News and views NCC for Coumou&Rahmstorf 2012

Friederike E. L. Otto
friederike.otto@ouce.ox.ac.uk
Environmental Change Institute, University of Oxford, South Parks Road, OX1 3QY, Oxford, UK.

Extreme Weather Events
The art of attribution

A "Paris Hilton" event occurring at the end of a decade of extreme weather events led to the emergence of a new branch of science: extreme event attribution. The challenge is now to come from attributing meteorological variables to assessing risks people care about.

Nobody is talking about the decade of extreme weather events [1] when referring to the first 10 years of the 21st century anymore with the spate of extreme events that have occurred in the last couple of years (fig 1). 2015 and 2014 were each at the time the hottest year on record by a large margin [2], and 2016 started with record breaking superlatives as the hottest January with the biggest increase over previous record and hottest anomaly for any single month ever [2]. However, Coumou and Rahmstorf's review in Nature Climate Change [1] 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 describe have become paradigmatic events, 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 passed almost unnoticed then are now subject to fierce debates.

The detection and attribution of long-term trends in observed records (mainly temperature) has been routinely done at least since the second IPCC report in 1995. But attributing individual extreme events was deemed impossible until later when Allen [3] described the theoretical possibility and Stott et al. [4] applied it to show that the likelihood of the European heatwave of 2003 was at least doubled due to human influence. However, it took another paradigmatic event, the Russian heatwave of 2010, to start the scientific community to analyse not just events, but also scrutinise the methodologies, realise the importance of framing the question they attempt to answer and of defining the event. The 2010 heat wave in Russia has been dubbed the "Paris Hilton event" by some climate scientists: it is not that obvious from a meteorological perspective why this event is so famous since there have been many other extremes in following years and in other parts of the world with at least as high impacts. It was however the first extreme weather event analysed in two extreme event attribution studies with apparently contradictory results. Dole et al. [5] analysed the magnitude of the event and found no significant anthropogenic signal while Rahmstorf and Coumou [6] found that such a heatwave was five times more likely compared to preindustrial times due to human induced climate change. Reconciling both

views, Otto et al. [7] showed that these are two complementary aspects of an event and not mutually exclusive [1]. Picking up this example and the ostensible large number of meteorological records being broken around the same time Coumou and Rahmstorf [1] reviewed the state of scientific knowledge. They highlighted that heat waves are no surprises in a warming world and neither are floods and droughts, making all of these events consistent with what we expect in a changing climate; however when aiming to say more and actually attribute an individual extreme event the community needs to tackle some challenges.

One of the harder challenges is the fact that we do expect all those heat waves and extreme rainfall events only to 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 all else may not remain equal. Identifying changes in the dynamical drivers of extreme weather events requires climate models that are able to reliable simulate these drivers. Not all general circulation models are up for this task which led some scientists to conclude we shouldn't even try [8]. Recent studies however showed 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. This is a known fact, but still, model evaluation has been remarkably absent in many attribution studies, [e.g. 11]. However, when scrutinised it emerges that general circulation models do exist that are fit for purpose [e.g. 12] and robust attribution of the overall change in risks of devastating extreme events are far from impossible today [13].
But when analysing such changes in the overall risk, we consider an event as a class, not a single individual event exactly as happened. A known fact [1] that has recently led to some controversy about whether or not a very narrow definition of an event leads to informative attribution studies, given that each event is unique and will never occur again [14]. One consequence of this uniqueness of individual extreme events is that we will never be able to say a single event could not have occurred without human-induced climate change. Here Coumou and Rahmstorf [1] were wrong; we simply can never say this with certainty.

Coumou and Rahmstorf [1] led out some of the different approaches to take for attributing extreme weather events, all of which have since developed into complex methodologies [13]. At the same time a realisation set in that if we want to really inform the stakeholders asking for information on concrete extremes we have to go beyond meteorological variables. The temperatures reached may not have set the Russian heat wave apart, but the large effects it had on grain prices might justify exposing this event more than the climate science community thinks. Attributing such impacts is harder as many factors other than the weather influence grain prices and vulnerability and exposure are crucial. But there are steps in between single model studies on a single meteorological variable and complete end-to-end attribution analysis. The community has come a long way towards applying different methodologies and combining meteorological variables to indices of relevance to people [e.g., 15], making impact attribution the challenge for the community in the coming years.

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Impact attribution was not on the to-do list Rahmstorf and Coumou [1] compiled for advancing the field. That it would be on there today shows how much progress has been made and it highlights the importance of their paper. We, the community that emerged in the last 5 years, have worked off the list and made advances on all points. If we now want to make comparable progress on the impacts of events that really matter, we will need to start with great advances on what Coumou and Rahmstorf [1] presented as prerequisite to every attribution study: high-quality observational data. We can make progress there but to do so we will need to grow the community to include scientists from all regions of the world.

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