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Subcommittee on Science, Oceans, Fisheries, and Weather

Atmospheric Science Research and Forecasting Innovation
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Mr. Chairman, and Members of the Subcommittee, my name is Radley Horton. I am an Associate Research Professor at Columbia University's Lamont-Doherty Earth Observatory. Thank you very much for the opportunity to participate in this hearing. I have served as an author on the 3rd and 4th U.S. National Climate Assessments, and as a Lead Principal Investigator within NOAA's Regional Integrated Sciences and Assessments (RISA) Program. I speak to you today though in my personal capacity as a private citizen.

Extreme weather events, such as tropical storms, heat waves, inland flooding, and droughts, threaten the economic livelihood of our nation and the health and safety of our communities. In 2017, Hurricane Harvey caused an estimated $125 billion in losses, with an estimated 200,000 homes experiencing damage. Ongoing flooding in the Upper Midwest is sure to produce agricultural losses alone in the billions of dollars, and extreme drought across much of the U.S. in 2012 caused $33 billion in losses (NCEI, 2019). In light of growing federal, state, and local costs of extreme weather events, preparedness and early warning to reduce vulnerabilities is critical. Better forecasts, and enhanced communication of scientific information with decision-makers, are necessary preconditions for increased preparedness, improved disaster response, and long-term resilience.

As my colleagues have described, we are seeing rapid advances in scientific understanding and forecasting of extreme weather events, but continued success will hinge on continued investment in the science, and in insuring that information is communicated in ways that can benefit decision-making.

Extremes events operate across a range of time and space scales, from for example: a tornado less than one mile in diameter that may touch down for only minutes; to: a drought that may span half the U.S. and persist for several years. Our forecasting and prediction of these events must similarly range from the traditional multi-day weather forecast, through the subseasonal (two weeks to 3 months), and out to the seasonal and multi-decadal scales. Continued forecast improvements across these scales will require new data—from the atmosphere, ocean, land, and cryosphere—as well as improved models that can better reproduce the key physical processes and interactions among these complex systems, including our human systems.

As one example, the surface of the ocean has warmed more than one degree Fahrenheit since 1900, which loads the dice towards 1) heavier rain events extending far inland, and 2) combinations of high heat and humidity that put the health of our vulnerable populations, as well as outdoor labor productivity, at risk. But more research, with the best models and the latest data, is needed to understand just how much these extreme events will be affected by ocean temperature extremes. Similarly to ocean temperatures, changes in Arctic sea ice--volume had declined by more than 50 percent in the past 40 years--are impacting extreme weather events in the U.S., but our understanding of exactly how remains in its infancy. More data and modeling are urgently needed given the rapid changes we are observing in the Arctic, and the potential implications for National Security.

As another example, in the western United States, including Colorado, an observed increase in the number of large wildfires since the 1980s is putting human health and assets at risk, with potential cascading impacts ranging from insurance markets to the financial health of utilities (Wuebbles et al. 2017). Weather and climate are clearly a large part of the story, with the 'noise' of individual weather systems encountering a 'signal', or new baseline, of warmer average temperatures and long-term decline in mountain snow pack. But forecasting fire risk also requires integration of environmental data such as historical forest management decisions, risk of new ignitions, and how dry the fuel source is.

As a final example of the need to integrate diverse types of information to produce the best forecasts, marine heat waves, which now occur against a backdrop of warmer baseline ocean temperatures, are interacting with emerging ocean acidification and in some regions de-oxygenation, to threaten our fisheries and coastal ecosystems in complex ways.

But as NOAA's Weather Bill of 2017 acknowledges, advances in our scientific understanding of extreme events alone do not ensure societal risk reduction. Working with communities and businesses helps ensure that the most useful information is being generated, and that it is being communicated as effectively as possible for diverse audiences. I'd like to briefly describe one model for how scientists can work hand-in-hand with stakeholders and decision makers to make scientific research and information responsive to their needs, adding value to existing federal investments in scientific research.

NOAA's RISA team in the south-central U.S. worked with the Strategic Petroleum Reserve to identify strategies to secure the nation's 32-day, $33 billion, supply of oil in the face of hurricane-related storm surge along the Gulf of Mexico. After Hurricane Sandy inflicted $20 billion in damages in the greater New York Metropolitan Region, our RISA team partnered with local, state, and federal entities, including the USACE and FEMA, to provide the science foundation and tools to support for example NYC's $20 billion resilience plan (Horton et al. 2016).

In the remainder of my time, I want to emphasize a little appreciated point: that small shifts in long-term average conditions—what we call climate—can have a large effect on the frequency of extreme weather events. Higher average temperatures have already loaded the dice towards more heat extremes and fewer cold extremes, just as sea level rise is already causing coastal flooding to happen more often than it used to, with trillion-dollar implications that extend to every state. It follows that if we hope to reduce economic and safety risks to the nation, climate changes must play a central role in research on extreme weather and its impacts.

Since 1900, global temperatures have increased by about 2 degrees Fahrenheit (Wuebbles et al. 2017). One could be forgiven for initially thinking, 'so what'? or 'how could 2 degrees matter?' given the much larger temperature variations we experience from one day to the next. But with 2 degrees of warming, record high temperatures become much more common, and record low temperatures much less common. In fact, so far this century the U.S. has experienced roughly twice as many daily record high temperatures as low temperatures.

It is a very similar story with sea level rise. Globally the oceans have 'only' risen about 7-8 inches since 1900 (Wuebbles et al. 2017). How could that matter, when for many places the elevation change over the course of six hours between high tide and low tide is a few feet?

Sea level rise means more frequent coastal flooding and more intense/higher magnitude coastal flooding (Wuebbles et al. 2017). Already we are seeing nuisance (also known as 'sunny-day') flooding happen far more often than it used to across the U.S. coastline, as shown in Figure 1. For some locations, the past two generations have seen a 5 to 10-fold increase in the number of days with nuisance flooding. (It should be noted that some of these places, including the Mid-Atlantic states, have had more sea level rise than the global average, but even for those states that have not, the trend towards more nuisance flooding is clear.) From Miami to Norfolk, this means for example: 1) more stores unable to open for normal business, with associated ripple effects on the economy; 2) people not able to drive home along their normal routes, leading to delays, and 3) more water in people's basements. These events perhaps deserve to be called a mere 'nuisance' when they only happen a few times per year—but at what point does it become something more than a nuisance?

Now lets look to the future of coastal flooding. And instead of looking at nuisance flooding, lets look at the big coastal floods—what are colloquially known as the '1 in 100 year' events—heights that flood insurance, and zoning decisions are made based upon (Figure 2). Lets take the most optimistic scenario sea level rise scenario imaginable for late this century. With just one to two feet of sea level rise, and even if coastal storms do not change at all, the 1 in 100 year high water levels of the past become events that for most of the U.S. coast will be experienced within the 30-year lifetime of the typical home mortgage. In some areas, these high water levels could happen every couple of years in the future. Rather than focusing on the exact numbers in any one location, I would encourage you to note how the statistics shift strongly across the entire U.S. And once again, this is a low-end sea level rise scenario, and one that includes no assumptions about coastal storms changing in the future. For hurricanes, this assumption is probably somewhat optimistic, since the balance of evidence suggests that major hurricanes will become more frequent and intense, in large part due to the warming of the upper oceans (Weubbles et al. 2017).

But sea level rise does more than just cause more frequent flooding. It means that when a coastal storm makes landfall, additional areas are flooded that would not have flooded before. And deeper floodwaters, which allow for greater wave penetration, cause more economic damage and loss of life. If the foot of sea level rise in the Greater New York/New Jersey Metropolitan Region since 1900 had somehow not occurred, 2012's Superstorm Sandy would have flooded the residences of 80,000 fewer people (Climate Central 2013; Miller et al. 2013).

The more frequent and intense coastal flooding brought on by sea level rise will impact all Americans. Along our coasts are assets worth trillions of dollars. From our homes, to critical service providers, to critical infrastructure including interstates like I-95, rail lines including Amtrak, airports, and municipal water treatment plants.

And sea level rise is also a public health and safety issue. It means less time to evacuate from low lying areas in advance of a coastal storm, and greater risk of injury and death for those vulnerable members of our communities who are unable to evacuate.

And just as all Americans suffer when the health and safety of any American is imperiled, so too will all Americans suffer the economic costs of sea level rise. It is after all U.S. taxpayers who bear much of the bill for coastal flood damages. And coasts are economic hubs for the entire nation. Our ports, which almost by definition are vulnerable to sea level rise, serve inland interstates and rail systems, as well as regional distribution centers. If ports are damaged or operating at reduced capacity, we therefore see supply chain implications, and economic disruption.

And then there are the national security implications. From NASA's Kennedy Space Center on Florida's Space Coast and Johnson Space Center outside Houston, to Norfolk's Naval Base and shipyards, what happens along U.S. coasts can have global implications. Recent coastal storm damages made worse by climate change have led to billions in damages at an Air Force base and a Marine Corps camp.

And of course, extreme events interact. For example, for a low lying coastal city, even a small increase in rainfall intensity, combined with a small increase in a hurricane's storm surge could lead to a large increase in flooding if accompanied by even modest sea level rise.

To conclude, extreme events sit at the interface between great potential for advances in scientific understanding on the one hand, and great societal need on the other. Through investment in science and science communication geared towards the specific questions decision-makers are asking, there is thus great potential for risk reduction and new opportunities across the U.S. economy. It is becoming clear that groups such as large investors and infrastructure stewards realize that they must plan for rapidly evolving risks of extreme weather events. As one of many examples, Moody's Investors Service, a major credit ratings agency, has put cities on notice that if they do not plan for both historical and emerging weather and climate risks, their credit ratings, and thus ability to finance future expenditures, may be at risk. Growing numbers of investors and companies are now making similar demands, while recognizing the opportunities for first movers.

Thank you for inviting me to testify, and I look forward to our discussion.

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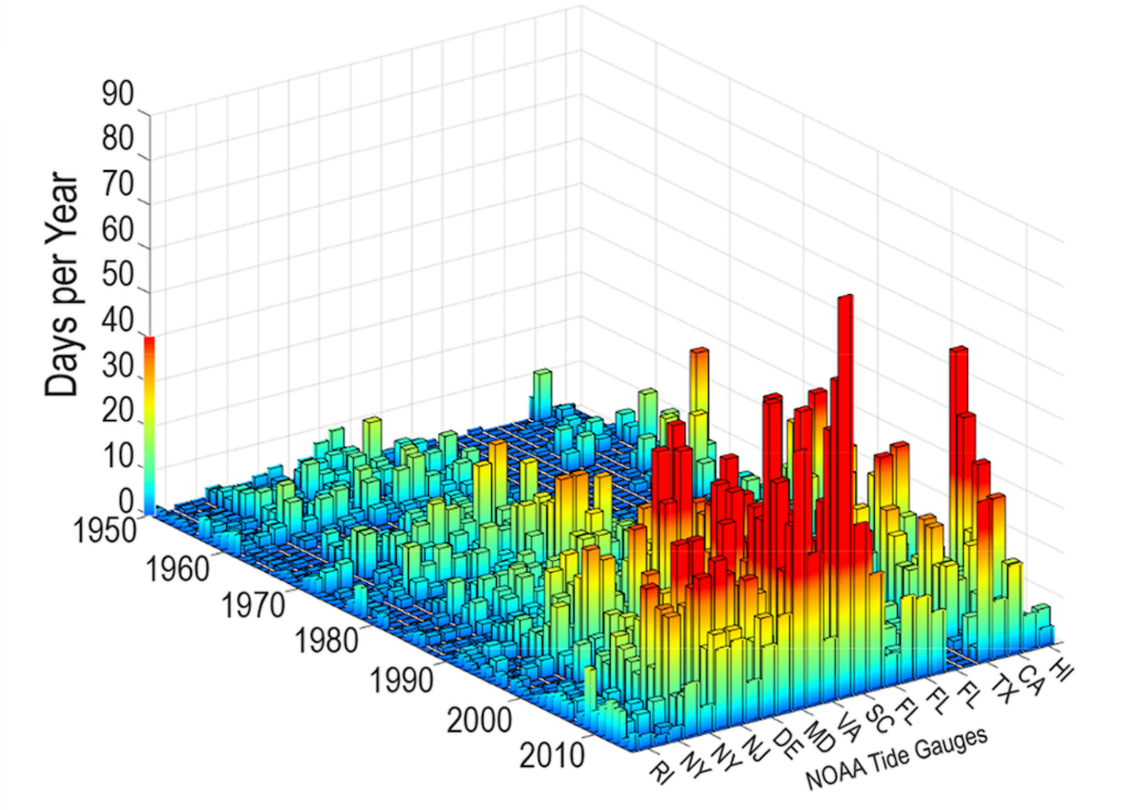

Figure 1. Tidal floods (days per year) exceeding NOAA thresholds for minor impacts at 28 NOAA tide gauges through 2015. Source: Sweet et al., 2017.

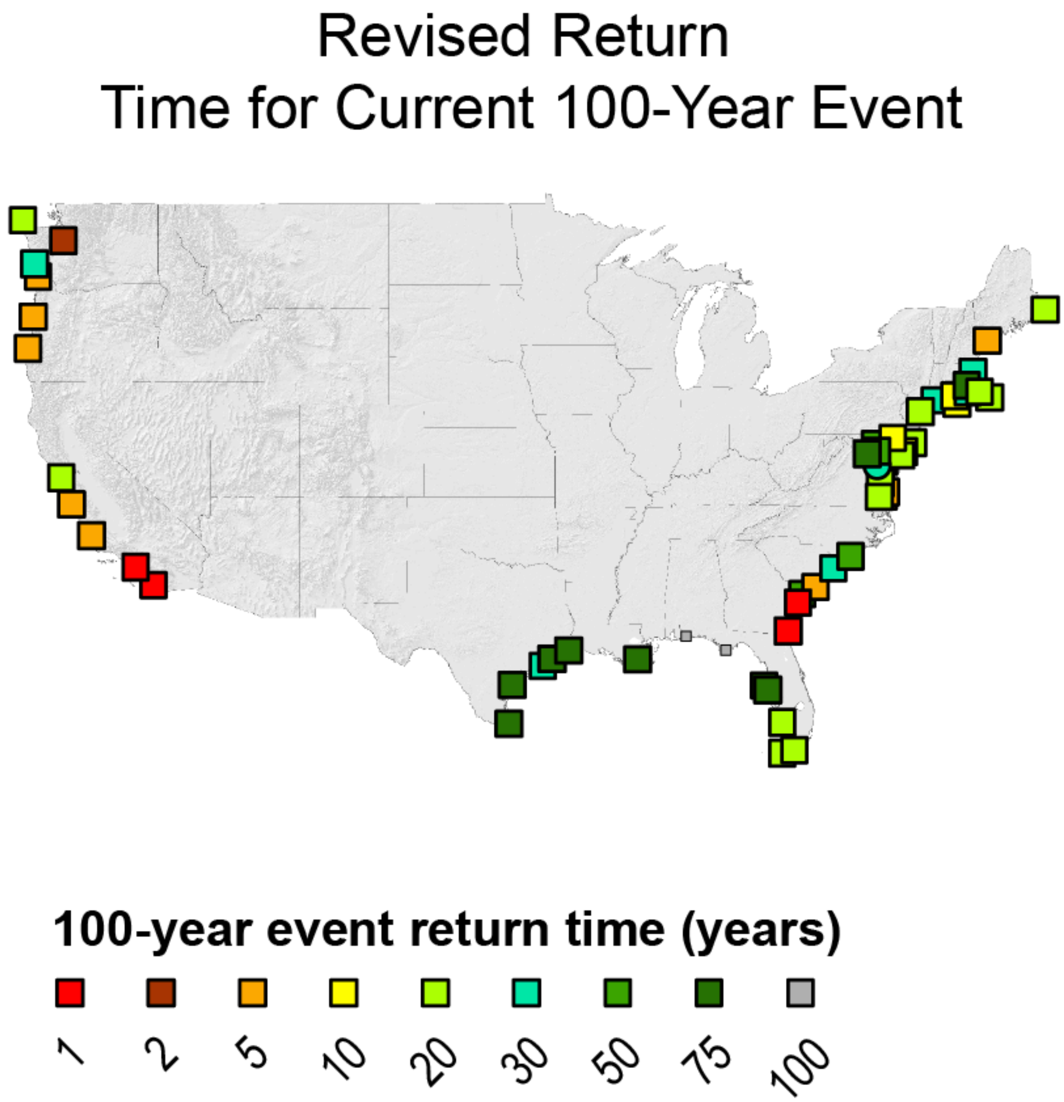

Figure 2. The amount of sea level rise (SLR) by 2050 will vary along different stretches of the U.S. coastline and under different SLR scenarios, mostly due to land subsidence or uplift. This figure shows how a 1.05-foot SLR by 2050 could cause the level of flooding that occurs during today's 100-year storm to occur more frequently by mid-century, in some regions as often as once a decade or even annually. All estimates include the effect of land subsidence. Source: Moser et al., 2014.