The Science Connecting Extreme Weather to Climate Change

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Appendix B: Figure Methodology

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The figure was developed based on careful evaluation of the *Climate Science Special Report* (CSSR), the first volume of the *Fourth National Climate Assessment* from the US Global Change Research Program, and the *Fifth Assessment Report* (AR5) of the Intergovernmental Panel on Climate Change, *Climate Change 2014: Synthesis Report*. Since some of the climate attribution statements used in the figure do not apply globally (e.g., Atlantic hurricane activity, western wildfire activity), this figure should be used as a guide only for extreme events in the continental United States.

Both reports use definitions of likelihood and confidence to describe the strength of evidence supporting connections between extreme weather events and human-caused climate change. Likelihoods describe probabilistic measures of uncertainty while confidence levels are based on qualitative measures like the type, amount, quality, and consistency of evidence. CSSR and AR5 use the same definitions for likelihoods but different descriptions of confidence levels (Table B1).

To allow for comparisons of statements of likelihood and confidence within and between the two reports, we assigned each likelihood and confidence level a value of 0 to 99. A value of 0 reflects a statement that shows little or no evidence to support a claim, and a value of 99 reflects findings with a likelihood of "virtually certain."

Values for likelihood terms "likely" and higher were based on the lower bounds of their ranges, the term "about as likely as not" was assigned value of 50, and the terms "unlikely" and lower were based on the upper bounds of their ranges. We assigned high confidence a value of 83, medium confidence a value of 50, and low confidence a value of 17. (There were no event types we included that had a very high confidence level.) Event types with likelihood or confidence levels with values equal to or higher than 50 were included on the right side of the break in the figure, indicating at minimum strong support for a connection. Event types with values less than 50 were included on the left side of the break, indicating events with weak or growing support for a connection.

Statements from CSSR were preferred to those from AR5 since CSSR includes important research not yet published at the time AR5 was released. Table B2 shows the event types included in the figure, the physical driver associated with the event type, and the corresponding attribution statement.

TABLE B1. Likelihoods and Confidence Levels Used in CSSR and AR5

Likelihoods								
Exceptionally unlikely	Extremely unlikely	Very unlikely	Unlikely	About as likely as not	Likely	Very likely	Extremely likely	Virtually certain
0%-1%	0%-5%	0%-10%	0%-33%	33%-66%	66%-100%	90%-100%	95%-100%	99%-100%

Confidence Levels		
CSSR	Low	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts
	Medium	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought
	High	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus
	Very high	Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus
AR5	Low	Low agreement, varying evidence (limited, medium, robust) by type, amount, quality, consistency
	Medium	Medium agreement, varying evidence (limited, medium, robust) by type, amount, quality, consistency
	High	High agreement, varying evidence (limited, medium, robust) by type, amount, quality, consistency

TABLE B2. Attribution Statements Used in Figure

Event Type	Associated Phenomenon or Mechanism	Likelihood or Confidence Level	Value	Attribution Statement	Source
Extreme heat	Frequency and intensity of daily temperature extremes	Very likely	90	"It is **very likely** that human influence has contributed to the observed global scale changes in the frequency and intensity of daily temperature extremes since the mid-20th century."	IPCC 2014
Extreme rainfall from hurricanes	Upper ocean heat content[1]	Very likely	90	"It is **very likely** that anthropogenic forcings have made a substantial contribution to increases in global upper ocean heat content (0–700 m) observed since the 1970s."	IPCC 2014
High-tide flooding and increased storm surge	Global mean sea level rise	High confidence	83	"Human-caused climate change has made a substantial contribution to GMSL rise since 1900 (**high confidence**)"	Sweet et al. 2017
Parched soil	Hydrological drought (i.e., surface soil moisture deficits)	High confidence	83	"...much evidence is found for a human influence on surface soil moisture deficits due to increased evapotranspiration caused by higher temperatures. (**High confidence**)"	Wehner et al. 2017
Extreme precipitation (rain and snow)	Continental heavy precipitation (where data are sufficient)	Medium confidence	50	"There is **medium confidence** that anthropogenic forcing has contributed to global-scale intensification of heavy precipitation over land regions with sufficient data coverage."	Easterling et al. 2017
More Atlantic hurricanes	Post-1970s hurricane activity	Medium confidence	50	"There is **medium confidence** that [greenhouse gases and aerosols have] contributed to the observed increase in Atlantic hurricane activity since the 1970s."	Knutson et al. 2017
Western wildfire activity	Increased temperature and evapotranspiration[2]	Low to medium confidence	33	"There is ... **low to medium confidence** for a detectable human climate change contribution [to increased forest fire activity] in the western United States."	Knutson et al. 2017
Little or no rain	Meteorological drought (i.e., precipitation deficits)	None	0	"The human effect on recent major U.S. droughts is complicated. **Little evidence** is found for a human influence on observed precipitation deficits."	Wehner et al. 2017
Tornados and thunderstorms	Convective storms[3]	None	0	"[There is] **little or no confidence** [in attribution findings of anthropogenic influence] for convective storms."	Knutson et al. 2017

[1] Upper ocean heat content, along with atmospheric temperatures and other factors, is a significant driver of extreme rainfall from hurricanes. Since the release of AR5 and CSSR, numerous studies have shown stronger evidence of a connection between human-caused climate change and factors influencing hurricane rainfall intensity than was expressed in the two reports (see: Trenberth et al. 2018; Risser and Wehner 2017; van Oldenborgh et al. 2017).

[2] "Evapotranspiration" is the transfer of water to the atmosphere via evaporation from the land and ocean and transpiration from plants (IPCC 2013).

[3] "Convective storm" is the scientific term for a thunderstorm and is the atmospheric phenomenon that can produce tornados (Kossin et al. 2017).

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