

The Science Connecting Extreme Weather to Climate Change

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Appendix A: List of Climate Attribution Studies

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TABLE A1. Climate Attribution Studies with Evidence of a Climate Change Connection

Event Type	Event	Period	Region	Attribution Statement	Source
Drought	Southern African droughts	December 2015 - February 2016	Southern Africa	"...climate change likely increased the intensity of the 2015/16 El Niño, contributing to further decreases in SA precipitation, crop production and food availability."	Funk et al. (2018)
	Southern African droughts	November 2015 - April 2016	Southern Africa	"...there is a substantial increase in concurrent droughts and heatwaves in [Southern Africa], with flash drought increased by 220% from 1961 to 2016. Although both the anthropogenic and natural signals are detectable in attributing the flash drought changes, the anthropogenic influence is mainly responsible for the increasing flash drought over [Southern Africa]."	Yuan, Wang, and Wood (2018)
Extreme cold	Southeastern Europe cold	January 2017	Southeastern Europe	"The temperature of these cold waves has increased since 1950. This increase is not statistically significant due to the variability of the weather, but climate models show the same increase. Before global warming, an extreme cold snap like the recent one in southeastern Europe would have been even colder."	van Oldenborgh, Philip, and de Vries (2017)
	Eastern China extreme cold	January 21-15, 2016	Eastern China	"Anthropogenic influences are estimated to have reduced the likelihood of an extreme cold event in midwinter with the intensity equal to or stronger than the record of 2016 in eastern China by about two-thirds."	Qian et al. (2018)
	China cold surge	December 2015 - February 2016	China	"Human influence decreased the probability of a cold surge occurrence in China."	Sun et al. (2018a)
Extreme heat	Euro-Mediterranean heat wave	Summer 2017	Euro-Mediterranean region	"...climate change increased the chances of seeing a summer as hot as 2017 by at least a factor of 10 and a heat wave like Lucifer by at least a factor of four since 1900."	World Weather Attribution (2017)
	European heat wave	June 2017	Western Europe	"...climate change made the intensity and frequency of such extreme heat at least twice as likely in Belgium, at least four times as likely in France, Switzerland, the Netherlands, and central England and at least 10 times as likely in Portugal and Spain."	World Weather Attribution (n.d. a)
	US heat wave	February 2017	Eastern United States	"...the chances of seeing a February as warm as the one experienced across the Lower 48 has increased more than threefold because of human-caused climate change."	van Oldenborgh et al. (2017a)
	Australian extreme heat wave	December 2016 - February 2017	New South Wales, Australia	"Comparing the likelihood of this record in the climate of today compared with the climate of around 1910 (before global warming had a big impact on our climate system and when reliable observations are available), the team again found at least a 50-fold increase in the likelihood of this hot summer."	World Weather Attribution (n.d. b)

Extreme heat	Arctic warmth	November - December 2016	Arctic	"...the highly anomalous Arctic warmth during November-December 2016, as estimated in five observed datasets, most likely would not have been possible without anthropogenic forcing."	Kam et al. (2018)
	North Pole heat wave	November - December 2016	North Pole	"...a warm event like the one of this year would have been extremely unlikely in the climate of a century ago. The probability was so small it is hard to estimate, but less than 0.1 percent per year."	van Oldenborgh et al. (2016a)
	Thailand heat and dryness	April 2016	Thailand	"The record temperature of April 2016 in Thailand would not have occurred without the influence of both anthropogenic forcings and El Niño, which also increased the likelihood of low rainfall."	Christidis et al. (2018)
	Alaska marine heat wave	2016	Alaska	"The 2016 Alaska marine heat wave was unprecedented in terms of sea surface temperatures and ocean heat content, and CMIP5 data suggest human-induced climate change has greatly increased the risk of such anomalies."	Walsh et al. (2018)
	Arctic warmth	2016	Arctic	"...about 60% of the 2016 Arctic warmth was likely attributable to human-induced climate change."	Sun et al. (2018b)
	Asian extreme heat	2016	Asia	"The 2016 extreme warmth across Asia would not have been possible without climate change. The 2015/16 El Niño also contributed to regional warm extremes over Southeast AsiaThe 2015/16 El Niño also contributed to regional warm extremes over Southeast AsiaThe 2015/16 El Niño also contributed to regional warm extremes over Southeast Asia and the Maritime Continent."	Imada et al. (2018)
	European heat wave	July 2015	De Bilt, The Netherlands; Madrid, Spain; Mannheim, Germany; Beauvais, France; Zürich, Switzerland	De Bilt: "...a 3-day period as hot as experienced over this past week is now roughly 7 times more likely to occur than it was around 1900. ... climate change has made the observed heat wave almost 2 times more likely to occur."; Madrid: "...a 3-day period as hot as experienced over this past week now occurs about 4 times more often than around 1950. ... climate change has made the observed heat wave 5 times more likely to occur."; Mannheim: "A 3-day period as hot as experienced over the past week is now roughly 8 times more likely than it was in the 1930s. ... climate change made the observed heat wave almost 4 times more likely to occur."; Beauvais: "...a 3-day period as hot as experienced over this past week is now roughly 4 times more likely than it was around 1950. ... climate change has made the observed heat wave 35% more likely to occur."; Zürich: "...a 3-day period as hot as experienced over the past week is now roughly 8 times more likely than it was around 1900. ... climate change has made the observed heat wave about 3 times more likely to occur."	World Weather Attribution (2015a)
	European heat wave	Summer 2003	Paris; London	"In summer 2003, anthropogenic climate change increased the risk of heat-related mortality in Central Paris by ~70% and by ~20% in London."	Mitchell et al. (2016)

Extreme heat	European heat wave	Summer 2003	Continental Europe	"It is very likely (confidence level >90%) that human influence has at least doubled the risk of a heatwave exceeding this threshold magnitude."	Stott, Stone, and Allen (2004)
Extreme precipitation	Louisiana floods	August 2016	South Louisiana	"All observational analyses found clear positive trends, with an increase in probability for the regional event of about a factor of 6.3 (97.5 % certain more than 2.1) and an increase in intensity of 12 to 35 %."	van der Wiel et al. (2017)
	Wuhan extreme rainfall	June 30 - July 6, 2016	Wuhan City, China	"Human-induced warming and El Niño may have substantially increased the probability of the occurrence of such events as the July 2016 extreme precipitation over China's Wuhan."	Zhou, Wang, and Qi (2018)
	Extreme rainfall	June - July 2016	Yangtze-Huai region of China	"Both the 2015/16 strong El Niño and anthropogenic factors contributed to the June-July 2016 extreme precipitation (R20mm, RX5day) in Yangtze-Huai, China. Combined, they increased the risk of the event tenfold."	Sun and Miao (2018)
	Extreme rainfall	June - July 2016	Yangtze River, China	"Anthropogenic climate change has increased the risk of 2016 Yangtze River extreme summer rainfall by 17%-59%, and the increase could reach 37%-91% in El Niño years."	Yuan, Wang, and Hu (2018)
	UK Storm Desmond	December 4-6, 2015	Northern England and Scotland	"...the effect of climate change is positive, making precipitation events like this about 40% more likely, with a provisional 2.5-97.5% confidence interval of 5-80%."	van Oldenborgh et al. (2015)
Extreme rainfall from hurricanes	Hurricane Harvey	August 25-30, 2017	Texas	"...global warming made the precipitation about 15% (8%-19%) more intense, or equivalently made such an event three (1.5-5) times more likely."	van Oldenborgh et al. (2017b)
	Hurricane Harvey	August 2017	Houston, Texas	"Human-induced climate change likely increased the chances of the observed precipitation accumulations during Hurricane Harvey in the most affected areas of Houston by a factor of at least 3.5. Further, precipitation accumulations in these areas were likely increased by at least 18.8% (best estimate of 37.7%)."	Risser and Wehner (2017)
	Hurricane Harvey	August 2017	Texas	"Record high ocean heat values not only increased the fuel available to sustain and intensify Harvey but also increased its flooding rains on land. Harvey could not have produced so much rain without human-induced climate change."	Trenberth et al. (2018)
Record temperature	Record global temperatures	2016	Global	"The 2016 record global warmth was only possible due to substantial centennial-scale anthropogenic warming."	Knutson et al. (2018)
	Record hot year	2015	Global	"Of that 1.05°C temperature departure from pre-industrial, roughly 1.0°C is due to the anthropogenic forcing."	World Weather Attribution (2015b)

Record temperature	European heat	2014	Europe	"...the odds of average temperatures across Europe reaching this year's record-setting levels were increased by at least 35 to 80 times due to human influence on our climate."	World Weather Attribution (n.d. c)
Storm surge	Hurricane Sandy	October 2012	New York	"A largely anthropogenically driven global sea-level (GSL) rise of 20cm during the 20th century [Church and White, 2011] caused Sandy to flood an area ~70km ² greater than it would have in 1880."	Miller et al. (2013)
Wildfire activity	Western US wildfires	1979-2015; 1984-2015	Western United States	"Human-caused climate change caused over half of the documented increases in fuel aridity since the 1970s and doubled the cumulative forest fire area since 1984."	Abatzoglou and Williams (2016)
	Western US and Australian wildfires	Summer 2016; Summer 2015/16	Western United States; Australia	"Extreme vapor pressure deficits (VPD) have been associated with enhanced wildfire risk. Using one model, we found for 2015/16 that human influences quintupled the risk of extreme VPD for western North America and increased the risk for extratropical Australia."	Tett et al. (2018)

TABLE A2. Climate Attribution Studies with No Evidence of a Climate Change Connection

Event Type	Event	Period	Region	Attribution Statement	Source
Drought	Kenyan drought	2016	Kenya	"...we found no consistent signal from human-induced climate change and thus conclude that it has not greatly affected the likelihood of low rainfall such as in 2016. However, 2016 was a La Niña year and we show that this event was indeed more likely because of the specific sea surface temperatures."	Uhe et al. (2017)
	Somalia drought	2016	Somalia	"...the effect of climate change on dry extremes in Somalia and Somaliland in the autumn (Deyr) rains is small compared to natural variability. We cannot show that climate change influenced the probability of drought."	van Oldenborgh et al. (2017c)
	Ethiopian drought	2015	Northeast and central Ethiopia	"No influence of climate change could be found, with the spread of possible trends ranging from drought being 40 percent less to four times more probable."	World Weather Attribution (n.d. e)
	Southeast Brazilian drought	January 2014 - February 2015	Southeast Brazil	"Anthropogenic climate change is not found to be a major influence on the hazard."	Otto et al. (2015)
	Northeast Brazil drought	2012-2016	Northeast Brazil	"Northeast Brazil experienced profound water shortages in 2016 due to a five-year drought. Using multiple methods, we could not find sufficient evidence that anthropogenic climate change increased drought risk."	Martins et al. (2018)
Extreme cold	US deep freeze	December 2016	North America	"The cold air outbreak of the next few days is nothing unusual, and neither inconsistent with an overall picture of a warming world, nor evidence that global warming is making cold weather more extreme."	van Oldenborgh, de Vries, and Allen (2016)
Extreme heat	Warm December in France	December 2015	France	"December 2015 in France was an extreme of circulation and temperature. Both circulation and climate change partly explain the 4°C anomaly. We found no link between climate change and circulation."	Jézéquel et al. (2018)
	Indian heat wave	May 2015; May 19, 2016	Rajasthan, India; Andhra Pradesh, India	"...the two approaches that are trusted give an increase in probability of heat waves in both regions, but the increase is not statistically significant and can be due to data inhomogeneities."	World Weather Attribution (n.d. d)

Extreme precipitation	Extreme rainfall	September 2016	Australia	"The effect of increasing atmospheric CO2 on the extreme September 2016 rainfall across southeastern Australia was minimal, with changes in circulation and static stability driving a tendency towards drier conditions."	Hope et al. (2018)
	Record wet winter	July - September 2016	Southeast Australia	"Warmth in the east Indian Ocean increased the likelihood of the record wet July-September in southeast Australia by at least a factor two. The role of climate change was minimal."	King (2018)
	Winter storm Jonas	January 2016	Mid-Atlantic United States	"Model simulations indicate that anthropogenic climate change has made extreme snowstorms less likely over the mid-Atlantic United States. Empirical evidence shows no decline since 1901, with recent storms colder than before."	Wolter et al. (2018)
	Chennai floods	December 2015	Chennai, India	"No effect of global warming was detected, likely caused by aerosols counteracting greenhouse gases up to now."	van Oldenborgh et al. (2016b)
	Extreme California rains	1983; 2016	Southern California	"Failure of heavy rain in Southern California during the 2016 strong El Niño compared to flooding rains during the 1983 strong El Niño does not constitute a climate change effect."	Quan et al. (2018)

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