Energy&Climate
INTELLIGENCE UNIT

Even Heavier Weather

Tracking the fingerprints of climate change, three years after the Paris Agreement

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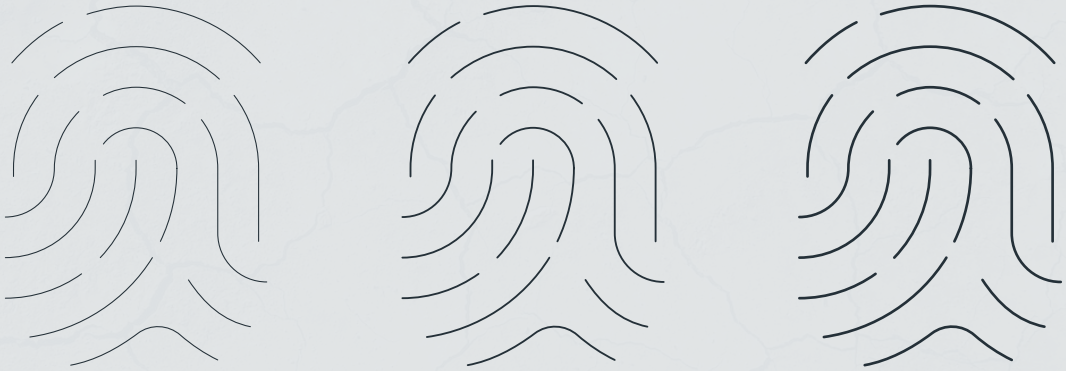

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Executive Summary

A growing body of evidence demonstrates that climate change is already amplifying extreme weather events, such as heatwaves, droughts and floods, making them either more frequent or more intense. Awareness of this trend was among the factors leading to the Paris Agreement in 2015, with governments, businesses, the military and health professionals among the constituencies highlighting the growing impacts of extreme weather in the run-up to the summit.

A year ago, the Energy and Climate Intelligence Unit (ECIU) published an analysis detailing what scientists had discovered about the links between climate change and extreme weather in the two years since the Paris Agreement.[1] Today, we update that analysis with a further year's-worth of scientific papers. This strengthens further the case that climate change is driving an increase in the frequency and intensity of extreme weather events, documented on every continent except Antarctica.

In last year's analysis, we identified **59** papers published in 2016 and 2017 exploring a possible link between climate change and amplification of extreme weather events, of which **41** found a positive signal of climate change. The additional year has brought a further **43** papers, of which **32** found a positive link from climate change to the event's likelihood or intensity. Of the new batch, only **four** found that climate change decreased the chances of a particular extreme event, and these all involved snow and/or cold temperatures.

The new studies encompass heatwaves in France, China, Thailand and the US; drought in the US and Africa; heavy rains in France, China, the US and Africa; storms forming in the Pacific and Atlantic Oceans; wildfire risk in Australia and North America; and extreme snow and cold in China and Australia. The figures suggest that both the pace of investigation and the rate at which positive links are being uncovered are accelerating.

A clear view of the science is essential for policymakers – not least those connected with the UNFCCC process, where it is highly relevant to discussions on Loss and Damage – as well as to businesses, insurers and many other constituencies impacted by, or charged with managing impacts of, extreme weather.

1 https://eciu.net/reports/2017/heavy-weather

Introduction

The UN climate convention, the Paris Agreement and event attribution

In 1992, governments ushered into existence the United Nations Framework Convention on Climate Change, whose central goal is to achieve 'stabilisation of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.'[2] What degree of climate change should be considered 'dangerous' is a question that has seen much discussion in the years since; but in 2015, at the Paris climate summit, it became evident that for much of the world's population and much of its nature, the maximum permissible level of global warming is 1.5°C.[3]

Western Cape drought (South Africa, 2015-17)

The region around Cape Town saw three consecutive years of below-average rainfall, leading to prolonged drought conditions. The low rainfall, together with infrastructure inadequate for the region's growing population, created acute water shortages, and at one point Cape Town was said to be in danger of running out of water entirely ('Day Zero').

Scientific conclusion: 'Synthesising the results... gives a significant increase by a factor of three (95% confidence interval 1.5–6) of such a drought to occur because of anthropogenic climate change.' [1]

1 http://iopscience.iop.org/article/10.1088/1748-9326/aae9f9

The point has often been made, though, that even this degree of 'anthropogenic interference with the climate system' carries impacts. And one of the most obvious is its effect on extreme weather. The point was made graphically during the Paris summit itself, when Storm Desmond let loose its destructive rains on parts of the UK – an event which, it was later shown, was made significantly more likely by climate change.[4]

2 https://unfccc.int/process/the-convention/history-of-the-convention#eq-1
3 https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
4 https://www.worldweatherattribution.org/uk-storm-desmond-revisited-december-2017/

Extreme weather events such as hurricanes, floods and droughts occur naturally, and would continue to do so even in the absence of climate change. The questions that the science of event attribution asks are: 'Did the presence of climate change make a specific event more or less likely, or more or less intense? If so, by how much?'

Scientists use a variety of methods to answer these questions, but they fall into two broad categories:

- Analysis of historical data to see whether an unequivocal change in frequency or intensity can be identified
- Use of computer models to assess any effect of climate change in terms of changing occurrence rate, intensity or duration – and sometimes to link that to a change in a specific outcome.

Scientists use a number of different ways of expressing a link between climate change and the observed event. They may use the form 'climate change made event X 40% more (or less) likely to occur; or talk about a change in the expected time interval between events, for example 'what would be expected once every 100 years is now expected every 50 years' (climate change has 'halved the expected return time'); or they may discuss a specific impact, eg 'climate change explains half of the observed increase in hospital admissions.'

Extreme rainfall and flood (France, 2016)

Heavy rainfall began in late May 2016 in central-northern France and continued into June, with the Seine and Loire river basins heavily affected. In Paris, the Seine burst its banks in early June. Thousands had to leave their homes. The cost of the damage was estimated at more than €1 billion.

Scientific conclusion: '...the probability of such rainfall has increased over the last century by about a factor of 2.2 (>1.4) on the Seine and 1.9 (>1.5) on the Loire due to anthropogenic emissions.' [1]

1 https://journals.ametsoc.org/doi/full/10.1175/JHM-D-18-0074.1

The first study examining the impact of climate change on extreme weather dates back to 2004, when Peter Stott of the UK Met Office and colleagues showed that climate change had at least doubled the odds of the previous summer's heatwave in Northern Europe – an event that caused thousands of additional deaths across affected nations.[5,6]

Since then, scientists have published at least 200 papers in the field. And as analysis becomes faster and easier, the pace is picking up; of those 200+ studies, as we document here, more than 100 have come in the last three years. Scientists can now perform an initial analysis in a period of several days (although peer-reviewed publication takes longer). This was shown during the 2018 European summer when the World Weather Attribution network published an initial study of the Northern European heatwave, showing climate change made it at least twice as likely to have occurred.[7]

The Intergovernmental Panel on Climate Change (IPCC), in its Special Report on the 1.5°C global warming target, confirmed in October that increases in the frequency and intensity of some types of extreme weather have been observed over the last few decades.[8] It noted that even global warming limited to 1.5°C is forecast to bring 'increases in frequency, intensity, and/or amount of heavy precipitation in several regions, and an increase in intensity or frequency of droughts in some regions.'

5 https://www.nature.com/articles/nature03089
6 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1950160/
7 https://www.worldweatherattribution.org/attribution-of-the-2018-heat-in-northern-europe/
8 https://www.ipcc.ch/sr15/

Methodology and Findings

As with our 2017 analysis, our goal with this update was to identify as many attribution studies as we could, published in peer-reviewed English-language science journals over the period in question, identified by a literature search.

We have not looked for studies published in other languages, and we have been conservative in other ways – for example, we did not include studies whose primary aim was to explore methods of attribution. We have however included a few studies finding a positive signal of climate change in marine heatwaves; though these fall outside a conventional definition of 'weather', they do carry a human impact, not least through their effect on fisheries.

Great Barrier Reef marine heatwave (Australia, 2016)

In 2016, at the height of the El Niño event, a quarter of the global ocean surface experienced either the longest or most intense marine heatwave since satellite records began in 1982. [1] On the Great Barrier Reef, corals began to die – over the warmest period, species such as staghorns suffered a die-off scientists described as 'catastrophic', transforming nearly one-third of the reef. Ecological changes to the reef may be permanent.

Scientific conclusion: '...the fact that anthropogenic forcing reduced return periods by a factor of up to two hundred indicated that it was extremely unlikely that natural variability alone led to the observed anomalies. [2]

1 https://www.nature.com/articles/s41586-018-0041-2
2 http://www.ametsoc.net/eee/2016/ch9.pdf

We identified **43 papers** published **between December 2017 and November 2018** examining the possible impact of climate change on extreme weather events. Of these, 32 showed that climate change made the specific event either more likely or more intense.

Four showed climate change decreasing the likelihood or intensity; all of these cases referred to cold weather and/or snowfall. The remaining seven studies either concluded there was no signal of climate change, or could not gather sufficient data to reach a conclusion.

Signal	2017 Analysis (papers published in 2016 & 2017)	2018 Analysis (papers published in 2018)	Combined
Positive	**41**	**32**	**73**
Neutral	7	6	13
Negative	**4**	**4**	**8**
Not enough data	7	1	8
Total	59	43	102

Both the rate of publication of studies and the proportion showing a positive link are larger than those in our previous analysis, which covered research published between December 2015 and November 2017. The studies – both old and new – are itemised on a spreadsheet available here.

Unlike in our 2017 analysis, we do not this time list information on human and economic impacts of the extreme events, as there was very little available.

Of the various types of extreme event that we look at, the category showing the clearest signal of climate change is heatwaves, where every single study we identified published during 2018 (and indeed during the three-year period covered by both reports combined) found a positive link from climate change.

The climate change signal in droughts, wildfires, storms and rainfall, and even extreme cold and snow, are all more positive than negative.

Signal	Heatwave	Drought	Rainfall / Flooding	Storms	Wildfires	Cold, Snow, Ice	Total
Positive	**11**	**4**	**7**	**6**	**1**	**3**	**32**
Neutral		2	3		1		6
Negative				**1**		**3**	**4**
Not enough data		1					1
Total	11	7	10	7	2	6	43

Conclusion

Increases in either the occurrence or intensity of extreme weather events are not the only markers of climate change, nor are they the sole impacts relevant to human society and nature. They sit alongside myriad observed progressive changes – temperature increases on land, water and air, sea-level rise, disintegration of mountain glaciers and Polar ice, ocean acidification, migration of species – on occasion, interacting with those progressive changes to increase the impact of events such as storm surges.

But increases in extreme weather events are among the most tangible and impactful manifestations of climate change. One need only think of the damage inflicted on crops across much of Europe this summer by the heatwave, an event that two studies have now concluded was made more likely by climate change. [9], [10]

The results presented here fall short of being a comprehensive picture of the extreme weather impacts of climate change. We have been conservative in our compilation; more importantly, resources currently available to attribution science allow studies to be conducted on only a small proportion of extreme events. Thus it is highly likely that the true impact of climate change on extreme weather today is considerably higher than this or any analysis is able to present.

Our analysis adds to the growing weight of evidence that climate change is already increasing the incidence and severity of extreme weather events in virtually every part of the world. As such, it provides vital information for policymakers (including those working within the UNFCCC process), businesses, insurers, health professionals and other relevant sectors of society – and to the world's citizens, who ultimately will decide our collective response to climate change.

9 https://www.worldweatherattribution.org/attribution-of-the-2018-heat-in-northern-europe/
10 https://www.metoffice.gov.uk/news/releases/2018/2018-uk-summer-heatwave

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