science, Space and Technology Subcommittee on Environment

On
Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector

June 6, 2023

Section 1.: Opening Statement

Chairman Miller, Ranking Member Ross, and Members of the Subcommittee, thank you for the opportunity to testify today and to speak on the use of weather data in agriculture.

My name is Eric Snodgrass, and I'm the Senior Science Fellow and Principal Atmospheric Scientist at Nutrien, the world's largest provider of crop inputs and services. As a global agricultural retailer, our aim is to provide everything the producer needs at the farm level through our over 1,200 retail locations nationwide. My role in this industry is to provide accurate and timely weather forecast information - which is critically important in every decision our grower customers make. At present, my forecasts are delivered to over 25,000 farmers daily, I maintain an ag-weather website with 4 terabytes of traffic each month and speak at over 120 conferences and grower meetings each year on weather risk in production agriculture. Accurate and timely weather predictions that our farmer customers rely on are dependent on accurate and timely weather data.

Weather risk is ubiquitous in agriculture. In a recent survey published by the University of Illinois' FarmDocDaily[1] – a widely read publication in the agricultural community – weather was identified as the main source of risk for farmers by more than double the next highest category (output price). The United States has nearly 900 million acres of farmland[2] that contribute over $1.26T to the US economy[3] and it is the uniqueness of the geography of this country that creates the variety of weather that sustains US agriculture.

The atmosphere can be unforgiving at times. High impact weather events like the Midwest tornado outbreak on March 31 of this year, or the derecho that hit Iowa in August 2020, or drought in Fall 2022 that dropped the Mississippi River to historic low levels, or the persistent onshore flow of the Atmospheric Rivers that hit the West Coast this January and March delivering over 900" of snow to some of the Western Mountains, determine the success of US crops.

We often focus on NOAAs life-saving efforts in each of these events – which it is unmatched at providing - but I see NOAAs utility as something significantly more vital to the US economy. The severe storm outbreak in March also aided in the reviving of Midwest soil moisture. It was NOAAs radars and rain gauges that captured every move of these storms. NOAAs monitoring of the hydrology of the Mississippi River was strategically used in the repositioning of barge traffic carrying grain and fertilizer during the drought last Fall. And the incredibly deep Western US snowpack has filled reservoirs this spring allowing California, which leads the nation in the production of over 40 different fruits and vegetables (and milk), to precisely and responsibly use this water for agricultural.

I prepared a list of all the resources from NOAA that my team at Nutrien uses daily to provide weather insight to our grower customers and that list has over 30 products. These data and analyses are compulsively consumed by the agricultural industry. Nearly every decision a grower makes is about the future success of their crops and the future success of their business. Weather is uncontrollable, but it is observable and predictable at certain time scales, and our customer-growers consume NOAAs products as a part of every on-farm decision. An average Midwest corn and soybean farmer averages $800/acre in expenses resulting in $1-$1.5M in annual cashflow through their farm. Weather impacts everything from crop type to ideal planting windows, to optimal fertilizer application timing, to how vegetative and reproductive crop stages will impact yield, how the market will react, and how insurance premiums are set just to name a few examples.

Agriculture is pushing the limits of atmospheric science by increasing the demand for sub seasonal-to-seasonal forecasting. Successful farming requires accurate and skillful long-term planning and long-range weather forecasts provided by NOAA are essential to crop planning and marketing. Just as valuable are NOAAs incredibly rich historical weather and climate records. Farmers study and examine historical weather and climate data to understand climatic shifts that could impact their farming decisions. These same data are used to compile sustainability metrics which are of high demand in food production in the US.

The US is a global powerhouse in agricultural productivity, and we are integral to the food security of this nation and the world. NOAAs data and forecasting are mission critical to the success of US agriculture. Investment in computing infrastructure, data assimilation, increased capacity for observation, and industry partnerships are vital to the continued success of NOAA.

Section 2.: Supporting Information

Section 2.a: NOAA - World Class Organization With Global Competition

Data Access and Ease of Use

NOAAs data collection, quality control, and dissemination are world class. Data are easy to access via ftp servers[4], APIs[5], and numerous https websites. Their quality control measures are the industry standard, and it is rare that their services are unavailable. When comparing the access and ease of use of the products NOAA curates to foreign government weather agencies (i.e., Australia's Bureau of Meteorology, Environment Canada, ECMWF, UK MET Office, Brazil's

National Institute of Meteorology to name a few) NOAA's data delivery and access methods are second to none. They offer data in numerous formats including GIS-ready shapefiles and kml/kmz files, GRIB, NetCDF, ASCII, text, JSON, GeoJSON, TIFF, HDF, and many others. This variety allows the user community to build efficient systems to process and analysis these data to turn them into actionable weather insights for the private sector. As an example, please visit https://www.ag-wx.com and see the list in the Appendix of all the NOAA products currently used by Nutrien's team of meteorologists.

Comments on the Competition with the ECMWF

It is well known that the ECMWF (a.k.a "European Model") has an advantage over all weather forecast models due to its data assimilation technique, 51-member ensemble, and higher resolution. The ECMWF routinely outperforms the US flagship forecast model, the Global Forecasting System Model (GFS), by ~3% on an anomaly correlation skill score. Farmers know about its superior performance and prefer to use it daily to make their on-farm decisions and to judge market reaction. Figure 1 shows 500 hPa Anomaly Correlation skill score computed by Dr. Ryan Maue. This score compares the forecast from two flagship models, the ECMWF (blue) and GFS (red), from 5 days ago for today's mid-level atmospheric flow.

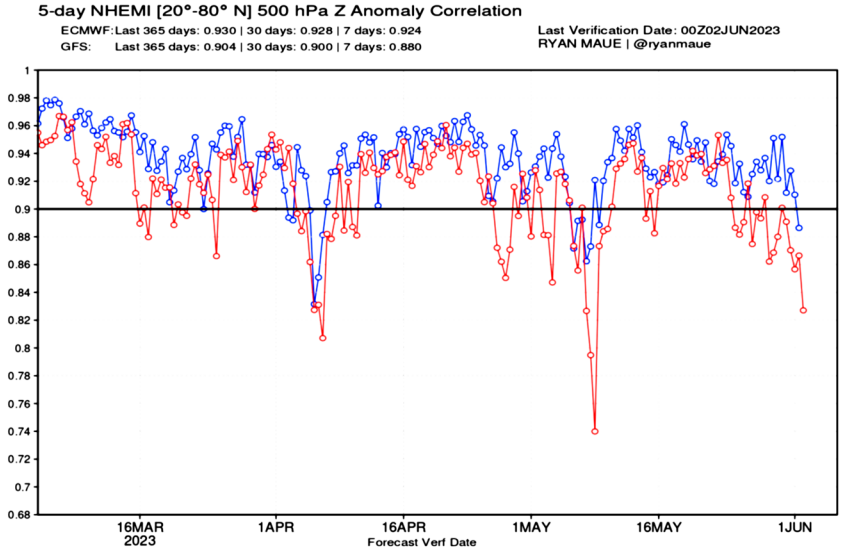


Figure 1. 5-Day Northern Hemisphere 500hPa Geopotential Height (Z) Anomaly Correlation. Over the last 365 days, the ECMWF has a ~3% advantage in skill over the GFS. Image courtesy of Ryan Maue https://climatlas.com/temperature/ecmwf_gfs_nh_f120_recent.png

The US forecast model suite maintained by NCEP could greatly benefit from a re-tooling and computing infrastructure upgrade to be able to adopt the techniques used by the ECMWF. This would be a strategic investment in forecast skill and accuracy and would allow NOAA's suite of models (GFS, NAM, HRRR, RAP, etc.) to collectively outperform the ECMWF.

Section 2.b: Investment in Meteorological Observations

The accuracy and skill of a dynamical weather forecast model is highly dependent on the quality and density of the observations used to initialize the model. It is typical for a farmer to plan their operations on a 10-day forecast horizon for activities such as planting, harvesting, making strategic in-season hiring decisions, contracting truck drivers and applicators, and making certain insurance purchases (like additional severe weather coverage) just to name a few.

One of the most critical aspects of farming - application of fertilizer, pesticides, fungicides, and herbicides - can only be done under strict meteorological guidelines. These guidelines are in place to prevent chemical drift, runoff, or deactivation due to weather conditions. Higher spatial resolution meteorological observations (i.e., a national mesonet) would ensure they are applying within the optimal range of meteorological conditions. Nutrien has built tools using high resolution weather forecast models (i.e., the North American Mesoscale Model or NAM) to forecast temperature inversions, surface humidity, wind speed and direction, plus precipitation timing to provide the best meteorological guidance to a grower during application. Predicting optimal application timing would not be possible without NOAAs high resolution forecast models. Figure 2 shows an example of a forecast from the Nutrien's Pocket Spray Smart mobile application which uses the high-resolution NAM forecast model to predict vital weather conditions for applying chemical to a field.

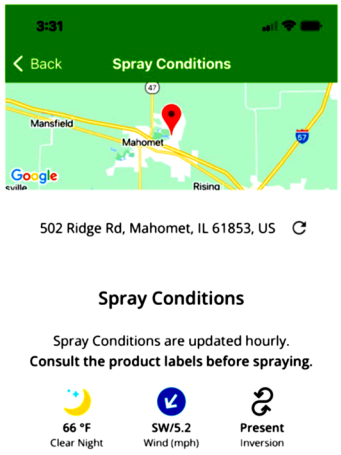


Figure 2. A screen capture of Nutrien's Pocket Spray Smart mobile application.

National Mesonet

There are a few states that have a high spatial density network of surface weather stations. These "mesonets" are critical to the observation and nowcasting of high-impact weather events but they are also extremely valuable for monitoring weather conditions that impact farming decisions. For example, farm irrigation systems are designed to optimize water application to not waste water. A mesonet provides real-time evaporation, wind, humidity, temperature, and weather conditions reporting to optimize that timing and therefore improve the efficiency of irrigation. A nation-wide mesonet would also increase weather model forecasts accuracy through better model initialization. Additionally, a mesonet enhances record keeping during farm applications of fertilizer, pesticides, and herbicides to prove that the farmer completed the application of these chemicals during weather conditions specified by the product labels. Building a national mesonet maintained by NOAA and its high standards for equipment and data quality would be a massive benefit to US agriculture.

A critical but missing piece across the US weather observation network is surface and sub-surface soil moisture monitoring. Soil moisture is a critical variable for farming, but it is poorly observed. A mesonet with soil moisture probes would greatly improve forecast model performance by more accurately capturing the hydrology and mass transfer of water into the lower atmosphere through evaporation. Farmers test soil moisture routinely throughout growing season and make several decisions based upon those measurements. Figure 3 shows a soil sample taken in Champaign, IL on June 1, 2023, in a field that has not received rain in 23 days. The farmer was concerned about flash drought and is potential impact on yield but as you can see, the sub-surface moisture content was still adequate (noted by the wet, black dirt). Additionally, soil moisture measurements will improve irrigation efficiency which can reduce farming's use of precious water resources like the Colorado River or Ogalala Aquifer. It would also inform the decisions by ranchers as they move livestock between pastures across the US rangelands.

Figure 3. A close look at a 12” soil sample in Champaign, IL on June 1, 2023. Image courtesy of Eric Snodgrass

NEXRAD Radar Network

The US has 160 WSR 88-D radars that use the latest technology in dual-polarization observations to monitor nearly every aspect of precipitation. It is arguably the most reliable and best covering radar network in the world, yet key growing areas are missed. This is not only a potential problem for the issuance of severe storm and tornado warnings, but it reduces that accuracy of rainfall estimations across highly productive farm and rangeland. This is a well-known shortcoming of the NEXRAD radar network. For example, notice the lack of coverage parts of the Midwest like northern Missouri, Nebraska, and in the Northern Plains, Western Plains, and Lower Mississippi River Valley. Investment in additional radars to fill in these holes is tremendously valuable to farmers in these areas and help with insurance (ie., the National Pasture, Rangeland, and Forage Insurance Programs), crop planning, in-season application, and severe weather monitoring. It would also enhance the accuracy of tools that growers use that are powered by NOAAs NEXRAD system. For example, one of Nutrien’s most popular mobile application is called Pocket Rain

Gauge which we developed using NEXRAD and MRMS (Multi-Radar/Multi-Sensor System) to accurately record field level precipitation statistics.

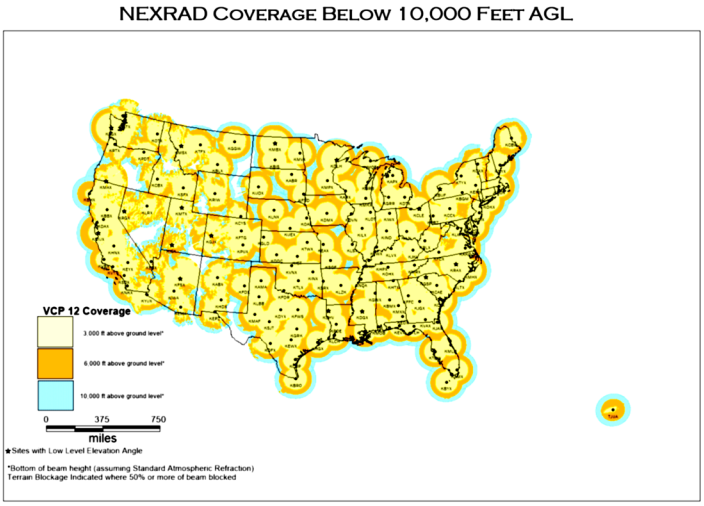


Figure 4. NEXRAD radar coverage below 10,000 feet Above Ground Level from its network of 160 WSR 88-D radars. Source: https://www.roc.noaa.gov/WSR88D/maps.aspx

Meteorological Soundings

The US launches weather balloons twice per day at 92 National Weather Service (NWS) Offices. These data are vital for weather forecast model initialization, high-impact weather prediction, aviation, and farming. During special events, like a landfalling hurricane or severe weather outbreak, the NWS will perform additional weather balloon launches to enhance weather model performance. This practice should be done routinely. It is also recommended that we increase the number of locations that launch weather balloons to better capture the atmospheric profile and greatly improve weather forecast accuracy[6].

Section 2.c: NOAA and the Success of US Agriculture – Sub-Seasonal to Seasonal Forecasting

I cannot stress enough how vital NOAAs operations are to the success of US agriculture. Decision support using weather analysis and forecasting is mission critical across all aspects of agriculture, from the grower to the businesses and industries supporting agriculture like Nutrien. Successful food production and security rely on NOAA's timely and accurate observations and predictions. The agriculture industry would benefit immensely from improved forecast skill in the Sub-Seasonal to Seasonal (S2S) time scale of 2 weeks to 2 months. More accurate weather forecasts at this time scale would improve market stability, improve prediction of high-impact events like

drought, flood, heat waves, and cold air outbreaks, and improve crop planning decisions. The "S2S Prediction Gap" as noted in Figure 5 represents one of the greatest challenges to atmospheric science and NOAA is well-equipped to conquer this gap and provide the needed skill for all weather sensitive aspects of the US economy – especially agriculture.

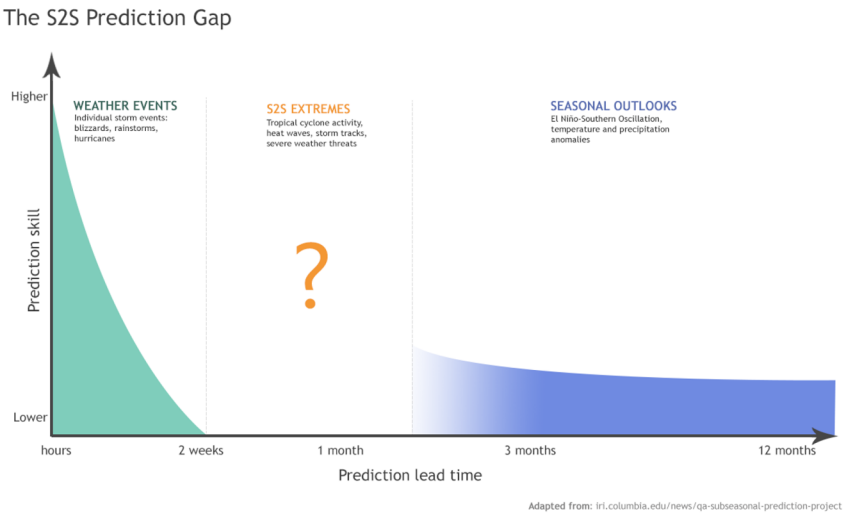


Figure 5. Prediction skill plotted again prediction lead time. Source: https://cpo.noaa.gov/Divisions-Programs/Earth-System-Science-and-Modeling/MAPP/ArtMID/6170/ArticleID/818/Advancing-the-Prediction-of-Subseasonal-to-Seasonal-Phenomena

Section 2.d: Conclusion

I want to conclude by thanking the Subcommittee for inviting me here today to share with you the importance of weather data to the agriculture industry. The success of US Agriculture is dependent on accurate and skillful weather analysis and prediction and NOAA represents the industry standard for world class meteorology. Continued adequate funding plus strategic investment as outlined in my statement would ensure its continued success and be in the best interest of US businesses and the general population. NOAAs data and services are mission critical to farmers, our food supply, and businesses like Nutrien that support US agriculture.

1 https://farmdocdaily.illinois.edu/2023/01/the-use-of-climate-information-in-midwest-agriculture-results-from-a-farmer-survey-part-i.html
2 https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0222.pdf

3 https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58270#:~:text=Agriculture%2C%20food%2C%20and%20related%20industries,0.7%20percent%20of%20U.S.%20GDP.
4 https://nomads.ncep.noaa.gov/
5 https://www.weather.gov/documentation/services-web-api
6 Privé, N. C., R. M. Errico, and K. Tai, 2014: The Impact of Increased Frequency of Rawinsonde Observations on Forecast Skill Investigated with an Observing System Simulation Experiment. *Mon. Wea. Rev.*, **142**, 1823–1834, https://doi.org/10.1175/MWR-D-13-00237.1.

Appendix.

List of current NOAA agencies, models, observations, and products routinely used by the team of meteorologists at Nutrien.

CPC - Climate Prediction Center
CFSR - Climate Forecast System Reanalysis
MRMS - Multi-Radar/Multi-Sensor System
AHPS - Advanced Hydrologic Prediction Center
NAM - North American Mesoscale Model
GFS - Global Forecast System Model
GEFS - Global Ensemble Forecast System
SREF - Short Range Ensemble Forecast
HRRR - High Resolution Rapid Refresh
RTMA - Real-Time Mesh Analysis
NLDAS - North American Land Data Assimilation System
GLDAS - Global Land Data Assimilation System
NOAA VIIRS - Visible Infrared Imaging Suite
NMME - National Multi-Model Ensemble
NEXRAD - Next Generation Radar
SPC - Storm Prediction Center
NHC - National Hurricane Center
WPC - Weather Prediction Center
NOHRCS - National Operational Hydrologic Remote Sensing Center
METAR (ASOS/AWOS) - Meteorological Aerodrome Reports, Automated Surface Observing System, Automated Weather Observing System
NDFD - National Digital Forecast Database
CDAS - Climate Data Assimilation System
NOAA SSTs (Coral Reef Daily Watch)
Drought Monitor
CFSv2 - Climate Forecast System Version 2
CFS - Climate Forecast System
GHCN - Global Historical Climatology Network
Observed Soundings
Fire Weather

MOS - Model output Statistics
NAEFS - North America Ensemble Forecast System
RAP - Radii Refresh Model
Hysplit Trajectory Model
NBM - National Blend of Models
URMA - Unrestricted Mesoscale Analysi
GLERL - Great Lakes Environmental Research Laboratory
GOES - Geostationary Operational Environmental Satellites

Eric Snodgrass is the Senior Fellow Scientist and Principal Atmospheric Scientist for Nutrien's retail division, Nutrien Ag Solutions, where he develops predictive, analytical software solutions to manage weather risk for global production agriculture. He provides frequent weather updates that focus on how high-impact weather events influence global agriculture productivity. His current research uses machine learning to better understand field-level weather impacts on yields in the US and to increase confidence in long-range weather prediction. He presents his research as a featured speaker at over 120 conferences annually where he provides logistical guidance and solutions to weather sensitive financial institutions, farmers, commodity traders, and other stakeholders.

Snodgrass is a co-founder of Global Weather and Climate Logistic, LLC and Agrible, Inc which were both acquired by Nutrien Ag Solutions in 2018. From 2006-2019, Eric was the Director of Undergraduate Studies for the Department of Atmospheric Sciences at the University of Illinois at Urbana-Champaign where he taught over 20,000 students across a wide range of course work in Atmospheric Science. He won many prestigious teaching awards at the University of Illinois including College of Liberal Arts and Sciences Teaching Excellence award, the Campus Teaching Excellence Award and the Campus Teaching Excellent Award in Online and Distance Education.

Eric Snodgrass
Senior Science Fellow and Principal Atmospheric Scientist, Nutrien
Eric.snodgrass@nutrien.com

Attached below is a hi-res photo.

Chairman MILLER. Thank you, Mr. Snodgrass.

I now recognize Dr. Kathie Dello for five minutes to present her testimony.

TESTIMONY OF DR. KATHIE DELLO, PH.D.,
STATE CLIMATOLOGIST OF NORTH CAROLINA,
AND CO-DIRECTOR, NOAA CAROLINAS CLIMATE
ADAPTATION PARTNERSHIP (CAP/RISA)

Dr. DELLO. Good morning, Chairman Miller, Ranking Member Ross, Members of the Subcommittee. It is truly an honor to be here with you today.

We are approaching the five-year anniversary of Hurricane Florence, a category one hurricane that caused unprecedented damage in eastern North Carolina. Communities are still recovering. Despite the magnitude of this event, weather and climate data availability is still inadequate following this generational storm. And in a changing climate, our flood risks are increasing statewide and across the country.

You've likely seen the videos of houses falling into the ocean on the Outer Banks of North Carolina. However, you may be unfamiliar with the area known as Down East. It's a coastal community of 13 unincorporated villages. The population living in this community is aging, and most of these families have lived in Down East for generations. This community has seen the impacts of flooding firsthand from big events like Florence to daily nuisance floods that interrupt their lives in countless ways. These flooding events are more than short-term inconveniences. They threaten public safety and health. Two-lane roads are often flooded, and no shoulders exist in many places. Highway 70, a Federal highway, is the only corridor available to these residents. The one hospital in the county is located 52 miles away from the residents in Cedar Island.

People in these rural coastal areas nationwide need weather and climate data to help them understand how high to raise their houses, businesses, schools, and churches; translational services and channels to communicate these data to community members who are grappling with other stressors; and daily tidal flooding data to learn when roads are impassable.

Down East is not an anomaly. There are Down Easts all over this country. We play a role as the boots on the ground for NOAA and other Federal agencies in the States in developing and cultivating community partnerships and filling in the gaps in these critical climate and weather data. One of our climate adaptation partnership investigators, along with her research team, is filling in key gaps in coastal flooding or sunny day flooding data using low-cost sensor technology. They find that coastal flooding is happening more often than past studies have shown and that projections of future coastal flooding are likely underestimated. In Beaufort, North Carolina, they documented 24 floods in five months. In comparison, the National Weather Service would have reported eight. Twenty-five percent of those events were due to a combination of rain and tide, which NOAA tide gauges are not designed to capture. Our coastal communities need this really important information.

Perhaps the most visible footprint of my office, the State Climate office, is North Carolina's Mesonet, the Econet. This weather and

climate network measures and delivers weather and climate data in support of the National Weather Service and public safety, agriculture, transportation, and tourism in North Carolina. Our goal is to have at least one Econet station at each of one—each of North Carolina's 100 counties. The demand is there, and the need is, too. Our stations are located in places where there isn't a NOAA weather or climate station.

Furthermore, as known officials in our State using the trusted NC State University name and our land grant designation, we are able to identify key partners and end users of the data in a way that a Federal agency like NOAA cannot. Our office also serves as a translator of these massive and occasionally complicated data sources. We ensure free and equitable access to all of our publicly funded data through a series of user-friendly portals.

Despite the overwhelming demonstrated need for more data, there are serious limitations. The major challenge is adequate funding. State Mesonets receive some funding from the National Mesonet Program via NOAA, but it pales in comparison to what States like North Carolina need to run a fully functioning statewide Mesonet. And despite the enormous demonstrated value to NOAA and cost savings provided by this life- and property-saving data, the short-term and low-value contracts from the National Mesonet Program reduce our ability to focus on the task at hand.

So with the *Weather Act* reauthorization, I ask NOAA to increase funding to State Mesonets through the National Mesonet Program for this critical life and property-saving data; ensure equitable access to publicly funded data for all, including translational services for those folks who can't sit down and sift through climate data; ensure that we're making forward progress to maintain the safety of life and property in a changing climate and not just continuing to ask communities what they need and not delivering in one-off engagements. We need to scale and transfer nationwide some of the fairly low-cost research that our CAP/RISA (Regional Integrated Sciences and Assessments) team is doing and monitoring like the sunny day flooding and urban heat islands. And we need to ensure that the vulnerable, rural, and remotely located Down Easts of the country get the same amount of attention as the larger, more resourced cities. We are always thinking of the next hurricane Florence, the next tropical storm Fred and the next Hurricane Floyd.

I thank you for your time and attention, and I'm happy to answer your questions.

[The prepared statement of Dr. Dello follows:]

Dr. Kathie Dello
North Carolina State University

Environment Subcommittee Hearing - Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector

Chairman Miller, Ranking Member Ross, and members of the subcommittee. It is my honor to be here with you today, and thank you for a chance to testify about the need for robust weather and climate data; outline how we at the State Climate Office of North Carolina interface with NOAA weather and climate services; and provide some examples of how states like North Carolina help to fill critical gaps in NOAA's weather and climate data and research.

My name is Dr. Kathie Dello. I am the Director of the State Climate Office of North Carolina and serve as our State Climatologist. Our office is located in North Carolina's capital city, Raleigh, at North Carolina State University.

The need for weather and climate services in North Carolina

Let me share a community story with you. You've likely seen videos of houses falling into the ocean on the Outer Banks of North Carolina. However, you may be unfamiliar with the area known as Down East, North Carolina. It is a coastal community of 13 unincorporated villages with populations of less than 1,000 that are located just inside the Outer Banks area near Cape Lookout lighthouse. The population living in this community is aging, and most of these families have lived in Down East for generations. This community has seen the impacts of flooding firsthand -- from big events like Hurricane Florence, to daily nuisance floods that interrupt their lives in countless ways. People in these areas need climate data to help them understand how high to raise houses, business, schools and churches; channels to communicate these data to community members who are grappling with other stressors; and daily tidal flooding data to learn when roads are impassable. These flooding events are more than short-term inconveniences, they threaten public safety and health. Two-lane roads are often flooded and no shoulders exist in many places. Highway 70, a federal thoroughfare, is the only public access corridor available to these residents. The one hospital in the county is located in Morehead City, 52 miles away from the residents in Cedar Island. Retreat is not an option for Down East; this community lives with the water. This community needs data to inform solutions, and they need to know how to access funding for these solutions.

The need for such climate services in our state and our southeast region is clear. I have dozens of other stories from other communities that face challenges similar to Down East.

North Carolina is getting hotter, wetter, and more humid. Flood risks are prevalent statewide. We are approaching the five-year anniversary of Hurricane Florence, a Category 1 hurricane that caused unprecedented damage in eastern North Carolina. Florence was a generational storm that turned portions of Interstate 40 into a river and cut most of North Carolina off from the rest of the country. Storm-related flooding isn't contained to the coastal plain. Two years ago, Tropical Storm Fred caused catastrophic flooding in the North Carolina mountains, where valleys shaped like egg cartons are magnets for fast-flowing water. Warming nighttime temperatures threaten the development of crops such as berries and stone fruits. Agriculture is the cornerstone of North Carolina's economy – we sent the Capitol its christmas tree last year and we're among the top christmas tree producers nationwide. Hot Carolina days, increasingly warm overnights, and increased humidity present a public health risk that impacts everything;high school football; the workplace safety of rural farmworkers; low-income communities' and impact the health of pregnant women. Five years after Florence, you'll be hard pressed to find someone in North Carolina who does not acknowledge that the state's climate is changing. Our residents need quality weather and climate data coupled with solutions for their communities to truly thrive.

North Carolinians have been clear about their weather and climate data and research needs. Citizens need locally relevant, high-quality data that is actionable and that can inform solutions. Residents facing rising sea levels and more frequent flooding hazards need to know how to access the funding to implement solutions. As one of the most densely rural states in the country that is also rapidly urbanizing, North Carolina has unique challenges when it comes to adapting and responding to climate change.

The State Climate Office of North Carolina

The State Climate Office of North Carolina is a University of North Carolina System Public Service Center dedicated to serving the needs of North Carolinians by translating climate information into useful and usable knowledge, and bridging the gap between scientists, decision-makers, and community members. We are one of the largest and most productive state climate offices in the country. We have a full-time staff of 10, and numerous graduate and undergraduate students. We work with faculty across the UNC System, leveraging research and disseminating it across the state. We have strong ties with NC Cooperative Extension, including sharing a position in our office to interface with our state's county extension agents. North Carolina's county extension agents are located in every county in North Carolina and interface directly with the state's agriculture and forestry producers.

We work closely with other local, county and state agencies. The State Climate office runs the North Carolina ECONet, or Mesonet, a 44-site research-grade weather observing network sending nearly 1.5 million observations back to Raleigh each day.

Additionally, the State Climate Office enjoys a longstanding and fruitful relationship with NOAA. We are co-located with the National Weather Service (NWS) on North Carolina State University's Centennial Campus in Raleigh. This allows for collaboration, connection and the facilitation of data transfer to communities. We especially partner closely with the NWS on drought monitoring activities in the state. We are also located in the same state as NOAA's National Centers for Environmental Information in Asheville and have worked with the staff there to use their high-quality daily climate observations to help contextualize some of our work. I have two cooperative agreements with NOAA's Office of Atmospheric Research's Climate Program Office, including the aforementioned CAP/RISA. We have a contract with the National Mesonet Program through the National Weather Service. Our staff have participated in National Integrated Drought Information System activities, including helping to disseminate effective communications templates to other states for their use. And finally, in 2021, we were one of the lead organizations on the NOAA/National Integrated Heat Health Information System Urban Heat Mapping Campaigns in Raleigh and Durham, NC. These relationships bolster the capacity of the State Climate Office and the CAP, but also help NOAA reach a broader constituency in North Carolina.

Our recent external five-year review in February of 2023 noted that, "as an agency serving the people and government of North Carolina, the State Climate Office has all the hallmarks of a 'best in class' climate services organization, ranking among the top state climatologist offices in the nation. The staff is passionate and knowledgeable, excelling at education and outreach, climate and weather monitoring, and providing valuable knowledge and services to other state agencies and the North Carolina public. During the review, stakeholders from state universities and agencies highlighted the significant value provided by the State Climate Office, including data, summary reports, student mentoring and general operational advice."

The role of State Climate Offices and CAP/RISAs

State Climate Offices and CAP/RISAs play an integral role as the "boots on the ground" for NOAA and other federal agencies in the states, in developing and cultivating community partnerships, and filling in the gaps in critical climate data. Our CAP/RISA is targeting the communities that are hit first and worst by climate change. In North Carolina, having the two entities co-located has provided an advantage. We are able to understand where there are critical data gaps and leverage the data and resources of the State Climate Office. My

co-director, Dr. Jennifer Runkle, is co-located at NOAA's National Center for Environmental Information, and is also able to uniquely identify needs and pressing opportunities. With a strong foundation of leveraged climate data, research, and NOAA resources, we are able to seek out opportunities to work with communities on solutions and planning. While we are a newer CAP/RISA, only starting in late 2021, we have made significant progress in furthering community climate resilience. We are working with local public health departments, city and regional planners, and community organizations to help them respond to the needs of their local residents.

A few examples of how our CAP/RISA is addressing community weather and climate data needs:

One of our CAP/RISA investigators, Dr. Miyuki Hino, along with her colleagues at UNC Chapel Hill and NC State University, have developed low-cost, open-source sensors to detect "sunny-day" or tidal flooding in Coastal North Carolina. These sensors have filled in critical gaps in NOAA data. They find that coastal flooding is happening more often than past studies have shown, and projections of future coastal flooding are likely underestimated. In Beaufort, NC, they documented 24 floods (standing water on road) in five months; in comparison, NOAA would have reported four events and NWS would have reported eight over the same time period. Twenty-five percent of those events were due to a combination of rain and tide, which NOAA tide gauges are not designed to capture. Dr. Hino and her team are working with coastal communities to incorporate these data into planning and solutions.

Our Carolinas CAP/RISA team is working closely with the Eastern Band of Cherokee Indians in Western North Carolina and the US Department of Interior Southeast Climate Adaptation Science Center to create a climate action plan for the next seven generations. In our conversations with the tribe, the need for high-quality weather data of their own was identified in early conversations. In response to that needs assessment, the State Climate Office will be installing an "ECONet Extended" station in Cherokee, co-located with air quality monitoring equipment. These data sources will aid in the tribe's air quality monitoring and communications efforts, and also give them crucial data and information that they need to apply for external funding. We are committed to providing communities with resources through our CAP/RISA, and this is one way we can give back.

In Raleigh and Durham, our CAP/RISA team is focused on understanding compounding hazards. We are taking the Urban Heat Island mapping data from 2021, other sensors including the North Carolina ECONet, and local observations of flooding and heat using other local sources (e.g., street cameras, kestrels, flood activation signs) to use machine learning approaches to understanding compounding heat and flood hazards. We are

assessing when and where extreme heat and flood have sequentially occurred, evaluating whether the probability of their co-occurrence has changed over recent decades, and working with community partnerships to inform adaptation and mitigation efforts.

These three examples demonstrate where local research, partnerships and understanding have filled in gaps in NOAA's data at the community level, and where CAP/RISA capacity helped to connect data to solutions.

Service to the State of North Carolina

A central component of the State Climate Office's mission is its commitment to serving the State of North Carolina, which is a key consumer of our research, outreach, and decision-support activities. This effort by the Center creates efficiencies, saves the state significant time and money and adds valuable climate expertise capacity that state entities do not possess in-house. A few examples of the State Climate Office's services:

Cardinal and Station Scout Data Retrieval System

When I assumed the directorship in 2019, a top priority was to eliminate barriers to data access for communities, including offering all publicly funded data free of charge. In partnership with NC Cooperative Extension, the State Climate Office custom-built Cardinal and Station Scout tool, released in Spring 2021, puts the State Climate Office's 145 terabytes of publicly-funded climate data, including NOAA data, in the hands of all North Carolinians. This powerful and new user-friendly tool enables users to download, plot and explore North Carolina's climate and weather data without prior programming knowledge. Cardinal was developed in-house by Center staff, and the State Climate Office refines the tool quickly and often based on user requests. Prior to 2021, clients would have to request climate data manually by completing an electronic form or via email and, on average, each data request would take about 20 minutes of staff or student time. The State Climate Office charged $60/hr for large requests. With the development of Cardinal, the State Climate Office saved about 200 person days per year of employees' time while completing requests free of charge, and creating immense value to the state.

Multi-sensor Precipitation Estimate (MPE) Tool with the North Carolina Department of Transportation (NCDOT)

The State Climate Office created and upgraded the MPE tool in response to a contract with the NCDOT. The tool provides rainfall monitoring and alert services to DOT employees and their contractual partners, based on weather-radar-based rainfall estimates and gauge data from NOAA and the NC State Climate Office. Users can view and explore rainfall over

different time periods across North Carolina using the MPE map. The North Carolina State Climate Office developed a system for users to set their own location sites across the state to subscribe to near-real-time alerts based on user-defined rainfall thresholds and time periods. Previously, contractors would have to check rain gauges manually for state and federal water quality monitoring compliance. It is estimated that this tool saves NCDOT about $3 million each year. The State Climate Office collaborates with NCDOT on other efforts, including updating intensity-duration-frequency precipitation curves and other research topics. This collaborative effort also allows for informal conversations; SCO staff are able to brief NCDOT staff and leadership on emerging climate trends and issues.

These are just two examples of the State Climate Office's numerous state collaborations. We also work closely with NC Department of Health and Human Services, NC Department of Agriculture and Consumer Services, the NC Department of Environmental Quality and other state agencies to build custom tools, participate in outreach events and do original research.

North Carolina ECONet (Mesonet)

Perhaps the most visible footprint of the State Climate Office is the NC ECONet, North Carolina's Mesonet. This research-grade environment and climate observing network measures 16 environmental variables in one-minute intervals. Some of these stations date back to the late 1970s, and new stations are added to fill in critical gaps (e.g., Nags Head/Jockey's Ridge State Park on the Outer Banks) or as an opportunity to collaborate with another sector or entity (e.g., UNC Asheville and academic training). To better understand heat stress, black globe thermometers were added to all 44 sites in the NC ECONet network, rendering it the only state Mesonet with black globe thermometers installed. These thermometers allow us to calculate wet bulb globe temperature, or a more precise measure of heat stress on the human body. ECONet provides key partners, like the National Weather Service and the NC Department of Emergency Management, with critical weather observations required for agriculture, transportation and public safety. During Hurricane Florence, National Weather Service forecasters were able to rely on our data to give them real-time data on the storm. Our stations run on solar power and were able to stay powered to provide life-saving information and data.

Staff use ECONet data to create custom web tools and dashboards for agricultural producers. One such tool issues alerts for the safe spraying of herbicides based on atmospheric conditions; we look for the presence of an inversion using wind and temperature data. We work with NC State's Plant Pathology, Crop Science and Entomology extension experts to issue alerts on the potential for peanut disease and to advise growers on the best times to apply fungicides. We have created custom tools for the North Carolina

Corn Growers Association and to help producers explore accumulated growing degree days. These tools are often developed using NC ECONet data, and NOAA data in some cases – including Climate Prediction Center seasonal outlooks.

ECONet is funded in part by NOAA's National Mesonet Program, and with additional support from NC State University and some individual donors. The ECONet is also a catalyst for workforce development. ECONet staff are cross-trained in station maintenance, tool development, GIS and coding in entry-level positions. We are able to offer internships to work with the ECONet team to NC State University students. The ECONet is at the center of State Climate Office activities, and is integrated into our tools, our outreach, and our training and workforce development opportunities. Growth of our network would allow us to offer more opportunities to students and early career professionals.

Despite the overwhelming demonstrated need for more, actionable, localized, high-quality data in communities, there are serious limitations. The goal is to have at least one ECONet station in each of the 100 counties. The demand is there, and the need is too. Our stations are located in places where there isn't a NOAA weather or climate station. Dewpoint, black globe, wind and/or humidity data are lacking in some of these other networks, which are critical for agriculture and public health. These data sources fill in crucial gaps in our understanding of North Carolina's environment. Furthermore, as known officials in our state, using the trusted NC State University Extension name and our land-grant designation, we are able to identify key partners and end-users of this data in a way that a federal agency like NOAA cannot. Our office also serves as a translator of these massive data sources and are trusted messengers in and around the southeast US.

One major challenge is adequate funding. The State Climate Offices receive some funding from the National Mesonet Program via NOAA , it pales in comparison to what states like North Carolina need to run a fully-functioning, statewide mesonet. Despite the enormous demonstrated value and cost-savings provided by this life and property–saving data, only $92,655 was sent to North Carolina in the last term of the National Mesonet Program contract for a period of 10 months ending in April 2023. This current contract, totaling $328,083 for the three years, has lapsed. We have been promised another five-month increment/extension, but NC State is having to supplement the funding until we get it. In the meantime, we are still responsible for meeting our data availability targets during this lapse in funding. This is a huge burden for states without a safety net like the bridge funding we're receiving. Furthermore, these short-term extensions are a significant additional administrative burden on the staff of the State Climate Office staff, NC State contracts and grants office and on NOAA contractor program staff. The short-term contracts reduce our ability to focus on the task at hand, which is providing high-quality, real-time research grade weather data to the state of North Carolina. Additionally, these short-term,

low-value contracts prevent us from expansion. With unstable funding mechanisms, we are reluctant to expand into areas that may need these data streams. There is room for NOAA and the National Mesonet Program to make a solid investment in state mesonet data, with significant benefit to myriad NOAA programs, not just the National Weather Service. We have demonstrated the need for local-scale climate and weather data through our CAP/RISA work. Put simply, the investment in our state's ECONet/Mesonet by the National Mesonet Program is far below what it should be given the value of the network and data to NOAA and the State of North Carolina.

We know that what we have in North Carolina is special and we are fortunate. The North Carolina State Climate Office provides enormous value to the State of North Carolina through community and state agency partnerships, and a long legacy of trust and delivery of climate services across all 100 counties. The addition of the CAP/RISA at NC State has allowed us to better connect this data and knowledge with communities to further the development of solutions. The support of NC State University coupled with the university's land grant mission allow for us to truly serve the public. Co-location and cooperation with NOAA entities allow us to leverage NOAA data, people and products for use in our communities. Partnerships with other federal climate efforts like the Southeast Climate Adaptation Science Center ensure that we're using taxpayer dollars to their fullest and not duplicating efforts. We have smart, savvy engaged community stakeholders and some of the nation's top research universities. In North Carolina, we come together to solve the state's biggest challenges – as evidenced by a $25 million bipartisan effort to create a flood modeling blueprint for the state – we can put political differences aside to ensure that our communities survive and thrive in the face of climate change.

Not all states are as data-rich or as aligned as North Carolina. Demand still outweighs capacity in North Carolina and the challenges are greater in other states. Despite considerable leverage and careful coordination, NOAA weather and climate data efforts, while admirable, are often uncoordinated and are siloed in line offices, resulting in duplication of tasks and effort. Despite frequent engagements from NOAA entities on climate and weather in communities, NOAA has completely failed to respond to requests in some instances. One example of the most requested and the most basic weather and climate data needs of the communities has been the extremely delayed update to historical precipitation curves (Atlas-14) that are used extensively in planning and projects. I know that there has been movement and funding to deliver these products, but we need urgent action to complete this task. The State Climate Office has worked with NOAA to ensure that they have all the relevant data for North Carolina. But it is too little, too late. These historical updates will unfortunately be outdated when they arrive in Atlas 15 in 2027 and are coupled with future projections. In North Carolina, we could not wait. We have updated these precipitation frequency curves to include climate projections, a project that is a

collaborative effort between NC State, NC Department of Transportation, and the North Carolina Office of Resiliency and Recovery.

It is difficult for us in positions like mine to recommend that our communities invest in climate engagement efforts that may not result in tangible data and products. And while efforts like the urban heat mapping projects generate a lot of buzz, useful data and products – they represent an enormous time commitment and we cannot sustain the massive community weather and climate data needs on the backs of citizen volunteers. With the reauthorization of the Weather Act, we hope NOAA can do the following:

- Step up as the authoritative weather and climate data source for the nation by coordinating climate efforts across line offices and being responsive to state and community weather and climate needs.
- Increase funding to state mesonets through the National Mesonet Program for critical life and property saving data.
- Continuing to fund the CAP/RISA program at current or higher levels. The CAP/RISAs are an important mechanism that communities can use to turn climate data into solutions.
- Ensure equitable access to publicly-funded data for all, including translational services.
- Funding positions in state offices like mine to ensure that we're making forward progress to maintain the safety of life and property in a changing climate and not continuing to ask communities what they need and not delivering in one-off engagements.
- Scale and transfer nationwide some of the fairly low-cost research and monitoring, like the sunny-day flooding monitors and urban heat island monitoring using micronets.
- Ensure that vulnerable, rural, and remotely located Down Easts of the country get the same amount of attention as the larger, more-resourced cities. We are always thinking of the next Florence, the next Fred, the next Floyd.

Short Biography

I have been in the position of the State Climatologist for North Carolina for more than four years. Before coming to North Carolina, I spent nearly a decade as the Associate Director of the Oregon Climate Change Research Institute at Oregon State University. Additionally, since late 2021 I have co-directed the NOAA Climate Adaptation Partnership (CAP, formerly RISA) for the Carolinas. I was also involved in the former Climate Adaptation Partnership/RISA in the Pacific Northwest, the Climate Impacts Research Consortium, or CIRC.

I have nearly 15 years of experience in state-level climate service boundary organizations that span weather and climate data and science and decision-making. I led Oregon's first climate assessment report in 2010, participated in two others, and was an author on North Carolina's first climate assessment report in 2020. I am an author on the Southeast Chapter of the 5th National Climate Assessment, due out this fall. I have worked extensively with state, local, and county governments; state agencies; and on federal research grants. I have participated in state-level climate adaptation efforts in New York, Oregon, and North Carolina.

I thank you for the opportunity to testify today and I look forward to answering any questions you may have for me.

Dr. Kathie Dello *Director / State Climatologist*

Dr. Kathie Dello is the state climatologist of North Carolina and the director of the North Carolina State Climate Office at North Carolina State University. She is the 5th permanent director and first woman to hold this position at the NCSCO in the office's history. Kathie also serves as the co-director of the NOAA Carolinas Climate Adaptation Partnership (CAP/RISA), which moved to NC State in late 2021.

Kathie is involved with climate resilience planning and impacts assessment. She is also a proficient science communicator, and frequently collaborates with local and national media, NGOs, and other climate organizations. She works closely with North Carolina's state agencies to help them understand their climate risk. She led Oregon's first Climate Assessment in 2010, and was a co-author in 2017 and 2019. Kathie was a lead author for the 2020 North Carolina Climate Science Report and a member of the Climate Advisory Panel. She has also participated in adaptation planning in New York and Oregon, and was a technical advisor to North Carolina's 2020 Risk and Resilience Plan. Kathie is an author on the Southeast chapter of the 5th National Climate Assessment.

Kathie comes to us from Oregon State University, where she was the associate director of the Oregon Climate Change Research Institute and the deputy director of the Oregon Climate Service for almost 10 years.

She has a Ph.D. in Environmental Sciences from Oregon State University, a Master's in Geography and a Bachelor's in Atmospheric Science from the State University of New York at Albany.

Chairman MILLER. Thank you, Dr. Dello, and I thank the witnesses for their testimony.

The Chair now recognizes himself for five minutes.

Mr. Snodgrass, in your testimony, you mentioned the overlooked utility of NOAA's data as a more significant piece to the U.S. economy than meets the eye. We know that food security is a national security issue, and one out of every seven jobs in my State of Ohio is in agriculture. Several of our State's top crops, including corn and soy, rely on good weather conditions to have a successful, profitable year. We've talked about the importance of forecasting, be it one to three days out, or seasonal to subseasonal forecasting in the context of agriculture. So can you elaborate on the ways in which forecasting factors into every decision from crop insurance selection, planting fertilizer, and pesticide application, as well as harvesting and marketing?

Mr. SNODGRASS. Yes. How much time we got here? This is——

Chairman MILLER. Only five minutes?

Mr. SNODGRASS. Yes, that's right. This is every decision a grower makes, and this is what's critical about this. So they rely heavily on everything that's in the future, right? So anything a farmer decides to do is always about the future success of what they just did. So there's not a whole lot of living in the past when it comes to agriculture. So these one- to three-day forecasts are critical to figure out, can I spray a particular crop with a particular application where I obey the label restrictions and do that so that there's no, you know, outside effect on what I'm doing other than when I'm applying? Am I going to be able to apply fertilizer in a way that it doesn't end up getting washed out or leached into the river systems or volatizing it into the atmosphere? Can I get the best possible use out of that? You then go forward from there.

You asked about marketing decisions. I mean, right now, while we're talking, weather is being traded on our markets for corn, soybeans, and other crops, given the extensive drought that is of course in your home State as well and States around you, including mine in Illinois. So it is the No. 1 thing that they're hanging on to every single day, and it is this constantly changing thing that's happening in the future that these growers are watching. And it goes across, like I said, all timescales to monitoring the weather right now with the radar network and with the Mesonets that have been discussed to try and to see with high resolution models that NOAA maintains when and where it's going to rain. But we were talking about cutting hay earlier. If you do not get your timing right on that rain, you're going to lose what you just cut, the quality will go down, and you can't even sell it.

So looking at subseasonal things, how do we plan for next year's crop cycle? What do we do in terms of planting, in terms of trying to get the crop in as soon as possible? There—I actually can't find a part of this sector that isn't weather-sensitive. I think every decision made is having to deal with weather and its impact. So, yes, it's of utmost importance.

Chairman MILLER. Thank you, Mr. Snodgrass, and I appreciate your directness in answering the question.

We all know that accuracy of weather predictions in any given area may vary within a few miles, making it difficult for farmers

making real-time decisions as it relates to planning, fertilizing, and applying crop protection tools, even where there is accurate forecasting in the broader area or region. Given rising input costs and inflation, accuracy is now more important than ever. To that end, many farmers utilize tools like their own on-farm weather stations and precision ag sensing technologies. Yet there's still resources to be desired on a larger scale. For all of our witnesses, where could NOAA better allocate resources in order to collect or provide the most accurate data that would lend better outcomes for farmers and producers? And this is a question for any one of you who would like to answer.

Dr. DELLO. I'll jump in. As I mentioned in my testimony, the National Mesonet Program is a vehicle that's already in place. We are receiving funding from them. If we got more funding, then we could serve more people. So there is not a week that goes by that we don't get a call in our office from a farmer, from a producer who wants an Econet station of their own, and we just can't promise it with the amount of funding that we get right now.

Mr. MCMANUS. I'd also like to jump in on the National Mesonet Program. While Oklahoma has a robust and the so-called gold standard for Mesonets, we are impacted by the lack of Mesonet coverage in other States in our border areas. So if you're in the southern region of Oklahoma along the Red River, there's not a northern Texas Mesonet, so those counties on our southern border are not allowed to have the same type of coverage in the central part of the State that has Mesonet coverage. So weather traveling north from Texas is not covered for those folks. So, you know, not only for those Mesonets that exist, but further funding to establish Mesonets in States that don't have the more robust coverages.

Chairman MILLER. Thank you.

Ms. JONES. And if I could chime in as well, in California, we've partnered with NOAA in the funding and installation of atmospheric river observatories to capture these very large, important winter storms that cause flooding, and we've been making great progress, even using hurricane hunter flights to go out and improve the forecasts of these. But getting the locations of these storms right is very important.

Chairman MILLER. Thank you, Ms. Jones. And I'm sorry, Mr. Snodgrass, I'm out of time and I yield back.

But I now recognize Ranking Member Ross, five minutes of questions.

Ms. ROSS. Thank you, Mr. Chairman. As I noted in my opening statement, NOAA supports and facilitates the transfer of information and data to the many users through the Climate Adaptation Partnership Program. Programs like these are critical to ensuring information is reaching the right users in a format tailored to their needs. Dr. Dello, I'm sure you're surprised my first question is for you. You have vast experience developing and overseeing NOAA CAP programs, including North Carolina's. Could you elaborate on what the CAP program is doing well and how it could be improved to serve the public better?

Dr. DELLO. Yeah, thank you for your question. The CAP program has been around for I want to say almost 30 years, and it's well-established, it's well-known. You can go into a community and say

we are with the CAP/RISA, and there's a bit of credibility with that. Again, the funding is very limited, and it has to go across multiple institutions across North and South Carolina in our case. And also, we are trying to give back to the communities that we work in so that we don't just parachute in, have our five-year grant, and leave, that we leave the communities better than we found them, but we're also working with them to coproduce knowledge.

So I think some of the fundamentals of the CAP program have worked really well, but we just can't reach all the communities, so we need to think a little bit more about how we're scaling that knowledge, transferring that knowledge, how States without a CAP/RISA, including the Midwest, can benefit from some of the work that we've done, and how we can pull in some of the other Federal climate centers a little bit better like the Department of Interior and USDA (United States Department of Agriculture) climate centers as well. So I think, you know, the CAP program has a lot of momentum, it has a lot of promise, but we are just underresourced.

Ms. ROSS. And can you tell us a little bit about those relationships with the communities? So after you've developed those relationships, are there any kind of ongoing projects that go on with those communities and give an example of one that's been successful?

Dr. DELLO. Yes, so we started in late 2021, so there was a fair bit of trust building that we're doing, but we were also building off relationships that those of us had in the region. And I will pick one community out in particular. It's the Eastern Band of Cherokee Indians in western North Carolina, federally recognized tribe. They approached us and said we need help planning for the next seven generations. We're thinking about climate change. They're up in western North Carolina where it's very mountainous. They're flood-prone, they're fire-prone, and they just wanted us to step in. We spent a year getting to know each other, understanding concerns, making sure we trusted each other. They've been burned by researchers in the past. But one of the things that we started to do was just start to offer small things that we could do to start to build climate resilience. So in a couple of weeks, we are giving them an Econet station, and they will be able to then pair it with their air quality data and then go after funding and understand a little bit more about their air and climate risks in their community.

And we also really like putting the data in the hands of the community. When they feel like they have ownership over the data, they may be more willing to trust it. So that's a—it's a burgeoning relationship. It's still growing, they're always still growing, but we feel really good about that one.

Ms. ROSS. That's a great example. Just one final question for you. As—and also for Mr. McManus if we have time for both of you. As State Climatologists, I'm sure you're familiar with long-term considerations in the context of planning for extreme weather events and climate change. Can you elaborate on the concerns of your constituents in these areas and what information from NOAA goes into the constituents' decisionmaking? And I'll have my con-

stituent go first, and then hopefully there'll be a few minutes for you, Mr. McManus.

Dr. DELLO. Yes, I'll try to save some time for you, Gary. So I work really closely with North Carolina Department of Transportation. They're building bridges and roads for the next 50, 100 years. And Hurricane Florence turned Interstate 40 into a river itself. So they're thinking about what routes needs to be prioritized. They're calling them resilient routes to preserve public safety and infrastructure, and they want to know how high should these bridges be? Should we buildup the road? Should we have wider shoulders? Should we have deeper culverts? So working with them to provide current and future data about some of the flooding risk.

Ms. ROSS. Thank you. Mr. McManus?

Mr. MCMANUS. Very quickly, coming from the calamitous weather capital of the United States, we're interested in all changes of hazardous weather in the next few decades, especially agriculture, which we hear a lot about, and we reference or leverage our NOAA partners for that type of information very heavily and provide that.

Ms. ROSS. Thank you, Mr. Chairman, and I yield back.

Chairman MILLER. Thank you, Ms. Ross.

I now recognize the Member—the Chairman of the Full Committee, Mr. Lucas from Oklahoma.

Chairman LUCAS. Thank you, Mr. Chairman.

As we heard from Mr. McManus' testimony, the Oklahoma Mesonet is a tremendous resource to the State. However, we are not the only State that boasts this capacity as North Carolina is another leader within the National Mesonet Program. And I'm sure both Mr. McManus and Dr. Dello would share my personal disappointments to see that NOAA's proposed funding decrease for the National Mesonet in 2024 just to be upfront about it.

And my next question kind of goes back to, Gary, your earlier comments. Although most of the National Mesonet data is just sent over an integrated system—State systems, some of it is collected by NOAA and its partners. So I put this question to both you and Dr. Dello to expand on what you've previously said. Could you talk more about how you use the National Mesonet Program and what it offers to States that that systems that States simply cannot provide? And note for the record when Gary talks about the adjoining States, literally the States that Oklahoma joins takes us all the way to the west State line of New Mexico, the north State line of Colorado, the Mississippi River on the east side of Missouri, literally to the Mississippi, and Arkansas, the international border of Mexico. So this issue about adjoining systems really matters, doesn't it, Gary?

Mr. MCMANUS. Yes, indeed it does. And of course when we talk about the National Mesonet Program, I know that it's very important for our National Weather Service forecasters in the State of Oklahoma, to be able to see those Mesonet stations and the data beyond our geopolitical boundaries because the weather, especially severe weather, knows no geopolitical boundary. So they do have that information at their disposal.

Now, when I talk to Oklahoma emergency managers and public safety officials, they don't have that National Mesonet data at their disposal. They want that national—they want something from the

National Weather Service or from NOAA that will allow them to see that broader range of the National Mesonet data so that they can use that in their ability to keep their people safe.

Now, when we talk about just the mere aspect of the funding for the National Mesonet Program, that actually does allow Oklahoma to continue to maintain its outreach program, so like OK-First, OK-Fire. When there are, you know, other States that try to emulate those programs, there's simply not the funding available from their State coffers. So the National Mesonet Program is extremely important for Oklahoma in allowing us to keep our citizens safe and to keep our economy safe during that inclement weather that we get so often in the State of Oklahoma.

Chairman LUCAS. Dr. Dello, would you like to expand on that?

Dr. DELLO. Yes, so we use the funding, and we get a larger chunk of funding for the North Carolina Econet from North Carolina State University. It's very important for the College of Agriculture and Life Sciences. We partner closely with extension. We take that extra pot of National Mesonet Program funding and we hire entry-level technicians. We train them in coding, we train them in maintenance, we train them in just basic weather patterns and climate science, and then hopefully, you know, send them out into the world to do big things. So we use it as sort of a training program for our staff. We would love to have more people on board. North Carolina is a very long State, and for them to get from one end to the other, it takes a long time.

Chairman LUCAS. To touch just for a moment on a personal nature, in the Southern Plains and on the east side of the Rockies, fire is a very important part of Mother Nature. The restorative nature of it, it's just critically important, and we have a lot of prescribed burn organizations doing those in Oklahoma, volunteer groups, working with local fire entities and with their own equipment who need the kind of data you provide to be able to address those issues. It's not just wind direction or wind speed as you know, Gary. It's the humidity level. You produce those fire index statistics that they all use. No one goes into the field without their cell phone tuned in to your resources.

As you alluded to on the nature of things, I live in Roger Mills County on the west State line, so there's always a bit of sensitivity about what's coming from Texas when we don't know for sure. But without the information the Mesonet provides, we could not be able to mimic nature in the preservation of the ecology in our area.

And with that, just a thank you for what you do and all of you do, and we need to work together to make sure that the successes at State and Federal level continue.

With that, I yield back.

Chairman MILLER. Thank you, Mr. Chairman.

I now recognize the Ranking Member of the Full Committee, Ms. Lofgren from California, for five minutes.

Ms. LOFGREN. Thank you very much. This is a very interesting hearing and I hope will lead to further success.

You know, every 10 years we have redistricting in California. We have a citizens commission, and they did kind of an unusual thing. My district for many years has been Silicon Valley. I now have a district that's half Silicon Valley and half agriculture. And the tech,

I hope, will be able to help the agricultural part. I mean, I've got—if you're eating strawberries, you're probably having a taste of Watsonville. If you're eating artichokes, you're having a taste of Castroville. If you're eating leafy greens that came from the Salinas Valley, it's the salad bowl of the world, and it's very vulnerable to climate catastrophes. This is an overstatement, but the flood control infrastructure was really aimed toward normal weather and not toward extremes.

And I remember this early spring I was at Tanimura's headquarters, a big farm in Salinas Valley. I remember looking out saying these beautiful lakes, and they said, well, actually, those are our fields. So there was tremendous damage done to the ag sector, the series of storms in January, again in March. And having the S2S forecasts I think would assist us, the longer range in terms of first having more permanent infrastructure to protect important areas, but also emergency steps that could be taken. We were doing that in the rain, riprap, to try and prevent some flooding and it did work.

So I'm interested, Ms. Jones, on the pilot project that you discussed. Obviously, NOAA does great work, but we want to do more. Could you give me the details of what's envisioned by that pilot project and what we might see from it?

Ms. JONES. So one of the difficulties with improving S2S forecasting is that there's really been so little research in the subject, so this is an area that very much needs the research. And as two National Academy of Sciences reports have pointed out, as well as NOAA's own report, it isn't just one silver bullet that is the answer. It's a little bit of everything, improving the models, data assimilation, high-performance computing capacity, targeted research to improve forecasts. And by doing all of these things we can make progress, and this includes fairly simple things like some of the research that we funded in California, just pointing out if we can do much better than NOAA's NMME (North American Multi-Model Ensemble) with a simple statistical forecast, this shows us how much we need to improve.

One of the areas that clearly needs to be improved is that NOAA's existing outlooks rely very heavily on El Niño Southern Oscillation, or ENSO conditions, but we now know that for much of the West, including California and the Upper Colorado River Basin, that's only a really small piece of actually what happens. So it's figuring out what other things besides ENSO are contributing to these factors that would improve forecasting not just for California, but also for the rest of the Nation as well because if you fix models for one part of the country, you help out others as well.

Ms. LOFGREN. What are the other pieces other than El Niño?

Ms. JONES. Well, it could be things like the Madden-Julian Oscillation, for example, at the subseasonal timescale, tropical convection that occurs well to the west of us, then propagates in our direction that really influences things that are short time period. And improving these subseasonal forecasts would be really helpful for Forecast-Informed Reservoir Operations, or FIRO. And we are now doing three FIRO pilot projects in California that demonstrate significant potential for improving the efficiency of reservoir operations.

Ms. LOFGREN. That's very helpful. Thank you so much to each one of you for your excellent and informative testimony, and I yield back.

Chairman MILLER. Thank you, Ranking Member Lofgren.

I now recognize Mr. Posey out of Florida for five minutes.

Mr. POSEY. Thank you very much, Mr. Chairman. I was—learned a lot already this hearing. I always thought that all the weather folks were much better connected. You know, I really did. I just thought it was a system that worked well. And, unfortunately, I'm kind of sad to hear it's more like Congress, you know?

You all represent different areas of the country and have different views. And, you know, on the Space Coast, obviously, we need up-to-date, timely weather information for our launch schedules, or, you know, we're in deep yogurt. So I just wonder if each of you could speak to the relationship that you have with NOAA to receive the information that you need on a timely basis. Just kind of capsulate it. You've all touched on it a little bit already.

Mr. MCMANUS. You bet, and thanks, Congressman Posey. And it's great to recognize an accent finally that I can get in line with. You know, we get our—all the data and the information from NOAA, and it's really our job to translate and disseminate that information. So whether it's the subseasonal or seasonal forecasts, whether it's outlooks or anything of that nature that we get from NOAA, we then take and we try and translate that for the decisionmakers and the citizens of the State of Oklahoma. You know, it's important that we not only translate that data but prevent bad translation, so in some ways, it's a preemptive strike because when you're talking about, let's say, the subseasonal outlooks, just the June outlook that just came out, those will get very badly misinterpreted by those in parts of the weather community. So if I translate those to the best of my ability from working with those NOAA partners, then I can possibly prevent that from getting too far out of bounds to our users.

Dr. DELLO. At the North Carolina State climate office, we're colocated with the National Weather Service in Raleigh, and that's a really great model. They send their climate questions downstairs, we send our weather forecast questions upstairs, and we're able to work together to understand where we need new Mesonet stations, where some data are missing, where we can fill some gaps.

We're also—we work closely with the National Center for Environmental Information in Asheville, North Carolina. We use a lot of their data to contextualize what we're doing in communities. We have, I would say, a really strong NOAA alignment in North Carolina. Sometimes it can get jumbled across NOAA line offices. We'll be hearing from the Weather Service, and we'll be hearing from the Office of Atmospheric Research, and it sometimes doesn't seem like they're talking.

Mr. POSEY. Mr. Snodgrass?

Mr. SNODGRASS. Yes, I would kind of consider myself a super user of NOAA's data. About every day, I pull down roughly four terabytes of their information and process it to build applications that allow the U.S. grower to understand weather risk. And I'll just say this because I also work in other parts of the world, including Australia, Europe, South America. NOAA's data dissemination

comparatively is second to none. That doesn't mean there isn't improvement, but the availability of datasets that come in all varieties of formats that we are used to in software development plus APIs (application programming interfaces), that's a major step up from some other places.

But, as you all know, getting raw data requires, as was mentioned here, interpretation and understanding, and that's where our role is vital in the partnership with NOAA to make sure that information is out there in a timely and accurate way that's interpretable. So it's a big task, but NOAA does a good job at it.

Mr. POSEY. Ms. Jones?

Ms. JONES. So we have a great relationship with NOAA at the weather timescale. One of NOAA's 13 river forecast centers, the California Nevada River Forecast Center, is co-located with our office at the Department of Water Resources, and we work very closely with them. Likewise, in the Colorado River Basin Forecast Center, the basin States work closely with them on their development of the water supply forecasts for the Colorado River. And interestingly, we've identified that one of the difficulties with their forecasts, about half of the forecast error in the runoff forecasts is because of the lack of quality of the subseasonal precipitation forecasts. So we have a long working relationship with NOAA at the weather timescale. And at the subseasonal, seasonal timescale, we've funded research work with NOAA to improve that, and I particularly want to call out our partnership with the Earth Systems Research Lab in Boulder.

Mr. POSEY. OK. Thank you. Thank you, Mr. Chair. And I see my time is about to expire, and I yield back.

Chairman MILLER. Thank you, Mr. Posey.

I now recognize Ms. Bonamici from Oregon for five minutes of questions.

Ms. BONAMICI. Thank you, Mr. Chairman. Thank you to the witnesses for your testimony. It's been fascinating to listen to because back in the 115th Congress and for some time even before that I worked with now-Chairman Lucas and colleagues on the bipartisan *Weather Research and Forecasting Innovation Act* and hearing some of the challenges is exactly what we were intending to address, acknowledge the progress made and the need to do more. You know, we really wanted to strengthen the capabilities and the communication.

So reauthorization is necessary to again sustain and buildupon the achievements that we made and the advancements. Actually, one of my first bills as a Member of Congress—I represent the north coast, as Dr. Dello knows, in in Oregon, the Pacific Northwest coast, and one of my first bills was to reauthorize the Tsunami Warning Program, which expires this year, and so I'm hopeful we can work on that because it really does play a critical role in saving lives, minimizing property damage, fostering community resilience by offering early warnings and enhancing public safety.

So, Dr. Dello, you mentioned the important role that State climate offices play—thank you for all you did for Oregon and all you're doing for North Carolina—in translating climate information into useful and usable knowledge and bridging the gap between scientists and decisionmakers and community members. So I know

you appreciate the risk of tsunami. You know, we have the Cascadia Subduction Zone off our coast. So from your perspective, how important are warning systems like the tsunami warning system? And how do these systems enhance your ability to respond to potential weather-related hazards and safeguard the well-being of those at risk from tsunami or severe weather events?

Dr. DELLO. Yes, thank you for your question. Oregon will always have a deep place in my heart. So yes, they're so critical. Anytime I would go to the Oregon coast, I would see the signs, I would look for safe places, I would think about where my exits would be. And I think just those small bits of communication and outreach that people are doing on the Oregon coast are very effective, and we need those warning systems so that people can then actually use them.

Ms. BONAMICI. You don't have a lot of time to outrun a tsunami, maybe 15 minutes——

Dr. DELLO. No, yes——

Ms. BONAMICI [continuing]. For a nearshore tsunami.

Dr. DELLO. And I'm going to also point to another event in your region, the Pacific Northwest heat dome, 116 degrees in Portland, Oregon. I remember sitting there looking at my iPhone and seeing the forecast and saying this is impossible. It's impossible. And it verified. And this was something that we weren't expecting to happen in Oregon in 2021. And there's limited data in a lot of the areas in Oregon. Oregon doesn't have a Mesonet. There's not constant urban heat monitoring in places like Portland that lack shade. So having a heat warning system for the Pacific Northwest, which I never thought I'd be sitting in Congress talking about, is crucial, too.

Ms. BONAMICI. Exactly. You anticipated my next question, Dr. Dello, because you mentioned, you know, 2021, you were one of the lead organizations on the NOAA National Integrated Heat Health Information System's (NIHHIS's) urban heat mapping campaign. Boy, that's long. But, you know, of course, NIHHIS is the program to—we need to formalize this in its efforts and require NIHHIS advanced research on extreme heat, environmental justice and equity. And there was someone from Portland State, a Portland State University professor who was doing some of that work, and it was actually in parts of Portland even hotter, up in the 120's, which is really dangerous.

So how do partnerships like this bolster the climate assessment program's capacity to reach a broader constituency, promote awareness, and inform decisionmaking? And could the *Weather Act* reauthorization help increase partnerships like NIHHIS urban heat mapping campaigns to increase the likelihood that resources are actually going to use—be used to address community specific demands?

Dr. DELLO. Yes. So we did the mapping campaign in Raleigh and Durham in 2021, and both Durham County and the city of Raleigh have taken that and implemented policy off of it. And because they were involved, because community members were involved, they are a little bit more likely to trust the data. They helped generate it, they see it, they see their communities, and they see the disparities across Durham, which was redlined. In Raleigh, that wasn't.

And I think they are really good programs for generating buzz, getting one-time maps, but we need constant monitoring of urban heat. We just can't sustain urban heat monitoring on the backs of 150 volunteers that I bought doughnuts for who showed up at 6 a.m. and drove their cars around that day.

So I think one of the things that we're doing with the North Carolina Mesonet is that we have black globe thermometers, which help us calculate heat stress. So expanding those across the country's Mesonet system would be really crucial and a first step.

Ms. BONAMICI. Thank you. I appreciate that. And I'm out of time, but I really—I'll submit this for the record—want to ask about the extreme weather events and emergency response agencies and first responders. So I'll submit this to the record because I'd like to hear from all of you about how you've worked in emergency response context, and—but I'm out of time. I yield back. Thank you, Mr. Chairman.

Chairman MILLER. Thank you, Ms. Bonamici.

I now recognize Mr. Garcia from California for five minutes of questions.

Mr. GARCIA. Thank you, Mr. Chairman. Thanks for letting me join the Subcommittee here, very important discussion. Thanks to our witnesses for the testimony.

I come from California, southern California, North L.A. County, and we would be the benefactors of this technology being fully realized, the forecasting models being tightened up. Obviously, I would submit—and, Ms. Jones, you can probably either validate this or not, but I would submit that in California specifically, it's not that we don't get enough rain over a certain period of time, maybe a 10- to 12-year paradigm, and it's not even necessarily that we don't have enough capacity. It's that we don't necessarily have the information needed to make timely decisions around the water management itself, how we're moving water from one storage facility to the next, and even implementing drought sort of provisions on residents and farmers throughout the State.

Can you walk me through—I know Ms. Lofgren asked about this pilot project that you guys are working, but can you walk me through sort of what the end state sort of nominal vision is, the ebb and flow of droughts, and then these atmospheric rivers, to be able to forecast those correctly to be able to then compensate for them correctly during a drought, hold the water during the atmospheric rivers, be able to move water to areas for storage in anticipation of the next sort of drought period? But let's assume we've gotten all of the technology investments and the tools matured. From an operational perspective, what would that look like in California as far as water management after that?

Ms. JONES. Well, so this water year would be a great example because we went into the wet season after having the three driest years of record, and all of a sudden, we were handed very large amounts of precipitation in a very short time, that, frankly, overwhelms the capacity of water infrastructure to manage. So while it's great we had a lot of water, all of our reservoirs are full. We can only store so much of it. We are then in a flood response mode. And as was mentioned in the Salinas Valley area, the Pajaro River, for example, experienced flooding challenges.

But one of the big outcomes of this is how could we better improve groundwater recharge? Because that's a very important part of our water budget in California is we don't have these big events very often, but when we do, we need to put as many molecules of that water underground as possible so we can use them again in a future dry year. And we've taken a number of steps this winter to try emergency and urgent groundwater recharge opportunities, including executive orders facilitating this, and—or even providing a service where we have secured a number of high capacity, large rental pumps, and we are providing those to agencies that can put some of this water in places that aren't usually used for recharge such as orchards or dormant fields. So if we can fine tune and maximize that kind of capacity, that's a huge step in when we do get these occasional various bounteous years, of setting that aside for the drier ones.

Mr. GARCIA. Would you say that right now from an infrastructure perspective, from a just volume of capacity, either in the groundwater storage facilities or in potential groves and farmlands that we have enough capacity right now? Or should we—while we are also investing in the technology—also be investing in the infrastructure to enhance and increase the capacity so that when we get to the drought periods, we can still meet the demands without telling farmers they can't water their—you know, their almond trees and without telling residents they can't water their lawns? They may get close to depleted, but we ultimately can still meet those demands. From a capacity perspective are we as a State there yet or do we need more?

Ms. JONES. Well, the enactment of our *California Sustainable Groundwater Management Act* really puts a premium on increasing groundwater recharge everywhere we can, and to do that in much of the State, we will need a significant investment in conveyance capacity to move these very high flows that occur during infrequent wet events to someplace where they can be managed and stored for future use. A number of local agencies have made good starts in that area, but there's a lot more to be done.

Mr. GARCIA. So pumps and channels and canals to manage that conveyance.

Last question, have we gotten any more sophisticated I'll say in terms of measuring snowpack? You know, for the last several decades, it seems there's a guy with a stick that goes up there and measures the—it seems like with LIDAR (light detection and ranging) and ground-penetrating radar and AI (artificial intelligence) and advanced algorithms, we should be able to quantify the volume of water in the mountains without having one dude on—with a stick on one peak or a few. Has that changed at all?

Ms. JONES. Yes, we've made a big investment in aerial monitoring from aircraft. And I know I'm out of time now, but we are spending a lot of money on that right now, but it's very expensive.

Mr. GARCIA. We'll help you with that as well, as well as the Coast Guard to hurricane hunters in the ARs.

So I yield back. Thank you, Mr. Chair.

Chairman MILLER. Thank you, Mr. Garcia.

I now recognize Mr. Frost from Florida for five minutes of questions.

Mr. FROST. Thank you, Mr. Chairman. And thank you so much for being here.

Section 104 of the 2017 *Weather Act* created a mandate to develop and extend hurricane forecasts and warning. As a result of that mandate, this year sees the first use of the Hurricane Analysis Forecasting System, or HAFS. Because it can track multiple storms at the same time and factor in how storm systems interact, HAFS should be—should make hurricane forecasting 30 percent more precise.

Dr. Dello, hurricane season started last week, and once again, my central Florida constituents live in the path of a potentially devastating storm. What will hurricane forecasting that is 30 percent more precise mean for my constituents?

Dr. DELLO. Yes, so you and I know that it just takes one hurricane, but the amount of lead time that we have is crucial, especially for low-income people who may not be able to just pick up and leave their lives behind and have to make alternate plans to live in a place for a few weeks. So even getting 48, 72 hours on a forecast is crucial. And the National Hurricane Center does really, really good work, and they've improved so much in the past 20 years, but if we can even push it a little bit further, I think that will, you know, help some of the most vulnerable among us.

Mr. FROST. A hundred percent. I mean—and hurricanes are not, you know, news to Floridians. I mean, the hurricanes are devastating. I grew up, you know, doing hurricane parties with my family, right? It's a very normal part of living in the State of Florida. But what matters is where and when it's going, right, where it's going and when it's going to come. A recent example is Hurricane Ian. Until late—very late in its path, as we all know, it was supposed to hit the Tampa area and it hit it up—ended up hitting southwest Florida where it completely decimated Fort Myers Beach. And many people did not understand the danger they were in until it was too late.

The purpose of section 406 of the *Weather Act* is to create warnings that prevent the loss of life and property. Mr. McManus, not all people who can evacuate ahead of a storm do. And how can a renewed *Weather Act* help us get a better understanding of the social and behavioral factors that go into why some people might choose not to evacuate?

Mr. MCMANUS. Yes, thank you for the question. Of course in Oklahoma, you know, Okies are born and raised with weather warnings, weather watches of all manner, but those warnings are not always heeded by the public, as you said. So that's where the social sciences need to come in and better translate those warnings to where the public can understand those but also take the proper heed when necessary.

You know, in Oklahoma, we still have people that think the tornado sirens are for people sitting in their houses watching TV or sleeping when they're mainly for outdoors. So it's those kinds of challenges that need to be studied by the social sciences and, you know, elaborated on to—and the end product would help save lives for the betterment of all the communities.

Mr. FROST. Thank you. And, Dr. Della, I mean, you know from your work in North Carolina, we might experience the same storm

in name, but we don't always experience the same storm in terms of impact. Not everybody has a smartphone or cable television with the up-to-date—up-to-minute warnings or a car to make their escape or a neighborhood free of flooding. That happened in my district. The neighborhoods that were hit the hardest in terms of storm surge were poor neighborhoods. Or not everyone has a landlord that keeps their apartment up to code. Disability advocates in Florida will also tell folks that they face numerous dangerous planning oversights when trying to plan an evacuation.

Dr. Dello, through a renewed *Weather Act,* what additional steps can we take to improve last-minute, last-mile warnings and getting vulnerable populations to safety?

Dr. DELLO. Yes, this is a great question. So obviously, warnings need to not just be in English but also Spanish in many areas in this country. We need to ensure that we're not just relying on people having cell phones or broadband technology. There are places in North Carolina that are still on dial-up. And we have to work with community groups. They are on the ground. They know how to reach people. And it won't be one size fits all. What works in Florida may not work in North Carolina. But we're going to have to do this at the community level using those trusted messengers to ensure that the people who are hit first and worse by climate change are safe.

Mr. FROST. The vast majority of Floridians that died in Hurricane Ian were over 65 years old, and when you get into the details, it's heartbreaking because a lot of them died from—you know, in very horrible ways, people deprived of oxygen because they lost power, people going without dialysis, people having their hearts go out in extreme heat. And so there's a lot of work to do here, but I know together we'll be able to make a safer Florida and ensure that we have the resources necessary to get our most vulnerable populations, especially our seniors, to be safe in these storms.

I'd like to thank the witnesses for being here, and I yield back.

Chairman MILLER. I thank the witnesses for their valuable testimony and the Members for their questions. The record will remain open for 10 days for additional comments and written questions from Members.

This hearing is adjourned.

[Whereupon, at 11:21 a.m., the Subcommittee was adjourned.]

Appendix

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Gary McManus

Questions for the Record

Congresswoman Suzanne Bonamici – June 6, 2023

House Committee on Science, Space, and Technology

Subcommittee on Environment Hearing:

Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector

Questions For the Record

Extreme weather events have already caused $19 billion in damage and taken 97 lives this year. Emergency response agencies and first responders need access to timely and accurate information about extreme weather events to provide effective responses.

- **ALL** – Have you or your constituents used NOAA's information and services in an emergency response context this year, and did the products meet your needs?
- **ALL** – How could NOAA's products, data, and services be improved to meet the challenge of increasingly severe climate and weather disasters?

Thank you for the questions, Congresswoman Bonamici. I'll attempt to answer both questions in the same reply. I don't recall an instance where the Oklahoma Climatological Survey or Oklahoma Mesonet used NOAA products in a weather-related emergency response in 2023. However, we do serve as an information conduit of NOAA and other weather-related information of varying sources to our state's Public Safety decision makers and Emergency Managers. I queried our Oklahoma Mesonet personnel that work directly training and providing certification to the state's Public Safety decision makers for more insight. Through our OK-FIRST and OK-FIRE programs, we train those decision makers (Emergency Managers, Firefighters, etc.) to use NOAA data to manage a variety of hazardous weather events, such as severe thunderstorms and tornadoes, flooding, winter storms, and fire weather. While the data are high quality and lifesaving, there are situations when the data become unavailable for different reasons such as a radar site going down or the data feed being interrupted (sometimes upstream of us, and sometimes locally). Those data interruptions increase the difficulty for our users to manage an event and require leaning on other datasets and information sources including satellite, surface observations, spotter reports, NWSchat, and media sources. While NOAA information and services are extremely high quality and help our constituents keep their communities safe, this infrequent, untimely interruption to data availability is the primary item we would identify as an opportunity for improvement to NOAA information and services. Increasing the resilience of NOAA information and services (backup data feeds, backup data

Questions for the Record
sources, etc.) will be critical in a future with more hazardous weather events.

Representative Mike Collins

June 6, 2023

In January this year, a series of devastating storms hit several states in the South. Regrettably, multiple people across these states, including a 5-year-old boy near my hometown of Jackson, Georgia, were tragically killed in these extreme weather events.

- **Mr. McManus:** What technological advances in weather forecasting are in the works that would help give Americans more notice to prepare for severe weather, and will we be able to predict dangerous events like tornadoes earlier than we can currently?

Thank you for the question, Congressman Collins. As a State Climatologist, my expertise doesn't extend too far into the severe weather forecasting realm. However, discussing the question with some of my National Weather Service colleagues, the consensus seemed to coalesce around the issue of numerical weather prediction, with another nod towards radar advancements. Testing continues with the phased array radar, which gives much better scanning strategies for severe convection. However, to improve the ability to forecast small scale features like tornadoes, Convective Allowing Models (CAMs) are becoming more important within the weather community to improve forecasts to give warnings more than an hour in advance of storms. The Warn on Forecast System (WoFS) employed by NOAA does an increasingly effective job of identifying areas of impact well in advance of storms. Recall that WoFS is "a National Oceanic and Atmospheric Administration research project that aims to increase lead time for tornado, severe thunderstorm, and flash flood warnings," being conducted by the National Severe Storms Laboratory out of the National Weather Center in Norman, Oklahoma. (https://www.nssl.noaa.gov/projects/wof/)

Switching gears: I have a background in trucking and know firsthand how important weather conditions are when moving the freight that our communities rely on, be it construction materials, food, or retail items.

- **To any of the witnesses**: can you speak to the potential in which collecting more weather data from the transportation sector, particularly trucking, might help to enhance forecasting and weather data overall?

Questions for the Record

The collection of weather data from the transportation sector is an area where I lack specific expertise, however as a climatologist, meteorologist, and data manger myself, I do understand that such data—if properly quality assured and integrated—can provide valuable insight in forecasting, and especially Nowcasting.

Representative Rick Crawford

1. To cover the gaps in NEXRAD radar coverage, one option is to contract with private companies that potentially use less powerful X-band radar when compared to NEXRAD's S-band system. Mr. McManus and Dr. Dello, do either of your states experience radar gaps and how do you mitigate these gaps if so? Do you think X-band radars are a viable way to cover the gaps in NEXRAD radar coverage, while still providing weather data to meteorologists and communities on par with the quality of NWS S-band radars?

Thank you for the questions, Congressman Crawford. Unfortunately, Oklahoma does have areas with significant radar coverage gaps. One of those areas is in southern Oklahoma along the border with Texas, and just last year it resulted in a lack of advanced warning to the citizens in that area (Marshall County, March 21, 2022) during a severe weather outbreak. In fact, insufficient radar coverage is possibly the biggest complaint our Mesonet Public Safety personnel hear from Oklahoma Emergency Managers. We do recognize that there are attempts to establish smaller "gap-filling" radars via various efforts. The southern Oklahoma city of Durant in Bryan County recently received a grant in 2021 from the State of Oklahoma to install a smaller radar with the work just being completed in the spring of 2023. Tornadoes in Bryan County in 2016 and 2019 both resulted in fatalities, and were not detected by NWS radars until fully formed due to the distance from those radars and their inability to see into the lower levels at that distance. The C-band radar installed at Durant is a valuable addition to keeping the local citizenry safe, but the radar is certainly not at the resolution of the NWS' more powerful S-band radars. We feel that all Emergency Managers—and through them all citizens of the State of Oklahoma—deserve equitable radar coverage with the same resolution to support their operations. In addition to southern Oklahoma, northwestern Oklahoma and the Panhandle lack proper low level radar coverage and that most certainly impacts warnings and subsequently places local EMs and the communities they serve at a disadvantage.

2. State mesonets like they have in Oklahoma and North Carolina are effective tools in determining and verifying severe weather as well as equipping farmers with helpful climate data. Mr. McManus and Dr. Dello, what does it take to establish and, run a state

mesonet program like Oklahoma's or North Carolina's? In more direct terms, is it feasible to create mesonets in states like Arkansas, that do not have a large university with a meteorology program? And can mesonets be established and operated outside the scope of an academic partnership?

A state Mesonet requires both initial funding for all of the infrastructure (e.g., towers, sensors, dataloggers, cellular modems, solar panels, batteries, etc.) and ongoing funding for the maintenance and operation (e.g., electronics technicians, IT staff, data quality staff, calibration staff, vehicles, etc.). Thus, it often takes a combination of funding sources to establish and run a Mesonet. Without state and/or federal funding, an initial investment in Mesonet infrastructure would be at risk of shutting down as temporary grants and contracts end. It is possible for a Mesonet to operate outside of a large University with a meteorology program, but it would be more difficult to secure grants and contracts without the resources typically available in an Academic/University setting.

3. Automated Surface Observing Systems (ASOS) are another effective tool for weather forecast activities and aviation operations. There are more than 900 ASOS stations operating across the United States and its territories. For all of our witnesses, what is your level of involvement with ASOS and do you believe the construction of more ASOS's would be beneficial to your area of expertise?

I have no level of involvement with ASOS beyond being a user—and disseminator—of the data they collect. More data, if of sufficient quality and frequency, is almost always better for the experienced weather expert. However, great care must be taken to see if this money would be more valuable being reliably invested in Mesonet infrastructure.

4. An important way weather data during severe weather events is communicated to the public is the local news station as their meteorologist interrupt regularly scheduled tv programming to give updates to the viewing region of that station. For all our witnesses, is this an effective way to communicate or do you think the public would be more likely to pay attention to these important alerts if tv coverage interruptions could be limited only

to the people affected by watches and/or warnings instead of the whole viewing area.

Coming from a state with such a large geographical footprint AND proliferation of severe weather, I understand the frustration with having frequent interruptions to television programming due to severe weather coverage. However, let me make a counterpoint to that complaint: perhaps the coverage in other areas of the state will allow for citizens in areas *unaffected to that point* prepare in case it does approach their area at a later time. The attempt to limit disruptions to localized areas would also possibly place undue pressure on those that issue the warnings AND those that broadcast the coverage and warnings to decide how that would proceed—often at times when their focus is drawn away from such decisions due to the impactful weather.

Responses by Ms. Jeanine Jones

Q: Have you or your constituents used NOAA's information and services in an emergency response context this year, and did the products meet your needs?

A: NOAA's information and services were critical to the coordinated effort to respond to the flooding emergency in California this year. The forecast products provided essential advanced warning to emergency response agencies to make informed decisions to reduce loss of life and damage to property in their communities, and for informing water managers to help them operate reservoirs efficiently and reduce downstream flood risk. The California Department of Water Resources flood operations center, and the NWS Sacramento Weather Forecast Office, and California-Nevada River Forecast Center are co-located in the same building, allowing close coordination on dynamic flooding conditions and the ability to quickly interpret and disseminate changing forecast information. The products from the CNRFC were used daily are used daily in the flood operations center to provide warnings to flood emergency response partners.

Q: How could NOAA's products, data, and services be improved to meet the challenge of increasingly severe climate and weather disasters?

A: We value our partnership with NOAA in using its products at the short-term weather timescale. However, only a small fraction of water management decisions are made at the short-term scale of a seven- to ten-day weather forecast. As was demonstrated by California's precipitous shift from extreme drought conditions to flooding this winter, the crucial missing piece is skillful precipitation forecasts at the sub-seasonal to seasonal (S2S) time scale. This spring we were simultaneously operating under a proclaimed drought emergency and a proclaimed flood emergency. Longer forecast lead times are needed to support emergency response and recovery for these conditions. In the last two years the California Department of Water Resources obligated more than $800 million in emergency drought response grants to help communities respond to shortages and implement urgent water conservation programs, including providing hauled water and emergency well drilling. Although the wet winter provided a brief respite in the rapid decline in Colorado River Basin reservoir storage, water agencies there must prepare for future shortage risks. Drought is a slow-moving disaster and the needed response actions are costly and require time for implementation. Skillful longer-lead forecasts would support more efficient response and reduce water shortage risks, especially for small rural communities.

Q: For all of our witnesses, what is your level of involvement with ASOS and do you believe the construction of more ASOS's would be beneficial to your area of expertise?

A: I have no personal involvement with ASOS. As water agencies we benefit from them indirectly as they, along with other types of weather observing systems, feed basic data into the National Weather Service's systems to support its forecasts. Since ASOS are intended to support aviation, they are preferentially located at airfields and improve data coverage in areas that typically have higher levels of population, where they provide high-frequency observations. Some important remaining data gaps are in more remote mountainous areas where orographic processes affect precipitation.

Responses by Mr. Eric Snodgrass

Eric Snodgrass
Response to Questions for the Record
House Committee on Science, Space, and Technology
Subcommittee on Environment Hearing:
Reauthorizing the Weather Act: Users of Weather Data and Areas for Improvement by Sector
June 6, 2023

Qs from Rep. Suzanne Bonamici

Extreme weather events have already caused $19 billion in damage and taken 97 lives this year. Emergency response agencies and first responders need access to timely and accurate information about extreme weather events to provide effective responses.

- **ALL** – Have you or your constituents used NOAA's information and services in an emergency response context this year, and did the products meet your needs?
    - **A:** No, not in the context of emergency management. However, I daily use NOAA's weather products (especially the SPC, NHC, WPC, NEXRAD, NOAA Satellites, and the NOAA's All Hazards Alert/Watch/Warning system) to forecast and nowcast high impact weather events for US agricultural producers. These products have not only met our needs but often provide critical insights allowing for advanced warning and preparation. Given the size of the US and the extent of agricultural production, there is a daily use case for NOAA's life and property saving weather analysis and forecasting products. In agriculture, NOAAs data and services allow me to analyze potential losses and gains to agricultural productivity. For examples, extensive wildfires have a large impact on the forestry and lumber industry while the smoke from these can taint the highly diverse crops grown throughout the region. NOAAs fire weather forecast system plus its high-resolution models of vertically integrated smoke content allow producers to plan and potentially mitigate negative impacts from these weather events.
- **ALL** – How could NOAA's products, data, and services be improved to meet the challenge of increasingly severe climate and weather disasters?
    - **A:** Thankfully, it is extremely rare that a high impact or severe weather event is missed by NOAA. NOAAs rapid dissemination of data, analysis, advisories/watches/warnings is top notch and continual upgrading/enhancement of the computing systems used to deliver these data and alerts should be a top priority. Significant investment should be made in closing some of the observation holes we have with the NEXRAD radar network, which I laid out in my written statement. Investment in more frequent and higher spatial resolution observation of surface weather conditions plus increased coverage of weather balloon data would continue to improve NOAAs predictive skill while also providing a much richer dataset of historical weather observations. These observations are critical in the agricultural industry for application of chemical/fertilizer, planting, monitoring growing conditions, harvesting, and off-season field preparation to ensure the most efficient and sustainable practices.

Q from Rep. Mike Collins

Switching gears: I have a background in trucking and know firsthand how important weather conditions are when moving the freight that our communities rely on, be it construction materials, food, or retail items.

- **To any of the witnesses**: can you speak to the potential in which collecting more weather data from the transportation sector, particularly trucking, might help to enhance forecasting and weather data overall?
    - **A:** The commercial aviation industry uses the ACARS system to relay weather conditions during flight that are critical to NOAAs weather analysis and forecasting. A similar system could be developed and used by the overland trucking industry to monitor rapidly changing road conditions which would improve forecast skill throughout our nations road network. This would add much needed information to supply chain management decisions across many industries and allow emergency managers to better monitor and predict adverse road conditions. Monitoring road conditions in real-time through the trucking industry would enhance NOAAs ability to provide lifesaving forecast guidance during high impact winter storm events.

Qs from Rep. Crawford

- Automated Surface Observing Systems (ASOS) are another effective tool for weather forecast activities and aviation operations. There are more than 900 ASOS stations operating across the United States and its territories. For all of our witnesses, what is your level of involvement with ASOS and do you believe the construction of more ASOS's would be beneficial to your area of expertise?
    - **A:** I use these data constantly and they are a critical part of my weather forecasting and analysis at Nutrien. The agricultural industry heavily relies on these data from the ASOS stations. They provide critical information on weather variables that impact field operations, like chemical applications, which are completed under strict weather criteria. Furthermore, the pasture and rangeland regions of the US, which support our expansive livestock industry, rely on these data as livestock are moved throughout the Plains and West of the US. Many insurance products use the ASOS data as the verification dataset for claims too. I am convinced that an increase in the spatial coverage of the ASOS network would be beneficial because weather data collection is the most critical part of building an analysis (i.e., the current state of the atmosphere) and by extension, an accurate and skillful forecast. Forecast skill across the US would improve considerably with greater observation and there are many per-reviewed research papers that support this claim. Operationally, each time a high impact weather event is forecast by NOAA, like a land-falling hurricane, the NWS will increase its observational capacity through more frequent, coordinated weather balloon launches, higher resolution NEXRAD radar scans, and targeted 1-min scans from NOAAs satellite network. This is done to better initialize NOAAs forecast models to more accurately predict the path and impact of the hurricane. The US Gulf Coast and East Coast are built around waterways, bays with seaports, and large river systems such as the Mississippi which are vital to the US economy as they serve as the conduit for our agricultural goods and services to reach international markets. Increased observations from ASOS would increase our ability to predict the health of that river system and the tremendous amount of commerce that flows throughout that river system.

- An important way weather data during severe weather events is communicated to the public is the local news station as their meteorologist interrupt regularly scheduled tv programming to give updates to the viewing region of that station. For all our witnesses, is this an effective way to communicate or do you think the public would be more likely to pay attention to these important alerts if tv coverage interruptions could be limited only to the people affected by watches and/or warnings instead of the whole viewing area?
    - **A:** N/A/, this is outside of my area of expertise.

Responses by Dr. Kathie Dello, Ph.D.

Kathie Dello Responses

• ALL – Have you or your constituents used NOAA's information and services in an emergency response context this year, and did the products meet your needs?

We have been fortunate to avoid a direct landfall from a hurricane in North Carolina for the past 3 years. Hurricane Ian was a category 1 hurricane when it made its second landfall just south of the North Carolina border in September 2022. Five people died in North Carolina; three auto accidents, one drowning, and one instance of carbon monoxide poisoning. I do not know if NWS/NOAA data was received by these individuals or if emergency response changed as a result of NOAA data. At NC State University, where the State Climate Office is located, the University used NWS data and forecasts to move the university into reduced operations. North Carolina received a federal disaster declaration. In hurricanes, the National Weather Service in Raleigh and NC Emergency management work closely to monitor the forecast at the Emergency Operations Center in Raleigh. North Carolina Emergency Management uses NC ECONet (mesonet) data to help support the justification for a declaration.

Large events like hurricanes get ample attention at the state emergency response level, with coordination from NOAA and state entities. Smaller events like localized flash floods are less coordinated. In Downtown Raleigh, there are urban corridors that flood during short-term events with heavy rain, including the entrance to the Amtrak Station. NWS flash flood warnings are often coarser in resolution (e.g., not neighborhood scale). The city of Raleigh has installed flooding cameras in sensitive areas to monitor flooding and warn residents. There could be better coordination nationwide between communities (urban and rural) and NOAA to meet their needs, which are often at neighborhood/community scale, and not county/state scale.

• ALL – How could NOAA's products, data, and services be improved to meet the challenge of increasingly severe climate and weather disasters?

NOAA's products, data, and services can be improved in the following ways:

- Hiring social scientists to evaluate the efficacy of websites and other forms of external communication. NOAA needs to better understand how people receive information, and how they make decisions to save life and property.
- Offering clear and accessible ways to disseminate info beyond traditional channels. The National Weather Service badly needs a state-of-the-art mobile app in English and other languages with forecast information coupled with solutions/responses that folks can take to stay safe in extreme weather.
- Revamping National Weather Service websites to put the top line message up front, and removing esoteric data and links meant for niche groups to other spots on the webpage.

- Working with other Federal agencies, including USDA and DOI to connect with the working lands and tribal communities.
- Coordinating across line offices, especially the National Weather Service (operations) and Office of Atmospheric Research (research/evaluation).
- Building and deploying early warning systems for extreme heat and flooding. These early warning systems should build off of lessons learned from NIDIS DEWS, but also act as less of a convening/stakeholder needs info gathering mechanism and scale rapidly from research to operations partnering with urban and rural communities.
- Building out state mesonet networks, which are reliable sources of data for National Weather Service and North Carolina Emergency Management forecasters. For example: in Hurricane Florence, forecasters were able to rely on North Carolina ECONet (Mesonet) data for longer than other networks (AWOS/ASOS), because our stations run on solar power and had enough power stored in the battery.