COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER

Understanding, Forecasting, and Communicating Extreme Weather in a Changing Climate

Thursday, September 26, 2019
10:00 a.m.
2318 Rayburn House Office Building

PURPOSE

The purpose of this hearing is to understand the state of the science related to extreme weather events. This hearing will provide an opportunity to examine the role of climate change and other weather and climate factors in causing and exacerbating extreme weather events, to discuss economic and other societal impacts of extreme weather, to explore the state of forecasting and prediction of extreme weather with a focus on how to communicate uncertainty, and to identify gaps in the science.

WITNESSES

- **Dr. J. Marshall Shepherd (SHEP-erd),** Georgia Athletic Association Distinguished Professor of Atmospheric Sciences and Geography, Director, Atmospheric Sciences Program, Department of Geography, University of Georgia, 2013 President, American Meteorological Society
- **Dr. James Done (DOE-n),** Project Scientist III and Willis Research Fellow, Capacity Center for Climate & Weather Extremes, Mesoscale & Microscale Meteorology Lab, National Center for Atmospheric Research
- **Dr. Adam Sobel (SO-Bull),** Professor, Lamont-Doherty Earth Observatory and School of Engineering and Applied Sciences, Columbia University, Director and Chief Scientist, Initiative on Extreme Weather and Climate, Columbia University
- **Dr. Berrien Moore (MORE),** Director, National Weather Center, University of Oklahoma
- **Dr. Ann Bostrom (BOS-trum),** Weyerhaeuser Endowed Professor in Environmental Policy, University of Washington

OVERARCHING QUESTIONS

- What is the current state of science on understanding the causes of extreme weather events?
- What are the greatest challenges associated with forecasting extreme weather events, and how do we improve forecasts and models?
- What is the relationship between climate change and extreme weather events?

- What impacts does extreme weather supercharged by climate change have on vulnerable people and property?
- How can we improve the way extreme weather forecasts are communicated to the public to ensure people take the necessary safety precautions?
- What are the current federal funding needs for enhanced observations, model improvements, and research and development activities related to extreme weather?

BACKGROUND

July 2019 was the hottest month on record for the planet. Temperatures soared worldwide, in a global pattern of warming that has increased in recent years.[1] Though the United States is no stranger to extreme weather events, with different parts of the country experiencing heatwaves, cold snaps, wildfires, tornadoes, hurricanes, and flooding, there has been an increase in the frequency and intensity of certain extreme weather events over the past few years.[2]

The fifth IPCC Assessment Report (AR5), details the observed changes in extreme weather events that have occurred since 1950.[3] It notes that decreases in cold temperature extremes, increases in warm temperature extremes, increases in heavy precipitation events in certain regions, and an increase in extreme high sea level, can be firmly linked to human influences.[4] It also concludes that "[i]mpacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability."[5]

The ability to accurately predict extreme weather has advanced greatly in the last few decades; however, there is much room for improvement.[6] Recent extreme weather events such as Hurricane Dorian have highlighted the uncertainty that remains in understanding and predicting severe storms, as well as the need for further investment in observations, improvements to models, and overall research and development activities. Accurate forecasts are instrumental in preparing our communities for extreme weather events and minimizing property damage and injury. Investigating the underlying causes of extreme events and how they have changed over time helps to improve forecasting capabilities.[7]

Communicating extreme weather forecasts is an ongoing issue for local, state, and federal officials. More social and behavioral science research is needed to understand how people interpret and respond to weather forecasts.[8] Even with improvements in prediction and warning systems, extreme events still result in great loss of life and other preventable costs. Impacts of weather are strongly dependent on behavioral responses to forecasts; thus, increased investment in social

[1] https://www.noaa.gov/news/july-2019-was-hottest-month-on-record-for-planet
[2] Third National Climate Assessment. 2014. https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather
[3] https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf
[4] Ibid.
[5] Ibid.
[6] National Academies of Sciences, Engineering, and Medicine. 2016. *Attribution of Extreme Weather Events in the Context of Climate Change*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21852.
[7] Ibid.
[8] National Academies of Sciences, Engineering, and Medicine. 2018. *Integrating Social and Behavioral Sciences Within the Weather Enterprise*. Washington, DC: The National Academies Press. https://doi.org/10.17226/24865 .

science is needed to understand how social factors affect how the public prepares for and responds to extreme weather events.[9]

Certain populations are more vulnerable to extreme weather than others. The poor, elderly, disabled, people of color, and other at-risk groups are more likely to experience negative health and other impacts of severe weather.[10] There is an urgent need to understand the intersection between extreme weather and vulnerable communities in order to prepare and protect them from increasingly damaging and frequent extreme weather events.

UNDERSTANDING THE CAUSES OF EXTREME WEATHER EVENTS

The underlying physical processes that lead to the development of extreme weather events are in different stages of understanding. For example, scientists have a high level of understanding of how thunderstorms, hurricanes, and droughts form.[11] There remains a need for additional research to better understand the fundamental physical processes behind the formation of other types of severe weather, such as tornadoes, which less well understood.[12]

The nascent field of attribution science seeks to determine if extreme weather events can be attributed to anthropogenic climate change.[13] Some events are easier than others to confidently attribute to climate change. Confidence is strongest for drought and heavy precipitation events, and events related to temperature, such as extreme heat or cold.[14] For these events, there is a well understood and simulated physical mechanism that relates it to long-term human-caused climate change. Events that are more difficult to attribute to climate change may be complicated by natural variability or a lack of understanding of the basic underlying science, such as tornadoes. In addition, non-meteorological factors can limit the accuracy of model simulations of some events, such as with drought or wildfire.

A continued, focused effort to improve specific aspects of the analysis of weather and climate extremes is needed to improve both attribution science and the underlying physics of severe weather.[15] Many attribution analyses depend on estimations of event probabilities or distributions of event magnitude simulated by models. Consequently, confidence in attribution results relies on the skill of the model. More emphasis on evaluating models is needed across studies on event attribution.

FORECASTING EXTREME WEATHER EVENTS

Developments in observations, numerical monitoring, and data assimilation have led to major improvements in weather forecasts over the past few decades. At present, a 5-day forecast is as

[9] Ibid.
[10] https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf
[11] https://www.nssl.noaa.gov/education/svrwx101/
[12] https://www.nssl.noaa.gov/education/svrwx101/tornadoes/
[13] NASEM. 2016. https://doi.org/10.17226/21852
[14] Ibid.
[15] Ibid.

accurate as a 1-day forecast in 1980.[16] Global data collection systems contribute daily to forecasting models. There are more than 10,000 manned and automatic surface weather stations, 1,000 upper-air stations, 7,000 ships, more than 1,000 buoys, 3,000 aircraft, a constellation of Earth-observing satellites, and hundreds of radars that monitor and collect land, atmosphere, and ocean condition data every day.[17]

Enhancing our understanding of the underlying science of extreme weather, coupled with sustained observations and improvements in modeling, are needed to increase forecasting capabilities of these events. Forecasting goals include the ability to deliver predictive forecasts of future extreme weather events with lead times of days, seasons, or longer, and aim to account for natural variability and anthropogenic influences on the weather-climate system. [18] In addition, the Earth-observing satellite system must be protected from interference by 5G operations to safeguard future capabilities. Additional information on National Oceanic and Atmospheric Administration (NOAA) forecasting and potential impacts to forecasting due to 5G spectrum auctions can be found in the Charter from the May 16, 2019 Subcommittee on Environment Hearing titled *"The Future of Forecasting: Building a Stronger U.S. Weather Enterprise."*[19]

COMMUNICATING EXTREME WEATHER EVENTS

Even though reliable forecasts of some extreme weather events are available days in advance, severe weather continues to cause avoidable deaths and other losses. There is a "growing recognition that a host of social and behavioral factors affect how we prepare for, observe, predict, respond to, and are impacted" by extreme weather.[20] In order to receive the greatest return on meteorological research and numerical weather prediction, the social and behavioral sciences (SBS) must be fully engaged in the communication of extreme weather.

There are a multitude of factors that affect the way in which people interpret forecasts. The effect of past weather experiences, and people's perceptions and attitudes, impact their response to weather forecasts and warning messages.[21] The effect of these messages depends on the characteristics of the audience receiving them. Questions remain as to how the weather enterprise can provide information when and where it is needed, and in the most accessible format for all stakeholders.[22]

Researchers are beginning to look into the design, interpretation, and effect of weather forecasts and messages on different populations. For example, they have used eye-tracking technology to ascertain how people interpret weather messaging.[23] This type of technology can also provide insight into how forecasters make decisions about how to use information in complex forecasting situations.[24] Gaps remain in message design research, and more studies are needed to determine

[16] https://science.sciencemag.org/node/721705.full
[17] https://public.wmo.int/en/our-mandate/what-we-do/observations
[18] NASEM. 2016. https://doi.org/10.17226/21852
[19] https://docs.house.gov/Committee/Calendar/ByEvent.aspx?EventID=109467
[20] NASEM. 2018. https://doi.org/10.17226/24865
[21] Ibid.
[22] Ibid.
[23] Ibid.
[24] Ibid.

which types of messages have the maximum impact. In addition, more focus is needed on how forecasters can effectively communicate uncertainty in forecasts.

There is an increasing emphasis within the weather enterprise that SBS must be integrated into research and operations to improve public safety in the face of extreme weather.[25] To accomplish this, there must be investment in leadership to build awareness, and capacity built throughout the weather enterprise, with a focus on critical knowledge gaps in order to integrate SBS knowledge into weather forecasting and communications. Over the past year, some steps have been taken within the weather enterprise, but progress remains slow.[26] More emphasis on building SBS capacity is needed from the research to the operational stage, at every level of government and in partnership with the private sector and academia. The federal government can foster collaborations with social scientists, institutions of higher education, and private sector actors. Platforms should be created for interagency and intersectoral efforts, such as workshops, interagency working groups, university-based centers with federal funding, or other intersectoral mechanisms for achieving SBS integration into the weather enterprise.[27]

IMPACTS OF EXTREME WEATHER EVENTS

Many sectors of U.S. society are vulnerable to extreme weather events and their resulting costs.[28] A reliable, safe and efficient U.S. transportation system is threatened by heavy precipitation, coastal flooding, heat, wildfires, and other extreme events. Extreme heat events can have a negative impact on pavement and flooding will cause vehicle delays; both events will increase road maintenance costs and disproportionately impact vulnerable populations. Coastal communities will suffer from the increasing frequency of flooding events and sea level rise. By the middle of the century, flooding and storms are likely to destroy billions of dollars of property, with the Atlantic and Gulf regions facing the greatest risk. Forest structure and function will change rapidly with increasingly severe ecological disturbances caused by extreme weather. Agricultural and rural communities will face degradation of soil and water resources with an increase in extreme precipitation events.[29]

A recent study found that in 2012, 10 extreme weather events, boosted by climate change, caused $10 billion to the U.S. healthcare system.[30] The study looked at 10 climate-sensitive events across 11 states, including Superstorm Sandy, wildfires in Colorado and Washington, extreme heat in Wisconsin, harmful algal blooms in Florida, and more. These events led to 1,000 more deaths and over 20,000 additional hospitalizations. Two-thirds of these public health costs were paid by Medicare and Medicaid. [31]

The study is the first of its kind to investigate the economic toll of climate-sensitive public health costs of extreme weather. Additional research is needed to more fully understand the financial toll

[25] Ibid.
[26] Ibid.
[27] Ibid.
[28] Fourth National Climate Assessment. 2018. https://nca2018.globalchange.gov/downloads/NCA4_2018_FullReport.pdf
[29] Ibid.
[30] Estimating the Health-Related Costs of 10 Climate-Sensitive U.S. Events During 2012. 2019. https://doi.org/10.1029/2019GH000202
[31] Ibid

of deaths, hospitalizations, visits to the emergency room, and associated medical care as a result of extreme weather events. In order to reduce the health-related costs of extreme weather, improvements must be made in public health preparedness, resource deployment, and public outreach and communication, particularly in vulnerable communities.[32]

As of July 9, 2019, the U.S. has experienced six weather and climate disasters that had losses exceeding $1 billion each.[33] Without mitigation and adaptation, these numbers will continue to grow as more extreme events occur. Extreme weather events will also affect other countries, and can slow or reverse social and economic progress in developing countries, exacerbate conflict, and negatively impact global trade. This poses a major threat to U.S. national security, as does the risks from extreme weather impacts on military assets, such as roads, runways, and other infrastructure, both at home and abroad.[34]

According to the 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5°C, every increment of warming will exacerbate the impacts of extreme weather worldwide. For example, more people will experience extreme heat and drought, particularly in urban areas. [35] In high latitude and mountainous regions, there will be heavier precipitation and flooding. [36] For information on the Special Report on Global Warming of 1.5°C and its findings on the relationship between climate change and extreme weather, see the Charter from the February 13 Hearing titled *The State of Climate Science and Why it Matters*.[37]

ADDITIONAL READING

Weather, Climate & Catastrophe Insight, 2018 Annual Report.
http://thoughtleadership.aonbenfield.com/Documents/20180124-ab-if-annual-report-weather-climate-2017.pdf

The 1.5 Health Report: Synthesis on Health & Climate Science in the IPCC SR1.5.
https://www.who.int/globalchange/181008_the_1_5_healthreport.pdf

United in Science: High-level synthesis report of latest climate science information convened by the Science Advisory Group of the UN Climate Action Summit 2019.
https://public.wmo.int/en/resources/united_in_science

[32] Ibid.
[33] https://www.ncdc.noaa.gov/billions/
[34] https://nca2018.globalchange.gov/downloads/NCA4_Report-in-Brief.pdf
[35] https://report.ipcc.ch/sr15/pdf/sr15_chapter3.pdf
[36] Ibid.
[37] https://docs.house.gov/Committee/Calendar/ByEvent.aspx?EventID=108915