

# The Science Connecting Extreme Weather to Climate Change

From heat waves to hurricanes, heavy rain to severe drought, people across the United States regularly confront the negative effects of extreme weather events—and the cost of these events is increasing. Of the 20 costliest weather and climate disasters that have occurred in the United States since 1980, eight have taken place since 2010, and four of these eight in 2017 alone (NCEI 2018). In total, extreme events occurring in the United States since 1980 have resulted in nearly 10,000 deaths and more than \$1.5 trillion in damage, according to official estimates, though these estimates likely undercount deaths (Kishore et al. 2018; NCEI 2018; Schmeltz et al. 2015).

As the economic and human toll of extreme weather events has grown, so too has our understanding of the role climate change plays in worsening many types of extreme events. Over the past decade, the scientific field known as “climate attribution” has developed rapidly as scientists have been increasingly able to identify and quantify the part human-driven climate change plays in increasing the frequency and intensity of many types of extreme weather events.

In a landmark 2004 paper, researchers determined that climate change had at least doubled the risk of occurrence of the record-breaking 2003 European summer heat wave, which



Federal Emergency Management Agency (FEMA) officials perform a water rescue following Hurricane Harvey. Human-caused climate change made the record rainfall that hit Houston during Hurricane Harvey roughly three times more likely and 15 percent more intense (van Oldenborgh et al. 2017a; van Oldenborgh et al. 2018). Source: FEMA.

resulted in the deaths of tens of thousands of people (Stott, Stone, and Allen 2004). A 2016 study of the same heat wave concluded that human-caused climate change had increased the risk of heat-related mortality during the event by about 70 percent in central Paris and about 20 percent in London (Mitchell et al. 2016).

Numerous authoritative scientific institutions and government agencies have released studies in recent years that reflect how much the science of climate attribution has developed:

- The *Bulletin of the American Meteorological Society* has dedicated a special issue each year since 2012 to assessing whether and how much climate change may have contributed to extreme weather events. The 2016 special issue states, **“The science has now advanced to the point that we can detect the effects of climate change on some events with high confidence”** (Herring et al. 2016).
- The National Academies of Sciences, Engineering, and Medicine issued a report in 2016, *Attribution of Extreme Weather Events in the Context of Climate Change*, that states, **“In the past, a typical climate scientist’s response to questions about climate change’s role in any given extreme weather event was, ‘We cannot attribute any single event to climate change.’ The science has advanced to the point that this is no longer true as an unqualified blanket statement”** (NASEM 2016).
- The US Global Change Research Program released the first volume of the *Fourth National Climate Assessment*, the *Climate Science Special Report*, in November 2017. The report states this key finding: **“The attribution of extreme weather and climate events has been an emerging area in the science of detection and attribution. Attribution of extreme weather events under a changing climate is now an important and highly visible aspect of climate science”** (Knutson et al. 2017).

**Over the past decade, scientists have been increasingly able to identify and quantify the part human-driven climate change plays in extreme weather events.**

## Strength of the Evidence

Strong evidence suggests that extreme heat waves, coastal flooding resulting from storm surge and regular high-tide events, and extreme precipitation—including hurricane downpours—bear a strong climate change signature. Scientists are better able to identify climate change’s relative contribution for these types of extreme weather events than for others (Knutson et al. 2017). The science is currently less conclusive for tornados, thunderstorms, and some types of droughts, and there is growing evidence for wildfires (Figure).

In the case of wildfires, a combination of factors influences risk. Those tied to human-caused climate change, such as warming temperatures and drying soils, have contributed to observed increases in wildfire activity—area burned, the number of large wildfires, and wildfire season length—in the western United States in recent decades (Abatzoglou and Williams 2016). It is important to note, however, that factors unrelated to climate change, including land use and fire suppression practices, also affect wildfire risk (Wehner et al. 2017). In southern California, for example, while climate change plays a role, development and seasonal Santa Ana winds also contribute to increased wildfire activity (Jin et al. 2015; Miller and Schlegel 2006). However, in high elevation forests where there has been minimal human activity, climate change plays a greater role (Crockett and Westerling 2017; Westerling 2016).

An extreme weather event’s intensity is another important factor for determining whether climate change played a role. While many individual extreme events could have occurred in the past, before the advent of human-caused climate change, they likely would not have been as intense without its influence (Fahey et al. 2017). Recent studies find that some record-breaking heat events were so extreme that they would have been nearly or entirely impossible if it were not for human influence on the climate system (Imada et al. 2018; Knutson et al. 2018; Walsh et al. 2018).

## Individual Event Attribution

Over the past several years, scientists have been able to discern the influence of climate change on individual extreme weather events, including heat waves, extreme precipitation and flooding events, droughts, and extreme cold snaps, as well as on the intensity of hurricanes.<sup>1</sup>

When scientists investigate climate change’s effects on extreme events, they are not asking whether climate change caused an event. Instead, they attempt to determine whether and by how much climate change has affected the likelihood or

## The Connection Between Extreme Weather and Climate Change



Little or no rain



Extreme precipitation  
(rain and snow)



High-tide flooding and  
increased storm surge



Extreme heat



Tornadoes and  
thunderstorms



Western wildfire  
activity



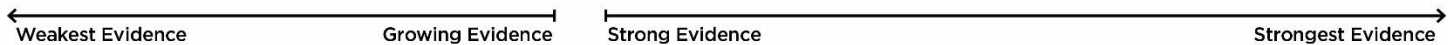
More Atlantic hurricanes



Parched soil



Extreme rainfall from  
hurricanes



Scientific evidence for connections between extreme weather events and climate change is stronger for some types of events than for others. Strong evidence exists to connect events to the right of the line break to climate change. Evidence is currently weak or growing for events to the left of the break.

Note: A figure methodology can be found online at [www.ucsusa.org/climateattribution](http://www.ucsusa.org/climateattribution).

SOURCES: USGCRP 2017; IPCC 2014.

intensity of an event (Stott et al. 2015). They often rely on real-world observations incorporated into climate models, which make calculations to simulate what would likely happen if individual conditions—such as global average temperatures—were different.

Extreme events are by definition rare—if they occurred regularly, we would likely not consider them extreme. By running climate models that recreate real-world conditions at the time of an event, scientists can determine just how rare—that is, how likely or unlikely—an event that actually occurred really was. Researchers then determine the likelihood of the same event under a different set of conditions by repeating the process using a climate model that simulates a hypothetical world in which humans have no influence on the climate (Knutson 2017; NASEM 2016). By comparing the likelihoods under these two scenarios, researchers can determine the extent to which human-caused climate change affected an event.

Recent US extreme weather events that scientists have tied to climate change include:

- **Hurricane Harvey (August 2017):** Human-caused climate change made the record rainfall that hit Houston during Hurricane Harvey roughly three times more likely and 15 percent more intense (van Oldenborgh et al. 2017a; van Oldenborgh et al. 2018).
- **US winter heat wave (February 2017):** Human-caused climate change made the heat wave that spread across the contiguous United States in February 2017 more than three times more likely (van Oldenborgh et al. 2017b).
- **Louisiana floods (August 2016):** Human-caused climate change increased the likelihood of the extreme rain event that hit Louisiana on August 2, 2016, by at least 40 percent (van der Wiel et al. 2017).



Public health officials and volunteers go door-to-door to check on the safety of senior citizens and disabled residents in St. Louis during a heat wave in July 2011. The scientific evidence connecting extreme heat waves to climate change is among the strongest for all types of extreme weather events. Source: United Way of Greater St. Louis.

- **Hurricane Sandy (October 2012):** Hurricane Sandy's storm surge—already made more damaging by exceptionally high lunar tides—flooded an area about 27 square miles larger than it would have if the storm had hit in 1880 because human-caused climate change has caused global mean sea levels to rise by eight inches since then (Miller et al. 2013).

## Increased Risks, Increased Understanding

Climate attribution science is filling critical gaps in our understanding of the connection between extreme weather and climate change. This increased understanding presents an opportunity to determine whether the ways we currently plan for, respond to, and recover from extreme weather events are appropriate for a world where climate change makes many types of extreme events worse. Ensuring that we are fully aware of the risks posed by climate change when we make individual and institutional decisions about disaster planning offers us the best chance to protect livelihoods, homes, and communities.

### ENDNOTES

- 1 A detailed list of climate attribution studies can be found online at [www.ucsusa.org/climateattribution](http://www.ucsusa.org/climateattribution).

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