STATEMENT OF DR. ROGER PIELKE JR.
to the COMMITTEE on the BUDGET
of the UNITED STATES SENATE

HEARING on
Droughts, Dollars, and Decisions: Water Scarcity in a Changing Climate
Dirksen Senate Office Building 608
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"And it never failed that during the dry years the people forgot about the rich years, and during the wet years they lost all memory of the dry years. It was always that way." John Steinbeck, **East of Eden**, 1952

Summary: According to the Intergovernmental Panel on Climate Change (IPCC), human-caused climate change influences the global hydrological cycle in the context of significant natural climate variability. Influences on drought "are mostly related to heat and moisture exchanges, and are also partly modulated by plant coverage and physiology. They affect, for instance, atmospheric humidity, temperature, and radiation, which in turn affect precipitation and/or evapotranspiration in some regions and time frames."[1] However, the IPCC does not express high confidence in the detection or attribution of trends in drought to human influences in any region of the world, including the United States, and does not expect to observe with high confidence for many decades the signal of human-caused climate change in drought metrics. Such fundamental uncertainty has implications for climate mitigation and adaptation, as well as for scientific integrity.

Four Take-Home Points

1. My testimony today focuses on what the IPCC Sixth Assessment Report (AR6) Working Group 1 concluded about the detection and attribution of trends in drought at the global level and for the United States, for three types of drought: meteorological, hydrological, and soil moisture deficits (which the IPCC calls agricultural/ecological drought).
2. At the global scale, the IPCC AR6 has not detected or attributed trends in any of the three types of drought for any region with high confidence (i.e., 8 in 10 chance). For the United States, the IPCC AR6 has only low confidence (i.e., 2 in 10 chance) in detected or attributed trends in all three types of drought for all regions, except Western North America where it has medium confidence (i.e., 5 in 10 chance) in the detection and attribution of trends in agricultural/ecological drought.
3. Looking to 2100, at the global scale the IPCC AR6 does not expect that a signal of trends in drought will emerge in any region with high confidence (i.e., 8 in 10 chance). For the United States, the IPCC AR6 has only low confidence (i.e., 2 in 10 chance) that a signal of trends in drought will emerge from the background of natural variability in all three types of drought for all regions, except Western and Central North America where it has medium confidence (i.e., 5 in 10 chance) in signal emergence for agricultural/ecological drought (and hydrological drought in WNA) at a 2° Celsius temperature increase from an 1850-1900 baseline.
4. To be clear, I emphasize explicitly and unequivocally that human-caused climate change poses significant risks to society and the environment, and that various policy responses in the form of mitigation and adaptation are necessary and make good sense.

[1] IPCC AR6 Working Group 1, Chapter 11, p. 1570

The remainder of my written testimony elaborates on these four take-home points.

1. *My testimony today focuses on what the IPCC Sixth Assessment Report (AR6) Working Group 1 concluded about the detection and attribution of trends in drought at the global level and for the United States, for three types of drought: meteorological, hydrological, and soil moisture deficits (which it calls agricultural/ecological drought).*

The IPCC was established in 1988 by the World Meteorological Organization and United Nations Environment Program "to provide governments at all levels with scientific information that they can use to develop climate policies."[2] Scientific assessment of climate change research is necessary because of the enormous volume of research – according to Google Scholar more than 330,000 papers were published on climate change in 2023 alone.[3] If the IPCC did not exist, we would need to create it.

The IPCC is an institution charged with producing scientific assessments. The organization is comprised of hard-working and intelligent people who reflect a spirit of public service. They are also humans, and the IPCC is of course fallible. The findings and associated expressions of confidence and certainty that the IPCC reports in its assessment reports are snapshots in time and reflect the evolution of understandings.[4] My and my colleagues peer-reviewed research has been cited by all three Working Groups of the IPCC. With respect to the IPCC Working Group 1 assessments of the literature on extreme events in my areas of expertise, with few exceptions, the IPCC has consistently done an overall excellent job accurately reflecting the scientific literature.

The IPCC assesses peer-reviewed literature on climate change across its three Working Groups:

- Working Group I -- The Physical Science Basis
- Working Group II -- Impacts, Adaptation and Vulnerability
- Working Group III -- Mitigation of Climate Change

My testimony today focuses on what IPCC Working Group 1 of AR6 concluded with respect to the *detection* and *attribution* of trends in drought at the global level and for the United States, and its expectations for future detection and attribution.

Under the IPCC framework for detection and attribution, detection is defined as:

> "Detection of change is defined as the process of demonstrating that climate or a system affected by climate has changed in some defined statistical sense, without providing a reason for that change. An identified change is detected in observations if its likelihood of occurrence by chance due to internal variability alone is determined to be small, for example, <10%."

[2] https://www.ipcc.ch/about/

[3] https://scholar.google.com/scholar?q=climate+change&hl=en&as_sdt=0%2C6&as_ylo=2023&as_yhi=2023

[4] Some have used the IPCC assessment reports to try to police expert discourse on climate – suggesting that views at variance to those of the IPCC are illegitimate. Science advances because views are challenged, especially consensus views. There are many excellent scientists whose views are at odds with certain findings of the IPCC, and these views are perfectly legitimate-- including widely-respected scientists such as James Hansen and Judith Curry.

Attribution is defined as:

> "the process of evaluating the relative contributions of multiple causal factors to a change or event with an assessment of confidence."[5]

We know that global average surface temperatures have increased – detection – and that the overwhelming reason for that increase is increasing carbon dioxide from the burning of fossil fuels (among other factors) – attribution – because of IPCC's detection and attribution framework.

Detection and attribution are also fundamental to the IPCC's definition of *climate change*:

> "A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes."[6]

Drought is a more challenging type of extreme to achieve detection and attribution of trends than, say hurricanes or tornadoes, because it can be defined and measured in many different ways in the context of significant natural climate variability. Detecting and attributing trends in drought impacts is even more challenging.[7]

The Fifth U.S. National Climate Assessment (2023) explained,

> "Drought is such a complex phenomenon that it is a challenge to even define what it is: more than 150 different definitions have appeared in the scientific literature."[8]

The IPCC AR6 defines drought as:

[5] https://apps.ipcc.ch/glossary/

[6] Few are aware that the IPCC and UN FCCC utilize different definitions of climate change. These different definitions create challenges for climate policy. See: Pielke Jr, R. A. (2005). Misdefining "climate change": consequences for science and action. *Environmental Science & Policy*, *8*(6), 548-561.

[7] See our early work on the time of emergence for the detection of trends in extreme events and their impacts: Crompton, R. P., Pielke, R. A., & McAneney, K. J. (2011). Emergence timescales for detection of anthropogenic climate change in US tropical cyclone loss data. *Environmental Research Letters*, *6*(1), 014003.

[8] https://nca2023.globalchange.gov/chapter/2/

"periods of time with substantially below-average moisture conditions, usually covering large areas, during which limitations in water availability result in negative impacts for various components of natural systems and economic sectors."[9]

And explains:

". . . drought cannot be characterized using a single universal definition (Lloyd- Hughes, 2014) or directly measured based on a single variable . . ."

IPCC AR6 WG1 Chapter 11 on "Weather and Climate Extreme Events in a Changing Climate" emphasizes three types of drought, and the Chapter specifically (emphasis added),

"assesses changes in ***meteorological drought***, ***agricultural and ecological droughts***, and ***hydrological droughts***. Precipitation-based indices are used for the estimation of changes in ***meteorological droughts***, such as the Standardized Precipitation Index (SPI) and the number of consecutive dry days (CDD). Changes in total soil moisture and soil moisture-based drought events are used for the estimation of changes in ***agricultural and ecological droughts***, complemented by changes in surface soil moisture, water-balance estimates (precipitation minus ET), and SPEI-PM and PDSIPM. For ***hydrological droughts***, changes in low flows are assessed, sometimes complemented by changes in mean streamflow."[10]

The IPCC utilizes specific terminology to express its confidence in its findings:[11]

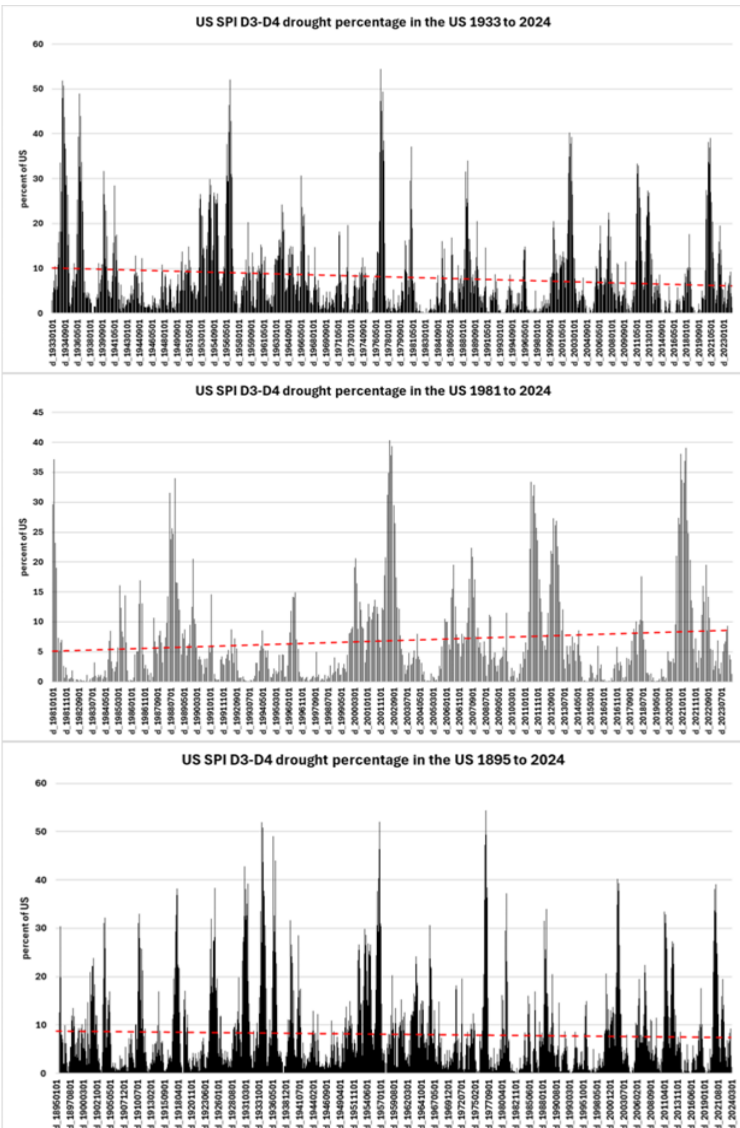
Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

With this context and background, I next turn to what the IPCC AR6 Working Group 1 findings with respect to detection and attribution of drought trends and its current view of the prospects for future detection and attribution.

[9] IPCC AR6 WG1 Chapter 11, p. 1570
[10] IPCC AR6 WG1 Chapter 11, p. 1572
[11] https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html

2. *At the global scale, the IPCC AR6 has not detected or attributed trends in any of the three types of drought for any region with high confidence (i.e., 8 in 10 chance). For the United States, the IPCC AR6 has only low confidence (i.e., 2 in 10 chance) in detected or attributed trends in all three types of drought for all regions, except Western North America where it has medium confidence (i.e., 5 in 10 chance) in the detection and attribution of trends in agricultural/ecological drought.*

The concepts of detection and attribution of often confused in the media and in political settings. Climate varies on all time scales, independent of any human influences. Consequently, trends may be observed in climate variables, but which reflect variability and not a change in climate. Further, the identification of a trend does not answer questions of causation.



For instance, the three graphs displayed to the left show one metric of meteorological drought -- Standardized Precipitation Index, SPI[12] – and displays the combined U.S. areal extent of extreme (D3) and exceptional drought (D4) for three different periods resulting in three different trends: down, up, and flat.

Top: 1933 to 2024, U.S. drought decreased by almost half.

Middle: 1981 to 2024, U.S. drought almost doubled

Bottom: 1895 to 2024, no trend

It would be a mistake to look at any one of these time series and conclude that climate change is making drought less common, more common, or has no effect on drought.

The IPCC considers multiple metrics of observed drought and modeling of drought dynamics in performing its assessment of a vast literature to arrive at its findings and associated levels of confidence in those findings.

[12] These data are from the National Oceanic and Atmospheric Administration: https://www.drought.gov/historical-information

The IPCC AR6 synthesized its assessment of the detection and attribution of trends in drought as follows (italics in original, quantification of expressed confidence in brackets has been added):

> In summary, human influence has contributed to increases in agricultural and ecological droughts in the dry season in some regions due to increases in evapotranspiration (*medium confidence* [5 in 10 chance]). The increases in evapotranspiration have been driven by increases in atmospheric evaporative demand induced by increased temperature, decreased relative humidity and increased net radiation over affected land areas (*high confidence* [8 in 10 chance]). There is *low confidence* [2 in 10 chance] that human influence has affected trends in meteorological droughts in most regions, but *medium confidence* [5 in 10 chance] that they have contributed to the severity of some single events. There is *medium confidence* [5 in 10 chance] that human-induced climate change has contributed to increasing trends in the probability or intensity of recent agricultural and ecological droughts, leading to an increase of the affected land area. Human-induced climate change has contributed to global-scale change in low flow, but human water management and land-use changes are also important drivers (*medium confidence* [5 in 10 chance]).[13]

For most of the contiguous U.S. the IPCC AR6 expressed low confidence (i.e., a 2 in 10 chance) in observed trends in drought or a human contribution, with the exception of soil moisture deficits in Western North America, where it expressed medium confidence (i.e., 5 in 10 chance) of an increase with a human contribution and Central North American where it expressed medium confidence (i.e., 5 in 10 chance) of a decrease in drought, but low confidence (i.e., 2 in 10 chance) and limited evidence for a human contribution. The IPCC's conclusions are summarized in the figure below, from its Table 11.21.

IPCC AR6 Working Group I, Chapter 11

Detection and Attribution of Trends in Drought in North America

OBSERVED TRENDS	Type of drought		
Region	Meteorological	Agricultural/Ecological	Hydrological
Eastern North America	Low confidence	Low confidence	Low cofidence Limited evidence
Central North America	Medium confidence of decrease	Limited Evidence	Low cofidence Limited evidence
Western North America	Low confidence	Medium confidence of increase	Low confidence

HUMAN CONTRIBUTION	Type of drought		
Region	Meteorological	Agricultural/Ecological	Hydrological
Eastern North America	Low cofidence Limited evidence	Low cofidence Limited evidence	Low cofidence Limited evidence
Central North America	Low cofidence Limited evidence	Low cofidence Limited evidence	Low cofidence Limited evidence
Western North America	Low cofidence Limited evidence	Medium confidence	Low confidence

Table 11.21, pp. 17011-1705

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Figure: Top left table summarizes IPCC conclusions for observed trends, bottom left table for a human contribution. The top right image shows AR6 IPCC regions. And the Bottom right table shows IPCC confidence terminology.

[13] IPCC AR6 WG1 Chapter 11, p. 1579

The Fifth U.S. National Climate Assessment (2023) did not adopt the detection and attribution framework of the IPCC.[14] However, the Fourth U.S. National Climate Assessment (2017) did utilize the IPCC detection and attribution framework and concluded of the detection and attribution of trends in drought in the United States:

> **Chapter 3, Detection and Attribution of Climate Change**[15]
> "While by some measures drought has decreased over much of the continental United States in association with long-term increases in precipitation, neither the precipitation increases nor inferred drought decreases have been confidently attributed to anthropogenic forcing."
>
> **Chapter 8, Droughts, Floods, and Wildfire**[16]
> "In summary, there has not yet been a formal identification of a human influence on past changes in United States meteorological drought through the analysis of precipitation trends. Some, but not all, U.S. meteorological drought event attribution studies, largely in the "without detection" class, exhibit a human influence. Attribution of a human influence on past changes in U.S. agricultural drought are limited both by availability of soil moisture observations and a lack of subsurface modeling studies. While a human influence on surface soil moisture trends has been identified with medium confidence, its relevance to agriculture may be exaggerated. . ."

These conclusions are consistent with those of the IPCC AR6 Working Group 1.

As the IPCC has consistently failed to achieve detection and attribution of trends with high confidence in most types of extreme events (the exceptions being extreme temperatures and heavy precipitation), some researchers have offered "event attribution" as an alternative to the IPCC's framework for detection and attribution.[17]

Most such studies are not in the peer-reviewed literature and the IPCC AR6 did not express high confidence in these approaches as related to drought, explaining:

> "As different methodologies, models and data sources have been used for the attribution of precipitation deficits, Angélil et al. (2017) re-examined several events using a single analytical approach and climate model and observational datasets. Their results showed a disagreement in the original anthropogenic attribution in a number of precipitation deficit events, which increased uncertainty in the attribution of meteorological droughts events."[18]

Methodologies of event attribution remained debated in the scientific literature and have yet to replace the IPCC's detection and attribution framework.[19]

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[14] The decision by the US NCA to abandon the IPCC detection and attribution framework is baffling. I have argued that the report "is much more a glossy promotional brochure than anything resembling a careful assessment of the scientific literature on climate change and the United States." See: https://rogerpielkejr.substack.com/p/original-sin
[15] https://science2017.globalchange.gov/chapter/3/
[16] https://science2017.globalchange.gov/chapter/8/
[17] See https://crsreports.congress.gov/product/pdf/R/R47583
[18] IPCC AR6 Working Group 1, Chapter 11, p. 1578
[19] For more discussion, see: https://rogerpielkejr.substack.com/p/how-to-be-a-smart-consumer-of-climate

3. *Looking to 2100, at the global scale the IPCC AR6 does not expect that a signal of trends in drought will emerge in any region with high confidence (i.e., 8 in 10 chance). For the United States, the IPCC AR6 has only low confidence (i.e., 2 in 10 chance) that a signal of trends in drought will emerge from the background of natural variability in all three types of drought for all regions, except Western and Central North America where it has medium confidence (i.e., 5 in 10 chance) in signal emergence for agricultural/ecological drought (and hydrological drought in WNA) at a 2° Celsius temperature increase from an 1850-1900 baseline.*

The IPCC AR6 concludes:

> "[T]here is limited evidence of drought trends emerging above natural variability in the 21st century."[20]

The AR6 further concludes, looking both at observations and projections:

> "There is *low confidence* in the emergence of drought frequency in observations, for any type of drought, in all regions. Even though significant drought trends are observed in several regions with at least *medium confidence* (Sections 11.6 and 12.4), agricultural and ecological drought indices have interannual variability that dominates trends, as can be seen from their time series (*medium confidence*) (H. Guo et al., 2018; Spinoni et al., 2019; Haile et al., 2020; M. Wu et al., 2020). Studies of the emergence of drought with systematic comparisons between trends and variability of indices are lacking, precluding a comprehensive assessment of future drought emergence."[21]

For most of the contiguous U.S. the IPCC AR6 expressed low confidence in projected trends in drought or a human contribution, with the exception of:

- Soil moisture deficits in Central North America, where it expressed medium confidence (i.e., 5 in 10 chance) of an increase under a 1.5° Celsius temperature increase from an 1850-1900 baseline;
- Soil moisture deficits in Western and Central North American where it expressed medium confidence (i.e., 5 in 10 chance) of an increase under a 2° Celsius temperature increase from an 1850-1900 baseline;
- Hydrological drought in Western North America where it expressed medium confidence (i.e., 5 in 10 chance) of an increase under a 2° Celsius temperature increase from an 1850-1900 baseline

The IPCC's conclusions are summarized in the figure below, from its Table 11.21.

[20] IPCC AR6 WG1 Chapter 12, p. 1770
[21] IPCC AR6 WG1 Chapter 12, p. 1855

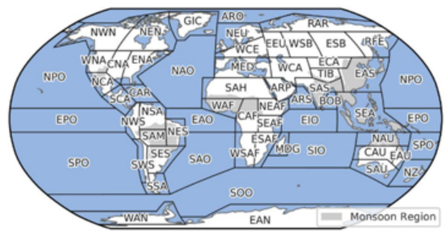
IPCC AR6 Working Group I, Chapter 11

Projections of Changes in Drought in North America at +1.5°C and +2°C

+1.5°C			
	Type of drought		
Region	Meteorological	Agricultural/Ecological	Hydrological
Eastern North America	Low cofidence Limited evidence	Low confidence	Low cofidence Limited evidence
Central North America	Low cofidence Limited evidence	Medium confidence of increase	Low cofidence Limited evidence
Western North America	Low cofidence Limited evidence	Limited evidence	Low cofidence Limited evidence

+2°C			
	Type of drought		
Region	Meteorological	Agricultural/Ecological	Hydrological
Eastern North America	Low cofidence Limited evidence	Low confidence	Low cofidence Limited evidence
Central North America	Low cofidence Limited evidence	Medium confidence of increase	Low cofidence Limited evidence
Western North America	Low cofidence Limited evidence	Medium confidence of increase	Medium confidence of increase

Table 11.21, pp. 1701-1705



Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Figure: Top left table summarizes IPCC conclusions for projections at a 1.5° Celsius temperature increase from an 1850-1900 baseline, bottom left table for projections at a 2° Celsius temperature increase from an 1850-1900 baseline. The top right image shows AR6 IPCC regions. And the Bottom right table shows IPCC confidence terminology.

The IPCC also summarizes its findings for detection, attribution, and future projections in its Table 11.A.2 for four types of extreme: hot extremes (HOT EXT.), heavy precipitation (HEAVY PRECIP), agricultural and ecological droughts (AGR./ECOL. DROUGHTS), and hydrological droughts (HYDR. DROUGHT).

The potion of the table summarizing results for Wester, Central, and Eastern North America is shown below.

Table 11.A.2 | Synthesis table summarising assessments presented in Tables 11.4-11.21 for hot extremes (HOT EXT.), heavy precipitation (HEAVY PRECIP.), agriculture and ecological droughts (AGR./ECOL. DROUGHT), and hydrological droughts (HYDR. DROUGHT). It shows the direction of change and level of confidence in the observed trends (column OBS.), human contribution to observed trends (ATTR.), and projected changes at 1.5°C, 2°C and 4°C of global warming for each AR6 region. Projections are shown for two different baseline periods: 1850–1900 (pre-industrial) and 1995–2014 (modern or recent past) – see Section 1.4.1 for more details. Direction of change is represented by an upward arrow (increase) and a downward arrow (decrease). Level of confidence is reported for LOW: *low*, MED.: *medium*, HIGH: *high*; levels of likelihood (only in cases of *high confidence*) include: L: *likely*, VL: *very likely*, EL: *extremely likely*, VC: *virtual certain*. See Section 11.9, Tables 11.4–11.21 for details. Dark orange shading highlights *high confidence* (also including *likely*, *very likely*, *extremely likely* and *virtually certain* changes) increases in hot temperature extremes, agricultural and ecological drought, or hydrological droughts. Yellow indicates *medium confidence* increases in these extremes, and blue shadings indicate decreases in these extremes. *High confidence* increases in heavy precipitation are highlighted in dark blue, while *medium confidence* increases are highlighted in light blue. No assessment for changes in drought with respect to the 1995–2014 baseline is provided, which is why the respective cells are empty.

Sub-region		OBS.	ATTR.	1.5°C	2°C	4°C	1.5°C	2°C	4°C
				BASELINE: PRE-INDUSTRIAL			BASELINE: 1995–2014		
W.North-America WNA	HOT EXT.	↑ L.	↑ MED.	↑ V.L.	↑ E.L.	↑ V.C.	↑ L.	↑ V.L.	↑ V.C.
	HEAVY PRECIP.	LOW	LOW	↑ MED.	↑ HIGH	↑ V.L.	LOW	↑ MED.	↑ L.
	AGR./ECOL. DROUGHT	↑ MED.	↑ MED.	LOW	↑ MED.	↑ MED.			
	HYDR. DROUGHT	LOW	LOW	LOW	↑ MED.	↑ MED.			
C.North-America CNA	HOT EXT.	LOW	LOW	↑ V.L.	↑ E.L.	↑ V.C.	↑ L.	↑ V.L.	↑ V.C.
	HEAVY PRECIP.	↑ HIGH	↑ MED.	↑ HIGH	↑ L.	↑ E.L.	↑ MED.	↑ HIGH	↑ V.L.
	AGR./ECOL. DROUGHT	LOW	LOW	↑ MED.	↑ MED.	↑ HIGH			
	HYDR. DROUGHT	LOW	LOW	LOW	LOW	LOW			
E.North-America ENA	HOT EXT.	LOW	LOW	↑ V.L.	↑ E.L.	↑ V.C.	↑ L.	↑ V.L.	↑ V.C.
	HEAVY PRECIP.	↑ HIGH	LOW	↑ HIGH	↑ L.	↑ E.L.	↑ MED.	↑ HIGH	↑ V.L.
	AGR./ECOL. DROUGHT	LOW	LOW	LOW	LOW	↑ MED.			
	HYDR. DROUGHT	LOW	LOW	LOW	LOW	LOW			

Confidence levels for changes in hot temperature extremes, agricultural and ecological drought, or hydrological droughts

High confidence (including *likely*, *very likely*, *extremely likely* and *virtually certain* changes) increases — *Medium confidence* increases

Confidence levels for changes in heavy precipitation — *Low confidence*

High confidence (including *likely*, *very likely*, *extremely likely* and *virtually certain* changes) decreases — *Medium confidence* decreases

Apart from hot extremes and heavy precipitation, the IPCC AR6 has low confidence (i.e., a 2 in 10 chance) in the detection (OBS) and attribution (ATTR.) of trends in drought (except agricultural and ecological drought in WNA with medium confidence (i.e., a 5 in 10 chance).

Note that the IPCC determined that expressing any level of confidence was appropriate in projected trends in drought at all future warming levels above a 1995 to 2014 baseline. To place the future temperature levels above a 1995 to 2014 baseline into context, they are about 1° Celsius above the values of the pre-industrial baseline.[22] For instance, 1.5° Celsius above a 1995 to 2014 baseline is about the same as 2.5° Celsius above a pre-industrial baseline and 2° Celsius above a 1995 to 2014 baseline is about the same as 3° Celsius above a pre-industrial baseline.

Under a "current policies" approach, the U.N FCCC concluded in 2023 the world is presently on track for a temperature increase in 2100 "in the range of 2.1–2.8 °C [above a pre-industrial baseline] depending on the underlying assumptions."[23]

[22] The different baselines are discussed in IPCC AR6 Working Group 1 Chapter 1, Section 1.4.1.
[23] https://unfccc.int/ndc-synthesis-report-2023 This is consistent with our research as well: Pielke Jr, R., Burgess, M. G., & Ritchie, J. (2022). Plausible 2005-2050 emissions scenarios project between 2 and 3 degrees C of warming by 2100. *Environmental Research Letters*.

Under currently expected global temperature changes to 2100, as shown above in the excerpt from Table 11.A.2 the IPCC does express at any confidence level how drought may change across U.S. regions as compared to the recent past (i.e., 1995 to 2014).

The IPCC further underscores this conclusion in its AR6 Working Group 1 Table 12.12, shown in full below. Note that for drought, signal emergence does not occur to 2100, even under the extreme and implausible RCP8.5 scenario.[24]

Climatic Impact-driver Type	Climatic Impact-driver Category	Already Emerged in Historical Period	Emerging by 2050 at Least for RCP8.5/SSP5-8.5	Emerging Between 2050 and 2100 for at Least RC8.5/SSP5-8.5
Heat and Cold	Mean air temperature	1		
	Extreme heat	2	3	
	Cold spell	4	5	
	Frost			
Wet and Dry	Mean precipitation		6 7	
	River flood			
	Heavy precipitation and pluvial flood			8
	Landslide			
	Aridity			
	Hydrological drought			
	Agricultural and ecological drought			
	Fire weather			
Wind	Mean wind speed			
	Severe wind storm			
	Tropical cyclone			
	Sand and dust storm			
Snow and Ice	Snow, glacier and ice sheet		9	10
	Permafrost			
	Lake, river and sea ice	11		
	Heavy snowfall and ice storm			
	Hail			
	Snow avalanche			
Coastal	Relative sea level		12	
	Coastal flood			
	Coastal erosion			
Open Ocean	Mean ocean temperature			
	Marine heatwave			
	Ocean acidity			
	Ocean salinity	13		
	Dissolved oxygen	14		

Table 12.12 | Emergence of CIDs [Climate Impact Drivers] in different time periods, as assessed in this section. The colour corresponds to the confidence of the region with the highest confidence: white cells indicate where evidence is lacking or the signal is not present, leading to overall low confidence of an emerging signal.

[24] On the implausibility of RCP8.5 see: Ritchie, J., & Dowlatabadi, H. (2017). Why do climate change scenarios return to coal?. *Energy*, *140*, 1276-1291, Pielke Jr, R., Burgess, M. G., & Ritchie, J. (2022). Plausible 2005-2050 emissions scenarios project between 2 and 3 degrees C of warming by 2100. *Environmental Research Letters,* and Burgess, M. G., Ritchie, J., Shapland, J., & Pielke, R. (2020). IPCC baseline scenarios have over-projected CO2 emissions and economic growth. *Environmental Research Letters*, *16*(1), 014016.

4. *To be clear, I emphasize explicitly and unequivocally that human-caused climate change poses significant risks to society and the environment, and that various policy responses in the form of mitigation and adaptation are necessary and make good sense.*

The IPCC has for more than 35 years through its Working Group 1 provided routine assessments of the physical science aspects of climate change.[25] The IPCC recently initiated its 7th assessment cycle. These assessments have documented consistently that changes in climate have been detected and attributed to human causes, notably the emission of carbon dioxide and other greenhouse gases, and that these changes pose risks to society and the environment.

My views on the importance of climate policy have been similarly consistent for almost three decades of research and writing. My 1994 PhD dissertation was on how the U.S. federal government might structure scientific research under the U.S. Global Change Research Program to most effective contribute to the development of climate mitigation and adaptation policies.[26]

I have also long supported the work of the IPCC. For instance, in 2006 I testified before the House of Representatives on the significance of the finding of the then-current IPCC assessment:

> ". . . on this basis alone I am personally convinced that it makes sense to take action to limit greenhouse gas emissions. Of course, the answer to what action is not at all straightforward. It involves questions of on what time scales, at what cost, with what consequences, with what foregone opportunities, and what mix of adaptation and mitigation."[27]

Making sense of such complexities is one reason why the provision of expert advice to Congress, the administration, and the federal agencies is so important.

Climate science is indeed complex and nuanced. It is essential that institutions such as the IPCC implement strong institutional practices that eliminate the possibility of advocacy capture and maintain the ability to accurately represent the evolving scientific literature on climate.

For a deeper elaboration of my views on the science and policy of climate, please see my book **The Climate Fix** (2010). Nothing in this testimony should be interpreted as downplaying the importance of climate change or policy responses to it.

In fact, the issue of climate change is so important that we should expect nothing less than the absolute highest standards of scientific integrity in research and the information being provided to policymakers.

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[25] https://www.ipcc.ch/

[26] Pielke Jr, R. A. (1995). Usable information for policy: an appraisal of the US Global Change Research Program. *Policy Sciences*, *28*(1), 39-77.

[27] https://www.govinfo.gov/content/pkg/CHRG-109hhrg29932/html/CHRG-109hhrg29932.htm

Biography of Roger Pielke Jr.

Roger Pielke, Jr. is concurrently a Nonresident Senior Fellow at the American Enterprise Institute and a professor at the University of Colorado Boulder. Roger has been on the faculty of the University of Colorado Boulder since 2001, where he is currently a professor in the College of Arts and Sciences. Roger teaches and writes on a diverse range of policy and governance issues related to science, technology, environment, energy, climate, innovation, and sports.

In 2024, Roger was elected to membership in the Norwegian Academy of Sciences and Letters. Roger is also an Honorary Professor at University College London, awarded in 2022.

Roger also oversees a popular Substack —***The Honest Broker*** — where he is experimenting with a new approach to research, writing and public engagement. The Honest Broker has more than 22,000 subscribers in all 50 states and in 150 countries. Roger is frequently called upon by governments businesses, universities, sport governance organizations and others around the world as a speaker and policy advisor. His research at the intersection of science, policy, and politics is widely cited in multiple fields. Roger's most recent NSF grant focused on science advice in the COVID-19 pandemic across the world.

Roger holds degrees in mathematics, public policy, and political science, all from the University of Colorado Boulder. In 2012, Roger was awarded an honorary doctorate from Linköping University in Sweden and was also awarded the Public Service Award of the Geological Society of America. In 2006, Roger received the Eduard Brückner Prize in Munich, Germany in 2006 for outstanding achievement in interdisciplinary climate research.

Roger has been a Distinguished Fellow of the *Institute of Energy Economics, Japan* since 2016 and a Research Associate of *Risk Frontiers*, in Sydney, Australia, since 2017. Roger was a Fellow of the NOAA/CU Cooperative Institute for Research in Environmental Sciences from 2001 to 2016. He served as a Senior Fellow of *The Breakthrough Institute* from 2008 to 2018. In 2007, Roger served as a James Martin Fellow at Oxford University's Said Business School. Before joining the faculty of the University of Colorado, from 1993 to 2001 Roger was a Scientist at the National Center for Atmospheric Research.

At the University of Colorado Boulder, Roger founded and directed the Center for Science and Technology Policy Research (2002-2020) and the Sports Governance Center (2016-2019). He also created and led the university's Graduate Certificate Program in Science and Technology Policy (2003-2020), which has seen its graduates move on to faculty positions, Congressional staff, the White House, presidential political appointees and in positions in business and civil society. Roger also led the development of the University of Colorado Boulder's graduate program in Environmental Studies that was focused on environmental policy (2002 to 2015).

His books include *Hurricanes: Their Nature and Impacts on Society* (with R. Pielke Sr., 1997, John Wiley), *Prediction: Science, Decision Making and the Future of Nature* (with D. Sarewitz and R. Byerly, 2001, Island Press), *The Honest Broker: Making Sense of Science in Policy and Politics* published by Cambridge University Press (2007), *The Climate Fix: What Scientists and Politicians Won't Tell you About Global Warming* (2010, Basic Books). *Presidential Science Advisors: Reflections on Science, Policy and Politics* (with R. Klein, 2011, Springer), and *The Edge: The War Against Cheating and Corruption in the Cutthroat World of Elite Sports* (Roaring Forties Press, 2016). His most recent book is *The Rightful Place of Science: Disasters and Climate Change* (2nd edition, 2018, Consortium for Science, Policy & Outcomes).