

What is the quantifiable link between rising global temperatures and the increasing frequency/intensity of extreme weather events?

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Executive Summary

Rising global temperatures are quantifiably linked to an increasing frequency and intensity of extreme weather events, with human activities identified as the dominant driver of this warming trend. Attribution science has advanced to reliably quantify the human contribution to specific events, demonstrating that approximately 70-80% of analyzed extreme events have been made more likely or intense by climate change [20]. While natural climate variability plays a role, anthropogenic forcing is increasingly dominant in shaping long-term trends, particularly for heatwaves and heavy precipitation.

Key Findings

Quantifiable Link to Extreme Events

A clear and increasingly well-documented link exists between rising global temperatures and the frequency and intensity of extreme weather events [1, 8, 9, 12]. Global average temperatures have risen significantly, with projections for 2026 indicating an increase of 1.4°C to 1.58°C above pre-industrial levels. This warming has accelerated, with the Earth now warming at a rate of around 0.35°C per decade, compared to an average of just under 0.2°C per decade between 1970 and 2015. As the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report found, "the human-caused rise in greenhouse gases has increased the frequency and intensity of extreme weather events" [15].

Strongest Links: Heatwaves and Heavy Precipitation

Heatwaves and heavy precipitation events show the strongest and most consistently quantifiable links to rising global temperatures [1, 8, 9, 12]. This relationship is rooted in fundamental physics: warmer air holds more moisture, intensifying rainfall, and directly

increases the likelihood of extreme heat events [1, 9, 11, 12]. The frequency of record-high temperatures has increased, exceeding expectations under stationary climate conditions [1, 2, 3, 5]. For example, attribution studies confirm that the 2003 European heatwave was made more probable by human-caused warming . Similarly, the proportion of land experiencing unusually high precipitation has been rising [18]. Mediterranean heatwaves have increased in frequency and are projected to become more intense with further warming [14]. South Asian monsoon rainfall is also experiencing increased intensity due to warmer air holding more moisture [1, 9, 12].

Advancements and Limitations of Attribution Science

Extreme event attribution (EEA) science has advanced significantly, enabling researchers to quantify the contribution of human activity to specific events [2, 6, 8, 14]. This involves comparing the probability of an event occurring in the current climate versus a hypothetical climate without human-induced warming [6, 8, 13, 19]. Approximately 70-80% of studies conclude that climate change increased the likelihood or intensity of the analyzed extreme event [20]. Despite these advancements, challenges persist, including accurately modeling complex interactions, accounting for natural climate variability, and limitations in data availability [7]. Methodological debates and uncertainties in assessments also continue [4, 5, 6].

Challenges with Compound Events and Hurricane Frequency

Current EEA methodology struggles to fully capture the complexities of cascading and compound events, potentially underestimating climate change's role [7]. Attributing compound events, such as heatwaves combined with drought, is particularly difficult due to the need for improved modeling capabilities and data collection [7]. Data gaps, especially in the Global South, hinder accurate model validation for these complex interactions [17].

Regarding hurricanes, while evidence suggests they are becoming more intense due to warmer ocean temperatures, the *overall number* of Atlantic hurricanes does not exhibit a clear long-term increasing trend [9, 11, 12]. Accurately attributing changes in hurricane frequency remains a challenge due to natural climate variability and limitations in historical data [9, 11].

Role of Feedback Loops

Specific feedback loops could dramatically accelerate the relationship between global warming and extreme weather events beyond current projections, though their likelihood remains uncertain [7]. The thawing of Arctic permafrost, for instance, releases significant carbon stores, estimated between 1,460-1,600 billion metric tons, which is comparable to twice the current atmospheric carbon. The Arctic is warming at a rate nearly four times faster than the global average, accelerating permafrost thaw and increasing the risk of reaching climate tipping points [5, 6, 13]. Increased wildfires in Arctic regions also release an additional 142 million tonnes of carbon annually [15]. These factors imply the potential for unforeseen accelerations, and current projections may underestimate future risks [7].

Dominance of Anthropogenic Forcing

While natural climate variability (e.g., El Niño-Southern Oscillation) continues to play a role, anthropogenic forcing is increasingly dominant in shaping long-term trends in extreme weather events, exceeding the influence of natural cycles [1, 9, 10, 13]. The planet is warming, and human activities are the dominant driver [1, 9, 10, 13]. This is evident in the quantifiable human contribution to specific extreme events [2, 6, 8], with approximately 70-80% of studies linking climate change to increased likelihood or intensity [20]. Future warming will exacerbate the risks associated with extreme weather [1, 8, 9, 15].

Implications

The quantifiable link between rising global temperatures and extreme weather events means that current confidence in attributing extreme weather to climate change justifies substantial mitigation and adaptation efforts [1, 8, 9, 12]. The increasing frequency and intensity of heatwaves and heavy precipitation, in particular, provide a strong basis for prioritizing strategies focused on these areas. While further research is crucial to refine predictive capabilities and address uncertainties, especially for compound events, the existing evidence is sufficient to warrant immediate action [7]. Continued investment in high-resolution regional modeling and multi-hazard risk assessment frameworks is necessary to improve the understanding and projection of complex, interconnected events [16].

Limitations and Caveats

Despite significant advancements, attribution science still faces limitations. Accurately modeling complex interactions, accounting for natural climate variability, and addressing data gaps, particularly for compound events like simultaneous heatwaves and droughts, remain challenging [7]. Different methodologies and model choices can lead to variations in attribution estimates [4, 5]. While the intensity of hurricanes is increasing, a clear long-term trend in their *number* has not been established [9, 11]. The precise quantification of specific feedback loops and their dramatic acceleration of warming's impact on extreme weather events beyond current projections also remains uncertain [7].

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