Written Testimony of

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**Climate Change Is an Urgent Threat**

Chairman Lowenthal, Ranking Member Stauber, and Members of the Subcommittee, thank you for the opportunity to be with you to discuss the threat of climate change. My name is Dr. Andrew Dessler, and I am a professor of atmospheric sciences and the director of the Texas Center for Climate Studies at Texas A&M University, located in College Station, Texas. I have been studying the atmosphere since 1988 and I have published extensively in the peer-reviewed literature on climate change, including studies of the physics of the climate system.

In my testimony today, I will review what I believe are the most relevant facts about climate science that need to be understood in order to appropriately evaluate all of the policy options available to respond to the threat of climate change.

First, the climate is warming. The Earth in the midst of an overall increase in the temperature of the lower atmosphere and ocean spanning many decades. Figure 1 shows that the Earth's average temperature has increased about 2°F since the 19$^{th}$ century. This may not sound like much, but later in my testimony I'll explain why this is important.

Second, the scientific community's best estimate is that all of this warming is due to emissions of carbon dioxide and other greenhouse gases caused by human activities, mainly from the combustion of fossil fuels. This conclusion comes from on several lines of evidence:

* Humans have increased the amount of carbon dioxide in the atmosphere from 280 parts per million in 1750 to 415 parts per million today. Methane levels have more than doubled over this period, and many other greenhouse gases are increasing (nitrous oxide, halocarbons).

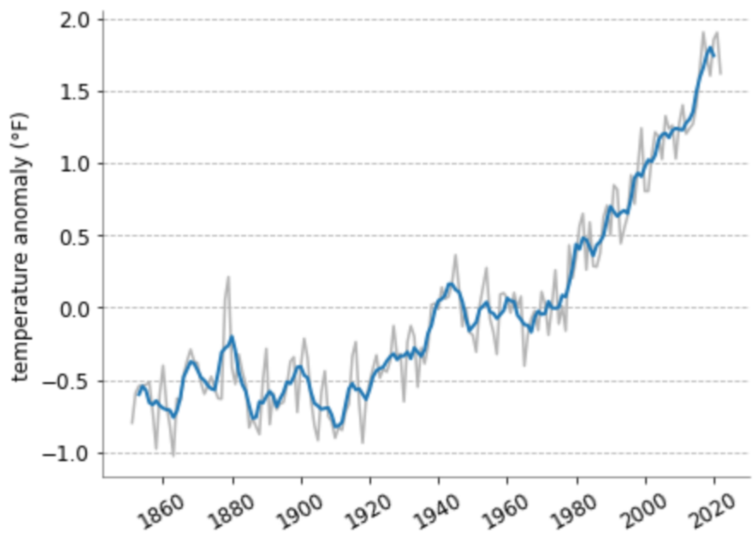


Fig. 1. Global annual average temperature change in °F; the gray line is the annual average, and the blue line is a smoothed time series. Data are from the Berkeley Earth Surface Temperature Analysis, downloaded from http://berkeleyearth.lbl.gov/auto/Global/Land_and_Ocean_summary.txt.

* The physics of the greenhouse effect is well understood, and it predicts that this increase in greenhouse gases will warm the climate.
* The actual amount of warming over the last century roughly is in accord with theory and climate models.
* Reconstructions of paleoclimate data over the last 60 million years show an association between changes in atmospheric carbon dioxide and changes in the climate.
* Finally, there is no credible alternative explanation for the recent warming other than an enhanced greenhouse effect due to human activities. There is no evidence that natural variability can explain the warming.

Third, we are on track to warm the planet about 5°F (3°C) above the Earth's temperature in the 19th century by 2100.  Such predictions come from computer simulations of the climate, generally referred to as climate models.  While criticizing climate models is a popular pastime in the public debate, climate models have shown great skill in predicting many aspects of the climate system. For example, predictions made in the 1970s and 1980s of how much the Earth would warm have closely tracked the actual warming (one prediction is shown in Figure 2), providing high confidence in predictions of future warming.

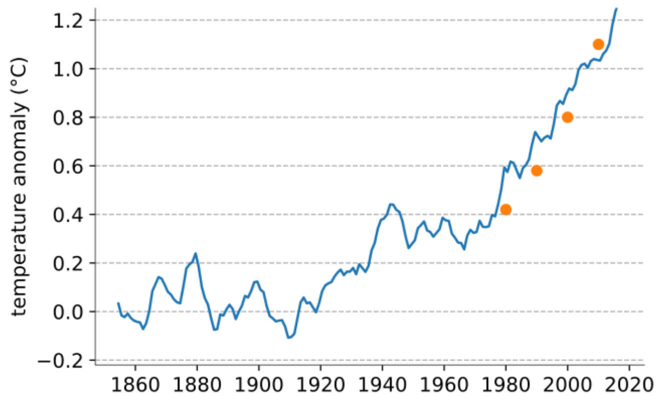


Figure 2. Predictions of future warming (orange dots) from Broecker (1975). Climatic Change: Are We on the Brink of a Pronounced Global Warming? Science, 189(4201), 460-463, doi: 10.1126/science.189.4201.460. Observations (blue line) from GISTEMP (Hansen et al. (2010). Global surface temperature change. Reviews of Geophysics, 48, doi: 10.1029/2010rg000345).

Fourth, warming of 5°F is a momentous amount of warming. Although you may experience much larger temperature changes over a day or season, such large, local variations tend to cancel when averaged over the entire globe. As a result, the global average temperature has small year-to-year variations, which you can see in Figs. 1 and 2.

To put 5°F of warming into context, realize that the warming that transitioned us out of the last ice age and into our present warm interglacial period was about 10°F. That warming radically altered the planet, removing ice sheets thousands of feet thick that covered much of North America and Northern Europe and raising sea level by 300 feet. It also drastically changed ecosystems and species around the world.

Thus, predicted warming for this century of 5°F should compel our attention. In fact, the 2°F of warming over the past 150 years (Fig. 1) is already turbocharging severe weather events and turning them into catastrophes. Examples include extreme precipitation events such as Hurricane Harvey, the 2021 Pacific Northwest heat wave, and the aridification of the U.S. Southwest. To be clear, climate change does not, in and of itself, cause these events. However, a new field of science, extreme event attribution, allows us to determine that climate change is making many of these events more severe and destructive than they would otherwise be.

These impacts are not surprising; in fact, they were predicted decades ago, along with many other impacts, such as the melting the Arctic and acidifying the ocean. And we can be certain that the worst is yet to come: impacts of the next 3°F of warming will be far worse than the impacts of the 2°F we have already experienced. To understand why future warming will be so bad, let me introduce the concept of non-linearity. In a linear system, things change in straight line. If climate impacts are linear, then every 0.1°C of warming would give you the same amount of damage.

In the non-linear world in which we live, however, every 0.1°F of warming produces more damage than the previous 0.1°F. For example, in a rain event, the first inch of rain typically does not cause any damage, however the 20$^{th}$ inch of rain can be catastrophic. The reason is that our society is carefully adapted to the typical range of weather we experience and it’s only when the weather departs these conditions that catastrophic impacts can occur.

In other words, individuals and communities are impacted by weather events when they pass thresholds built into the system. These thresholds are designed into a system when assumptions about the climate are built into the system. For example, when you build a bridge, you build in the capability for the bridge to expand or contract in response to a range of temperatures that you expect the bridge to experience. If the climate varies outside that range, the bridge may not preform to its design capability and may need to be closed.

With 2°F of global-average warming, we are departing the climatic conditions that much of 20th century infrastructure was designed for. Every 0.1°F of warming will push us past an ever-increasing number of these thresholds in the climate system and the economic and social disruptions from these will be substantial.

To the extent that we don't reduce emissions to avoid future climate change, we must adapt to the changing climate. No one really knows how expensive this will be: economists are split on whether this will cost a few percent of GDP, something that would not be too burdensome, or wipe out much of our wealth. As Nobel Prize winning economist William Nordhaus said, "Technological change raised humans out of Stone Age living standards. Climate change threatens, in the most extreme scenarios, to return us economically whence we came."[1]

One thing is abundantly clear, though: most of the world's inhabitants do not have resources to address the impacts of climate change. For example, if warming temperatures require us to air condition large swaths of the U.S. that did not previously require it (e.g., Seattle), who's going to pay for that? Installing air conditioning can cost thousands of dollars and many people simply do not have spare resources to do that. Then there is the cost of electricity to run the equipment.

Luckily, we still have the capability to avoid much of the projected future warming. The price of climate-safe wind and solar energy has been dropping rapidly over the past decade — solar has dropped 90% and on-shore wind has dropped 70% — and batteries are presently experiencing rapid price drops. Due to these price drops, the U.S. can build a largely carbon-free grid by the mid-2030s that produces power at prices lower than we pay today[2].

[1] https://www.nobelprize.org/uploads/2018/10/nordhaus-lecture.pdf
[2] The Berkeley 2035 report, https://www.2035report.com/electricity/

In conclusion, we are on the brink of potentially calamitous climate impacts. However, we also have the tools to solve the problem. The only question is which of these paths we choose.