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Did Climate Change Do That?

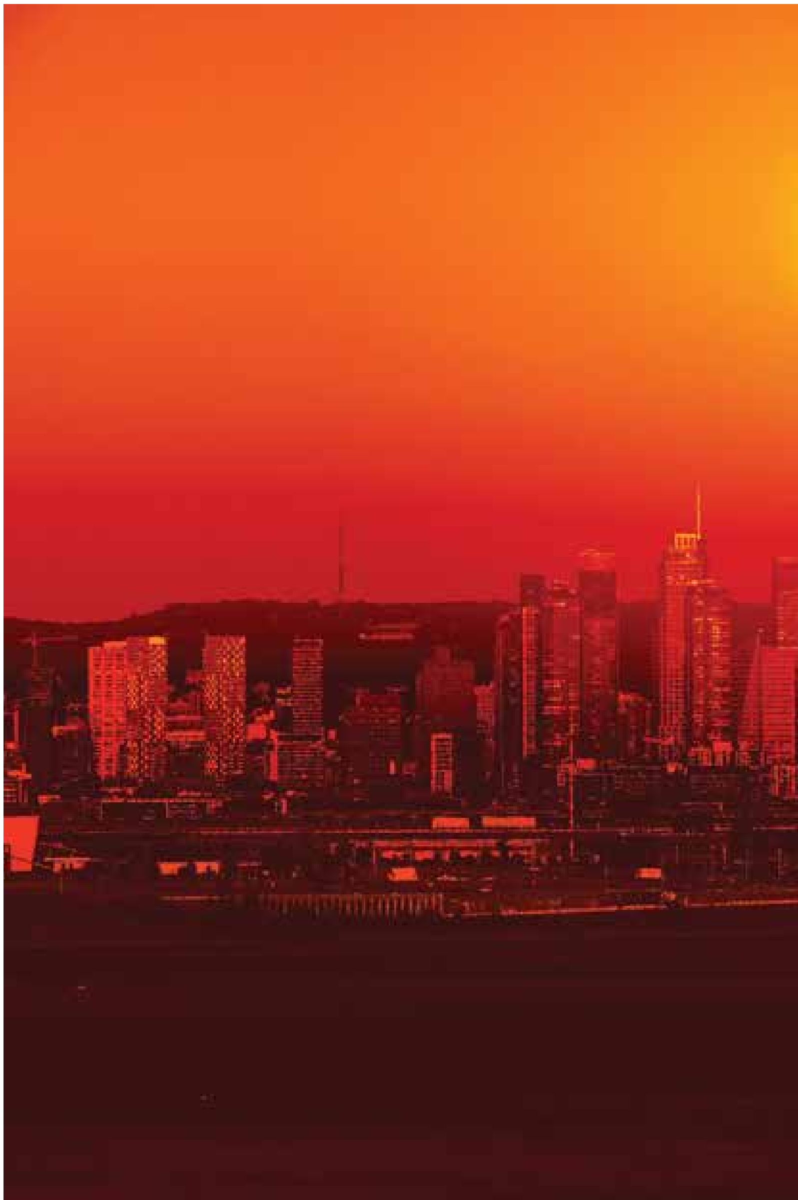
Warming is affecting weather, but attributing a particular disaster to climate change is dicey.

BY DAVID KEMP

In the wake of extreme weather or some natural disaster, the press is often quick to blame the event on human-induced climate change, citing scientists or studies linking the event to fossil fuel emissions. In recent years, these attributions have become more rapid. Articles tied the January 2025 Southern California wildfires to human-caused climate change, citing a World Weather Attribution (WWA) study (Barnes et al. 2025) released before the fires were fully extinguished. And events attributed to climate change seem to be happening everywhere. A 2021 *New York Times* editorial, "Postcards from a World on Fire," depicts the effects of climate change being felt around the globe, from severe droughts in Afghanistan to unseasonable rains in Yemen.

The apparent high level of confidence in the link between these events and anthropogenic climate change is in striking contrast to what is often deemed the foremost authority on warming, the Intergovernmental Panel on Climate Change (IPCC). The IPCC's Sixth Assessment Report (AR6), its latest synthesis of the scientific literature on climate change, offers a more balanced interpretation of the available evidence of effects of climate change. The AR6 finds that extreme heat events like heatwaves are becoming more frequent and intense, and these trends can be attributed to human activities (likewise, cold extremes are becoming less frequent and intense). However, other events—such as extreme precipitation, droughts, tropical cyclones, severe storms, flooding, and fire weather—have mixed evidence of observed changes in their likelihood or magnitude and whether those observed changes can be blamed on anthropogenic climate change.

What accounts for this disconnect? Over the past two



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decades, extreme event attribution has emerged as a prominent scientific discipline, fueled by growing interest in identifying climate change's tangible effects. Yet, this discipline's focus appears to be shifting from measured inquiry to a tool for persuasion. The WWA, for instance, emphasizes *rapid* analysis—often completed within days or weeks of an event—to seize public and political attention while the event is fresh in people's minds.

This trend toward science as a communication tool raises concerns about its usefulness and rigor. The push for quick, definitive answers may overshadow the uncertainties inherent in attribution studies, prioritizing a compelling narrative over a fully substantiated one.

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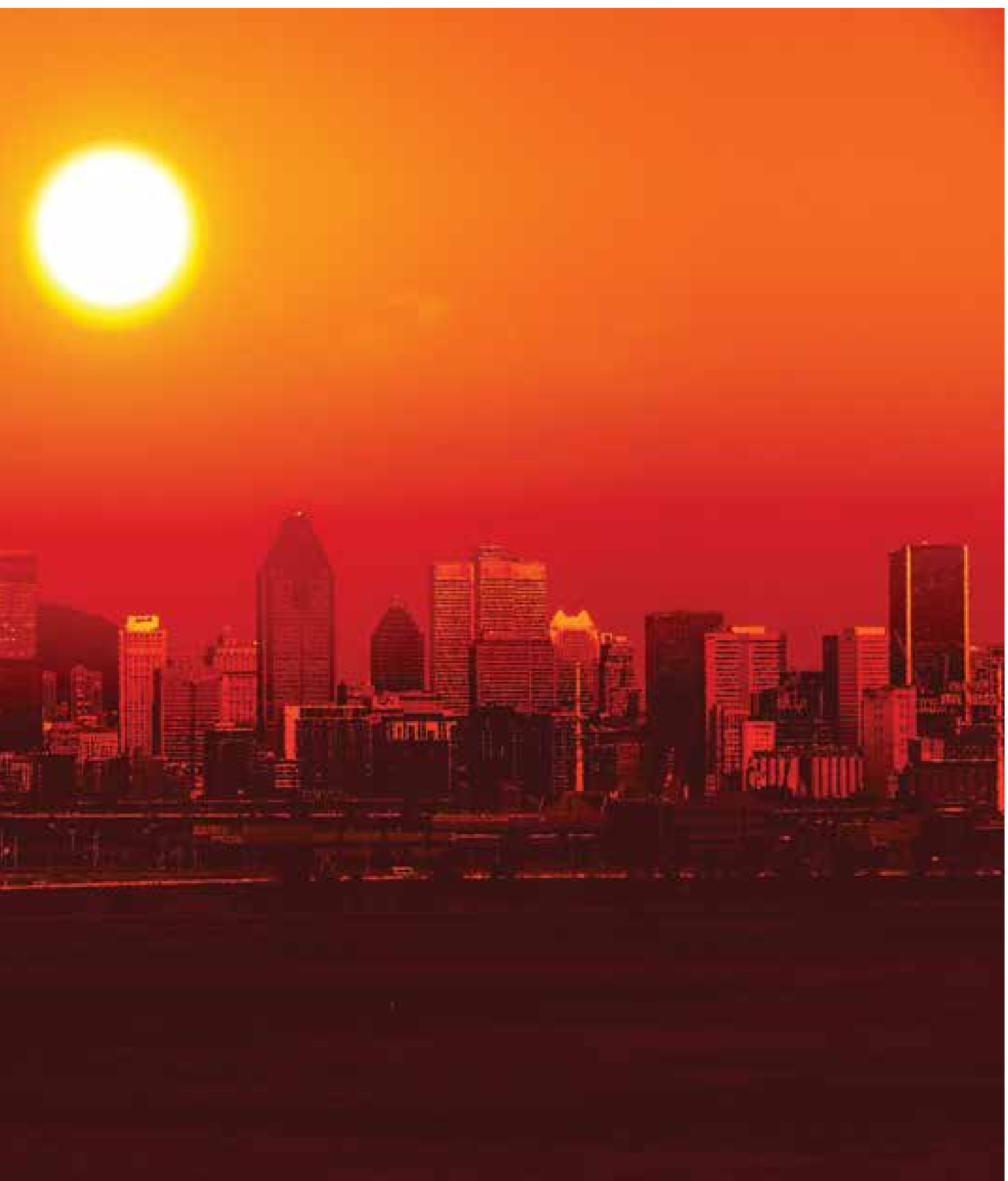
THE BASIS OF EXTREME EVENT ATTRIBUTION

"Climate" describes average atmospheric conditions over an extended period, typically 30 years or more, while "weather" reflects short-term conditions. An individual weather event is the outcome of a complex interplay of variables, including thermodynamic factors (e.g., radiative forcing, which is the difference between the energy Earth receives from the sun and the energy radiated back into space) and dynamic processes (e.g., atmospheric circulation, which is the large-scale movement of air that helps distribute heat across the Earth's surface). As greenhouse gas emissions alter the climate, weather patterns shift too. However, determining whether a specific weather event was "caused" by these emissions—rather than natural variations in other climate factors—is impossible.

Instead, extreme event attribution investigates whether anthropogenic warming has influenced an event's likelihood or severity. This approach originated with Allen 2003, who proposed linking weather events to greenhouse gas emissions by assessing how much they increase the odds of such events occurring. Stott et al. 2004 put this concept into practice in an analysis of the 2003 European summer heatwave. The study compared the probability of such extreme heat occurring in simulations with and without greenhouse gas emissions, concluding human activity had at least doubled the likelihood of the heatwave.



Risk-based attribution / Many extreme event attribution papers follow a similar "risk-based," or probabilistic, framework. The method typically begins by defining the event in question. For example, Ciavarella et al. 2021 define the 2020 heatwave in Siberia as the maximum temperature of the hottest day in June in the region. Zachariah et al. 2023 on heavy precipitation in Greece, Bulgaria, and Turkey analyze the four-day maximum accumulated rainfall in June to September of each year in that region. Observed data from weather stations or interpolated onto grids are analyzed against global mean temperature data to assess whether the frequency of the event in question has changed as global temperature has risen. Climate models then simulate the world with and without greenhouse gas emissions. Any change in frequency between the simulated world with human emissions and the counterfactual world without them is attributed to anthropogenic climate change.

Results are often presented as a change in probability, either as a relative risk (e.g., human-caused climate change doubled the probability of the event occurring), a fraction of attributable risk (e.g., 50 percent of the event's probability is due to anthropogenic warming, with the other 50 percent from natural conditions), or a shift in the return period between the preindustrial and present climates (e.g., what was a 100-year event in 1900 is now a 50-year event). Alternatively, the results may reflect a change in intensity (e.g., this event is 25 percent more intense than an event with equivalent probability would have been in 1900).

Ultimately, this analysis cannot confirm whether a *specific* event was caused by climate change. Hickman 2012 explains this using an often-cited analogy of a loaded die: If the die is weighted to double the odds of rolling a six, a six appearing doesn't *prove* the weighting caused it. All we can say is that the loaded die increases the chance of rolling a six compared to a fair die. Similarly, when asked whether a particular event was the result of human-induced climate change, the risk-based perspective can only state that climate change altered the probability of such an event occurring, not that it directly caused it.

Storyline attribution / An alternative method, the "storyline" approach, has gained favor among some scientists because it offers a potentially more satisfying answer. Instead of asking, "How much more likely did climate change make this event?" it asks, "Given that this event occurred, how did climate change influence its characteristics?" Compared to the probabilistic methods, the storyline approach is more narrative and has been likened to an autopsy (Lloyd and Oreskes 2018).

To build these narratives, the storyline method holds non-thermodynamic conditions like atmospheric circulation patterns fixed and evaluates how thermodynamic changes, such as temperature or humidity, would affect the intensity of the event (Shepherd 2016). For example, Van Garderen et al. 2021 on European heatwaves constrain large-scale atmospheric patterns in climate models to match observed conditions, then compare simulations with temperatures adjusted to reflect worlds with and without human-driven warming to assess climate change's role in amplifying the extreme heat. Similarly, Reed and Wehner 2023 on 2022 Hurricane Ian kept broader meteorological conditions fixed while altering sea surface temperatures and humidity, finding that the storm's rainfall was 18 percent higher than it would have been in a pre-industrial climate.

Comparison / Both methods have strengths and weaknesses (Stott and Christidis 2023) and are not mutually exclusive (Jézéquel et al. 2018). Probabilistic analyses provide a more generalizable answer to how climate change affects a class of extreme weather events, capturing its influence on dynamic and thermodynamic processes. Yet, they rely on models' abilities to reliably simulate extreme events over long periods and are prone to missing trends if natural variability is high or the trends are subtle. Storyline approaches are more likely to connect climate change to a specific event, but the results are less broadly applicable and are largely reliant on assumptions made about a counterfactual world.

Ultimately, both approaches rely on the quality of the data and modeling (Haskett 2023). Weather records stretching back over a century are subject to error from changes in measurement location and techniques. Efforts to correct these may introduce their own errors (Michaels 2008).

Furthermore, a causal link between an event's frequency and global temperatures depends on simulations of "actual" and "counterfactual" scenarios. If our general understanding of natural climate variability or the climate models are inaccurate, then the conclusions of extreme event attribution will also be wrong.

THE IPCC'S ASSESSMENT OF EXTREME EVENTS

A review of media coverage suggests anthropogenic climate change's effect on extreme weather is obvious and ubiquitous. The aforementioned *New York Times* editorial, for instance, cataloged immediate effects of climate change across all 193 UN member states. Yet, as political scientist Roger Pielke Jr. has frequently noted, such media claims contradict the IPCC's latest synthesis of scientific evidence (e.g., Pielke 2024).

The IPCC's AR6, in its chapter on extreme weather, notes:

> Scientists cannot answer directly whether a particular event was caused by climate change, as extremes do occur naturally, and any specific weather and climate event is the result of a complex mix of human and natural factors. (p. 1611)

The chapter examines whether trends in frequency or intensity, both globally and regionally, are detectable for events like heatwaves, heavy rain, floods, droughts, and storms. It also asks, if these shifts stem from human-driven warming and projects, how may they evolve as global temperatures rise? Drawing on the latest evidence, the IPCC concludes with at least medium confidence:

- Temperature extremes show clear global and regional increases in heat events and decreases in cold snaps (pp. 1548–1550).
- Heavy rain has likely risen globally, on some continents (particularly North America, Europe, and Asia), and in nearly half of the regions studied (pp. 1557–1561).
- Drought patterns vary, with some areas experiencing increasing dryness and others decreasing dryness (p. 1575).
- There is low confidence in attributing long-term trends in tropical cyclone overall frequency or intensity, though some characteristics—such as an increase in the proportion of Category 3–5 cyclones, rising frequency of rapid intensification, poleward migration, and slower hurricane translation speed over the United States—show trends in shorter timeframes (pp. 1585–1587).

- Coastal flooding from storm surge and heavy rainfall is increasing globally and in specific areas such as the US coasts (pp. 1599–1600).
- Combined droughts and heatwaves have become more frequent on a global scale—including an increase in the frequency of "fire weather," weather conditions conducive to triggering and sustaining wildfires—in some parts of Europe, the United States, and Australia (p. 1600).

For other events, including river floods, tornadoes, hailstorms, and extreme winds, the IPCC concludes that there is limited evidence of trends (p. 1568, pp. 1591–1598).

Identifying the existence of a trend, though, is not the same as attributing the trend to anthropogenic warming. The IPCC firmly ascribes changes in extreme heat and cold to greenhouse gas emissions (p. 1552), but other conclusions are more mixed. While global and continental trends in heavy rainfall are attributed to climate change, the IPCC concludes that increasing extreme precipitation can be blamed on humans in only two regions, Northern Europe and Central North America (pp. 1562–1563). Drought trends are attributed to anthropogenic warming in only a handful of regions: increasing dryness in the Mediterranean and Western North America, and decreasing dryness in Northern Europe (p. 1579). Changing tropical cyclone characteristics show some evidence of human influence, including high confidence in the findings of extreme event attribution studies that anthropogenic climate change has led to increased precipitation (pp. 1589–1590).

Overall, except for temperature extremes, the IPCC's conclusions are ambiguous, with limited evidence or lack of agreement for many events and regions. Media claims tying events in areas where there is either no clear trend or a trend that has not been conclusively attributed to climate change—such as extreme rain in Yemen or drought in Afghanistan—overstep current scientific knowledge of climate change, according to the IPCC.

There are, however, important caveats. No *observed* trend does not mean there is no trend (and an inability to attribute a trend to human activities does not mean that greenhouse gas emissions are not leading to changes in extreme events). These shifts may be underway, but we are not able to observe them. This is why the IPCC still projects changes in the frequency or intensity of many types of weather events as future temperature rises despite no observed trends or conclusive attribution.

However, the IPCC notes that many of these trends will not be observable for quite some time. Natural variability can obscure subtle human-induced shifts. Our ability to confidently observe climate effects depends on when the strength of those effects exceeds a threshold of natural variability. This is called the "time of emergence," the point at which a climate signal surpasses natural statistical noise. According to Chapter 12 of the AR6, signals for extreme heat and cold have emerged, but for most events the signal will not be distinguishable until much later. Under the most extreme warming scenario (Representative Concentration Pathway 8.5), the signal for heavy rain will not emerge until 2050 to 2100, and the signals for droughts, cyclones, severe storms, river floods, landslides, and fire weather will not emerge until at least 2100

ADVOCACY-DRIVEN ATTRIBUTION

Despite the absence of a clear climate signal, many extreme weather events are routinely blamed on climate change. A 2024 Pew Research poll found that most Americans who have experienced severe storms, prolonged heat, droughts, or wildfires saw climate change as a contributing factor (Kennedy et al. 2024). Yet, the AR6 warns that changes in the frequency or intensity of many such events won't be *statistically* detectable until at least the end of this century, implying these beliefs don't arise from direct experience. What, then, drives this perception?

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In 2005, a Yale School of Forestry and Environmental Studies conference on climate change explored the gap between scientific findings on climate change and political inaction. Abbasi 2006, summarizing the conference, noted in the context of Hurricanes Katrina and Rita and an unusually warm East Coast winter:

> Such events present what has become a recurring dilemma: Should those seeking to prompt action on climate change opportunistically exploit the spike in public concern? Or should they remain scientifically conservative and seek to disabuse people of the notion that individual weather events or seasons, alone, confirm that human-induced climate change is happening?

At that time, studies by climate scientists and psychologists found that many people viewed climate change as a distant threat (Leiserowitz 2005, Spence et al. 2012, Akerlof et al.

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2013). Ballew et al. 2022 found that perceived experience with climate change correlates with shifting perceptions of the risks of climate change.

Climate policy advocates have long realized that extreme event attribution could be an effective tool for persuasion. Hulme 2014 explored motivations for extreme event attribution. Along with scientific curiosity, attempts to improve adaptation efforts, and the possibility of assigning legal liability, Hulme argues that one reason for the scientific interest "is frustration with, and argument about, the invisibility of climate change."

The goal of a more informed public is fine. But prioritizing persuasion and dissatisfaction with science's limits in linking weather to human influence may erode the scientific standards used. Discussing the IPCC's caution over extreme event attribution, Pielke 2025 observes:

> One reason why the IPCC framework sets a high bar for detection of changes in climate variables and the attribution of detected change to causes is that it is so very easy for us to see patterns in randomness and ascribe causes that do not actually exist, or are not particularly significant. Frustration with the scientific rigor of the IPCC is one factor underlying the rise of far less rigorous approaches to detection and attribution.

Should we change the null? / The shift on attribution is exemplified by arguments in favor of changing scientific conventions for quicker affirmative answers about climate change's role in extreme weather. Traditionally, scientific analysis starts with a "null hypothesis"—the assumption that no effect or trend exists unless proven otherwise. Rejecting this assumption requires strong evidence. In an extreme event attribution study of heavy precipitation, for example, the null hypothesis is that there has been no trend in extreme rainfall over the past century. Researchers then attempt to disprove this by identifying a trend with a high level of confidence—conventionally 95 percent, meaning there is only a 5 percent chance that the observed data would arise under the null assumption of no real trend.

The confidence level chosen balances two types of errors. Type I error, or false positive, is the wrongful rejection of the null hypothesis and the conclusion that a climate change-driven trend exists when really it is just the outcome of chance. Type II error, or false negative, is the wrongful acceptance of the null hypothesis, or missing a real trend because of insufficient evidence or noisy data. The confidence level is a tradeoff between these errors. Raising the level (e.g., to 99 percent) reduces Type I errors but increases Type II errors; it requires stronger proof. Lowering the confidence level (e.g., to 90 percent) is less likely to miss real trends but also risks more false positives.

Trenberth 2011 proposes reversing these conventions. He argues that, given the reality of anthropogenic climate change, "Should not the burden of proof be on showing that there is no human influence?" He critiques probabilistic attribution studies for adopting a null hypothesis that climate change has not affected the frequency or intensity of extreme weather. This makes the studies more susceptible to false negatives and more likely to overlook human-driven warming's effects because of sparse evidence or large natural variability. He advocates a null hypothesis that human activity *has* influenced the climate system, thereby affecting weather patterns and extremes, and that attribution studies should seek to *disprove* this assumption. Trenberth et al. 2015 extend this, favoring storyline over probabilistic approaches, particularly where natural variability might overshadow climate change's role. Ultimately, Trenberth seeks to minimize the risk of false negatives, accepting a higher probability of false positives as a tradeoff.

Lloyd and Oreskes 2018 examine scientists' responses to Trenberth's proposal and argue for rethinking conventions. They suggest that many who resist Trenberth reflect a conservative stance prioritizing false negatives over false positives. For anthropogenic climate change, this is a choice between *overreaction* from false positives or *underreaction* from false negatives. They correctly note that this is a normative, not a scientific, decision.

There is nothing inherently wrong with challenging scientific conventions. If assumptions are transparent and tradeoffs are explicit, then altering the null hypothesis or varying the confidence level (e.g., 99, 90, or even 50 percent) is scientifically valid. What is troubling, however, is that in climate attribution discussions, arguments are guided more by advocacy than scientific concerns. Trenberth 2011, for example, warns that "the result of bad and misleading statements about attribution" from false negatives "is to grossly underestimate the role of humans in climate events of note in recent times to the detriment of perceptions about climate change and subsequent policy debates." But which misleads more, a study noting that

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our understanding of the climate suggests a class of extreme event is increasing yet lacking evidence in a specific case, or a study falsely declaring a particular event was "caused" by climate change?

Lloyd and Oreskes 2018 highlight the "challenge of communication" of conventional conservative conclusions:

> Because no event can be attributed to climate change without an attribution study, this effectively means that scientists following community norms will nearly always convey the message that individual events are not related to climate change—or at least, that we cannot say if they are. In short, it conveys the impression that we just do not know, which feeds into both contrarian claims that climate science is in a state of high uncertainty, doubt, or incompleteness, and the general tendency of humans to discount threats that are not imminent.

This implies that requiring robust evidence before linking events to climate change is detrimental because it fosters "too much" uncertainty, even though that uncertainty stems from conventional scientific standards.

Although extreme event attribution studies have not altered their null hypotheses, some scientists label traditional methods "overly conservative" and ethically suspect (Otto 2023). Olsson et al. 2022 argue that the probabilistic approach creates "data injustices" because it is less likely to find a climate change effect in regions with more limited climate data, such as sub-Saharan Africa and South America. In a 2023 review, Friederike Otto, co-leader of World Weather Attribution, stated that "undertaking extreme event attribution as a purely data-driven, statistical exercise would indeed be ethically questionable," noting recent studies have looked beyond just quantitative evidence and allow for "expert judgement and the inclusion of other lines of evidence to inform overarching results" (Otto 2023).

WWA studies / WWA exemplifies the potential for event attribution to be advocacy driven. As described on its Frequently Asked Questions webpage, the focus of WWA is *rapid* event attribution, published without peer review:

> The results are published days or weeks after the event to inform discussions about climate change, mitigation and adaptation, while the effects of the extreme weather event are still fresh in the minds of the public and policymakers, and decisions about rebuilding are being made. (WWA undated)

Though they cite rebuilding decisions, the urgency for insight into climate change's effects in the immediate aftermath of extreme weather seems overstated. Capitalizing on public attention to highlight climate dangers seems like a stronger motivation.

The organization stresses that, though its reports are initially not peer reviewed, they follow peer review methods and some studies are subsequently peer reviewed. To my knowledge, no WWA report has been substantially changed post review. But prioritizing rapid attribution inherently increases error risks. Peer-reviewed studies of the 2010 Russian heatwave (Otto et al. 2012) and a 2013 flood in Colorado (Trenberth et al. 2015, Hoerling et al. 2015) have come to different conclusions on the role of climate change based on framing or methodology. A 2018 real-time analysis of climate change's effects on Hurricane Florence saw its estimates drop by an order of magnitude after a peer-reviewed version was published months later (Johnson 2020). Rushing analysis risks overlooking important methodological issues or errors with major effects.

Rapid attribution studies from WWA range from more quantitively robust—where observed trends and modeled attribution to climate change are both statistically significant—to less grounded. WWA 2025, on the Southern California wildfires, firmly attributes higher fire probability to climate change, citing "lines of evidence" like observed and modeled links between fire weather, precipitation, and dry season length and global temperatures. None are statistically significant, though observed and modeled estimates mostly align in magnitude and direction. It attributes uncertainty to complex weather modeling challenges. Additional evidence includes rising winter Santa Ana winds (not linked to climate change) and simulations showing increased burned areas with climate change, despite not matching observed burned areas. Because these lines of evidence "overall point in the same direction" and are "in line with existing literature," the researchers conclude that they "have high confidence that human-induced climate change, primarily driven by the burning of fossil fuels, increased the likelihood of the devastating LA fires." Media coverage, such as an article from *ScienceNews* with the headline "Yes, You Can Blame Climate Change for the LA Wildfires," reported these results uncritically, citing point estimates despite their lack of significance.

More broadly, extreme event attribution's focus on single events distorts the study of climate effects. Climate change doesn't uniformly worsen weather; it can intensify some events while mitigating others. The AR6, for instance, notes in Chapter 11 that many climate models project an increase in the *proportion* of Category 4–5 tropical cyclones, but a decrease in the overall *frequency* of tropical cyclones because of fewer weaker storms (p. 1590). If these projections are correct then, all else equal, damages might remain the same or decline. Zhang et al. 2022 found that from 1980 to 2018, global extreme heat events grew in magnitude, but extreme cold events declined more rapidly, yielding a net reduction in the cumulative magnitude of extreme temperatures.

Brown 2024 argues that extreme event attribution is subject to selection bias: It only studies events that *occurred*, ignoring extreme events that *did not occur* because of a changing climate. Advocacy-driven science may amplify the risk of selection bias; the goal of media coverage favors studies that detect a human-induced climate change effect.

CONCLUSION

Until recently, debates over the extent to which the burning of fossil fuels has changed the frequency of extreme weather have been largely academic. As efforts to establish liability and compensation for climate change damages increase, the findings of extreme event attribution may soon have substantial economic consequences. In May 2024, Vermont enacted the Climate Superfund Act, modeled after the federal Superfund program, requiring major greenhouse gas emitters to pay for extreme weather damages calculated through event attribution science. Likewise, the United Nations' Fund for Responding to Loss and Damage, created to aid climate change–vulnerable developing nations, may rely on attributing extreme weather to anthropogenic climate change for disbursements. Once "science" plays an important role in quantifying liabilities, the differences between science and advocacy will become more difficult to discern. R

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