State of the Science FACT SHEET

Interpreting How Climate Change Affects Extreme Events

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION • UNITED STATES DEPARTMENT OF COMMERCE

This summary of extreme weather and climate events was developed by NOAA scientists and approved by NOAA's Research Council.

Extreme events have significant impacts on society and ecosystems.

Extreme events are those that rarely occur at a given location or have significant impacts on society or ecosystems. In 2013, there were seven weather and climate events with losses exceeding $1 billion in the U.S. and leading to 109 deaths. In 2012, the damage caused by Superstorm Sandy alone is estimated at over $65 billion. People and property are increasingly vulnerable to extreme events as populations grow in regions susceptible to such events – for example, sea level rise makes many coastal communities more vulnerable to hurricanes and storm surges. As impacts from extreme events continue to rise, NOAA scientists are increasingly being asked whether and how human-induced climate change and natural climate variations may contribute to extreme events. NOAA's research to understand the causes of extreme events helps improve America's ability to anticipate these events as our communities and businesses prepare for the future.

Scientists use multiple methods to assess the causes of extreme events.

Determining the underlying cause of a particular extreme event begins with a scientific understanding of how various natural and human factors influence weather and climate. Scientific observations, especially from past events with similar characteristics, are essential for advancing our understanding of extreme events. In addition, simulations using climate models are used to evaluate how different factors may have influenced an event. For example, scientific experiments with these models can vary a particular factor, like the concentration of a heat-trapping gas like carbon dioxide, while other factors are held constant. Also, geologic and paleoclimate records, as well as statistical methods, all contribute to our ability to detect and attribute influences on extreme events. Observations, models, and analyses together build the scientific foundation for determining how a particular factor did or did not contribute to an extreme event.



Billion Dollar Weather and Climate Disasters
(1980 – 2013) *(Consumer Price Index-Adjusted)*

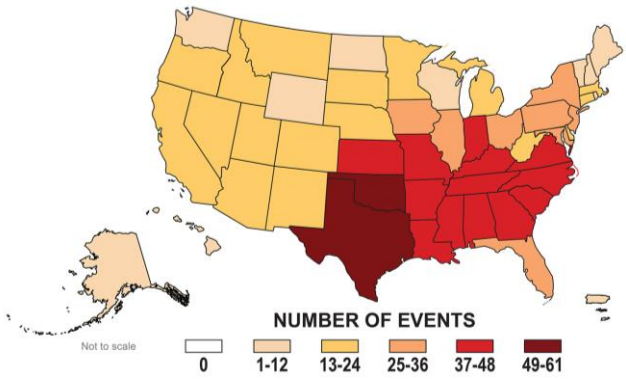

Figure 1: Shading represents the number of U.S. billion-dollar weather and climate disasters by state 1980-2013. Data and image available at: http://www.ncdc.noaa.gov/billions.

Both natural variability and human-caused climate change influence extreme events.

Natural variability refers to changes in weather and climate that are not caused by human influences. These naturally occurring changes in weather and climate patterns can be caused by variability within the climate system itself, like El Niño/La Niña. They can also be due to natural external factors like volcanic eruptions or solar variations. Many of the extreme events we experience today can be explained by natural variability alone. For example, atmospheric 'blocking' events (continental-scale stationary patterns in atmospheric pressure) or persistent weather patterns caused by El Niño/La Niña are often associated with extreme events like heat waves or flooding.

However, human-caused climate change can also be a factor in influencing the intensity or frequency of extreme events. In particular, it becomes increasingly important in explaining global and continental extremes spanning years and decades, like record low Arctic sea ice extent. Human-caused climate change has very likely (>90% chance) increased the number of extreme warm days and nights, and likely (>66% chance) lengthened the duration of heat waves. Impacts vary regionally and depend on the type of extreme considered. Increases in water vapor accompanying the warming have very likely led to more extremes in amount and intensity of rainfall in many regions. For other types of extremes, like hurricanes and tornadoes, there has been no detectable human influence to date. However, this does not rule out detecting human influences as our observational record and scientific understanding about these complex relationships improve over time.

Some analyses show human-caused climate change was likely a contributing factor to specific extreme events.

Human-caused climate change is not the sole cause of any single extreme event. While establishing causes of a specific extreme event can be difficult and requires case-specific methods, scientists can assess whether human-caused climate change influenced a specific extreme event. For example, researchers estimated that human-caused warming had increased the risk of anomalously warm springtime-average temperatures over the eastern U.S. -- like those occurring in 2012 -- by about a factor of 10. The challenge is similar to that of establishing the diagnosis of a disease or the causes of a car crash. In these cases, as with weather and climate events, causes can be complex and multiple factors can play contributing roles.

The science in this area is in a stage of rapid development. Some of the latest methods being applied to recent extremes can be seen in annual reports on explaining extreme events (see Additional Reading). As these reports illustrate, there are many factors that can introduce uncertainty in estimating the influence of human and natural factors on extremes. They include limitations on scientists' physical understanding, an incomplete observational record, and physical factors not accounted for in models. Therefore, findings of individual studies should be interpreted with caution. Assessments of past events may change over time as additional information and improved techniques become available. As the observed record for extremes continues to grow, the climate continues to change, and the state of science of establishing causes for extreme events advances, event-specific statements will improve in the future.

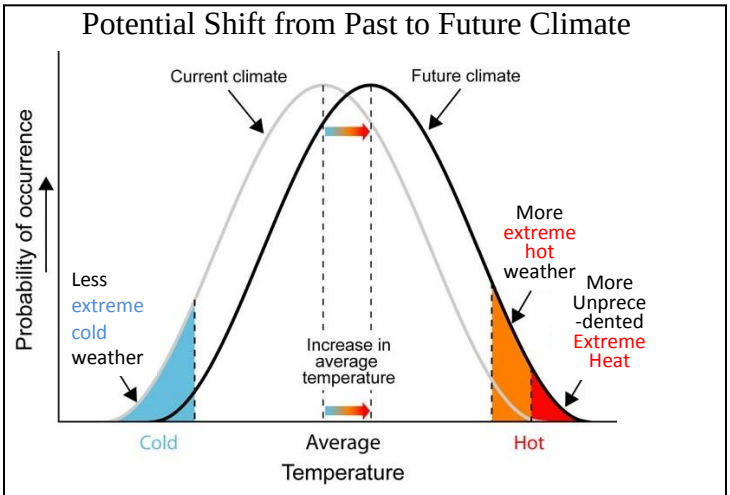

Figure 2. Illustration of a change in intensity and frequency of extreme heat waves. As the future climate warms, the distribution of temperatures will shift to the right. This causes the area under the curve for extreme hot weather to increase, indicating that events exceeding a certain threshold are more frequent. Also, the potential intensity of these events can increase resulting in more extremes of unprecedented intensity. Figure Adapted from the IPCC Special Report on Extremes

Climate change can influence an extreme event's *intensity* and *frequency*.

Climate scientists can assess the influence of human-caused climate change (or natural variability) on both the *intensity* and *frequency* of extreme events. Assessments of intensity and frequency are simply different ways of looking at extreme events and provide different insights on the role that human-caused climate change may have had on a particular event. For example, Fig. 2 depicts a changing climate where average temperatures become higher and the frequency of extreme hot weather increases by shifting the temperature distribution to the right. As shown in Fig. 2, warming of the background weather can make typical heat waves *more intense* and can also make intense heat waves *more likely to occur*. In general, the data record allows scientists to estimate changes in average intensity with higher confidence than they can estimate changes in the frequency of relatively rare events.

In the future, human-caused climate change is expected to exert a stronger influence on particular types of extreme events.

As the influence of human-caused climate change on the atmosphere and oceans continues to increase, some types of extreme events are expected to increase in intensity and frequency during the 21st Century, though changes are typically expected to be small compared to natural variability in the next few decades and will vary regionally. The vulnerability of coastal regions to storm-surge flooding is expected to increase with future sea-level rise and coastal development, although this vulnerability will also depend on future storm characteristics. It is virtually certain (99-100% chance) that the frequency and intensity of daily heat extremes will increase, and there will be fewer cold extremes. It is very likely the frequency of heavy precipitation events will increase over many regions, but there is uncertainty around effects on flooding in specific areas. Global tropical cyclone frequency is expected to stay the same or decrease, while the average intensity increases by up to 10%. For other extremes, like tornadoes, the influence of human-caused climate change remains very uncertain, and further observations and research are needed. NOAA is a leader in sustaining observations of the Earth system and extreme events, along with research to understand how extremes may change in the future. **NOAA's work informs how the nation manages the risks of extreme events to people's lives, livelihoods, and the ecosystems on which we all depend.**

Additional Resources

- Explaining Extreme Events from a Climate Perspective (2012), www.ametsoc.org/2012extremeeventsclimate.pdf
- Managing the Risks of Extreme Events and Disasters (SREX) (2012) http://ipcc-wg2.gov/SREX/
- IPCC: The Physical Science Basis (2013), *Attribution of Weather and Climate Events,* http://www.ipcc.ch/