ASPEN GLOBAL CHANGE INSTITUTE ENERGY PROJECT

November 2021 Research Review

Dusting for "fingerprints" on our climate: Innovations in the attribution of extreme events

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This blog is dedicated to the memory of Geert Jan van Oldenborgh, a pioneer in the attribution of extreme climate events. Van Oldenborgh passed away during the writing of this post. More about this scientist and the impact of his life work is available here.

The lived experience of much our planet's life now reflects what scientists have long expected: extreme climate and weather events are increasing as our planet warms. In many cases, the most intense heatwaves, droughts, fires, and floods have become not only more frequent but also more severe. For instance, the latest Intergovernmental Panel on Climate Change (IPCC) assessment of climate science finds that, globally, extreme heat events that used to occur once in every 50 years now happen nearly five times as often and are more than 1°C (1.8°F) hotter (IPCC, 2021).

These global trends raise local questions. Did global warming cause last week's heatwave (or wildfire or flood or hurricane) in my hometown? Scientists treat this inquiry a bit like detective work, attempting to find a human "fingerprint" in climate and weather phenomena. Extreme events, by definition, are rare. This makes identifying fingerprints for just a single occurrence more difficult than attributing global trends in extremes to human-driven climate change (as the IPCC does with increasing confidence).

However, scientists are finding ways to produce so-called "attribution" studies. Analytical advances, along with communicating findings better, mean attribution studies are now more relevant for impacted communities, policymakers, and the media in the wake of a particular extreme event.

For example, an attribution study by Phillip et al. on the Western North America (WNA) heatwave that crippled the Pacific Northwest in the summer of 2021 produced striking results. The analysis compared observations of the heatwave to the simulated climate of the region without elevated levels of greenhouse gases (GHGs). The authors found events like the WNA heatwave would be 150 times less likely to occur in a natural climate.

Even in our current GHG-polluted climate, the event would be expected to occur only once every 1,000 years. Furthermore, the same analysis calculated that the probability of future extreme heatwaves would increase to one every five to ten years in a world that experiences 2°C of climate warming—a future we are rapidly approaching, and which national commitments made at the recent COP26 in Glasgow fall short of preventing.

Perhaps as remarkable as the findings of the WNA heatwave study is how, and how quickly, scientists were able to produce the results. The study was conducted and disseminated within nine days of the event (light speed in the academic time-space continuum). Applying the peer-reviewed methods from a team of scientists called World Weather Attribution (WWA) made this rapid response possible. Examples of other studies this group has released since 2017 are shown in the table below, produced in the wake of natural disasters like Hurricane Harvey, the Australian wildfires, and the extreme floods in Europe and Bangladesh.

Event (link to study)	**Probability of occurrence in current climate**	**Probability of occurrence in 2º world**	**Attribution Summary**
2021 Western North American Heatwave	About 1 in 1,000 years	1 in every 5 to 10 years	Event was virtually impossible without human-driven climate change (150 times less likely to occur in natural climate).
2017 Hurricane Harvey (rainfall)	1 in 9,000 years	*Not available*	Human-driven climate change made precipitation 15% more intense, increased probability of event 1.5-5x.
2020 Australian Brushfire (fire weather)	1 in 33 years	4x more likely (at least)	Part of increase in fire weather index attributed to climate change, though extent may be underrepresented in models.
2017 Bangladesh Floods	*Not available.*	1 – 2x more likely	Cannot say with confidence that event was caused by human-driven climate change.

2021 Western European Floods	1 in 400 years	1.2 – 1.4x more likely	Climate change influenced rainfall but flooding driven by numerous factors. Small area and extensive storm damage to monitoring equipment limits conclusiveness.

WWA combines peer-reviewed methods with considerations for how best to convey and disseminate the outcomes of each study. A recent article in *Climatic Change* by Geert Jan van Oldenborgh and colleagues outlines this approach (2021). While Van Oldenborgh (who passed away during the writing of this piece) and many of his co-authors spent much of their careers advancing the physical science of attribution, their work's most lasting impact may be how they constructed a workflow that could rapidly relay attribution science's findings to larger audiences.

The attribution process begins with several judgment calls. Extreme events are almost always happening somewhere on the planet, so researchers must first decide which extreme events to study, given limited technical resources. They must also define the event in terms of climate variables, timing, and location. Any one of these choices can influence the outcome of an attribution study and its implications. For instance, van Oldenborgh et al. (2017) found that while the probability of Hurricane Harvey precipitation happening in Houston was one in more than 9,000 years, the interval for such a storm recurring anywhere in the Gulf was only one in 800 years.

Once researchers decide to study a specific event, the next phase is collecting and analyzing observations from the affected area. Some regions of the world have better monitoring coverage than others. Importantly, reduced coverage, quality, or access to data can increase the level of uncertainty about the extent to which a particular event exceeded historical levels. This is especially true in countries with low- and middle-income countries, where technical and financial resources to establish monitoring networks have disproportionately lagged.

Similarly, some events may take place at such a small scale that statistical confidence in the extremity of the event decreases. The physical impacts of some events can also directly impair the monitoring equipment during the event itself, as was the case in the 2021 Western Europe floods, which destroyed long-term flood monitoring stations and prevented a full accounting of the their magnitude.

In parallel to evaluating observational quality, the analysis phase of attribution relies on selecting climate models skillful at representing the historical distribution for the event type and region. Using models that meet a minimum performance standard helps researchers ensure they use the best possible simulated climate to compare observations. By comparing the observed world (with human emissions) and the simulated counterfactual world (without human emissions), researchers can calculate the likelihood an event is attributable to human-caused climate change. Observed events that significantly exceed ranges of variability from the counterfactual model reveal clearer fingerprints of human influence.

In characterizing conclusions, the attribution process that van Oldenborgh et al. outline attempts to provide several key results, including 1) the probability of the event occurring in the current climate, 2) the probability of the event occurring in a *future* climate with elevated warming, and 3) a synopsis appraisal of how (and how confidently) one can attribute the event to human-driven climate change. Often these results come with caveats, such as when modeling or observational data is limited or when climate impacts result from compounding factors (e.g., fires are often the result of heat, wind, precipitation, and various forms of ignition). Ultimately, any attribution result is probabilistic rather than unequivocal, owing to the statistical nature of how we understand the global climate.

Since the human mind gravitates toward events in the here and now, rapid response attribution studies have the potential to help people draw more tangible connections between global climate change and their own well-being. The World Weather Attribution's approach is exciting because it showcases how the scientific community can apply new computing tools, as well as new orientations toward public service, to make their research more actionable. Ultimately, though, as the IPCC shows us with increasing confidence, every fraction of degree of warming avoided will limit the further intensification of extremes.

Featured research

IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. In Press.

Philip, S.Y., Kew, S.F., Oldenborgh, G.J. Van, Yang, W., Vecchi, G.A., Anslow, F.S., Li, S., Seneviratne, S.I., Luu, L.N., Arrighi, J., Singh, R., Aalst, V., Hauser, M., Schumacher, D.L., Marghidan, C.P., Ebi, K.L., Vautard, R., Tradowsky, J., Coumou, D., Lehner, F., Rodell, C., Stull, R., Howard, R., Gillett, N., Otto, F.E.L., 2021. Rapid attribution analysis of the extraordinary heatwave on the Pacific Coast of the US and Canada June 2021 . 119–123.

van Oldenborgh, G.J., van der Wiel, K., Kew, S., Philip, S., Otto, F., Vautard, R., King, A., Lott, F., Arrighi, J., Singh, R., van Aalst, M., 2021. Pathways and pitfalls in extreme event attribution. Clim. Change 166, 1–27. https://doi.org/10.1007/s10584-021-03071-7

van Oldenborgh, G.J., van der Wiel, K., Sebastian, A., Singh, R., Arrighi, J., Otto, F., Haustein, K., Li, S., Vecchi, G., Cullen, H., 2017. Attribution of extreme rainfall from Hurricane Harvey, August 2017. Environ. Res. Lett. 12, 124009. https://doi.org/10.1088/1748-9326/aa9ef2