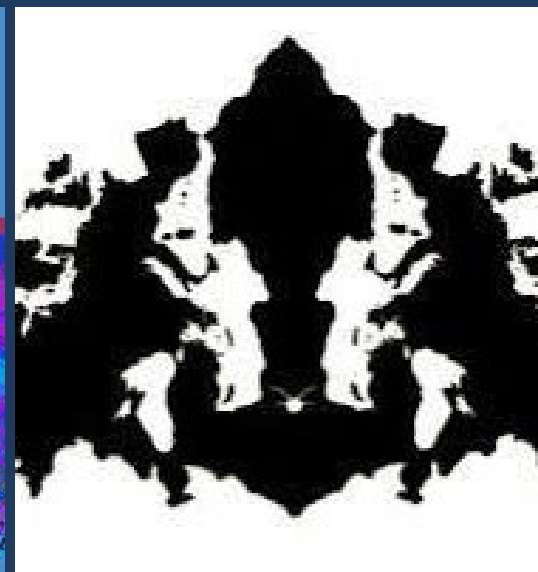
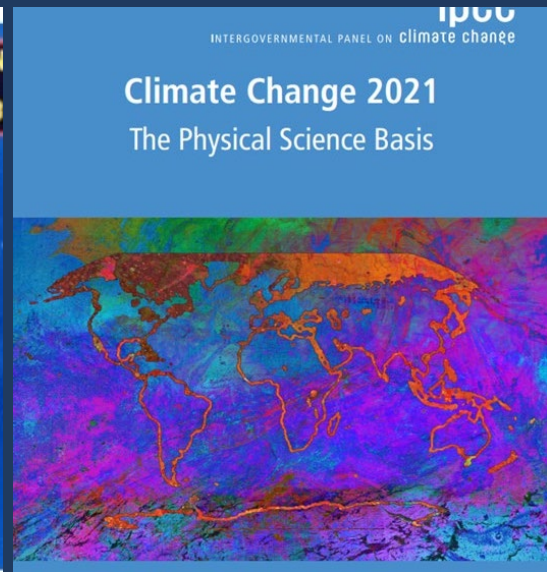




THB

What Climate Science Actually Says About Extreme Weather

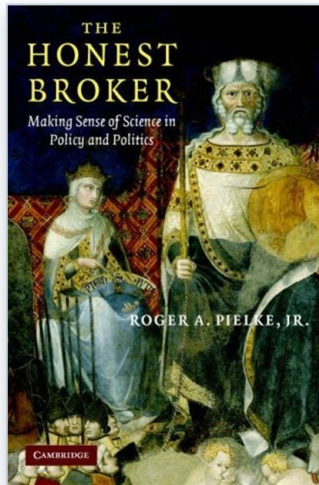


Roger Pielke Jr.

Senior Fellow, American Enterprise Institute
Professor Emeritus, University of Colorado Boulder
The Honest Broker

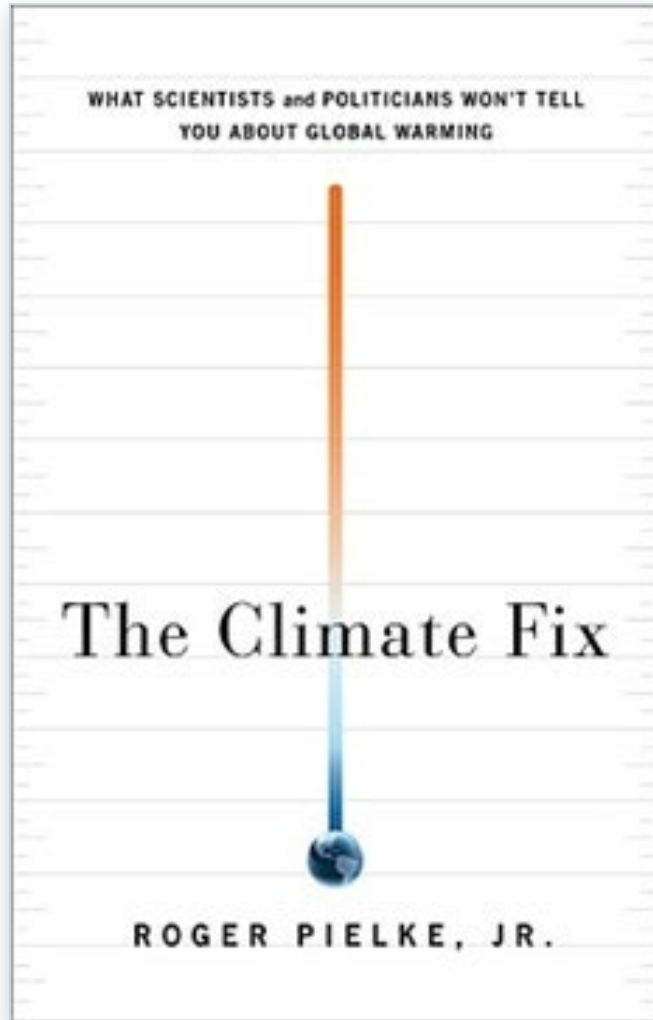
11 October 2026

Background



- Senior Fellow at the American Enterprise Institute (2025–), professor emeritus at the University of Colorado Boulder (2001–), and before that a staff scientist at the US National Center for Atmospheric Research (1993–2001)
- I study and write on contested science, often in highly politicized contexts
- PhD dissertation (1994): how to structure climate science to best support climate policy
- Work cited in all three Working Groups of the IPCC AR6
- Published widely on tropical cyclones, floods, wildfire, and other extreme events
- Testified before the US Congress many times
- I do my work in public and invite discussion and debate on important issues — see *The Honest Broker* on Substack
- **Scientific integrity: always the top priority**

Before diving in ... let's make this clear



Climate change:

- **Real**
- **Serious**
- **Deserving of serious attention to both mitigation and adaptation policies**

My views are in The Climate Fix

**For a deeper dive:
IPCC Working Group I**

The human influence on the climate system is well established and goes beyond just carbon dioxide, but carbon dioxide emissions from the burning of fossil fuels are a primary driver of changes in climate

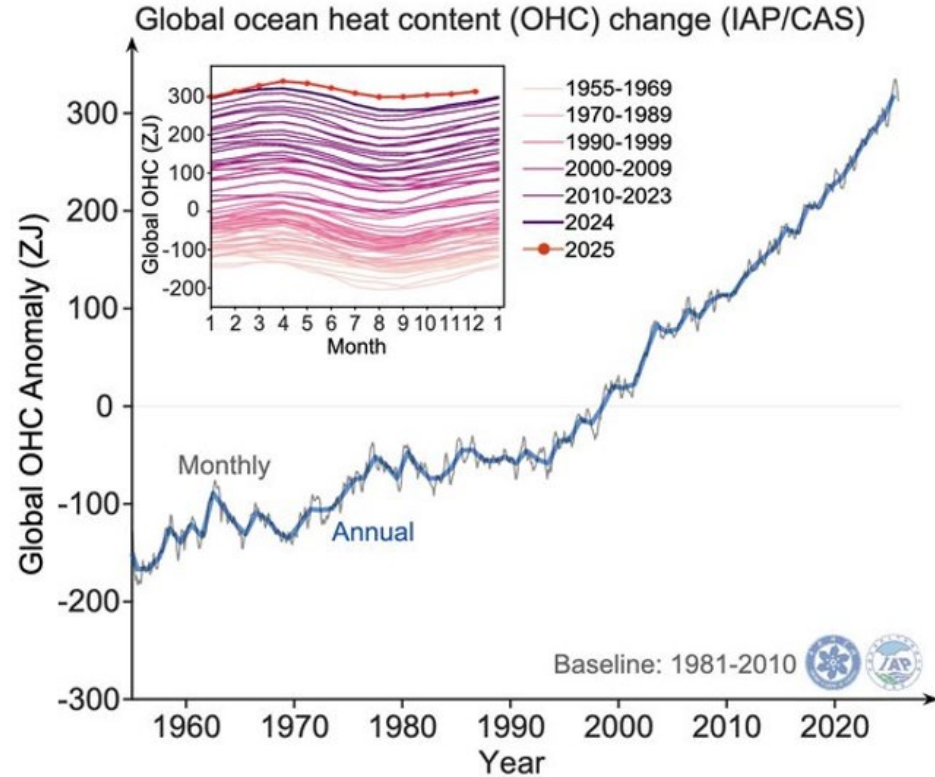


Fig. 2. Global upper 2000 m OHC changes from 1955 through 2025 (units: ZJ). The thick lines denote the annual values, while the thin lines represent the monthly values. The OHC anomalies are relative to the 1981–2010 baseline. The inner box shows the intra-annual variation of OHC, with 2025 values highlighted in red.

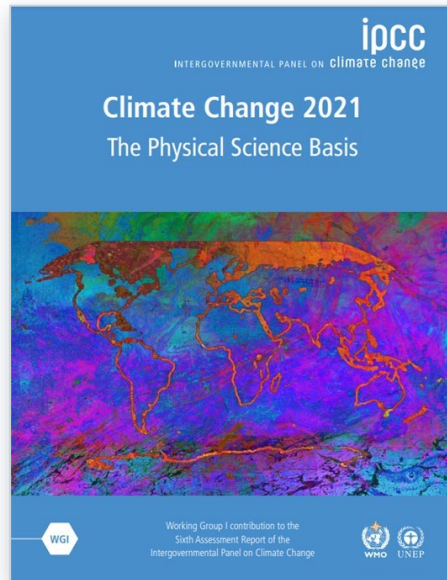
The debate to have is not about existence, but about risk, magnitude, and priorities.

My talk today has 2 goals:

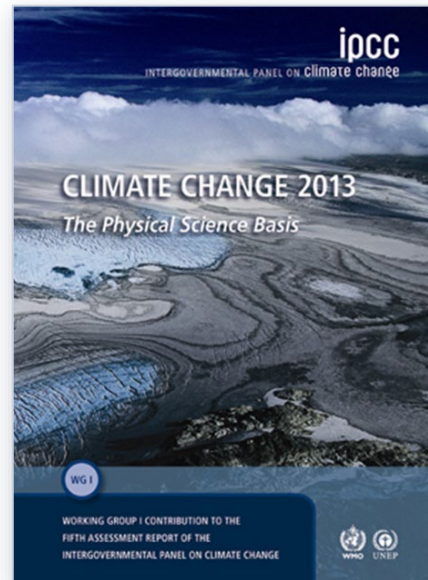
- To share some of my experiences in the climate discussion as an academic
- To provide the latest mainstream, consensus scientific understandings of extreme weather and climate

A note on references

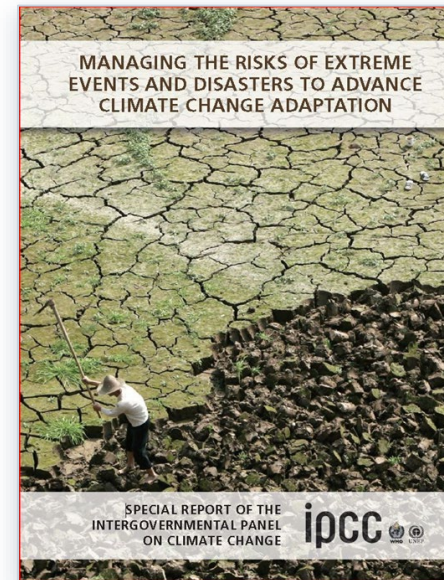
- IPCC = Intergovernmental Panel on Climate Change
- IPCC AR5 = 5th Assessment Report (2013/14); IPCC AR6 = 6th Assessment Report (2021); AR7 in preparation
- IPCC SREX = Special Report on Extreme Events (2012)
- US NCA = US National Climate Assessment (2017 science report; NCA5 in 2023)



IPCC AR6



IPCC AR5

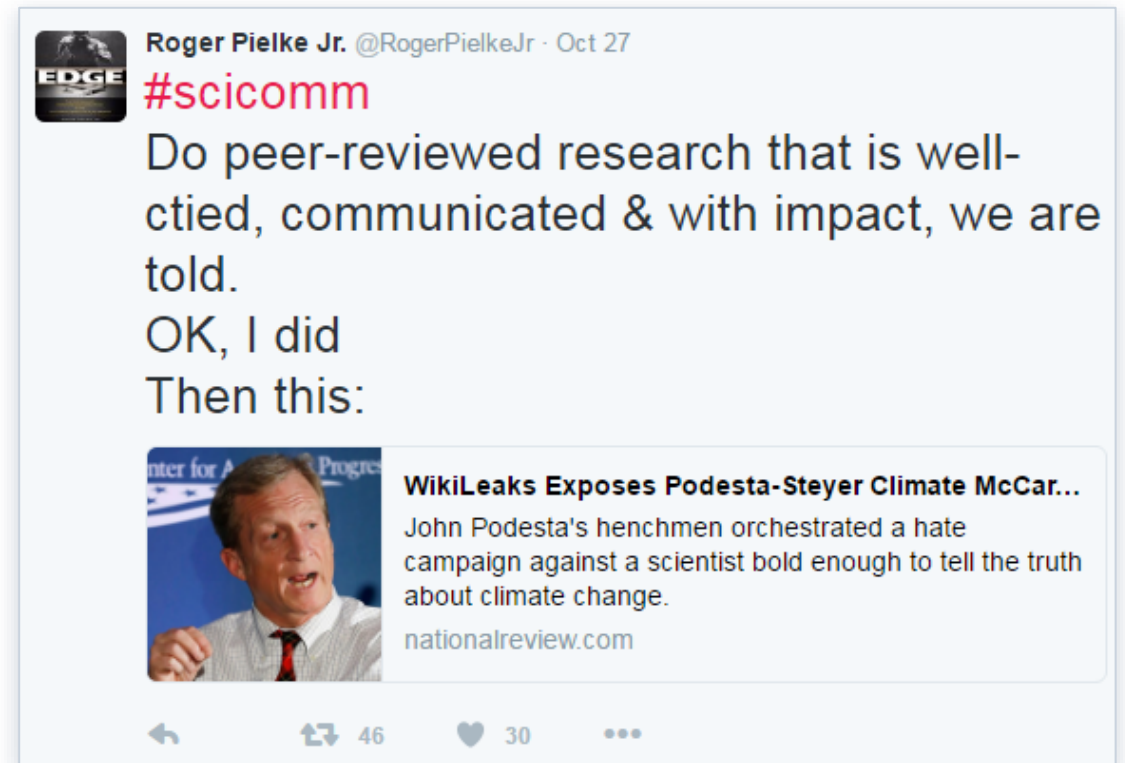


IPCC SREX



US NCA

“You are in the Wikileaks release today” — October 2016



A campaign funded by a billionaire to get me fired



“I think it’s fair say that, without Climate Progress, Pielke would still be writing on climate change for 538”

Email from Center for American Progress editor to billionaire donor Tom Steyer and John Podesta, after getting me fired from Nate Silver’s FiveThirtyEight



FiveThirtyEight



Roger Pielke Jr. · The Honest Broker

Work in Progress

Daily Camera
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HOT TOPICS: L'Atelier moving to Denver Palo Parkway housing Pearl Street bank ban Editorial: MacInty

SWEETHEART DANCE • NORTH BOULDER RECREATION CENTER

Home Top Stories **Story**

WikiLeaks exposes liberal group's efforts to thwart climate writings of CU's Roger Pielke Jr.

Email from 2014 is part of leak of John Podesta emails

By Sarah Kuta
Staff Writer

POSTED: 10/26/2016 06:19:33 PM MDT | UPDATED: 3 MONTHS AGO

A University of Colorado professor who's been criticized for his writings about climate change has been caught up in WikiLeaks' dump of emails involving John Podesta, campaign chairman for Hillary Clinton.

Roger Pielke Jr., who has been a faculty member on the Boulder campus since 2001, was the subject of a July 2014 email about an essay he wrote on climate change for the website FiveThirtyEight.

Pielke writes a regular column about sports governance for the Daily Camera.

The email was sent by Judd Legum, the editor of ThinkProgress, a site that's part of the Center for American Progress Action Fund, the advocacy arm of the liberal think tank Center for American



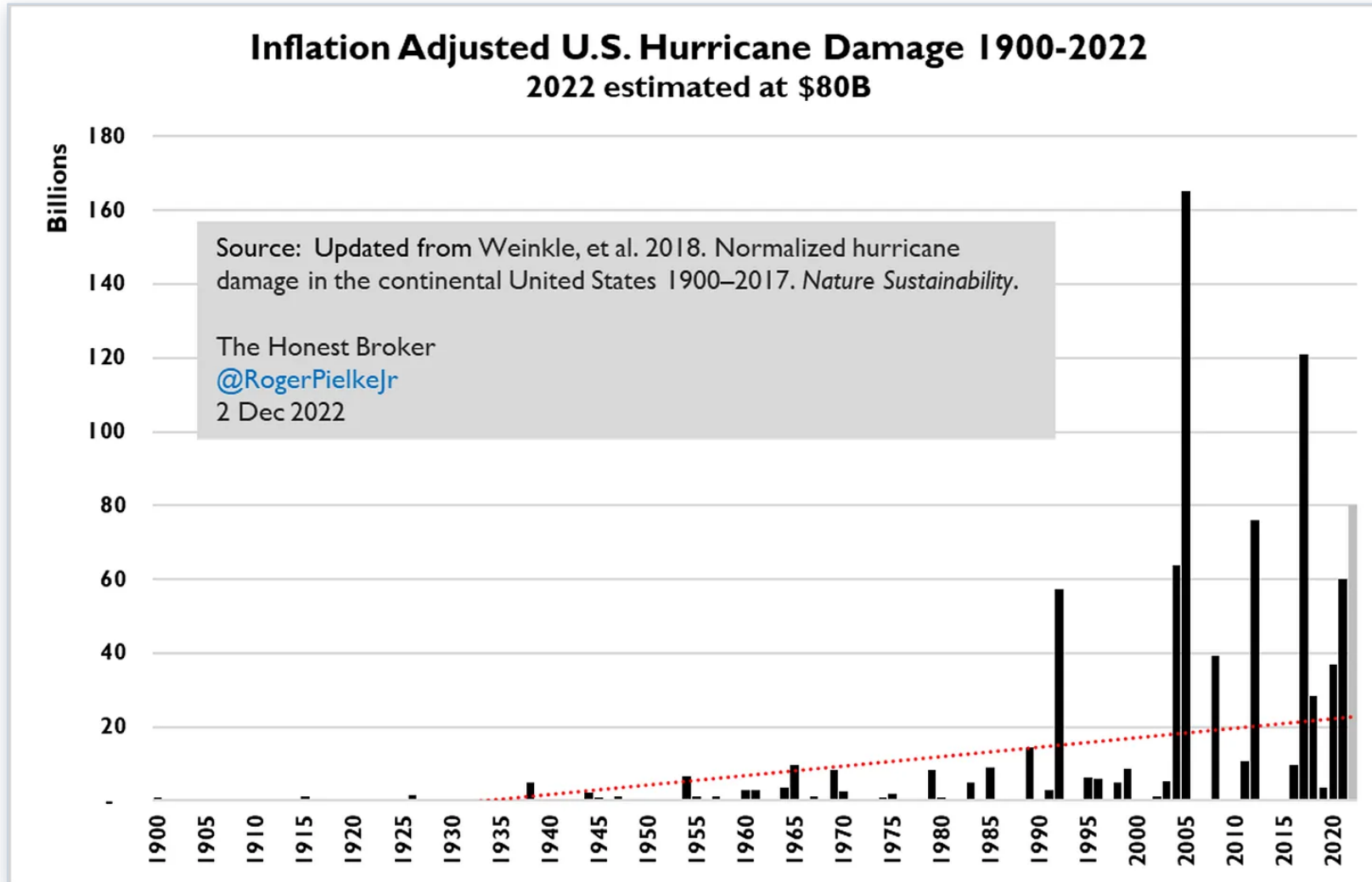
Roger Pielke Jr. (Courtesy photo)

Let's go back to the start ... ~1995

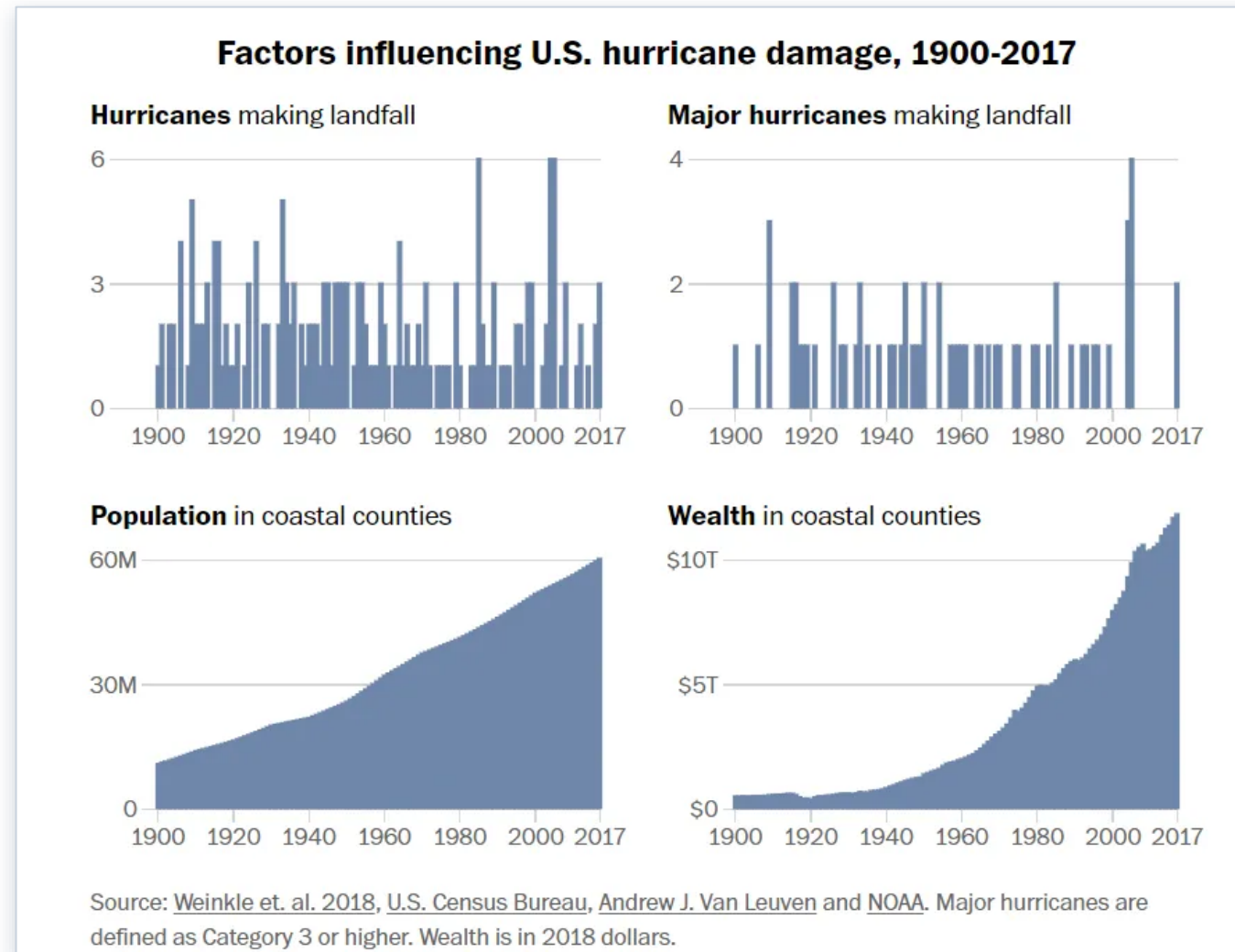


Chris Landsea, left, on board a NOAA Hurricane Hunter in the early 2000s.
Roger Pielke Jr. at the National Center for Atmospheric Research in the mid-1990s.
(Courtesy of Chris Landsea and Roger Pielke)

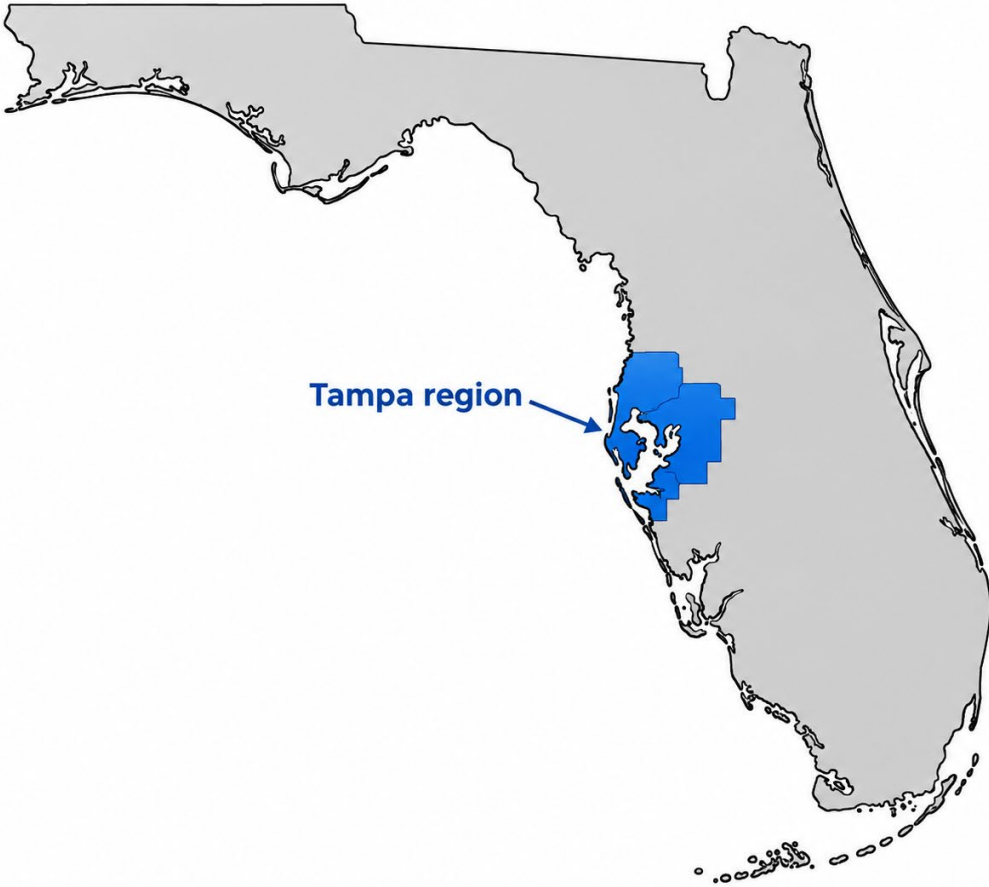
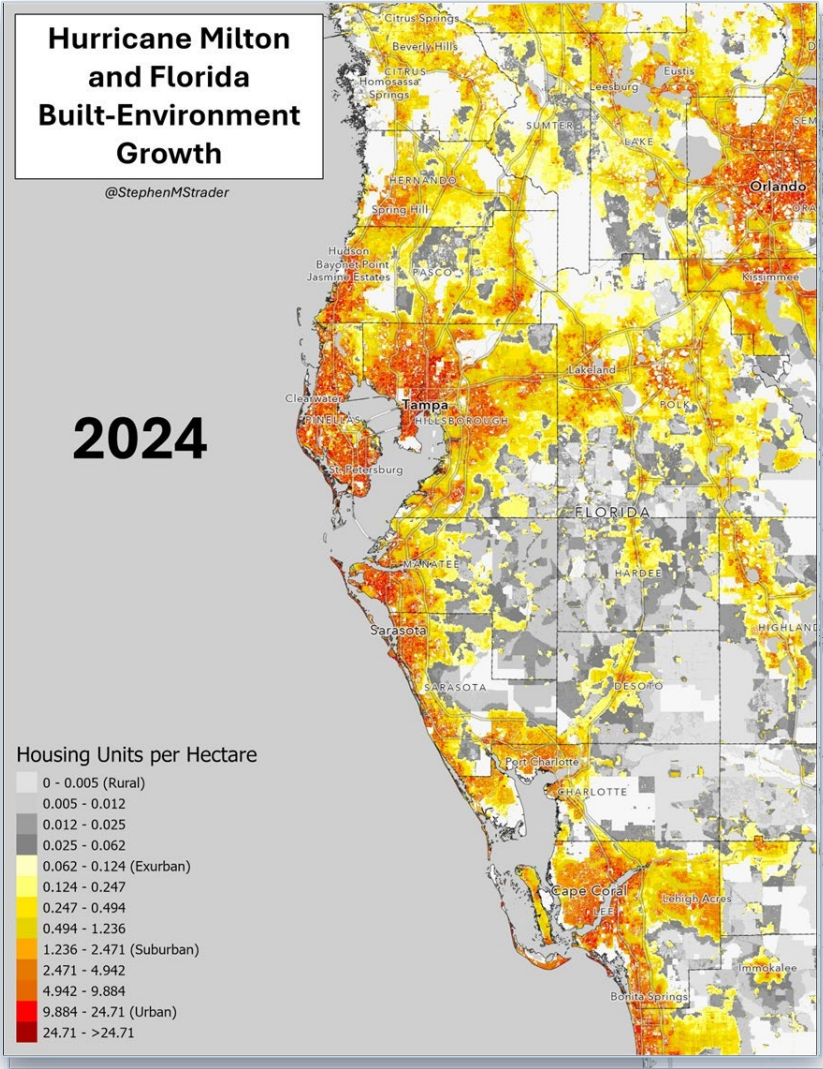
Inflation-adjusted US hurricane damage, 1900–2022



Factors influencing US hurricane damage, 1900–2017



Florida built-environment growth, 1940–2024



Images via Prof. Stephen M. Strader, Villanova University (@StephenStrader)

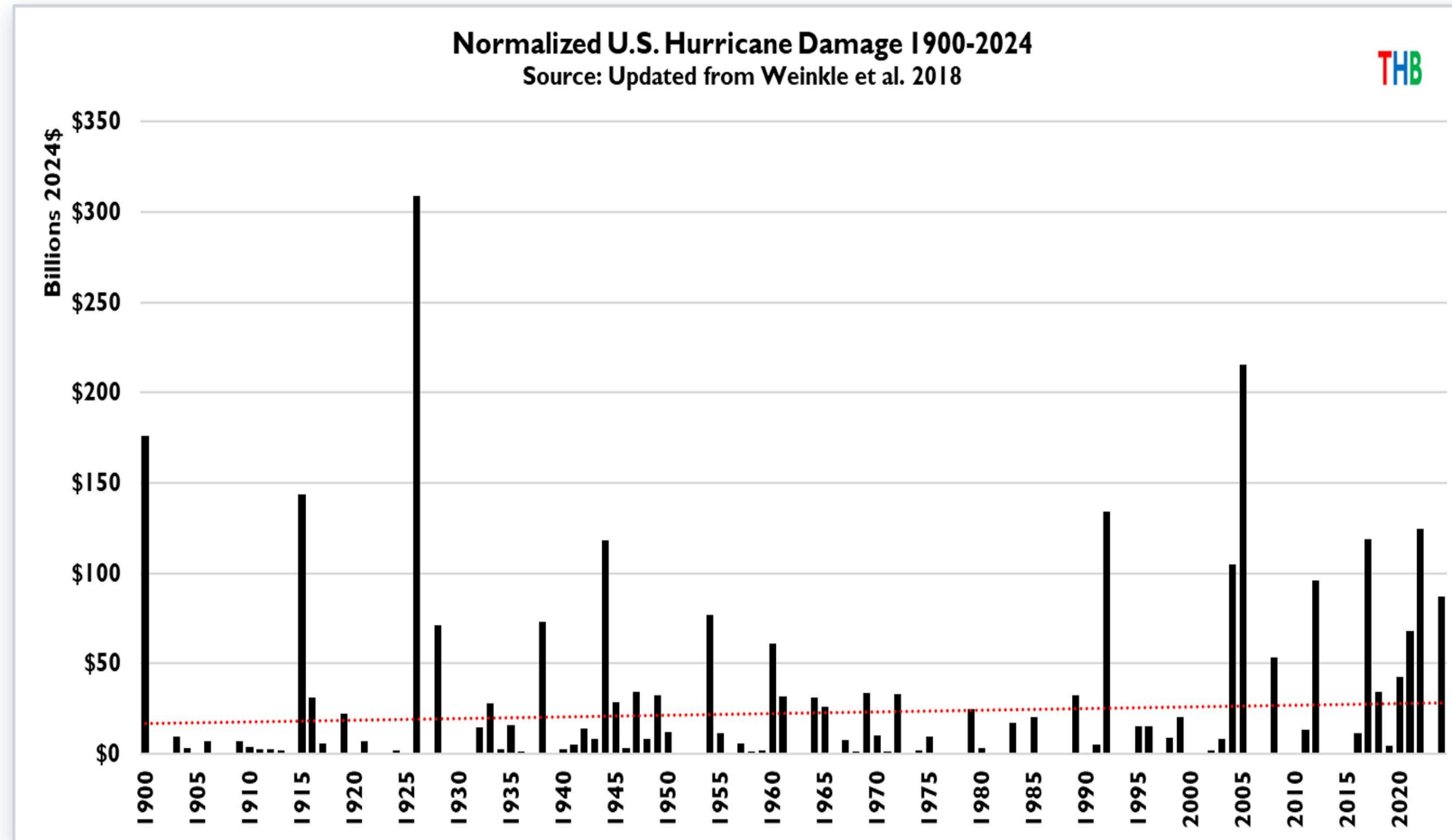
Miami Beach, 1926 and 2022



Normalized US hurricane damage, 1900–2024:

What if every past hurricane season happened in 2024?

How much damage would result?



nature
sustainability

ANALYSIS

<https://doi.org/10.1038/s41893-018-0165-2>

Normalized hurricane damage in the continental United States 1900–2017

Jessica Weinkle¹, Chris Landsea², Douglas Collins³, Rade Musulin⁴, Ryan P. Crompton⁵, Philip J. Klotzbach⁶ and Roger Pielke Jr.^{7*}

Direct economic losses result when a hurricane encounters an exposed, vulnerable society. A normalization estimates direct economic losses from a historical extreme event if that same event was to occur under contemporary societal conditions. Under the global indicator framework of United Nations Sustainable Development Goals, the reduction of direct economic losses as a proportion of total economic activity is identified as a key indicator of progress in the mitigation of disaster impacts. Understanding loss trends in the context of development can therefore aid in assessing sustainable development. This analysis provides a major update to the leading dataset on normalized US hurricane losses in the continental United States from 1900 to 2017. Over this period, 197 hurricanes resulted in 206 landfalls with about US\$2 trillion in normalized (2018) damage, or just under US\$17 billion annually. Consistent with observed trends in the frequency and intensity of hurricane landfalls along the continental United States since 1900, the updated normalized loss estimates also show no trend. A more detailed comparison of trends in hurricanes and normalized losses over various periods in the twentieth century to 2017 demonstrates a very high degree of consistency.

Landfalling hurricanes in the continental United States (CONUS) are responsible for more than two-thirds of total global catastrophe losses since 1980, according to data from Munich Re, a global reinsurance company, which are consistent with the academic literature on disaster loss trends and the assessments of the Intergovernmental Panel on Climate Change (IPCC). The management of economic risks associated with hurricanes largely relies on 'catastrophe models', which estimate losses from modelled storms in the context of contemporary data on exposure and vulnerability^{1,2}. As a complement to such model-based approaches, an empirical approach to hurricane loss estimation called normalization was first published in 1998, and then updated and extended in 2008³. A normalization estimates direct economic losses (damage) from an historical extreme event were it to occur under contemporary societal conditions. Normalization methodologies are widely employed for tropical cyclones, floods, tornadoes, fires, earthquakes and other phenomena in locations around the world⁴. The United Nations global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development have identified direct economic losses from disasters in the context of economic growth as a key indicator⁵. With respect to weather disasters, according to the IPCC, disentangling the relative roles of variability and changes in climate from changes in vulnerability and exposure could contribute information useful to sustainable development⁶. Future changes in the climatology of tropical cyclones (called hurricanes in the North Atlantic) are highly uncertain⁷. However, research is robust in concluding that, for many decades into the future, the primary driver behind increasing economic losses related to hurricanes is expected to be societal growth^{8,9}.

In this analysis we provide a comprehensive update of the leading dataset on normalized CONUS hurricane losses for the period 1900–2017. Earlier versions of this dataset (1925–1995³ and 1900–2005¹)

have been widely used in insurance and reinsurance industry analyses¹⁰, as well as in subsequent research and in policy settings. Our analysis provides a substantial advance on this earlier work. Specifically, we (1) extend the dataset by 12 years, through the 2017 Atlantic hurricane season, (2) introduce loss estimates for dozens of historical storms of the early twentieth century that previously lacked damage estimates (and thus did not appear in earlier datasets), (3) address methodological discontinuities newly introduced in US government hurricane loss records and (4) perform updated consistency checks of normalization results with independent data on the long-term climatology of landfalling CONUS hurricanes.

Results

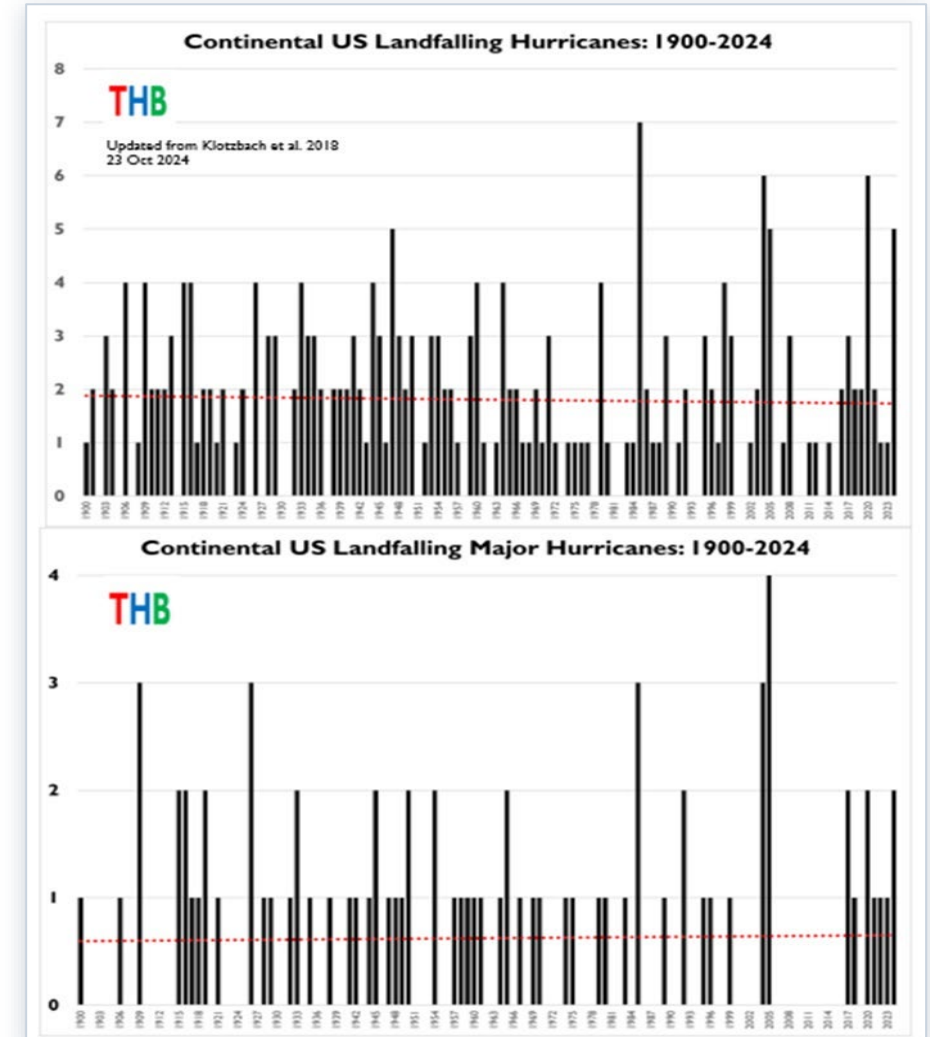
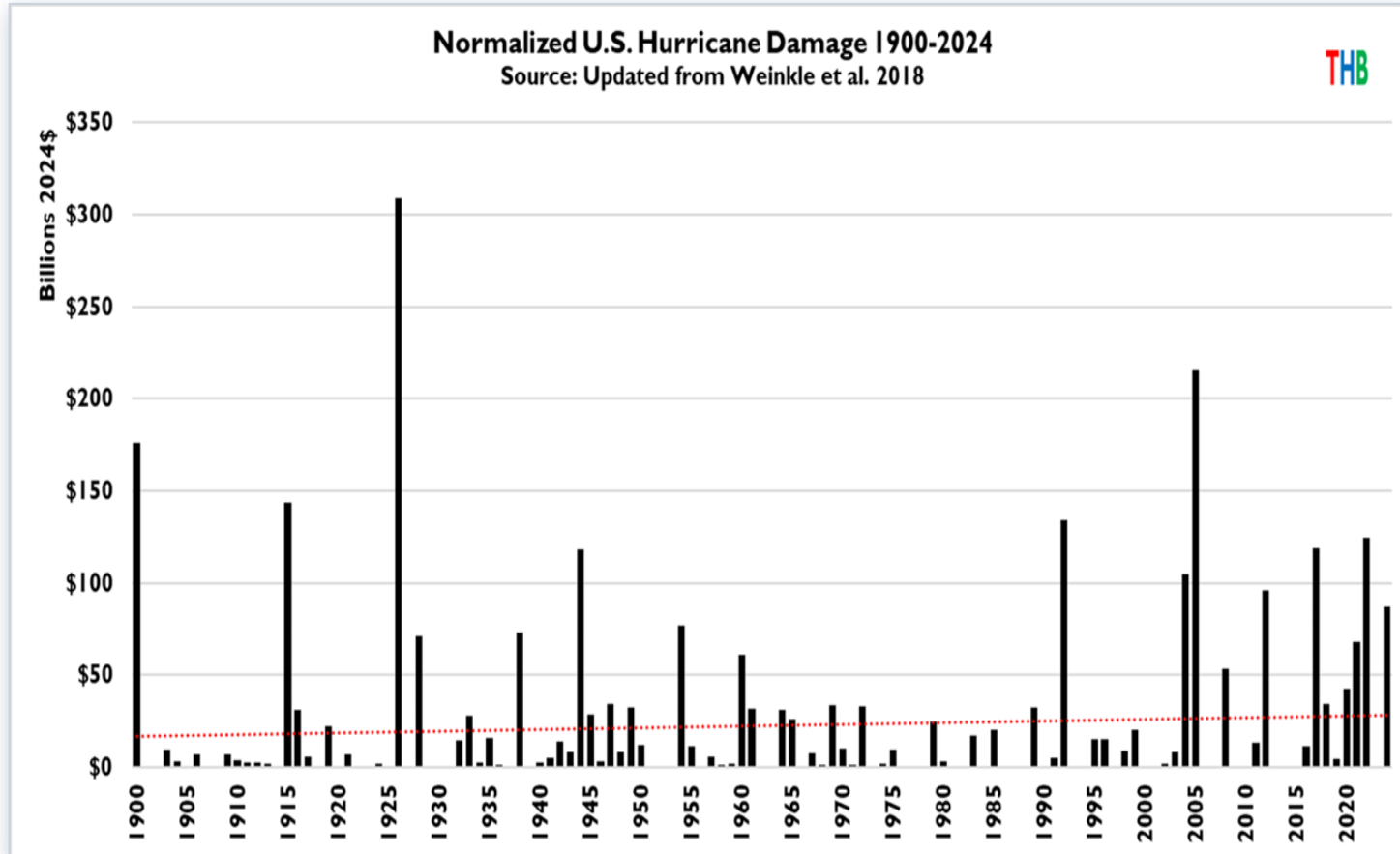
Figure 1 shows normalized hurricane damage in the period 1900–2017 for the Pielke Landsea 2018 (PL18) and Collins Lowe 2018 (CL18) methodologies. Total normalized losses over the 118-year study period are about US\$2 trillion under either method or an average of US\$16.7 billion per year. The figure also shows a trailing 11-year average, indicating that losses on a decadal scale were larger in the earlier part of the twentieth century, lower in the 1970s and 1980s, and then higher again in the first decades of the twenty-first century. Over the entire dataset there is no significant trend in normalized losses, CONUS hurricane landfalls or CONUS intense hurricane landfalls (discussed in greater detail in the Supplementary Information).

The greatest annual normalized damage occurred in 1926 (US\$244 billion, PL18), exceeding the next greatest loss year (2005) by about US\$74 billion. Most of the 1926 estimate comes from the Great Miami Hurricane of 1926, estimated to have caused damage of US\$105 million in 1926 US dollars (US\$76 million in Florida and US\$29 million on its second landfall in Mississippi). The hurricane devastated Miami, bringing the 1920s Florida land boom to a close and initiating an early onset of the Great Depression in this region¹¹.

¹University of North Carolina Wilmington, Wilmington, NC, USA; ²National Oceanic and Atmospheric Administration, Miami, FL, USA; ³Climate Index Working Group Chair, Casualty Actuarial Society, Harpswell, ME, USA; ⁴FB Alliance Insurance, Schaumburg, IL, USA; ⁵Risk Frontiers, St Leonards, NSW, Australia; ⁶Colorado State University, Fort Collins, CO, USA; ⁷University of Colorado Boulder, Boulder, CO, USA; ⁸e-mail: pielke@colorado.edu

NATURE SUSTAINABILITY | www.nature.com/nature

Normalized damage tracks the landfall record



The apex of my career — 15 March 2006



The National Academies of
SCIENCES • ENGINEERING • MEDICINE

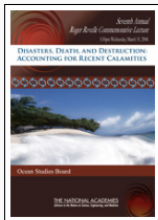
ROGER REVELLE LECTURE SERIES
PRESENTED BY THE OCEAN STUDIES BOARD

2006–Roger Pielke, Jr.



Roger Pielke, Jr. is a professor in the Environmental Studies Program and a fellow of the Cooperative Institute for Research in the Environmental Sciences (CIRES) at the University of Colorado. At CIRES, Dr. Pielke directed the Center for Science and Technology Policy Research from 2001-2007. From 1993-2001 he was a scientist at the Environmental and Societal Impacts Group at the National Center for Atmospheric Research in Boulder, Colorado, where he studied societal responses to extreme weather events, policy responses to climate change, and U.S. science policy. Dr. Pielke's research focuses on the relation of scientific information and public and private sector decision-making. His current areas of interest include the politicization of science, decision making under uncertainty, and policy education for scientists. Dr. Pielke chaired the American Meteorological Society's Committee on Societal Impacts 1999-2002, and has served on the

Science Steering Committee of the World Meteorological Organization's World Weather Research Programme and the Board on Atmospheric Sciences and Climate of the National Research Council, among other advisory committees. Dr. Pielke received his B.A. in mathematics, M.A. in public policy and Ph.D. in political science from the University of Colorado.



Disasters, Death and Destruction: Accounting for Recent Calamities

The recent devastation caused by Hurricane Katrina, the Indian Ocean tsunami, and South Asian earthquake has kept natural disasters at the focus of our attention. The past decades have seen a spectacular series of catastrophes around the world with ever increasing economic losses and horrific loss of life. The recent spate of disasters has created two common perceptions among decision makers and the general public. First, there is a sense that the economic impacts associated with extreme events have increased in recent years. Second, given that a human influence on the climate system has been well established, a perception exists that the recent increase in weather-related disasters like floods and hurricanes is in some way related to changes in climate. These perceptions beg two questions:

- › Have loss of life and damages associated with extreme weather events actually increased in recent years?
- › What factors account for observed trends in the impacts of weather on society?

WELCOME

In 1999, the Ocean Studies Board (OSB) launched the Roger Revelle Commemorative Lecture to highlight the important links between ocean science and public policy. The series was named in honor of the late Roger Revelle, a leader in the field of oceanography for over 50 years who spearheaded efforts to investigate the mechanisms and consequences of climate change. In recognition of the critical importance of education in linking science and public policy, the OSB has partnered with the National Science Resources Center and the Smithsonian's National Museum of Natural History to bring the Revelle Lecture to a broader audience. The lecture is held annually in conjunction with the OSB meeting in Washington, DC.



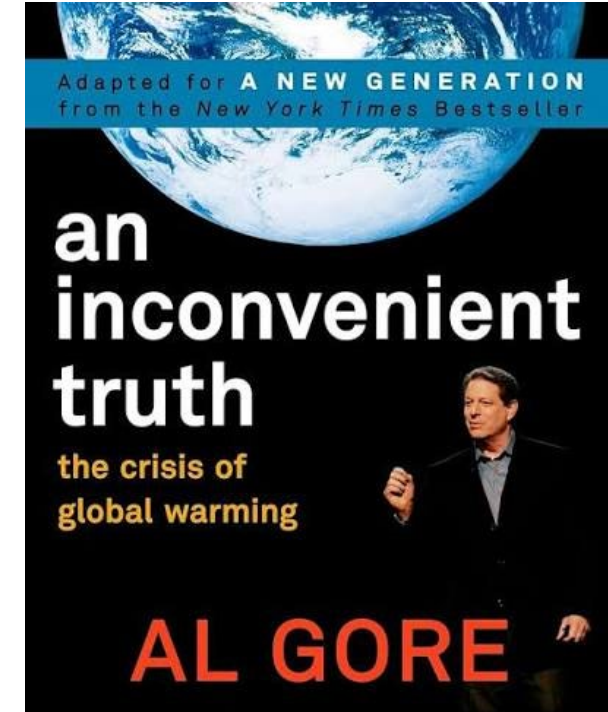
SPONSORS

- › National Science Foundation (NSF)
- › The Office of Naval Research (ONR)
- › The U.S. Geological Survey (USGS)
- › The National Aeronautics and Space Administration (NASA)
- › The National Oceanic and Atmospheric Administration (NOAA)
- › The Smithsonian Science Education Center
- › The Smithsonian Institution
- › The Gordon and Betty Moore Foundation

CONTACT INFORMATION



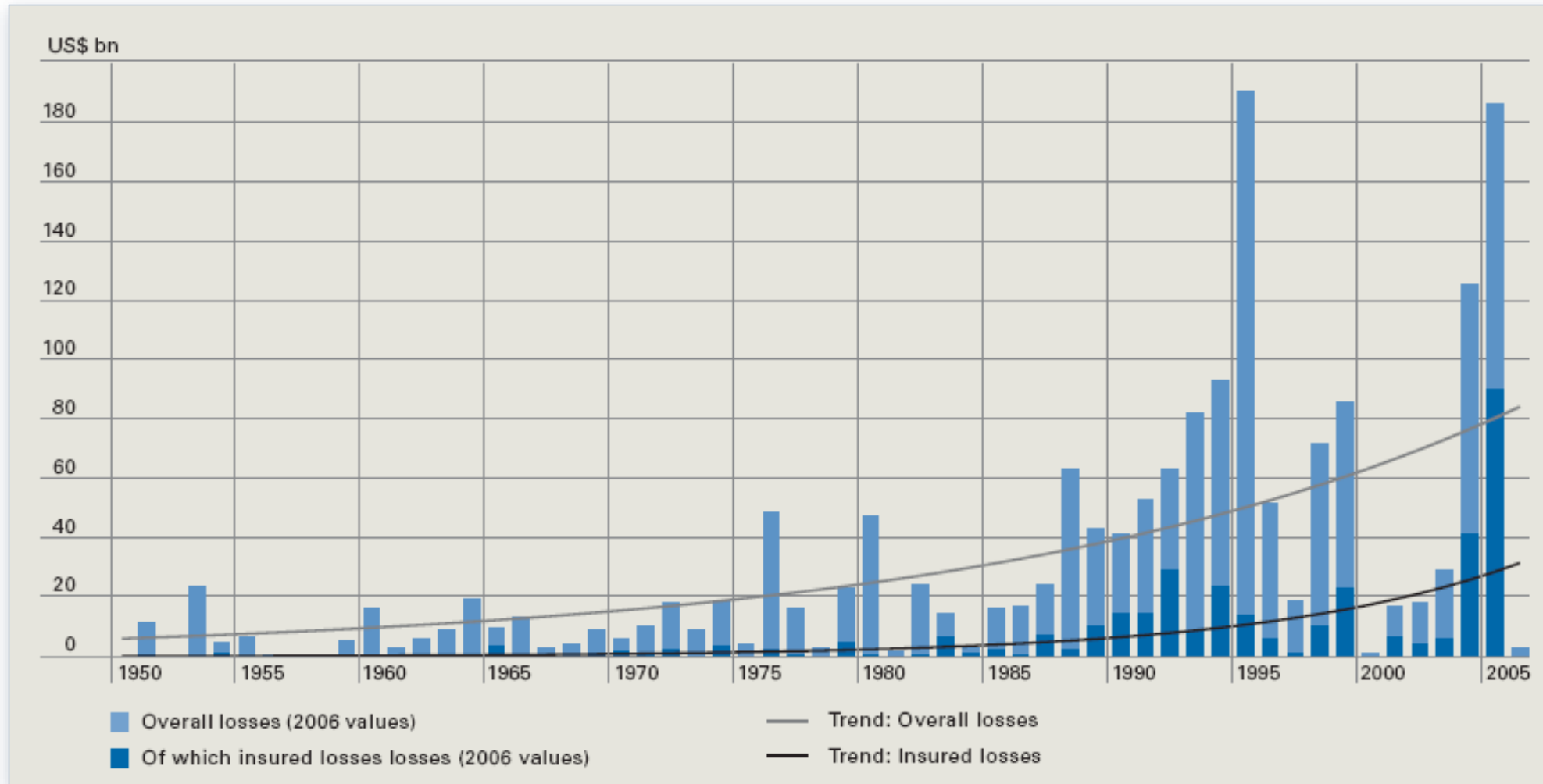
Two months later, May 2006 ...



Hohenkammer workshop, May 2006



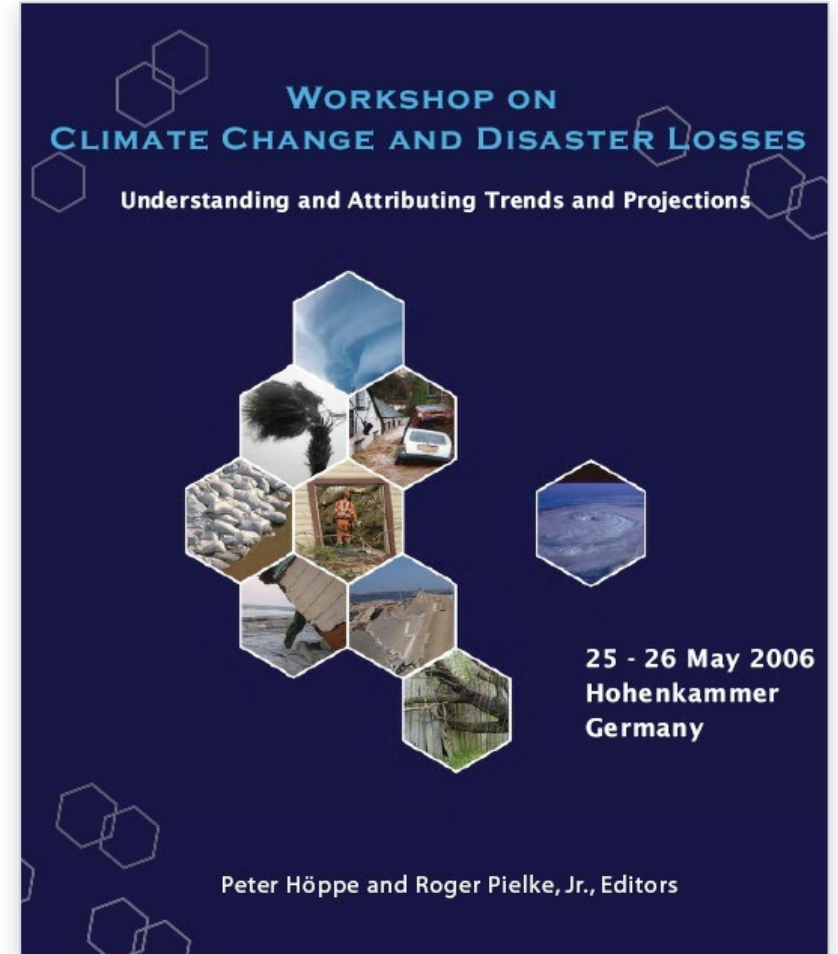
Increasing global losses from extreme weather ... why?



Source: Munich Re 2007

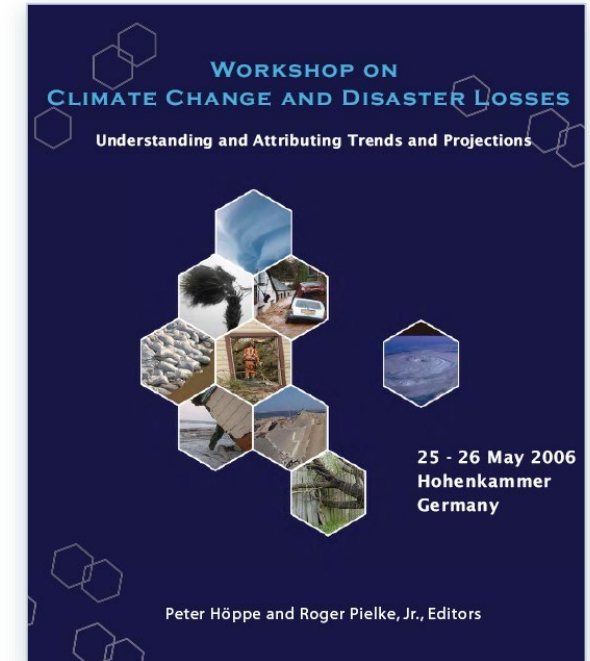
Hohenkammer workshop, May 2006

- Co-sponsors: US NSF, Munich Re, GKSS Institute for Coastal Research, Tyndall Centre for Climate Change Research
- 32 participants from 16 countries
- 24 background white papers
- Summary consensus report
- Consistent with IPCC WGI



Hohenkammer consensus statements, 2006

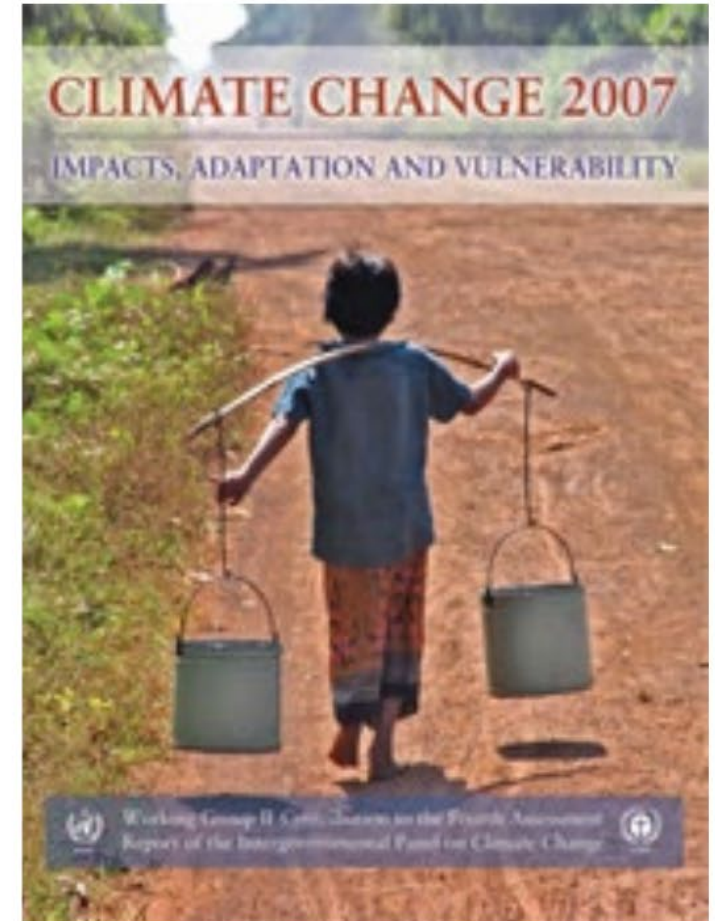
- Analyses of long-term records of disaster losses indicate that societal change and economic development are the principal factors responsible for the documented increasing losses to date.
- **Because of issues related to data quality, the stochastic nature of extreme event impacts, length of time series, and various societal factors present in the disaster loss record, it is still not possible to determine the portion of the increase in damages that might be attributed to climate change due to GHG emissions.**
- In the near future the quantitative link (attribution) of trends in storm and flood losses to climate changes related to GHG emissions is unlikely to be answered unequivocally.



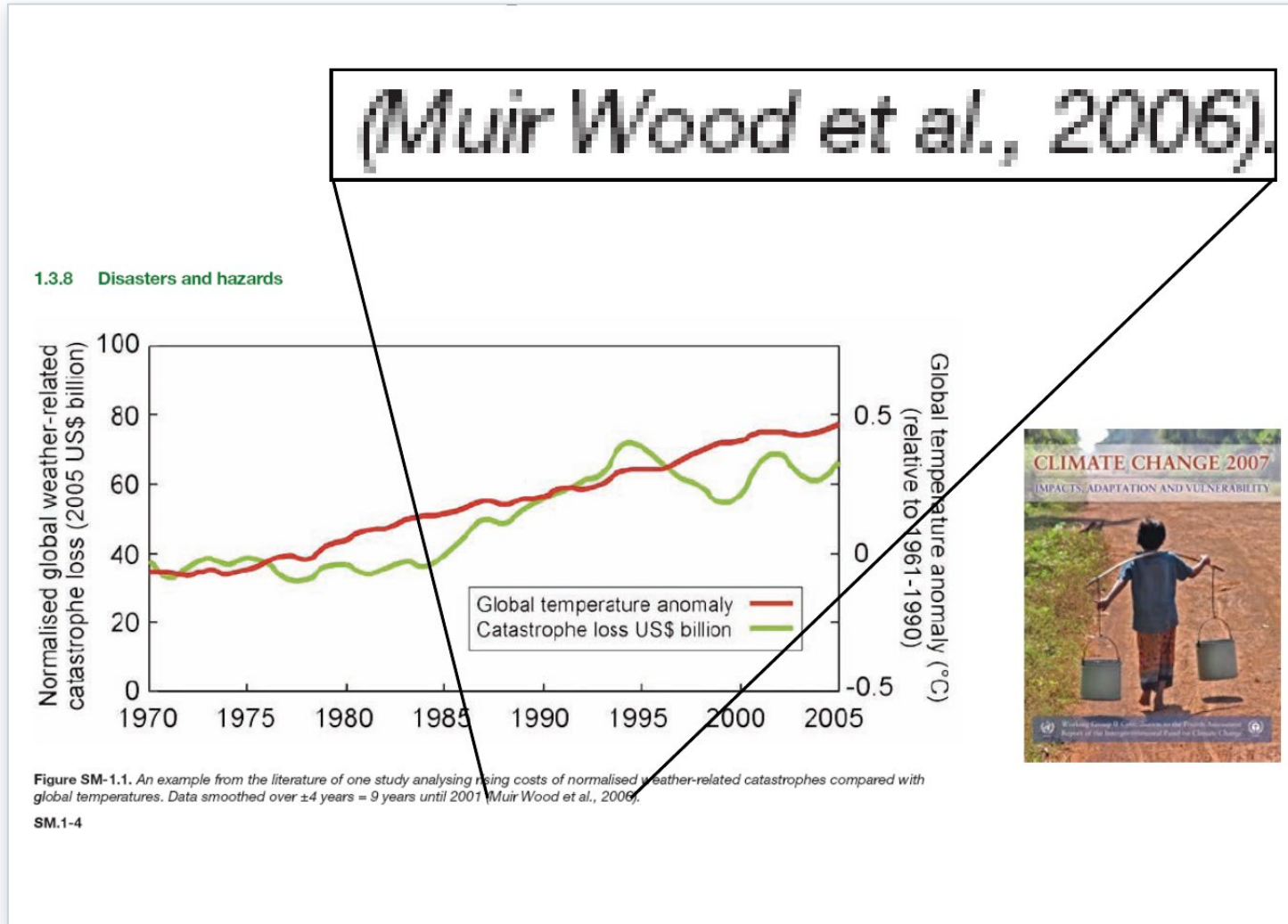
IPCC 2007: reliance on “one study”

1.3.8.5 *Summary of disasters and hazards*

Global losses reveal rapidly rising costs due to extreme weather-related events since the 1970s. One study has found that while the dominant signal remains that of the significant increases in the values of exposure at risk, once losses are normalised for exposure, there still remains an underlying rising trend.



Relies on “one study” — what “one study”?



The “one study”: a 2006 workshop paper

Systems in the Hindu Kush-Himalayan Region. ICIMOD, Bhutan, Kathmandu, 227 pp.

Moonen, A.C., L. Ercoli, M. Mariotti and A. Masoni, 2002: Climate change in Italy indicated by agrometeorological indices over 122 years. *Agr. Forest Meteorol.*, **111**, 13-27.

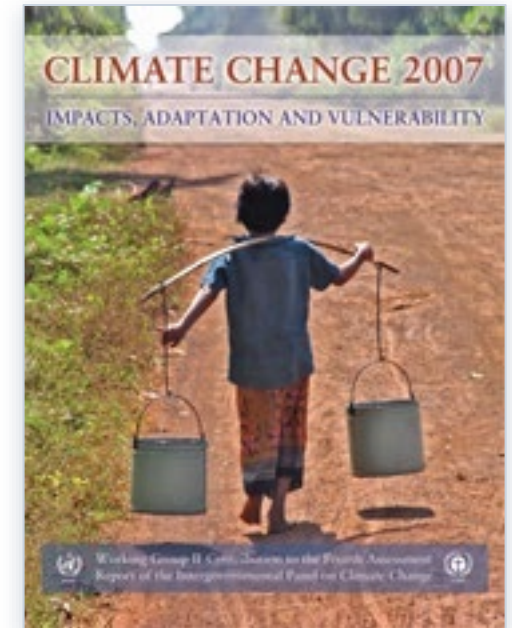
Mueller, D.R., W.F. Vincent and M.O. Jeffries, 2003: Break-up of the largest Arctic ice shelf and associated loss of an epishelf lake. *Geophys. Res. Lett.*, **30**, 2031, doi:10.1029/2003GL017931.

Muir Wood, R., S. Miller and A. Boissonnade, 2006: The search for trends in a global catalogue of normalized weather-related catastrophe losses. *Workshop on Climate Change and Disaster Losses: Understanding and Attributing Trends and Projections*. Hohenkammer, Munich, 188-194.

Munich Re Group, 2005: Annual Review: *Natural Catastrophes 2004*. WKD Offsetdruck GmbH, Munich, 60 pp.

Myneni, R.B., C.D. Keeling, C.J. Tucker, G. Asrar and R.R. Nemani, 1997: Increased plant growth in the northern high latitudes from 1981 to 1991. *Nature*, **386**, 698-702.

Nabuurs, G.J., A. Pussinen, T. Karjalainen, M. Erhard and K. Kramer, 2002: Stemwood volume increment changes in European forests due to climate change: a



Hey look! I co-organized that workshop!



Guess what?

- The IPCC graph does not appear in Muir-Wood et al. 2006
- Muir-Wood was a Lead Author of IPCC 2007
- February 2010, public debate at the Royal Institution, London:
 - Muir-Wood revealed that he created the graph, included it in the IPCC, and then intentionally miscited it to avoid the IPCC deadline for inclusion of published material
- Muir-Wood said the graph should never have gone into the report
- In 2006 Risk Management Solutions (Muir-Wood's employer) predicted a 40% increase in the risk of US hurricane damage, necessitating much higher insurance and reinsurance premiums (\$82 billion according to the Sarasota Herald-Tribune)

Post-script:

What the miscited paper said when finally published in 2008

“We find **insufficient evidence to claim a statistical relationship between global temperature increase and normalized catastrophe losses.”**

Miller et al. 2008 (Muir-Wood a co-author)



26 February 2010

From the article:

Chief beef: Hurricanes and the bottom line

Telling quote: “We cannot make a causal link between increase in greenhouse gases and the costs of damage associated with hurricanes, floods, and extreme weather phenomena.”

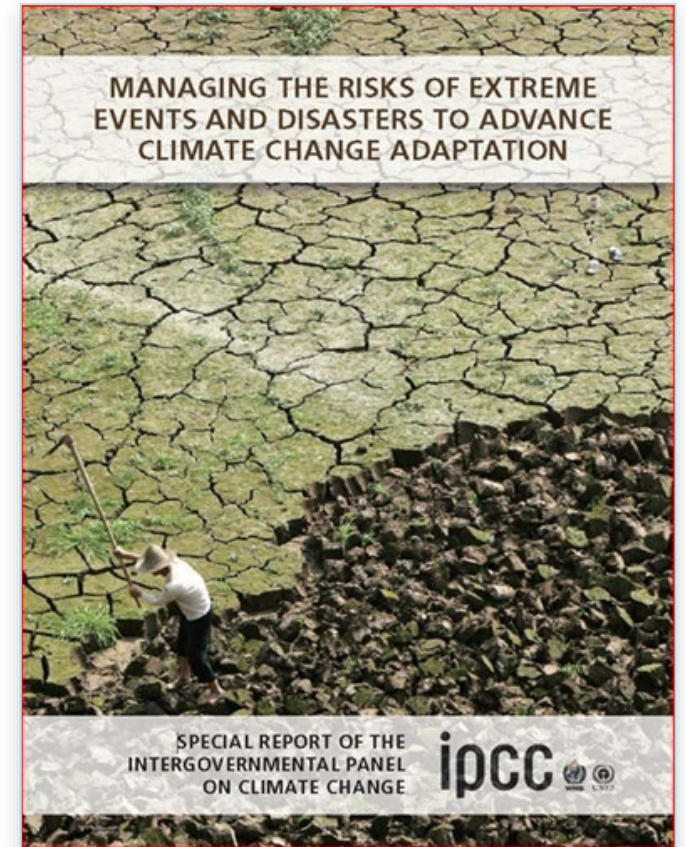
“... For his work questioning certain graphs presented in IPCC reports, Pielke has been accused by some of being a climate change ‘denier.’”



IPCC 2012 SREX on disaster losses

“Long-term trends in economic disaster losses adjusted for wealth and population increases **have not been attributed to climate change**, but a role for climate change has not been excluded (medium evidence, high agreement).”

IPCC SREX 2012



My 2013 Senate EPW testimony



February 2014: John Holdren, President Obama's science advisor, testifies before the same committee



Not long after: a congressional investigation



The New York Times

SCIENCE

Lawmakers Seek Information on Funding for Climate Change Critics

By JOHN SCHWARTZ FEB. 25, 2015

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Democratic lawmakers in Washington are demanding information about funding for scientists who publicly dispute widely held views on the causes and risks of [climate change](#).

Prominent members of the United States House of Representatives and the Senate have sent letters to universities, companies and trade groups asking for information about funding to the scientists.

The letters came after [evidence emerged over the weekend](#) that Wei-Hock Soon, known as Willie, a scientist at the Harvard-Smithsonian Center for Astrophysics, had failed to disclose the industry funding for his academic work. The documents also included correspondence between Dr. Soon and the companies who funded his work in which he referred to his papers and testimony as “deliverables.”

In letters sent to seven universities on Tuesday, Representative Raúl M. Grijalva, an Arizona Democrat who is the ranking member of the House committee on natural resources, sent detailed requests to the academic



Of course, both US parties play politics with the weather



President Obama's radio address, 29 June 2013



“[W]hile we know no single weather event is caused solely by climate change, we also know that in a world that’s getting warmer than it used to be, all weather events are affected by it — more extreme droughts, floods, wildfires, and hurricanes...

And Americans across the country are already paying the price of inaction in higher food costs, insurance premiums, and the tab for rebuilding.”

THB

Extremes: the perspective from 2026

What the IPCC actually concluded about detection and attribution

Detection and attribution: IPCC definitions



“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, $<10\%$.”

“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.”

Source: IPCC AR6 WG1 Glossary



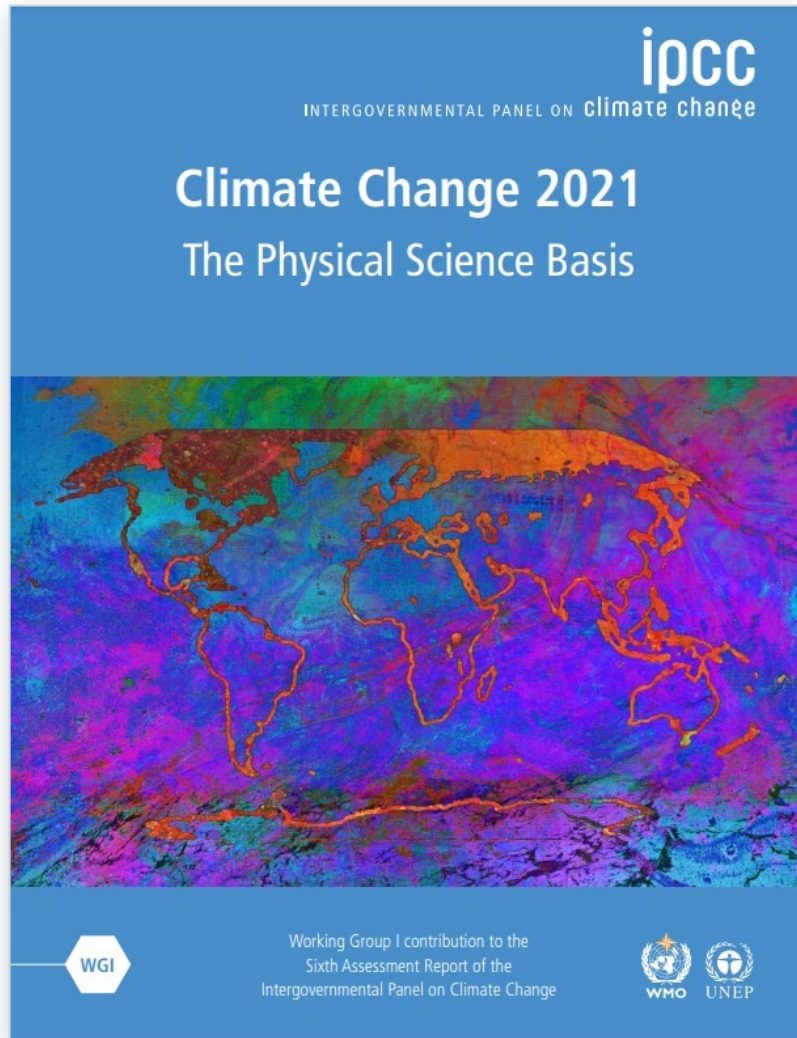
Disasters and climate extremes: IPCC definitions



Disaster: “A ‘serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts’ (UNGA, 2016).”

Climate extreme (extreme weather or climate event): “The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classified as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., high temperature, drought, or heavy rainfall over a season). For simplicity, both extreme weather events and extreme climate events are referred to collectively as climate extremes.”

Summary of IPCC AR6 WGI on extremes

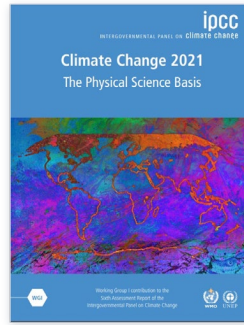


Phenomenon	Detection	Attribution
heat waves	yes	yes
heavy precipitation	yes	yes
flooding	no	no
meteorological drought	no	no
hydrological drought	no	no
Ecological/agricultural drought	yes	yes
tropical cyclones	no	no
winter storms	no	no
thunderstorms	no	no
tornadoes	no	no
hail	no	no
lightning	no	no
extreme winds	no	no
fire weather	yes	yes

Heat waves

Detection: yes

Attribution: yes



Screenshots from IPCC AR6 WG I unless otherwise noted

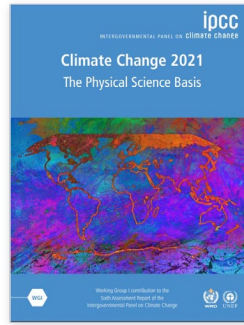
- Heat Waves: “It is virtually certain that there has been increases in the intensity and duration of heat waves and in the number of heat wave days at the global scale”

In summary, it is *virtually certain* that there has been an increase in the number of warm days and nights and a decrease in the number of cold days and nights on the global scale since 1950. Both the coldest extremes and hottest extremes display increasing temperatures. It is *very likely* that these changes have also occurred at the regional scale in Europe, Australasia, Asia, and North America. It is *virtually certain* that there has been increases in the intensity and duration of heat waves and in the number of heat wave days at the global scale. These trends *likely* occur in Europe, Asia, and Australia. There is *medium confidence* in similar changes in temperature extremes in Africa and *high confidence* in South America; the lower confidence is due to reduced data availability and fewer studies. Annual minimum temperatures on land have increased about three times more than global surface temperature since the 1960s, with particularly strong warming in the Arctic (*high confidence*).

Heavy precipitation

Detection: yes

Attribution: yes



Screenshots from IPCC AR6 WG I unless otherwise noted

- Heavy precipitation: “the frequency and intensity of heavy precipitation have likely increased at the global scale over a majority of land regions with good observational coverage”

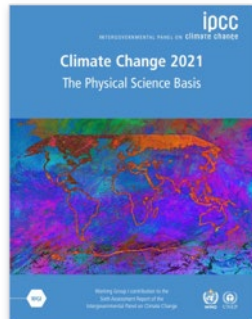
In summary, the frequency and intensity of heavy precipitation have *likely* increased at the global scale over a majority of land regions with good observational coverage. Since 1950, the annual maximum amount of precipitation falling in a day or over five consecutive days has *likely* increased over land regions with sufficient observational coverage for assessment, with increases in more regions than there are decreases. Heavy precipitation has *likely* increased on the continental scale over three continents, including North America, Europe, and Asia where observational data are more abundant. There is *very low confidence* about

Heavy precipitation does not always lead to greater flooding



Screenshots from IPCC AR6 WG1 unless otherwise noted

- The IPCC (in its accompanying FAQ) recognizes that “heavier rainfall does not always lead to greater flooding.” This is something that we first argued more than two decades ago ([here](#) and [here](#)), and it is great to see it explicitly acknowledged in the IPCC report. To make claims about trends in flooding, one should look at trends in flooding and not precipitation. The conflation of the two is a common error.



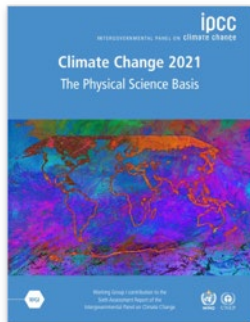
7 expected to be greater in the future, contributing to more severe flooding.
8
9 However, heavier rainfall does not always lead to greater flooding. This is because flooding also depends
10 upon the type of river basin, the surface landscape, the extent and duration of the rainfall, and how wet the
11 ground is before the rainfall event (FAQ 8.2, Figure 1) Some regions will experience a drying in the soil as
12 the climate warms, particularly in sub-tropical climates, which could make floods from a rainfall event less
13 probable because the ground can potentially soak up more of the rain. On the other hand, less frequent but
14 more intense downpours can lead to dry, hard ground that is less able to soak up heavy rainfall when it does
15 occur, resulting in more runoff into lakes, rivers and hollows. Earlier spring snowmelt combined with more
16 precipitation falling as rain rather than snow can trigger flood events in cold regions. Reduced winter snow
17 cover can, in contrast, decrease the chance of flooding arising from the combination of rainfall and rapid
18 snowmelt. Rapid melting of glaciers and snow in a warming climate is already increasing river flow in some
19 regions, but as the volumes of ice diminish, flows will peak and then decline in the future. Flooding is also
20 affected by changes in the management of the land and river systems. For example, clearing forests for
21 agriculture or building cities can make rain water flow more rapidly into rivers or low lying areas. On the
22 other hand, increased extraction of water from rivers can reduce water levels and the likelihood of flooding.
23

Flooding

Detection: no

Attribution: no

Screenshots from IPCC AR6 WG I unless otherwise noted



- Flooding (detection): “Confidence about peak flow trends over past decades on the global scale is low, but there are regions experiencing increases, including parts of Asia, southern South America, the northeast USA, northwestern Europe, and the Amazon, and regions experiencing decreases, including parts of the Mediterranean, Australia, Africa, and the southwestern USA.”

In summary, the seasonality of floods has changed in cold regions where snowmelt dominates the flow regime in response to warming (*high confidence*). *Confidence about peak flow trends over past decades on the global scale is low*, but there are regions experiencing increases, including parts of Asia, southern South America, the northeast USA, northwestern Europe, and the Amazon, and regions experiencing decreases, including parts of the Mediterranean, Australia, Africa, and the southwestern USA.

- Flooding (attribution): “there is low confidence in the human influence on the changes in high river flows on the global scale”

In summary there is *low confidence* in the human influence on the changes in high river flows on the global scale. *Confidence* is in general *low* in attributing changes in the probability or magnitude of flood events to human influence because of a limited number of studies and differences in the results of these studies, and large modelling uncertainties.

Drought: three types in the IPCC

Box 3-3 | The Definition of Drought

Though a commonly used term, drought is defined in various ways, and these definitional issues make the analysis of changes in drought characteristics difficult. This explains why assessments of (past or projected) changes in drought can substantially differ between published studies or chosen indices (see Section 3.5.1). Some of these difficulties and their causes are highlighted in this box.

What is Drought or Dryness?

The Glossary defines drought as follows: “A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.”

As highlighted in the above definition, drought can be defined from different perspectives, depending on the stakeholders involved. The scientific literature commonly distinguishes **meteorological drought**, which refers to a deficit of precipitation, **soil moisture drought** (often called **agricultural drought**), which refers to a deficit of (mostly root zone) soil moisture, and **hydrological drought**, which refers to negative anomalies in streamflow, lake, and/or groundwater levels (e.g., Heim Jr., 2002). We use here the term ‘soil moisture drought’ instead of ‘agricultural drought,’ despite the widespread use of the latter term (e.g., Heim Jr., 2002; Wang, 2005), because soil moisture deficits have several additional effects beside those on agroecosystems, most importantly on other natural or managed ecosystems (including both forests and pastures), on building infrastructure through soil mechanical processes (e.g., Corti et al., 2009), and health through impacts on heat waves (Section 3.1.4). Water scarcity (linked to **socioeconomic drought**), which may be caused fully or in part by use from human activities, does not lie within the scope of this chapter (see Section 4.2.2); however, it should be noted that changing pressure on water resources by human uses may itself influence climate and possibly the drought conditions, for example, via declining groundwater levels, or enhanced local evapotranspiration and associated land-atmosphere feedbacks. Drought should not be confused with aridity, which describes the general characteristic of an arid climate (e.g., desert). Indeed, drought is considered a recurring feature of climate occurring in any region and is defined with respect to the average climate of the given region (e.g., Heim Jr., 2002; Dai, 2011). Nonetheless, the effects of droughts are not linear, given the existence of, for example, discrete soil moisture thresholds affecting vegetation and surface fluxes (e.g., Koster et al., 2004b; Seneviratne et al., 2010), which means that the same precipitation deficit or radiation excess relative to normal will not affect different regions equally (e.g., short-term lack of precipitation in a very humid region may not be critical for agriculture because of the ample soil moisture supply). In this chapter we often use the term ‘dryness’ instead of ‘drought’ as a more general term.

- Drought. The IPCC has distinguished four types of drought: hydrological, meteorological, ecological and agricultural. That means that simply saying “drought” in the context of the IPCC report is incomplete, and potentially confusing. Here is what the report says about each:

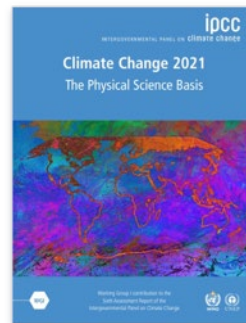
- Hydrological drought: “There is still **limited evidence** and thus **low confidence** in assessing these trends at the scale of single regions, with few exceptions”
- Meteorological drought: “The regional evidence on attribution for single AR6 regions generally shows **low confidence** for a human contribution to observed trends in meteorological droughts at regional scale, with few exceptions”
- Ecological and agricultural drought: “There is **medium confidence** that human influence has contributed to changes in agricultural and ecological droughts and has led to an increase in the overall affected land area”

IPCC SREX

- ¹⁵ **Agricultural and ecological drought (depending on the affected biome)**: a period with abnormal soil moisture deficit, which results from combined shortage of precipitation and excess evapotranspiration, and during the growing season impinges on crop production or ecosystem function in general. Observed changes in meteorological droughts (precipitation deficits) and hydrological droughts (streamflow deficits) are distinct from those in agricultural and ecological droughts and addressed in the underlying AR6 material (Chapter 11).

Drought: three types in the IPCC

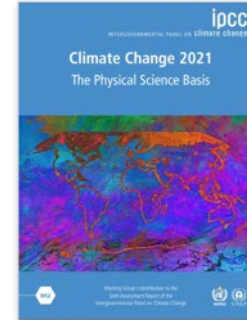
- | | | |
|---|-----------------------|-------------------------|
| • Meteorological drought | Detection: no | Attribution: no |
| • Hydrological drought | Detection: no | Attribution: no |
| • Agricultural/ecological drought
(soil moisture deficits) | Detection: yes | Attribution: yes |



Tropical cyclones

Detection: no

Attribution: no



Screenshots from IPCC AR6 WG I unless otherwise noted

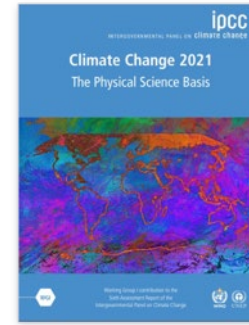
- Tropical cyclones: “There is low confidence in most reported long-term (multidecadal to centennial) trends in TC frequency- or intensity-based metrics”

Identifying past trends in TC metrics remains a challenge due to the heterogeneous character of the historical instrumental data, which are known as “best-track” data (Schreck et al., 2014). There is *low confidence* in most reported long-term (multidecadal to centennial) trends in TC frequency- or intensity-based metrics due to changes in the technology used to collect the best-track data. This should not be interpreted as implying that no physical (real) trends exist, but rather as indicating that either the quality or the temporal length of the data is not adequate to provide robust trend detection statements, particularly in the presence of multidecadal variability.

Winter storms

Detection: no

Attribution: no



Screenshots from IPCC AR6 WG I unless otherwise noted

- Winter storms: “There is low confidence in observed recent changes in the total number of extratropical cyclones over both hemispheres. There is also low confidence in past-century trends in the number and intensity of the strongest extratropical cyclones over the Northern Hemisphere...”

11.7.2.1 Observed trends

Chapter 2 (Section 2.3.1.4.3) concluded that there is overall **low confidence** in recent changes in the total number of ETCs over both hemispheres and that there is **medium confidence** in a poleward shift of the storm tracks over both hemispheres since the 1980s. Overall, there is also **low confidence in past-century trends** in the number and intensity of the strongest ETCs due to the large interannual and decadal variability (Feser et al., 2015; Reboita et al., 2015; Wang et al., 2016; Varino et al., 2018) and due to temporal and spatial heterogeneities in the number and type of assimilated data in reanalyses, particularly before the satellite era (Krueger et al., 2013; Tilinina et al., 2013; Befort et al., 2016; Chang and Yau, 2016; Wang et al., 2016).

Thunderstorms, tornadoes, hail, lightning

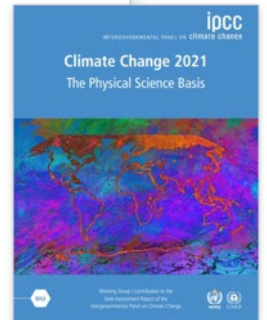
Detection: no

Attribution: no

Screenshots from IPCC AR6 WG1 unless otherwise noted

- Thunderstorms, tornadoes, hail, lightning: “observational trends in tornadoes, hail, and lightning associated with severe convective storms are not robustly detected due to insufficient coverage of the long-term observations”

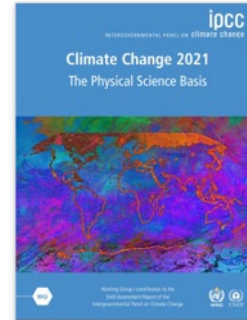
In summary, because the definition of severe convective storms varies depending on the literature and the region, it is not straightforward to make a synthesizing view of observed trends in severe convective storms in different regions. In particular, observational trends in tornadoes, hail, and lightning associated with severe convective storms are not robustly detected due to insufficient coverage of the long-term observations. There is *medium confidence* that the mean annual number of tornadoes in the United States has remained relatively constant, but their variability of occurrence has increased since the 1970s, particularly over the 2000s, with a decrease in the number of days per year and an increase in the number of tornadoes on these days (*high confidence*). Detected tornadoes have also increased in Europe, but the trend depends on the density of observations.



Extreme winds (between 60°S and 60°N)

Detection: no

Attribution: no



Screenshots from IPCC AR6 WG I unless otherwise noted

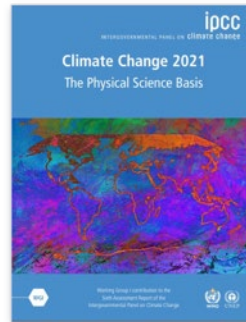
- Extreme winds (between 60S and 60N): “the observed intensity of extreme winds is becoming less severe in the lower to mid-latitudes, while becoming more severe in higher latitudes poleward of 60 degrees (low confidence)”

In summary, the observed intensity of extreme winds is becoming less severe in the lower to mid-latitudes, while becoming more severe in higher latitudes poleward of 60 degrees (*low confidence*). Projected changes in the frequency and intensity of extreme winds are associated with projected changes in the frequency and intensity of TCs and ETCs (*medium confidence*).

Fire weather

Detection: yes

Attribution: yes



Screenshots from IPCC AR6 WG I unless otherwise noted

- Fire weather: “There is medium confidence that weather conditions that promote wildfires (fire weather) have become more probable in southern Europe, northern Eurasia, the US, and Australia over the last century”

In summary, there is *high confidence* that concurrent heat waves and droughts have increased in frequency over the last century at the global scale due to human influence. There is *medium confidence* that weather conditions that promote wildfires (fire weather) have become more probable in southern Europe, northern Eurasia, the US, and Australia over the last century. There is *high confidence* that compound hot and dry conditions become more probable in nearly all land regions as global mean temperature increases. There is *high confidence* that fire weather conditions will become more frequent at higher levels of global warming in some regions.



Detection versus emergence: IPCC AR6 Table 12.12

*From the THB Global Extreme Weather Dashboard:
globalextremeweather.thehonestbroker.org*

Emergence: the IPCC definitions

Emergence (of the climate signal)

“... when a change in climate (the ‘signal’) becomes larger than the amplitude of natural or internal variations (defining the ‘noise’) ... emergence occurs at a defined threshold of this ratio (e.g., $S/N > 1$ or 2).”

Time of emergence (ToE)

“Time when a specific anthropogenic signal related to climate change is statistically detected to emerge from the background noise of natural climate variability in a reference period, for a specific region.”

- Detection: a verdict on whether a change appears in the observed record, with no claim about cause
- Emergence: a date on which a named anthropogenic signal exceeds natural variability, measured from a baseline — by default in AR6 Chapter 12, a pre-industrial baseline absent from the instrumental record

Source: IPCC AR6 WGI Annex VII (Glossary); THB Global Extreme Weather Dashboard

Four differences between detection and emergence

1 Cause

ToE names “a specific anthropogenic signal.”
Detection proceeds “without providing a reason for that change.”

2 Statistic

Detection: chance of internal variability alone producing the record ($<10\%$). Emergence: a signal-to-noise ratio above a threshold ($S/N > 1$ or 2).

3 Baseline

AR6 Chapter 12 measures emergence against a pre-industrial period by default. Detection uses the observed record over a quality-controlled window.

4 Output

Detection returns a verdict over a window. Emergence returns a date — the year the signal first exceeded the reference.

IPCC AR6 WGI Table 12.12: emergence of climatic impact-drivers

Type	Climatic impact-driver	Emerged in historical period	Emerging by 2050 (RCP8.5)	Emerging 2050–2100 (RCP8.5)
Heat and cold	Mean air temperature			
	Extreme heat			
	Cold spell			
	Frost			
Wet and dry	Mean precipitation		increase / decrease by region	increase / decrease by region
	River flood			
	Heavy precipitation and pluvial flood			
	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			
	Permafrost			
	Lake, river and sea ice			
	Heavy snowfall and ice storm			
	Hail			
	Snow avalanche			
Coastal	Relative sea level			
	Coastal flood			
	Coastal erosion			
Open ocean	Mean ocean temperature			
	Marine heatwave			
	Ocean acidity			
	Ocean salinity			
	Dissolved oxygen			
Other	Air pollution weather			
	Atmospheric CO ₂ at surface			
	Radiation at surface			

Legend

- High confidence of increase
- Medium confidence of increase
- Low confidence in direction of change
- Medium confidence of decrease
- High confidence of decrease

“White cells indicate where evidence is lacking or the signal is not present, leading to overall low confidence of an emerging signal.”

Source: IPCC AR6 WGI Chapter 12, Table 12.12, p. 1856. Regional footnotes omitted; mean precipitation increases in northern mid- and high latitudes and decreases in the Mediterranean, southern Africa and southwest Australia.

Extreme events in Table 12.12: two of 18 emerged, 15 with no emergence by 2100

9 of 33

climatic impact-drivers with emergence in the historical period

2 of 18

drivers naming a discrete extreme event with historical emergence

15 of 18

event drivers white in all three windows, even under RCP8.5 through 2100

Extreme heat	Cold spell	Heavy precipitation & pluvial flood
Frost	River flood	Landslide
Hydrological drought	Agricultural & ecological drought	Fire weather
Severe wind storm	Tropical cyclone	Sand & dust storm
Heavy snowfall & ice storm	Hail	Snow avalanche
Coastal flood	Coastal erosion	Marine heatwave

Red: emerged in historical period · Light blue: emergence assessed only 2050–2100 under RCP8.5 · White: no emergence in any window. The event/state grouping comes from the THB dashboard, not AR6.

THB Global Extreme Weather and Climate Change Dashboard

<https://globalextremeweather.thehonestbroker.org/>



Detection of Long-Term Change — Global

TROPICAL CYCLONES



No Detected Change

p=0.580 · since 1980

HEAT WAVES



▲ Detected Change

Increasing, 0.031/decade · 62% of variability · p=0.000

COLD EXTREMES — CSDI



▼ Detected Change

Decreasing, 0.464/decade · 68% of variability · p=0.000

TORNADOES (US)



No Detected Change

p=0.435 · since 1980

WILDFIRE



Time Series Too Short

since 2001

ETC INTENSITY



No Detected Change

p=0.488 · since 1980

METEOROLOGICAL DROUGHT



▲ Detected Change

Increasing, 1.37/decade · 50% of variability · p=0.000

FLOODING



No Detected Change

p=0.073 clears IPCC's 10% example threshold alone, but not this variable's multiple-comparisons-adjusted bar (p<0.0526, rank 30 of 57 tested) · since 1982

AR6 emergence alongside THB dashboard detection results

AR6 driver	AR6, historical period	THB dashboard: detected change
Extreme heat	High confidence of increase	Heat wave index, heat wave magnitude, TXx, WSDI, TN90p: detected increase (5 of 5)
Cold spell	Medium confidence of decrease	CSDI, TN10p: detected decrease; TNN: no detected change
Frost	Not emerged	Frost days: no detected change
River flood	Not emerged	Share of river cells in high flow: no detected change
Hydrological drought	Not emerged	Share of river cells in severe low flow: detected increase
Agricultural and ecological drought	Not emerged	Share of land in severe soil-moisture deficit: detected increase
Severe wind storm	Not emerged	Most extreme storm's minimum pressure: no detected change
Tropical cyclone	Not emerged	Storm count by peak category, % Cat 3+: detected increase; global ACE, lifetime ACE, rapid intensification, landfalls: no detected change

A detected change on the dashboard and an AR6 emergence assessment answer different questions; neither column tests the other.

Extreme event attribution: attribution by assumption

THB

The Washington Post
Democracy Dies in Darkness

Climate change made deadly Nepal glacier and rock collapse more likely, according to analysis

Human-caused global warming resulting in the Himalayan permafrost thawing was, in part, responsible for the catastrophic glacier and boulder collapse last month

AP WORLD U.S. POLITICS SPORTS ENTERTAINMENT BUSINESS SCIENCE NEWSLETTERS QUIZZES MORE

CLIMATE

Climate change made deadly Nepal glacier and rock collapse more likely, according to analysis

IN FOCUS German politics Canada AI Live TV

CLIMATE | NEPAL

How climate change worsened Nepal's deadly mountain collapse

Josh Axelrod
15 hours ago

A glacier and rock collapse in Nepal killed nearly 1,400 people and left thousands missing. Scientists say decades of warming helped set the disaster in motion.

f x

ALJAZEERA News Middle East Explained Sport Opinion Video

News | Climate Crisis

Climate change had major role in triggering Nepal floods, scientists say

The combined toll from the deadly incident now stands at 1,446 people dead and at least 6,669 missing.

Listen (3 mins) Save Share Add Al Jazeera on Google

The Guardian US

News Opinion Sport Culture Lifestyle

US news US politics Midterms 2026 World Climate crisis Middle East Ukraine US immigration Socio

Climate science

Climate crisis probably weakened glacier that caused devastating Nepal-Tibet floods, first study finds

Scientists say global heating was a destabilising factor in collapse of 200,000 sq metre glacier in August

World Weather Attribution: origins, funding, and a 96-study replication



Origins

Created by Climate Central, a climate advocacy group, in 2014; now housed at Imperial College London

Funding

Grantham Foundation, European Climate Foundation, Bezos Earth Fund

Latest

September 2026 Nepal flood and mudslide study: claims no early warning system could have helped, and calls for “a rapid transition away from fossil fuel use”

96

WWA studies replicated — every study with data and methods that allow it

~30

further WWA studies without enough data or method detail for replication

Findings from the replication: attribution by assumption, a method that attributes any trend, and press releases that depart from technical reports.

WWA's own papers state the assumption

“It is assumed that the main changes in the [statistical] distribution are due to global warming.”

Philip et al. 2020, Advances in Statistical Climatology, Meteorology and Oceanography

“[T]he [statistical] distribution only shifts or scales with changes in smoothed global mean surface temperature (GMST) and does not change shape, [and] global warming is the main factor affecting the extremes beyond year-to-year natural variability.”

van Oldenborgh et al. 2021, Climatic Change

“This assumes that the major cause of the trends from the late nineteenth century until now in the models is due to anthropogenic emissions of greenhouse gases and aerosols, neglecting natural forcings.”

van Oldenborgh et al. 2021, on the use of model experiments

The turnkey method, step by step: De Bilt, Netherlands, 2018



1

Regress

Warmest day of each year at De Bilt against GMST: about 2.8 °C of local warming per 1 °C of global warming

2

Shift

GMST rose ~1.1 °C from 1920 to 2018; $1.1 \times 2.8 \approx 3$ °C, so a 25 °C day in 1920 becomes a 28 °C day in the 2018 climate

3

Fit

Repeat for every year to build return-period curves for the 2018 climate and the 1900 climate — the same data, shifted

4

Declare

The 2018 record of 29.7 °C never crosses the 1900 curve: “formally the event was impossible in the climate of 1900”

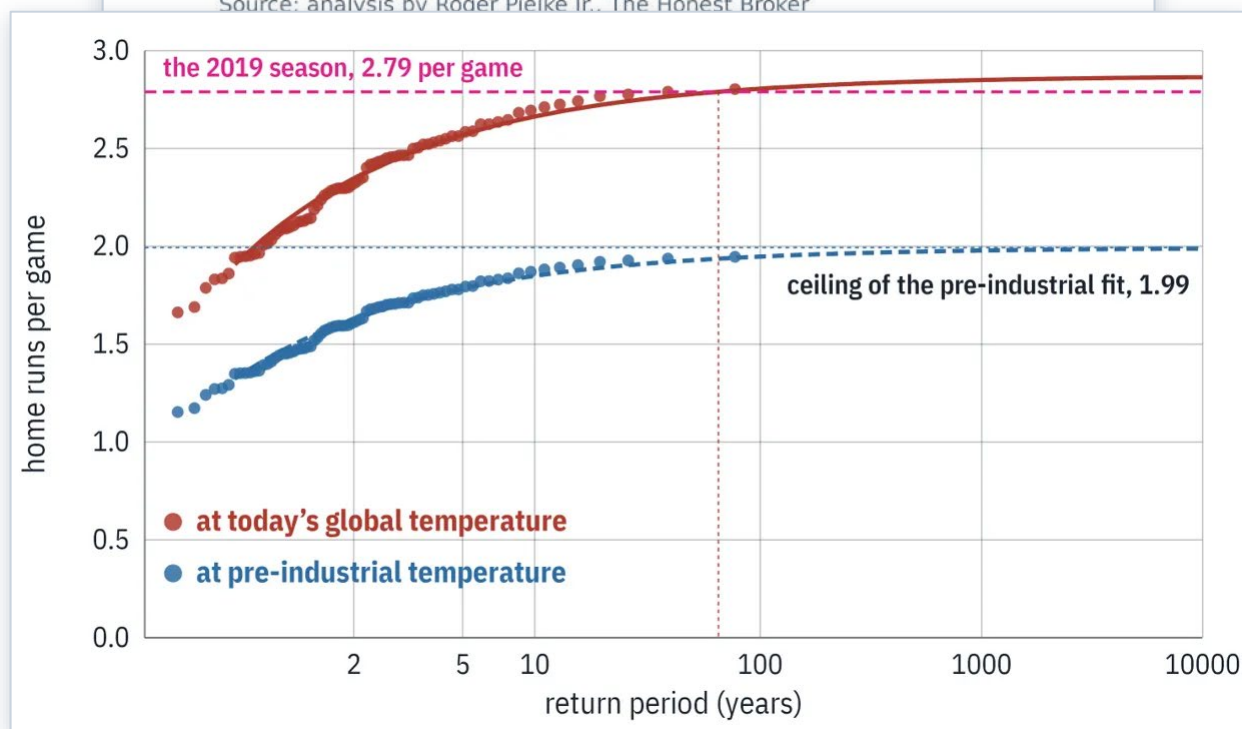
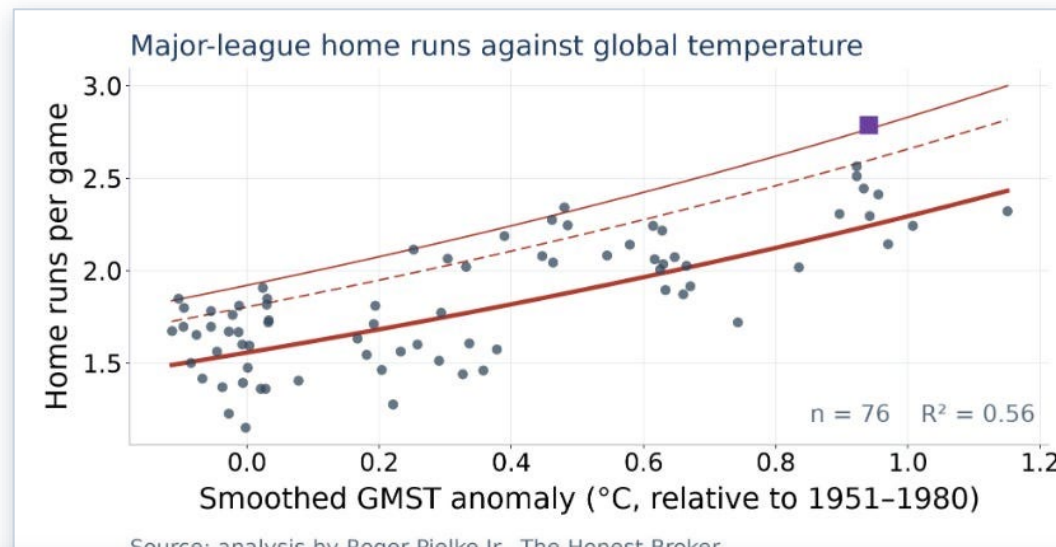
The attribution comes from the assumption in step 1: any variable correlated with GMST yields the same result.

Attribute anything: climate change and MLB home runs



6,776

home runs in MLB in 2019, a record

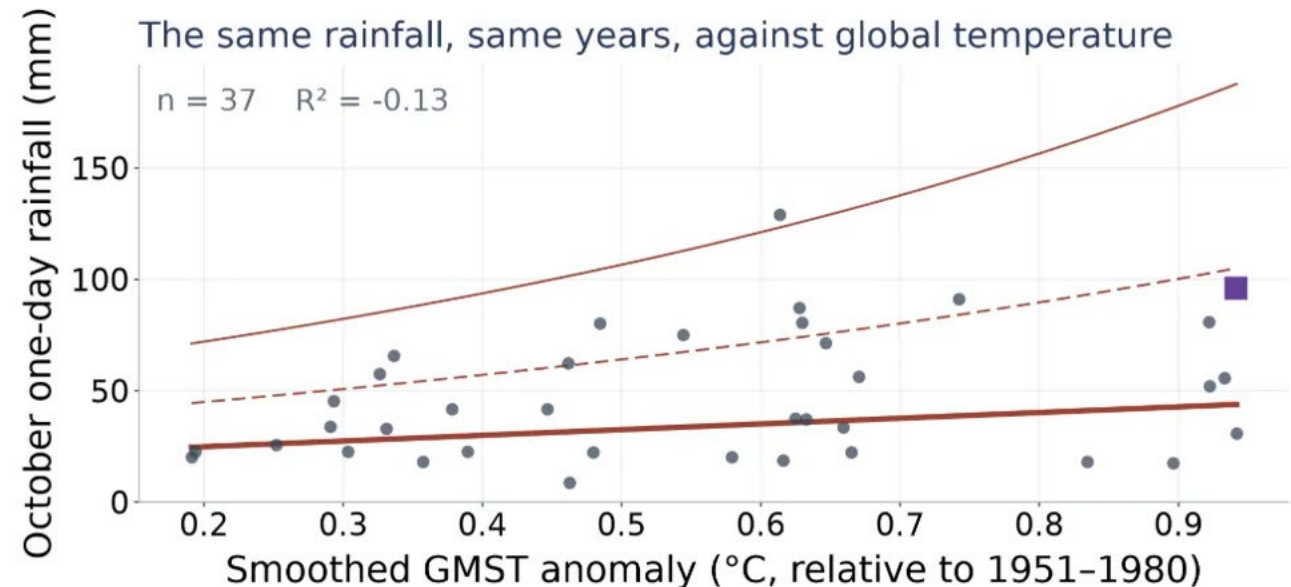
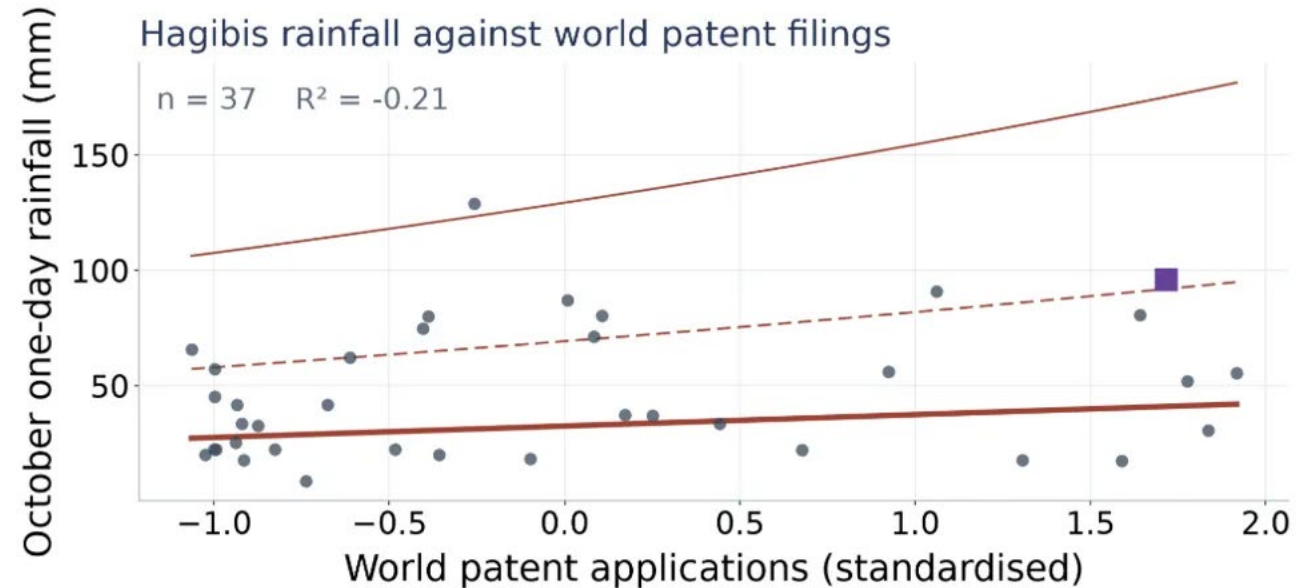


A placebo test: patent applications and 2019 flooding from Japanese Typhoon Hagibis

The same construction as the De Bilt example



— 1-in-40-year level — fitted location, μ ■ 2019 event
- - - 1-in-6-year level • observed years



NATION

Cities invest in greener transit future

New federal grants aim to expand electric bus networks nationwide.

PAGE 6



BUSINESS

Tech firms double down on clean energy

Major companies announce new solar and storage plans ahead of climate summit.

PAGE 12



LIFE

The power of a good night's sleep

Experts say better rest can improve focus, health and happiness at any age.

PAGE 18



Increasing patent applications cause greater rainfall in Japan

New study suggests link between innovation activity and regional climate changes

By Eleanor Park
Global Science Correspondent

TOKYO — A new study has found a surprising connection between rising patent applications and increased rainfall in Japan, suggesting that the country's surge in innovation activity may be linked to noticeable changes in regional weather patterns.

Researchers from the National Institute for Environmental Studies and several partner universities analyzed data spanning more than two decades, comparing annual patent application numbers with meteorological records. They found a consistent correlation: periods of higher patent activity were followed by significant increases in rainfall, particularly in eastern Japan.

"At first, we were skeptical," said Dr. Haruki Sato, the study's lead author. "But the data showed a remarkably strong association, even after accounting for traditional climate factors such as ocean temperatures and atmospheric conditions."



Rain falls over Tokyo on Monday as a new study suggests a link between Japan's rising patent applications and increased rainfall across the country. KYODO NEWS

The study, published this week in the *Journal of Environmental Dynamics*, proposes several possible explanations. One theory suggests that increased industrial and technological activity leads to greater emissions of aerosol particles, which can influence cloud formation and precipitation. Another hypothesis points to urban heat effects and land-use changes associated with growing innovation hubs.

pursue technological progress.

While the research does not claim that patent applications directly cause rain, it highlights a complex relationship between economic development and environmental systems.

"Our findings show that human innovation can have unintended and wide-reaching impacts on the natural world," Dr. Sato said. "This should encourage us to think more holistically about how we

Continued on Page 4

TODAY'S WEATHER



Tokyo
18°C
Showers
High 21° | Low 16°

Osaka	20°	14°
Fukuoka	22°	15°
Sapporo	12°	7°
Sendai	16°	10°

More weather on Page 20

Japan looks to turn innovation into a wetter, greener future

By Kenji Nakamura
Staff Writer

TOKYO — As new research suggests a link between rising patent applications and increased rainfall, some experts say the findings could offer unexpected opportunities for Japan's long-term environmental and economic goals.

Greater rainfall could help replenish water resources, support agriculture and ease the impact of rising temperatures, provided it is well managed. Government officials say they are closely reviewing the study and its potential implications for climate policy, innovation strategy and regional planning.

Continued on Page 5

Global leaders seek common ground at climate summit

By Maria Lopez
International Affairs Correspondent

PARIS — World leaders gathered in Paris this week for a renewed push on climate action, with a focus on financing, technology transfer and fairer emissions targets.

The three-day summit brings together representatives from more than 90 countries, as pressure builds to turn ambitious pledges into concrete results.



Delegates meet in Paris for the international climate summit.

PAGE 10

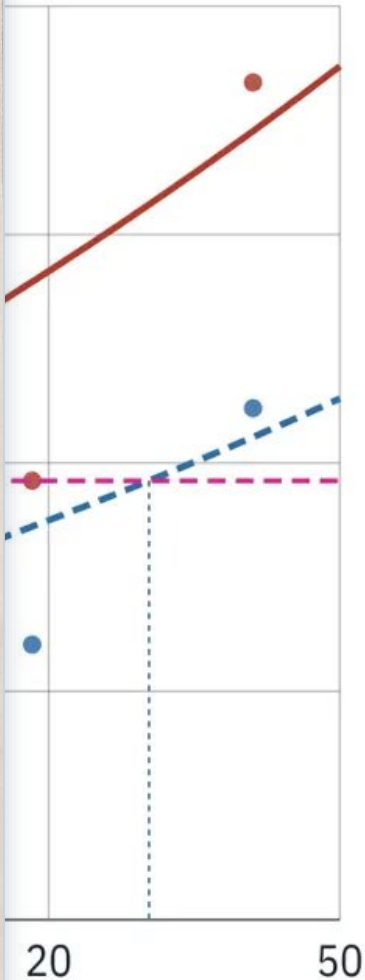
Historic temple reopens after decade-long restoration

By Aiko Tanaka
Staff Writer

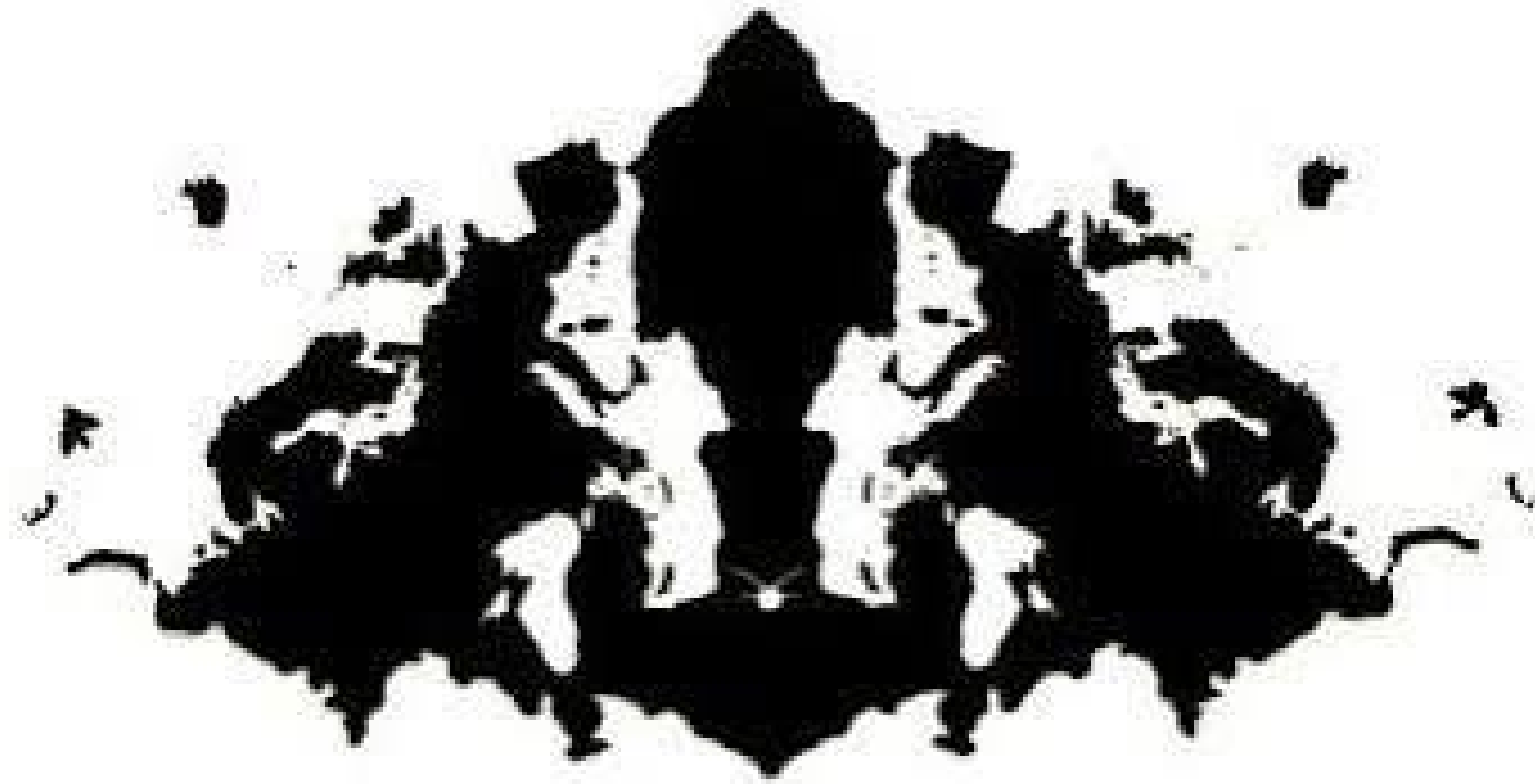
KYOTO — One of Japan's most beloved historic temples reopened to the public this week following a 10-year restoration project. The centuries-old site, known for its intricate woodwork and serene gardens, has been restored using traditional techniques



PAGE 14



Extreme event attribution – A Rorschach test



Concluding thoughts

- The IPCC matters — if it did not exist, we'd have to invent it
- IPCC, most types of extreme weather show no detection or attribution of a change on climate time scales (tropical cyclones, flooding, meteorological and hydrological drought ...); heat waves and, in some places, extreme precipitation offer the important exceptions
- Extreme event attribution assumes its conclusion; the same method attributes home runs to GMST and typhoon rainfall to patent applications
- Extreme weather has become politicized, but good science is out there

Contact and resources

- **Roger Pielke Jr.**

- Senior Fellow, American Enterprise Institute
- Professor Emeritus, University of Colorado Boulder

- **WRITING**

- **The Honest Broker on Substack**

- rogerpielkejr.substack.com

- **THB homepage**

- thehonestbroker.org

- **On X**

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THB DASHBOARDS

US ExtremeWeather and Climate Change Dashboard

extremeweather.thehonestbroker.org

Global ExtremeWeather and Climate Change Dashboard

globalextremeweather.thehonestbroker.org

GlobalTropical Cyclones

thehonestbroker.org/gtc

DecarbonizationAround theWorld

decarbonization.thehonestbroker.org

Build Your Own Climate Scenario

scenarios.thehonestbroker.org

