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

The Science Behind Impacts of the Climate Crisis

Friday, March 12, 2021
11:00 am ET
Cisco WebEx

PURPOSE

The purpose of this hearing is to discuss the importance of science in understanding the impacts of the climate crisis, as well as how climate change is already impacting the U.S. on regional and local scales, including the record-setting 2020 wildfire and Atlantic hurricane seasons and other recent climate disasters. This will include discussion of the disproportionate impacts of climate change on vulnerable communities. The Committee will consider new advancements in climate science and understanding, such as in observational and predictive capabilities and the ability to quantify climate impacts and assess societal risk. This hearing will also be an opportunity to discuss the importance of science in advancing adaptation and mitigation solutions.

WITNESSES

- **Dr. Michael Oppenheimer**, Albert G. Milbank Professor of Geosciences and International Affairs, Princeton University
- **Dr. Zeke Hausfather,** Director of Climate and Energy, The Breakthrough Institute
- **Dr. Noah Diffenbaugh**, Kara J Foundation Professor, Department of Earth System Science, Kimmelman Family Senior Fellow, Woods Institute for the Environment, Stanford University
- **Dr. Paula Bontempi**, Dean, Graduate School of Oceanography, Professor of Oceanography, University of Rhode Island

KEY QUESTIONS

- How is climate change already impacting the U.S. on regional and local scales, and how do current observations of climate change compare to previous predictions?
- What are the projected future impacts of climate change, and what will those look like if the world limits global warming to 1.5℃ or 2℃?
- How have recent updates to climate science improved our understanding of the timing, intensity, and location of climate events?
- How has our understanding of attributing extreme events like the 2020 wildfire season or the 2020 Atlantic Hurricane season to climate change improved?
- What is the state of the ocean-climate nexus and resulting impacts on ocean processes from global warming?
- What has led to the improvement in our ability to quantify impacts and societal risk associated with climate change?
- As attention shifts to mitigation and adaptation solutions, how can science continue to be part of the solution to the climate crisis?

- What are the remaining climate research gaps and how can the Science Committee address them?

Background

The science is clear: modern climate change is primarily driven by human activities, largely the burning of fossil fuels. Atmospheric greenhouse gas concentrations are greater than 500 parts per million (ppm),[1] compared to pre-industrial levels of 280 ppm. Humanity has already exceeded global warming of ~1.0℃ above pre-industrial conditions and is on track to warm at least an additional 1.5℃ between 2030 and 2052 at the current emissions rate.[2]

On February 19, 2021, the U.S. officially rejoined the Paris Agreement, which commits to limiting global warming to well below 2℃, preferably to 1.5℃, compared to pre-industrial levels. The U.S. is expected to announce its carbon emission reduction target under the Agreement, called its "nationally determined contribution," as well as an economic plan to achieve the new target, around an April 22 climate summit hosted by President Biden.[3]

The 2020 economic downturn resulting from the COVID-19 pandemic only reduced global carbon emissions by about 5.8 percent.[4] While a record reduction, it was "not even a blip"[5] in terms of total carbon dioxide in the atmosphere and did not have a measurable effect on ocean warming. Global emissions are already back to being 2.1 percent higher than before the pandemic hit, suggesting the world is off track from meeting long-term climate goals.

2020 was a record-setting year for the climate, tying with 2016 as the hottest year on record.[6] The U.S. experienced a record 22 climate disasters that each caused at least $1 billion in damage, totaling $95 billion in damage and 261 deaths, even with NOAA counting all of the distinct wildfires in the West as a single event.[7] Ocean temperatures in 2020 reached their highest level in recorded history,[8] which supercharged extreme weather, including a record-setting Atlantic hurricane season with 30 named storms.[9]

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[1] In carbon dioxide (CO_2) equivalents. https://www.esrl.noaa.gov/gmd/aggi/aggi.html
[2] IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels…* https://www.ipcc.ch/sr15/chapter/spm/
[3] https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/27/fact-sheet-president-biden-takes-executive-actions-to-tackle-the-climate-crisis-at-home-and-abroad-create-jobs-and-restore-scientific-integrity-across-federal-government/
[4] https://www.iea.org/news/after-steep-drop-in-early-2020-global-carbon-dioxide-emissions-have-rebounded-strongly
[5] https://www.theguardian.com/environment/2020/sep/11/impact-of-covid-slowdown-on-co2-in-the-atmosphere-not-even-a-blip-australian-scientist-says
[6] https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows
[7] https://www.ncdc.noaa.gov/billions/
[8] Cheng, L. et al. 2021. "Upper Ocean Temperatures Hit Record High in 2020." *Advances in Atmospheric Sciences.* https://doi.org/10.1007/s00376-021-0447-x.
[9] https://www.noaa.gov/media-release/record-breaking-atlantic-hurricane-season-draws-to-end

The effects of climate change often have disproportionate impacts on historically marginalized communities. "Climate justice" is a term that acknowledges that climate change can have detrimental social, economic, public health, and other impacts on underprivileged populations. [10] Low-income communities; Black, Indigenous, and people of color; people with disabilities; older or very young people; and women can be more susceptible to risks posed by climate change impacts such as floods, storms, wildfires, extreme heat, poor air quality, and access to food and water. Multiple studies show that communities of color are often at greater risk from air pollution caused by the burning of fossil fuels.[11]

Role of the Ocean in the Climate System

There is growing recognition of the ocean-climate nexus, or the major role that the oceans play in the climate system and the fact that global terrestrial warming would be much worse without the oceans "taking the heat." The oceans have absorbed more than 90 percent of the heat trapped by carbon emissions, resulting in rising ocean temperatures.[12] Oceans reached the highest temperatures on record in 2020,[13] and are heating faster than any period in the last 2000 years.[14] Warmer oceans also disrupt rainfall patterns on land, leading to floods, droughts, and wildfires.[15] One of the Earth's major ocean current systems, the Atlantic Meridional Overturning Circulation, is slowing due to warming and is the weakest it has been in the last 1,000 years, threatening to disrupt weather and climate patterns across North America and Western Europe.[16]

Ocean warming has also led to increased deoxygenation (oxygen loss), species shifts, marine heatwaves, coral bleaching, increased storm intensity, and sea level rise.[17] The oceans have also absorbed a significant portion (approximately 30 percent) of the excess carbon emissions from the atmosphere, resulting in more acidic conditions.[18]

Regional and Local Climate Impacts in the U.S.

Climate change is no longer a far-off reality; it is impacting the globe and the U.S. on regional and local scales. According to numerous studies, climate change is causing more frequent and intense storms, heat waves, floods, wildfires, and other extreme events.[19] Climate change is increasing the frequency of extreme events, causing more extreme events to occur

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[10] https://yaleclimateconnections.org/2020/07/what-is-climate-justice
[11] Ibid.
[12] IPCC, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.
[13] Ibid.
[14] Gebbie, G. 2021. "Combining Modern and Palaeoceanographic Perspectives on Ocean Heat Uptake." *Annual Review of Marine Science.* DOI: https://doi.org/10.1146/annurev-marine-010419-010844
[15] Wang, B., et al. 2019. "Historical change of El Nino properties sheds light on future changes of extreme El Nino." *PNAS*. DOI: https://doi.org/10.1073/pnas.1911130116
[16] Caesar, L., et al. 2021. "Current Atlantic Meridional Overturning Circulation weakest in last millennium. *Nat. Geosci.* DOI: https://doi.org/10.1038/s41561-021-00699-z
[17] Ibid.
[18] Ibid.
[19] Wuebbles, D.J., et al. 2017: Executive summary. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. U.S. Global Change Research Program, Washington, DC, USA, pp. 12-34, DOI: 10.7930/J0DJ5CTG.

simultaneously or back-to-back.[20] The following subsections outline some of the major impacts of climate change across the U.S.

Drought and Wildfires
The U.S. had its most active wildfire year on record in 2020 due to very dry and warm conditions in the West. Wildfires burned a record 10.3 million acres in the U.S. last year, exceeding the 2000-2010 average by 51 percent.[21] Climate change plays a role in creating conditions for wildfires in the West. Global warming has increased the frequency of extreme wildfire weather in recent decades due to long-term warming, which has resulted in more dry, flammable vegetation, and decreasing autumn precipitation. [22] The number of autumn days with extreme fire weather have more than doubled in California since the early 1980s due to climate change.[23]

Hurricanes and Extreme Weather
2020 saw a record number of Atlantic hurricanes impacting the Southeastern U.S., as well as more storms that intensified rapidly like Hurricane Laura. Scientists have established the link between climate change and hurricane intensity, due to warmer oceans supercharging hurricanes.[24,25] Climate change is creating conditions that could worsen the impacts of hurricanes as well; however, it is less clear whether climate change could lead to an increase in the number of hurricanes.[26] Preparation for and recovery from increasingly intense hurricanes disproportionately affects communities of color and families living in poverty that face additional barriers from historic discriminatory policies.[27]

Climate change may also increase the likelihood of more frequent and intense derechos, or extreme wind events, as a result of increasing atmospheric instability, such as the devastating derecho that across the Midwest last August, damaging crops, homes, property, and causing massive power outages.[28]

Extreme Precipitation and Flooding
There has been an increase in the number of flooding and rainfall-related extreme events across North America in recent years, totaling billions of dollars in damage.[29] For example, last May, extreme precipitation-caused flooding breached two dams in Central Michigan, forcing thousands to flee and threatening a chemical plant and toxic waste cleanup site. Global warming

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[20] Zscheischler, J. et al. 2018. "Future Climate Risk from Compound Events." *Nature Climate Change*. DOI: 10.1038/s41558-018-0156-3
[21] https://www.noaa.gov/stories/record-number-of-billion-dollar-disasters-struck-us-in-2020
[22] Goss, M. et al. 2020. "Climate Change is Increasing the Likelihood of Extreme Autumn Wildfire Conditions Across California." Environmental Research Letters. DOI: https://doi.org/10.1088/1748-9326/ab83a7
[23] Ibid.
[24] https://www.noaa.gov/media-release/record-breaking-atlantic-hurricane-season-draws-to-end#:~:text=In%20total%2C%20the%202020%20season,of%20111%20mph%20or%20greater).
[25] Kossin, J.P., et al. 2020. "Global increase in major tropical cyclone exceedance probability over the past four decades." PNAS. DOI: https://doi.org/10.1073/pnas.1920849117
[26] https://www.c2es.org/content/hurricanes-and-climate-change/
[27] https://www.brookings.edu/blog/social-mobility-memos/2017/09/18/hurricanes-hit-the-poor-the-hardest/
[28] https://www.sciencenews.org/article/2020-extreme-weather-climate-change-hurricane-derecho-wildfire
[29] Kirchmeier-Young, M.C. and Zhang, X. 2020. "Human influence has intensified extreme precipitation in North America." *PNAS.* DOI: https://doi.org/10.1073/pnas.1921628117

is causing the intensity of extreme precipitation events to increase.[30] A recent study found that climate change contributed to approximately 36 percent of the rising costs of flooding damages due to intensifying precipitation.[31]

Sea Level Rise and Coastal Flooding

Sea levels have already risen by 6.5 inches on average across the U.S. since 1950, with nearly half of it occurring in the last 20 years.[32] The East Coast of the U.S. has seen higher rates of relative sea level rise,[33] leading to "nuisance," or high tide, flooding.[34] The Biloxi-Chitimacha-Choctaw tribe in Louisiana is already having to relocate to higher ground due to higher sea levels and has been called America's first "climate refugees."[35] While thermal expansion of warming seawater has contributed to some of the rise, the majority is due to recent accelerated rates of ice melt.[36] The rate of ice loss has significantly increased since the mid-1990s, with especially pronounced loss in the ice sheets in Antarctica and Greenland. A recent study shows that the ice sheets are following the worst-case climate warming scenarios laid out by the Intergovernmental Panel on Climate Change (IPCC) and that the half meter of sea level rise expected by 2100 could now occur with just an increase of 0.5°C.[37]

Extreme Heat

Last summer, much of the U.S. experienced a heat wave with temperatures 5°F to 20°F above average.[38] The U.S. has experienced record breaking heat every summer in recent years, with the past six years being the hottest six years on record. Climate change is increasing the intensity, duration, and frequency of extreme heat events in the U.S.[39,40,41] Seniors, people with disabilities, and people with chronic illnesses are most affected by heat waves. In addition, from 2004-2018, Indigenous communities had the highest rate of heat-related deaths and Black communities had the second highest.[42] The Committee heard from experts on the topic of extreme heat and environmental justice at a hearing last summer.[43]

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[30] Myhre, G., et al. 2019. "Frequency of extreme precipitation increases extensively with event rareness under global warming." *Scientific Reports.* DOI: https://doi.org/10.1038/s41598-019-52277-4

[31] Davenport, F.V., Burke, M, and Diffenbaugh, N.S. 2021. "Contribution of historical precipitation change to US flood damages." *PNAS*. DOI: https://doi.org/10.1073/pnas.2017524118

[32] https://sealevelrise.org/#:~:text=Although%20the%20sea%20level%20has,flooding%20across%20the%20United%20States.

[33] https://www.epa.gov/climate-indicators/climate-change-indicators-sea-level

[34] https://oceanservice.noaa.gov/facts/high-tide-flooding.html

[35] https://www.nytimes.com/2016/05/03/us/resettling-the-first-american-climate-refugees.html

[36] NCA4, Chapter 4: Sea Level Rise and Implications for Low-Lying Islands, Coasts, and Communities (2018)

[37] Grinsted, A. and Christensen, J.H. 2021. "The transient sensitivity of sea level rise." *Ocean Science.* DOI: https://doi.org/10.5194/os-17-181-2021

[38] https://www.climatesignals.org/events/continental-us-heat-wave-july-2020

[39] Paciorek, C.J., Stone, D.A, and Wehner, M.F. 2018. "Quantifying statistical uncertainty in the attribution of human influence on severe weather." *Weather and Climate Extremes.* DOI: https://doi.org/10.1016/j.wace.2018.01.002

[40] https://www.worldweatherattribution.org/u-s-heat-february-2017/

[41] Diffenbaugh, N.S., et al. 2017. "Quantifying the influence of global warming on unprecedented extreme climate events." *PNAS.* https://doi.org/10.1073/pnas.1618082114

[42] Vaidyanathan A, et al. 2020. "Heat-Related Deaths — United States, 2004–2018." *MMWR Morb Mortal Wkly Rep* 2020;69:729–734. DOI: http://dx.doi.org/10.15585/mmwr.mm6924a1

[43] https://science.house.gov/hearings/sweltering-in-place-covid-19-extreme-heat-and-environmental-justice

Recent Advancements in Climate Science

In recent years, several major consensus-based assessment reports led by the IPCC and U.S. Global Change Research Program (USGCRP) provided major scientific updates to our understanding of climate change, including the Fourth National Climate Assessment (2018)[44] and IPCC Fifth Assessment Report (2014),[45] as well as three IPCC Special Reports on Global Warming of 1.5℃ (2018), the Ocean and Cryosphere in a Changing Climate (2019),[46] and Climate Change and Lands (2019).[47] Since the release of these last major consensus climate change reports, additional peer-reviewed studies have been published that advance our understanding of climate change and suggest an even greater role for climate change in explaining observed extreme events.

One major area of scientific advancement has been in the ability of researchers to confidently link more extreme weather events directly to climate change, known as attribution science. New attribution science methods not only measure whether climate change played a role in the occurrence of an extreme event but can help explain how. Furthermore, research has incorporated econometric techniques to help quantify the economic impacts. For example, a 2020 study estimated that approximately $67 billion worth of damages caused by Hurricane Harvey in 2017 were attributable to human-influenced climate change.[48] More extreme events are being attributed almost entirely to climate change, such as a 2017 marine heat wave off Australia's coast and a 2018 dead heat wave in Japan.[49] Attribution science is also helping shape public understanding of climate change, and shaping policy and litigation dealing with climate change.

Other new research improves our understanding of future predictions and the question of how hot Earth is going to get. A landmark 2020 assessment by a team of 25 scientists significantly narrowed the bounds for how much Earth is going to warm with a doubling of greenhouse gas emissions, called "climate sensitivity."[50] For the past 40 years, climate scientists predicted that the atmosphere will warm between 1.5℃ and 4.5℃, with a doubling of atmospheric carbon dioxide. The assessment found that "it now appears extremely unlikely that the climate sensitivity could be low enough to avoid substantial climate change (well in excess of 2℃ warming) under a high-emission future scenario," with warming now likely between 2.6℃ and 3.9℃.

While our understanding of the climate system is well established, the need to continue advancing our understanding of climate dynamics and impacts has not diminished. Continued improvements to climate observations and refinements to models, as well as interdisciplinary

[44] https://www.globalchange.gov/nca4
[45] https://www.ipcc.ch/report/ar5/syr/
[46] https://www.ipcc.ch/srocc/
[47] https://www.ipcc.ch/srccl/
[48] Frame, D.J., Wehner, M.F., Noy, I. *et al.* 2020. "The economic costs of Hurricane Harvey attributable to climate change." *Climatic Change*. DOI: https://doi.org/10.1007/s10584-020-02692-8
[49] https://slate.com/technology/2019/12/attribution-science-field-explosion-2010s-climate-change.html
[50] Sherwood, S.C., et al. 2020. "An assessment of Earth's climate sensitivity using multiple lines of evidence." Reviews of Geophysics. DOI: https://doi.org/10.1029/2019RG000678

research into societal and economic impacts, will help us better understand and predict future climate impacts and inform mitigation and adaptation solutions.

Upcoming Major Climate Reports

The IPCC's Sixth Assessment Report (AR6), Synthesis Report, and three Special Reports are currently under development, with the Synthesis Report due for release in June 2022.[51] Working Group (WG) I's contribution to the AR6 on the Physical Science Basis is expected in April 2021, WG III's AR6 contribution on Mitigation of Climate Change is expected in July 2021, and WG II's contribution on Impacts, Adaptation, and Vulnerability is expected in October 2021.

The USGCRP's Fifth National Climate Assessment is in the early stages of development and is anticipated to be delivered in 2023.[52]

[51] https://www.ipcc.ch/assessment-report/ar6/
[52] https://www.globalchange.gov/nca5