Publication Date: Thursday, 23rd May 2019

Attribution of Extreme Weather Events:

How does climate change affect weather?

Climate Science Communications Group Committee

Briefing paper: Issue 8

Acknowledgements

The Royal Meteorological Society would like to thank Friederike Otto and the members of the Climate Science Communications Group, for their effort and hard work in writing and editing this paper.

Also, thank you to Kevin Trenberth, Nikos Christidis and David John Karoly for reviewing the paper.

Attribution of Extreme Weather Events:

How does climate change affect weather?

Temperatures averaged over the Earth's surface have increased by about one degree since the industrial revolution and this increase can largely be attributed to emissions of well-mixed greenhouse gases and other forcings[1] from human activity like aerosol and ozone emissions and land-use changes. Globally averaged temperatures are the clearest indicator of the fact that the climate is changing but people do not experience averaged temperatures. People experience weather and are in particular impacted by extreme weather events.

Extreme weather in a warming world

In a warming world we expect the risk for some kinds of extreme weather events occurring to increase and other, like cold spells to decrease. With increasing temperatures in most parts of the world we expect more and hotter heat waves. At the same time, warmer air can hold more water and thus, we expect more extreme rainfall. And sure enough, whenever an extreme weather event happens anywhere in the world, people are asking the question about the possible role of climate change. However, the effect of climate change on extreme weather is not uniform across different regions and also varies between seasons and timescales. Furthermore, climate change does not only affect temperature but also the atmospheric circulation. This means the typical track of rainstorms or high pressure systems can change and thus, either counteract or amplify the effects from temperature changes. Individual weather events are ultimately unique and always caused by a combination of different factors including local variability in the weather, conditions of the land surface and its feedbacks with the atmosphere, large scale patterns of ocean temperatures and changes in the external drivers (e.g. greenhouse gases, aerosols). Therefore, it cannot be said that an extreme weather event was caused by climate change. However, we can now estimate whether and to what extent the likelihood or intensity of an extreme event occurring has changed due to human-induced climate change.

Attribution of extreme weather events

Extreme weather events are by definition rare. Thus, in the same way as it is not possible to determine from throwing a dice a couple of times whether or not it is loaded, we cannot say from a short observational weather record whether or not the number of a certain type of extreme events has increased. However, in some regions long, high-quality records exist and in many cases, it is possible to create a large record of simulated weather and extreme weather events with state of the art climate models and statistical methods. This allows scientists to estimate what is possible weather in the world we live in and to quantify what the likelihood of an observed extreme weather event is. Was it a 1 in 100 year event? Or a 1 in 10 year event? Having determined the likelihood of the event in today's climate, i.e. with climate change, we can then ask what the likelihood of the event would have been in a world without human-induced climate change. While we do not have observations of the world that might have been without climate change, we do know very well how much CO2 and other greenhouse gases we have emitted. This enables us to simulate possible weather in the world that might have been without human-induced climate change in the same way as we simulate possible weather events today. As with forecasts, the models used for attribution need to be able to reliably estimate the likelihoods of the types of events being attributed. While models have improved a lot there are still many aspects of extreme events, in particular with respect to the atmospheric circulation, where we cannot reliably estimate likelihoods of events and their changes.

Comparing these two likelihoods then allows quantifying the role of climate change. For example, a heat record of 40°C somewhere in Europe might now be expected to occur on average every 10 years but would have been a much rarer event of 1 in 100 years in a world without climate change. We can then say that climate change has made the event 10 times more likely. Similarly, if we find that a 1 in 10 year event in the world without climate change would be 38°C (so 2°C lower than in today's climate), it would lead to the conclusion that climate change contributed 2°C to the magnitude of the record. It is important to highlight that not all extreme weather events are being made more likely due to climate change and for every attribution study there are always 4 possible outcomes: (1) the event has been made more likely, (2) the event has been made less likely, (3) there is no detectable change in the likelihood of the event, (4) with current tools and understanding it is not possible to make an attribution statement.

The ability of state-of the art climate models to simulate weather events varies strongly between different types of events and different regions, which directly relates to the confidence in attribution statements. While we are very confident that the risk of a European heatwave like the one observed in 2003 has at least doubled due to climate change, we can currently not attribute small scale events like, e.g., flash floods, hail storms, or tornadoes. However, with better climate models and increasing numbers of scientists working on this question and scrutinizing each other's work, our methods are constantly improving.

Notes, further reading and references:

[1] Greenhouse gases are not the only emissions originating from human activity but the burning of fossil fuels and changes in land use also leads to the emission of aerosol particles (e.g. sulfates, soot, mineral dust) that influence the climate in various ways. Agents that influence the climate system like greenhouse gases or aerosols but also changes in the sun's orbit are called forcings.

Otto, F.E.L. (2017). Attribution of Weather and Climate Events. Annual Review of Environment and Resources, 42 (1): 627-646.
Stott, P.A, et al. (2016). Attribution of extreme weather and climate-related events, WIREs Climate Change, 7 (1): 23-41