Statement of Katharine Hayhoe

Professor, Department of Political Science

Co-Director, Climate Science Center

Texas Tech University

To be presented to:

United States House Committee on the Budget

June 11, 2019

Thank you, Chairman Yarmuth, Ranking Member Womack, and committee members for inviting me to speak today.

My name is Katharine Hayhoe. I am an atmospheric, or climate, scientist. I am also a Professor in the Department of Political Science at Texas Tech University in Lubbock, Texas, and a co-director of the Climate Science Center, an interdisciplinary effort that is part of the Department of the Interior's South-Central Climate Adaptation Science Center.

At our Centers, we work with stakeholders across Oklahoma, Texas, Louisiana, and New Mexico to quantify the impacts of climate variability and long-term trends on our region and provide the data and the science we need to be good stewards of our land and our resources. My own research focuses on understanding what climate change means to us in the places where we live. I evaluate global climate models at the regional scale, develop and test the methods we use to translate global climate model output into high-resolution projections, and work with federal,

state, and city organizations to incorporate this information into robust planning strategies that build resilience to a changing climate.

I also spend a great deal of my time talking about climate change – because according to the Yale Program on Climate Communication's public opinion surveys, while 70 percent of us agree that climate is changing and it will harm plants, animals, and future generations, only 41 percent of us believe that it will affect us personally.

Yet after serving a lead author on the Second, Third, and both Volumes 1 and 2 of the most recent Fourth National Climate Assessment over the last decade, I know this is not true. We care about a changing climate because it affects us personally, in the places where we live, in ways that matter to us. It is no longer only about the polar bears or people living on low-lying islands in the South Pacific or future generations. The message of the Fourth National Climate Assessment is crystal clear: climate change is already affecting every region of the U.S. and nearly every sector, including our agriculture, infrastructure, water, and more. Climate change is not just an environmental issue. It's a health issue, a resource issue, a national security issue, a humanitarian issue – and, most relevant to this committee, an economic issue as well.

My testimony today focuses on highlighting the findings of the Fourth National Climate Assessment for each region of the United States, with the addition of more recent scientific findings and/or events where relevant. In doing so, I am speaking on my own behalf, based on my technical expertise in regional climate impacts. This testimony is not a product of the

National Climate Assessment process, nor does it represent the positions of the U.S. Global Change Research Program or Texas Tech University.

The U.S. Global Change Research Program (USGCRP) was signed into law by President George H. W. Bush under the Global Change Research Act of 1990. It is tasked with producing a National Climate Assessment every four years, which among other goals is directed to analyze "the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity" and also "current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years."

The Fourth National Climate Assessment fulfills these goals. In nearly 500 pages, Volume 1 – which was released in November 2017 -- clearly documents how climate is changing, humans are responsible, and the impacts both globally as well as for the U.S. become more severe the more greenhouse gases we emit. In over 1600 pages, Volume 2 – the so-called "Black Friday" report that was released in 2018, the day after Thanksgiving – expands on how climate change is already affecting the United States' water; energy supply, delivery and demand; land cover and land use; forests; ecosystems, ecosystem services, and biodiversity; coasts; ocean and marine resources; agriculture and rural communities; built environment, urban systems and cities; transportation; air quality; human health; tribes and indigenous peoples; and international interests.

Volume 2 finds that people and organizations across the country are already responding and beginning to adapt to the changes that have already occurred. But – and this is a very important qualifier – it also concludes that we are not adapting fast enough; and the further and faster climate changes as a result of human emissions of heat-trapping gases, the more difficult and expensive and, in some cases, ultimately impossible it may be to adapt to future change.

Before I begin our brief tour of how climate change is already affecting, and is expected to continue to affect, each region of the U.S., I want to specifically discuss how the Fourth National Climate Assessment addressed the two goals above, in order to clarify some statements that have been made that you may have heard reported on in the media.

I am the lead author on Chapter 4 of Volume 1, which addresses future projections, uncertainty, and scenarios. As such, I can unequivocally state that our analysis was not based on a single or even a range of, quote, "most extreme" scenarios. Rather, we examined the impacts of a range of future scenarios, from higher scenarios where the world continues to depend on fossil fuels as our primary source of energy, to scenarios that are so low that we only have a matter of years left in the global carbon budget before they are off the table: specifically, one and a half years' worth of additional carbon emissions at present-day rates for a 50% chance of remaining below 1.5°C, and between 16 to 21 years' worth of additional carbon emissions to have a 50% chance of remaining below 2°C (Volume 1, Table 14.1). This is a very broad range of possible futures, and this range was carried throughout Volume 2, where the impacts by sector and region were clearly and unmistakably delineated as corresponding to a "higher scenario," a "lower scenario," and an "even lower scenario."

Which of these scenarios is most likely? Looking back over the last two decades, it is clear that "the observed increase in global carbon emissions over the past 15–20 years has been consistent with higher scenarios (very high confidence)." (Volume 1, Chapter 4). Looking to the future, however, the question of which scenario is more likely is not one that science can answer. Instead, the answer is up to *us*.

Today, "global climate continues to change rapidly compared to the pace of the natural variations in climate that have occurred throughout Earth's history," (Volume 1, Chapter 1) and "observational evidence does not support any credible natural explanations for this amount of warming; instead, the evidence consistently points to human activities, especially emissions of greenhouse gases, as the dominant cause." (Volume 2, Chapter 2)

"The magnitude of climate change beyond the next few decades will depend primarily on the amount of greenhouse gases (especially carbon dioxide) emitted globally." (Volume 1, Chapter 1) We are conducting an unprecedented experiment with the only home we have and, as Chapter 4 concludes, "the present-day emissions rate of nearly 10 GtC per year suggests that there is no climate analog for this century any time in at least the last 50 million years," a time that so far away that, though it sounds astronomical to us, subsequent research has found to be likely even further back than that.

Returning to our main theme: it's clear that climate change is no longer an issue that can be put on the back burner for future generations to worry about. It's already affecting us, right now, in

the places where we live. And the more greenhouse gasses we produce, the more serious the impacts we'll experience. The future is in our hands.

As climate changes and the planet warms, many of our naturally-occurring risks and our pre-existing vulnerabilities are being exacerbated in ways that affect us directly, here and now. One of the most important ways a changing climate affects us is by loading the natural weather dice against us. Specifically (Volume 2, Chapter 2),

- Heat waves have become more frequent in the United States since the 1960s, while extreme cold has become less frequent.
- Heavy precipitation is increasing in intensity and frequency across the United States and these observed increases are projected to continue in most parts of the U.S., particularly the Northeast and the Midwest.
- Soils are likely to become drier and snowpack in the western states is likely to decrease, increasing the intensity of droughts.
- Hurricanes are not becoming more frequent; but with 93% of the extra heat trapped inside the climate system by our heat-trapping gas emissions going into the ocean where it can power stronger tropical storms, we are seeing (and expect to continue to see) these storms intensifying faster, on average, and becoming on average stronger, bigger, slower, and with more rainfall associated with them.
- Global average sea level has risen by about 7-8 inches since 1900, and it's accelerating: almost half of this rise has occurred since 1993. The rate at which sea level is rising is now almost three times faster than the average rate over the last century.

- Coastal flooding, particularly what they call nuisance or “sunny day” flooding is now more frequent. In some cities, this type of flooding has increased by a factor of five to ten since the 1950s.

Typically, it isn’t a case of climate change creating new risks that have never existed before, but rather a case of climate change interacting with existing risks and exacerbating or amplifying them through exposure, vulnerability, and changes in extreme weather and climate events themselves.

We begin our tour in the Northeast U.S., where winters are milder, spring is coming earlier, and warming temperatures are altering many of the very things that make the region so unique, from its beautiful lakes to iconic crops like blueberries and maple syrup. Tourism is an important economic driver for many small towns: fall colors are multi-billion-dollar tourist attraction across the region, and in Maine alone, snowmobiling brings in well over 200 million dollars a year. But more and more often, the peak leaf season is shifting to earlier in the year, and as the mix of trees changes, the colors may not be as spectacular. And warmer winters mean less snow and ice for skiing, snowmobiling, and ice fishing. The impact of warm winters such as occurred a few years ago can be devastating for the economies of many rural communities. And the region’s coasts support fishing and aquaculture businesses: as sea level rises, the ocean warms, and ocean acidification continues, these are all under threat. The Gulf of Maine is warming faster than most ocean areas and that’s affecting shellfish and the lobster industry. Further north, in Maine, lobster harvests are doing well as the water has warmed to the ideal temperature but south of Cape Cod, these harvests are already collapsing as the water warms above the level

where lobsters can thrive. And then there's the fact that this region has seen the largest increase in heavy precipitation of any in the U.S. Cities with their paved surfaces are particularly at risk, and the economic impacts have the potential to be significant: since 1980, Northeast states have already experienced anywhere from 7, for Vermont, up to 19, for New York state, extreme precipitation events where damages from flood or snow topped a billion dollars.

The Southeast is next. It's no stranger to invasive species: it already costs between tens and hundreds of millions of dollars to remove kudzu, originally planted by farmers in the first half of the 20th century, from essential infrastructure. Palmer amaranth, known as the "superweed," is attacking fields in the region including corn, soybeans and cotton. Many people in the Southeast also live along the coastline, both the Atlantic and the Gulf of Mexico. This is one of the key areas where the "sunny day flooding" I mentioned earlier is already a problem, with roads, buildings, and even parking garages flooding even when there's no storm. This is already affecting property values in coastal cities like Miami where property prices for homes vulnerable to sea level rise have already dropped an average of seven percent relative to neighbors just a few blocks inland. If no action is taken to reduce carbon emissions, it's estimated that this type of flooding throughout the southern states could be a daily occurrence by the end of the century, putting hundreds of billions of dollars of infrastructure at risk, as well as key and iconic sites from the Florida Keys to the NASA Kennedy Space Center in Cape Canaveral. And of course sea level rise also exacerbates storm surge; and as I discussed above, hurricanes are not any more frequent than they used to be, but they are stronger, with more rainfall associated with them which, if we don't prepare for these changes, will increase the costs and damages from the storms.

The southern Great Plains, where I live, also lies along the Gulf of Mexico. Because of its geographic location, it is naturally at risk for a greater number of expensive weather and climate disasters, from ice storms to hurricanes, than any other region in the U.S. Since 1980, Texas alone has experienced 105 events that have caused at least a billion dollars' worth of damage; some events, like Hurricane Harvey, well over one hundred billion dollars. Of course hurricanes in the Gulf are nothing new – the Galveston hurricane of 1900 was devastating. But it's estimated that between 20 to nearly 40 percent of the rain that fell during Hurricane Harvey was the result of a warmer climate. Heavy rainfall from regular storms is also increasing, particularly across the eastern half of the region, and as temperatures increase, my own research shows that summer droughts will be getting stronger and more frequent as well. Natural patterns of feast and famine, flood and drought, are being amplified across much of the region, with potentially devastating consequences for our region's agriculture, water, and more.

Moving westward to the Southwest U.S., the story there is also about water: how there's already not enough. The Southwest has always been susceptible to mega-droughts, as far back as tree-ring records go, which in some locations is thousands of years; but as the world warms these naturally-occurring droughts are intensifying, getting hotter and longer. California, for example, has experienced many droughts, but 2011 to 2014 was the driest period for California since record-keeping began. The onset of the drought was consistent with natural patterns of precipitation variability, but record-high temperatures that accompanied the drought enhanced the atmospheric ridge of high pressure that diverted the winter storms away from the region when it needed them most. Over a hundred million trees died, hydroelectric power generation

dropped by two-thirds, and the economic impacts averaged between 2 to 3 billion dollars per year. The drought ended dramatically with the winter of 2016, which was also the wettest on record for Northern California. The rainfall was fueled by atmospheric rivers, which currently account for 30 to 40 percent of annual precipitation along the western US coast. The frequency and severity of these events are projected to increase due to warmer temperatures and more winter precipitation falling as rain and less as snow. This means less winter snowpack, which serves as a natural reservoir or storage for many states, from Colorado to California. All put together, this is an example of how multiple stressors can lead to a cascade of impacts, whereby drought dries the soil, creating conditions for wildfire to burn greater area, which clears vegetation such that when the rains come, there is little to hold the land in place, increasing the risk of landslides which can cut off critical services and carry their own economic costs.

Moving up to the Pacific Northwest, climate change threatens the diversity and the resources that make this region so unique. Those most at risk are communities that are already economically disadvantaged, or those that are most dependent on natural resources for their livelihoods, including many tribal nations. Since the 1950s, snowpack on April 1st has declined by an average of about 25 percent across the Cascades, with some locations experiencing up to 60 percent decrease. In the future, snowpack is expected to continue to decline, and the risk of wildfire is expected to increase due to warmer temperatures and earlier (and less) spring snowmelt. Across the entire west, the number of wildfires is not increasing, but the cumulative area burned since 1985 is approximately double what it would be in the absence of a changing climate and the season is beginning earlier and ending later. In addition to the destruction of

homes and infrastructure, wildfires also affect the region's agriculture, hydropower, and the quality of the air and the drinking water.

In the northern Great Plains, water is the lifeblood of the region. Even small changes in annual snow and rainfall totals can have significant impacts. As temperatures warm, more precipitation is likely to fall as rain, and less as snow. Across the entire northern Great Plains region, warming has already led to shorter snow seasons, lower summer streamflow, and higher water temperatures. This is affecting the region's wildlife, and local economies that depend on the tourism revenue from recreational activities like skiing, snowmobiling, and fishing. The good news is that agriculture in the northern Great Plains is benefitting from longer growing seasons and higher CO_2 levels. Farmers in North Dakota can now grow corn and soybeans in areas that were previously too cold to plant them. While this is increasing livestock production and extending the growing season for crops, it is also increasing the ability of weeds and invasive species to compete with crops for nutrients. With greater warming, more negative impacts are expected, with increasing risk of summer heat waves, extreme precipitation, and the northward migration of pests and invasive species previously kept at bay by cold winter temperatures.

The story in the Midwest is about agriculture and water too. In this region, not only are temperatures increasing but winter and spring precipitation increasing as well, as is the frequency of heavy precipitation. When fields are too wet in the spring, farmers have to delay their planting by weeks, as happened this very year. Climate change is also increasing flood risk in many areas throughout the Midwest. In Cedar Rapids and Des Moines, for example, what were considered 500-year floods just 30 years ago are now considered 100-year floods. Across the region, it's

estimated it will cost nearly half a billion dollars to adapt urban storm water systems to the more frequent and severe storms expected over this century.

Then there's Alaska, in many ways the poster child for observing a warmer planet with our own eyes. Temperatures in Alaska and the Arctic are warming twice as fast, on average, as the rest of the world. Much of Alaska's infrastructure, from buildings to roads to oil pipelines, is built on what used to be permanently frozen ground. As this permafrost thaws, infrastructure damages are estimated to range from about one hundred to nearly three hundred million dollars per year. Many remote communities in the far north, often populated by native Americans, are accessed solely by "winter roads" or rail lines. The winter road season is getting shorter, isolating many of these communities. And of course warmer temperatures and retreating sea ice are already impacting traditional Inuit livelihoods and culture, driving rapid changes to unique and fragile ecosystems on land and in the ocean, increasing the risk of wildfire and yes, endangering the polar bear. When it comes to climate change, Alaska truly is on the front lines.

And lastly, we can't forget the islands: Hawai'i, Puerto Rico, the U.S. Virgin Islands and the U.S. Affiliated Pacific Islands who are uniquely vulnerable due to their limited land area. Many islanders live along the coasts where sea level rise, stronger storm surge, and more powerful tropical cyclones, typhoons, and hurricanes put them directly in harm's way. The 2017 hurricane season showed how devastating these storms are to the Caribbean. Hurricane Irma decimated St John in the Virgin Islands and destroyed 95 percent of the homes on Barbuda, leaving it uninhabitable for months. Hurricane Maria was the worst disaster in recorded history to hit the islands of Puerto Rico and Dominica. Even without the effect of stronger storms, Hawai'i

estimates sea level rise will cost at least 15 billion dollars – over 50 times the entire annual budget of the state's Department of Transportation– just to raise or relocate basic roadways, bridges, and other infrastructure to preserve them from this slow-motion flooding. Islands are also very sensitive to drought. In both the Caribbean and the Pacific, freshwater resources are expected to decline over time as average rainfall decreases and rising sea level increases contamination of freshwater coastal aquifers due to saltwater intrusion. And finally, tourism and the fishing industry depend on the resources available off the coast. In Hawaii alone, it's estimated that coral reefs contribute nearly half a billion dollars to the local economy each year. Warming ocean waters, increasing acidification, and the added risk of deoxygenization all exacerbate existing problems of pollution, runoff, and unsustainable harvesting of resources, putting the regions' economies and livelihoods at risk.

We care about a changing climate because it's loading the dice against us. It's taking many of our naturally-occurring risks and our pre-existing vulnerabilities, and it's making them worse -- in ways that affect us directly, here and now.

I live in West Texas, where the roads are long and straight. So straight that, in some places, you could drive down the highway just looking in the rearview mirror. Until, that is, you hit a curve. And then, if you're looking backwards, you'll end up somewhere you didn't plan to be.

What does this have to do with climate? The same principle applies: the information we use to plan for our future is crucial. If we're relying on historical climate averages to determine future

risks, we'll end up far from where we wanted to be, unprepared for the intense flooding, record heat waves, or rising seas up ahead.

No matter where we live, we're on the curve today. And that's why it's so important to prepare: to build resilience to the risks we can't avoid, and to reduce our emissions of heat-trapping gases, to avoid the risks we can. The more carbon we produce, the more serious the impacts – not just for polar bears or future generations, but for us as well. We're all on the bus, heading around the curve, and our wheels are on the rumble strip.

The National Climate Assessment sounds the warning and provides the information we need to ensure that we all navigate that curve safely and provide the safe future we all want, regardless of our political affiliation or our priorities—because it's for ourselves, our communities, and most of all, our children. For me as a mother, there's no more powerful motivation than that.