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EXTREME EVENTS

The art of attribution

A high-impact weather event that occurred at the end of a decade of weather extremes led to the emergence of extreme event attribution science. The challenge is now to move on to assessing the actual risks, rather than simply attributing meteorological variables to climate change.

Friederike E. L. Otto

The first ten years of this century are no longer referred to as the decade of extreme weather events[1], given the spate of extremes that have occurred in the past four years (Fig. 1). 2015 and 2014 were each, at the time, the hottest year on record by a large margin[2]. Furthermore, 2016 started with record-breaking superlatives: the hottest January with the biggest increase over the previous record and the largest warming anomaly for any single month since records began[2]. However, Coumou and Rahmstorf's Review[1] in *Nature Climate Change* of the strong evidence linking many weather records broken since the beginning of the century to human influence on the climate is by no means old news. Some of the events they described have since become paradigmatic, studied over and over again. Most remarkably, this publication, together with a few other landmark studies, marked the beginning of a whole new branch of climate science, and facts that then passed almost unnoticed are now subject to fierce debate.

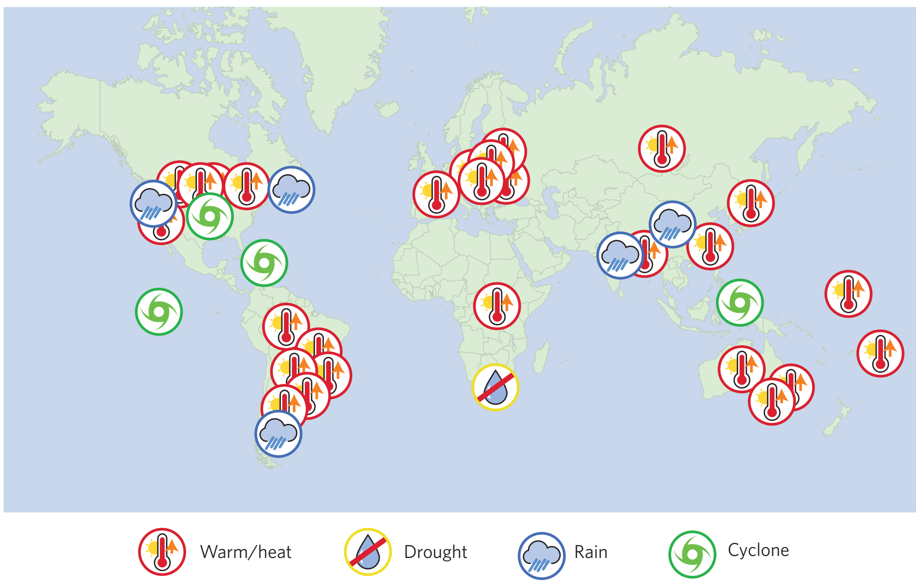

Figure 1 | Record-breaking extreme events, 2012–2015. The map shows record-breaking extreme weather and climate-related events listed in ref. 2, updating Fig. 1 in ref. 1. Information about the exact temporal and spatial extent of each event can be found in Supplementary Table 1.

The detection and attribution of long-term trends in observed records (mainly temperature) has been routinely carried out at least since the second IPCC report in 1995. But attributing individual extreme events was deemed impossible until later, when the theoretical possibility was first described[3] and then applied to show that the likelihood of the European heatwave of 2003 was at least doubled due to human influence[4]. However, it took another paradigmatic event, the Russian heatwave of 2010, to push the scientific community to start scrutinizing the methodologies of analysis as well as the events themselves, and to realize the importance of defining events and framing the exact question that any study attempts to answer. It is not that obvious from a meteorological perspective why the 2010 Russian heatwave in particular is so famous, as there have since been many other extreme events around the globe that had impacts at least as high. It was, however, the first extreme weather event analysed in two extreme event attribution studies with apparently contradictory results. One study analysed the magnitude of the event and found no significant anthropogenic signal[5], whereas another found that such a heatwave was five times more probable compared with pre-industrial times due to anthropogenic climate change[6]. Soon after, these views were reconciled when it was shown that these are two complementary aspects of an event[7] and not mutually exclusive[1]. Coumou and Rahmstorf[1] used this example, as well as the ostensibly large number of meteorological records being broken around the same time, to review the state of scientific knowledge in this field. They highlighted that heatwaves are no surprise in a warming world, and neither are floods and droughts; however, when aiming to go a step further and actually attribute an individual extreme event to a particular cause, the scientific community needs to tackle some challenges.

One of the harder challenges is based on the fact that we expect that the probability of all these heatwaves and extreme rainfall events occurring will only increase under the assumption that all else remains equal; in other words, that climate change does not affect the atmospheric circulation. But as Coumou and Rahmstorf[1] point out, this may not be the case. Identifying changes in the dynamical drivers of extreme weather events requires climate models that can reliably simulate these drivers. Not all general circulation models are up to this task, which led some scientists to conclude we should not even try[8]. Recent studies, however, have shown that it is possible to disentangle thermodynamic and circulation changes[9,10], but these studies are conditional[1] on the ability of the model to adequately represent the atmospheric circulation. Although this is a well-established fact, model evaluation has been remarkably absent in many attribution studies (such as ref. 11) — however, further scrutinizing reveals that general circulation models suitable for this purpose do actually exist (for example, ref. 12), and that robust attribution of the overall change in risks of devastating extreme events is far from impossible today[13].

But when analysing such changes in the overall risk, we consider an event as a class, and not as an individual entity — exactly as it happened. Recently, there has been some controversy over whether a very narrow definition of an event can lead to informative attribution studies, given that each event is unique and will never occur again[14]. One consequence of the uniqueness of individual extreme events is that we will never be able to say a single event could not have occurred without anthropogenic climate change. Here Coumou and Rahmstorf[1] were wrong; we simply can never say this with certainty.

Coumou and Rahmstorf[1] proposed a few different approaches to attributing extreme weather events, all of which have since developed into complex methodologies[13]. At the same time, a realization set in that if the climate science community really wants to respond to stakeholders asking for more concrete information on extremes, we have to go beyond meteorological variables. The temperatures reached in the 2010 Russian heatwave may not have set it apart from other similar events, but the large impacts it had on grain prices might justify the extra attention. Attributing such impacts is more difficult, as many factors other than the weather can influence grain prices, and vulnerability and exposure are crucial. But there are steps between single model studies on a single meteorological variable and complete end-to-end attribution analysis from such variables to their impacts. The event attribution community has come a long way towards applying different methodologies and combining meteorological variables to indices of relevance to people (for example, ref. 15), making impact attribution the challenge for the coming years.

Impact attribution was not on the to-do list that Coumou and Rahmstorf[1] compiled for advancing the field. That it would be there today shows how much progress has been made, and it highlights the importance of their paper. We, the community that has emerged in the past five years, have worked from their list and made advances on all points. If we now want to make comparable progress on the analysis of the impacts of events that really matter, we will need to start with major advances in what Coumou and Rahmstorf[1] presented as a prerequisite to every attribution study: high-quality observational data. We can make progress there, but to do so we will need to enlarge the community to include scientists from all regions of the world. ❐

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Additional information

Supplementary information is available in the online version of the paper.

TROPICAL STORMS

The socio-economics of cyclones

Understanding the potential social and economic damage and loss wrought by tropical cyclones requires not only understanding how they will change in frequency and intensity in a future climate, but also how these hazards will interact with the changing exposures and vulnerabilities associated with social change.

Ilan Noy

On 20 February 2016, tropical cyclone Winston made landfall in Fiji; the strongest cyclone ever recorded to hit the South Pacific nation, with estimated sustained winds of 230 km h^{-1}. For many communities, the consequences of tropical cyclones are cataclysmic. Recent storms such as Sandy (the USA in 2012), Haiyan (the Philippines in 2013) and Pam (Vanuatu in 2015) — which all caused terrible damage — clearly demonstrate this. Writing in *Nature Climate Change* in 2012, Mendelsohn *et al.*[1] suggested that the dramatic increase in the global impact of tropical cyclones over the past few decades was largely due to an increase in the exposure and vulnerability to cyclones, rather than an increase in their intensity or frequency. They also predicted an increase in damages in some geographic regions associated with future climatic influences.