

Explaining Extreme Events of 2020 from a Climate Perspective



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EXPLAINING EXTREME EVENTS OF 2020 FROM A CLIMATE PERSPECTIVE

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Cover: Low water bathtub ring on sandstone cliffs around Lake Powell in Glen Canyon National Recreation Area in Arizona. (credit: trekandshoot/Shutterstock.com)

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How to Provide Useful Attribution Statements: Lessons Learned from Operationalizing Event Attribution in Europe

Friederike E. L. Otto, Sarah Kew, Sjoukje Philip, Peter Stott, and Geert Jan Van Oldenborgh

Operational attribution protocols ensure transparency of assessments; communication needs to include future changes in extremes and meteorological development of the event to add value in local decision making.

In the immediate aftermath of an extreme weather- or climate-related event, the question is invariably asked whether and to what extent it was influenced by anthropogenic climate change. As a trusted source of weather information, national meteorological services (NMSs) in particular are facing this question and given their status as government services they are expected to answer, leading to calls for operationalizing event attribution studies. Under the umbrella of Copernicus, the European climate service provider, a team of scientists and several NMSs started a pilot project, following established protocols (van Oldenborgh et al. 2021; Philip et al. 2020) to test whether the task of attributing individual weather extremes can now be taken over by an operational service for the simpler extremes (e.g., cold and hot extremes or large-scale heavy rainfall).

While it has long been established that the likelihood and intensity of heatwaves and heavy rainfall events is increasing in a warming climate, the degree to which they are changing varies greatly depending on the exact temporal and geographical extent of the event (Harrington and Otto 2018; Leach et al. 2020).

In addition, anthropogenic climate change is far from being the only contributor to changing extreme

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weather events faced by natural and human systems. Other drivers such as population changes, water usage (Otto et al. 2015), surface roughness, or land use changes (Vautard et al. 2019) can also play a role. The final risk to extreme weather is compounded by exposure and vulnerability to hazards. These factors are continuously changing and in the short term the most amenable to protecting our society (e.g., through heat plans and updated building standards or improved water and drought management).

As such, it is important that all those aspects leading to damages and losses from extreme weather events that can be attributed and projected in a given location, like human-induced climate change, be disentangled from natural variability and other drivers in exposure and vulnerability in order to provide different European regions with the best available evidence to face global warming and give them ways to adapt to the changing nature of weather and climate extremes (van Oldenborgh et al. 2021; Shepherd 2019; Stone et al. 2021). To ensure relevance for society and decision makers it is extremely important to involve (local) exposure and vulnerability experts. Therefore, the pilot service decided not to use pre-calculated attribution statements (e.g., Christidis et al. 2015) but rather to follow the framework introduced by Philip et al. (2020), which takes these aspects explicitly into account.

When the pilot started, the science of attributing heatwaves and large-scale heavy rainfall events had been well established in the scientific literature with a large basis of scientific papers published, in particular on European events. For example the U.S. National Academy of Science assessed the “readiness” of these methods for implementation and concluded that for hot, cold, and wet events methods are indeed reliable (National Academies of Sciences, Engineering, and Medicine 2016). Thus, the primary aim of the pilot was not to test the reliability of the scientific methodology to attribute extreme weather events but to implement a scientific methodological approach into an operational protocol that can be applied within operational services and to test whether results are robust with respect to different models and datasets. These tests have been performed by undertaking four different event attribution studies, two slow ones reassessing previously published studies and two fast ones (see the online supplemental material) attributing previously unstudied events under quasi-real-time conditions.

In the remainder of this paper we discuss the two events that were re-attributed and compare them with the original attribution studies, we reflect on the functioning of the operational team, and finally we discuss several aspects that can act to strengthen attribution statements in the future. The term *operational* in this context means that clear procedures are followed that are independent of the event to be attributed and that the timeframe of the analysis is no longer than two weeks. We do not discuss whether event attribution should be operationalized but report on the outcome of the pilot project that was implemented following demand from national Met Services, who need to address questions on the role of climate change within the immediate aftermath of extreme events occurring.

Re-attributing of events.

The attribution procedure itself includes the trigger, the event definition, the trend detection in the observations, model evaluation, estimating the contribution from climate change, hazard synthesis, vulnerability and exposure analysis, and writing up the results. Based on an initial draft protocol, the attribution protocol has been tested thoroughly through test attribution studies each one led by a researcher from different NMSs. Two are highlighted below; the other two led to similar conclusions (see the supplemental material).

As the first slow attribution study the project reassessed the influence of human-induced climate change on the summer heatwave 2018. The study built on an earlier World Weather Attribution assessment (<https://www.worldweatherattribution.org/attribution-of-the-2018-heat-in-northern-europe/>). The scientific report can be found here: <https://attribution.climate.copernicus.eu/wp-content/uploads/2018-heatwave-study-tech.pdf>.

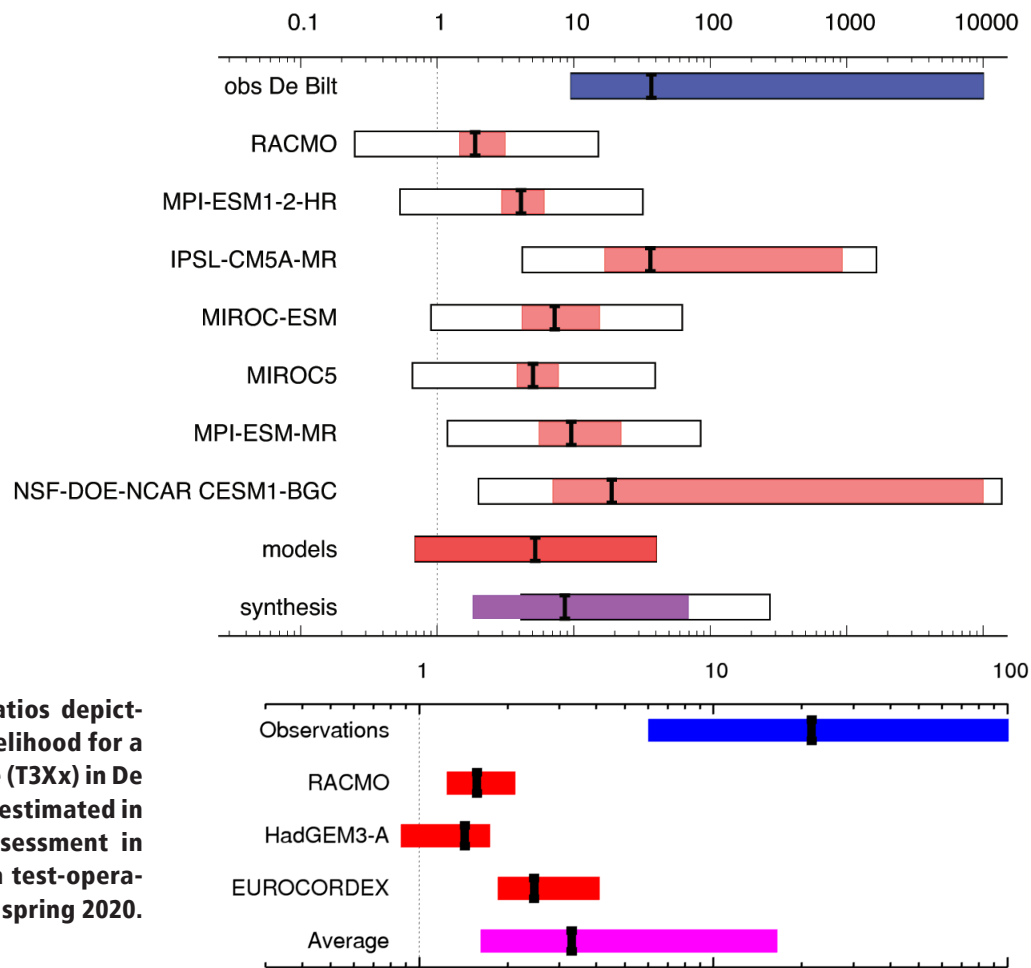


Fig. 1. Probability ratios depicting the change in likelihood for a 3-day 2018 heatwave (TX3x) in De Bilt (Netherlands) as estimated in (bottom) a rapid assessment in July 2018 and (top) a test-operational assessment in spring 2020.

Figure 1 shows the direct comparison of the attribution results for the station of De Bilt. The main result of the study, the attribution statement that human-induced climate change has increased the likelihood of the event to occur by a factor of at least 1.8 (2020 analysis), is within the uncertainties of the rapid assessment from July 2018, which gave an increase in the likelihood of a factor of 3.3 (1.6 ... 16). The main reason for the differences is the slightly different event magnitude. For the 2020 analysis under Copernicus the summer of 2018 was over and thus the chosen event, the hottest 3-day maximum (TX3x), was estimated at a temperature of 33.7°C. The rapid study in 2018 was undertaken before the end of the summer, in July 2018, so TX3x, the hottest 3-day maximum of the year *up until* July, was only 33.0°C. The difference of 0.7°C in event magnitude has large consequences on the upper bound in the observations based probability ratio and changes it from 500 in the 2018 analysis to infinity. In consequence, a quantitative best-estimate of the role of climate change cannot be given in the 2020 analysis and the overall probability ratio is unbounded. This means that the uncertainty range is so large that only the lower bound can be meaningfully quantified. However, due to the fact that the models considerably underestimate the trend, the estimates of the lower bounds given in both cases are very conservative, potentially dramatically underestimating the role of climate change (Lloyd and Oreskes 2018).

Between 30 May and 2 June 2013 intense rainfall led to flooding in many parts of Germany, most significantly in upper areas of the Danube and Elbe Rivers. Although there were few casualties, the flooding caused millions of euros of damage. An attribution study of the event had been published (Schaller et al. 2014) finding no significant role of climate change. Revisiting the analysis of the rainfall in the 4-day period in late spring 2013, including six more observational years, we still found that despite expecting the intensity of rainfall to increase on

a global average as a result of climate change, there was no statistically significant increase in the likelihood of this event due to human-induced climate change.

In this second study, about half the models that were used and passed the evaluation showed a significant increase in the likelihood of the event to occur, leading to an overall increase in the model result, which overall leads to an inconclusive result for the Elbe but an increase for the Danube, although again not significant.

From a very high-level perspective the results of the 2013 and 2020 studies are thus the same. However, these estimates, if presented only as inconclusive and thus demonstrating no attributable change, would result in a very conservative estimate, potentially downplaying the role of climate change. We know this as in the slow study from May 2020 the same event was also assessed for a future warming level of 2°, where for both basins an increase in the likelihood of a factor of 4.2 (Elbe) and 3.2 (Danube) respectively was found—a result that suggests that despite their statistical insignificance the trends toward a higher likelihood and intensity of the observed event are indeed due to climate change. This difference between models further supports the need for more process-based thinking to be included in future in operational attribution assessments in order to determine which models capture—or fail to capture—the relevant processes and thereby improve the robustness of such assessments, or indeed to lead to a change of the null hypothesis (Lloyd and Oreskes 2018). The third and fourth study are briefly described in the online supplemental material and highlight similar issues. Rapid attribution studies undertaken since by the World Weather Attribution Initiative (see the supplemental material) further corroborate the findings reported here.

Discussion.

Both events were performed by operational teams from the NMSs following a detailed protocol, and at the end of the four events the teams could do these attributions without guidance from scientists experienced in this established attribution framework. While a large team size ensures the use of multiple models and a wider public support, a larger team becomes more ponderous, with more decisions required and a higher level of detail in the protocol, yet still with need of expert judgment.

Both test studies showed that employing the published attribution methodology provides quantitative results that are robust against changes in models and datasets and, to the degree that this is expected in a non-stationary climate, also time. In that respect the protocols have been shown to be fit for the purpose and do not overplay the role of climate change (Bellprat and Doblas-Reyes 2016). However, the test studies have also shown that, especially when also taking the projected changes in the respective extreme events into account, the quantitative estimates are conservative.

It has been argued (Diffenbaugh 2020; Lloyd and Oreskes 2018; Lloyd and Shepherd 2020; Mann et al. 2017) that current practice is too conservative in emphasizing the robustness of the attribution assessment and focusing on lower bounds when these are least ill defined and thus underestimating the role of anthropogenic climate change and consequently misinforming the public.

These arguments are very valid, and follow-up research should investigate whether a storyline approach as suggested in Shepherd (2019) is more readily suited to operational attribution. Here we discuss, following social science research (Lahsen and Ribot 2021), whether the approach that has been used in the pilot delivers the local context of an event in a globally changing climate.

This purpose could be strengthened in the assessed pilot service by incorporating for example assessments of future changes in the likelihood of the event directly into the uncertainty assessment to calculate the synthesis result or to approach this issue within the communication of the results only and thus explicitly including prior information (Shepherd

2021) and connecting to IPCC research. The former will however only be meaningful if the climate change signal has simply not emerged from the noise; if, however, drivers other than greenhouse gases (e.g., aerosols) mask the effects (van Oldenborgh et al. 2018), errors would be introduced. In any case systematically assessing the reasons for discrepancies between present and future changes will improve the usefulness of attribution studies.

Communications needs to be very clear on what the limitations of an individual event attribution study are (i.e., that they present a snapshot of the role of climate change on a very specific event at a point in time). This is also a strength, in that several key factors of that event are taken into account (e.g., circulation change, possible other drivers) that give a trend that deviates from the global mean one.

Having tested the developed protocols for operational attribution in two instances, the performance of the protocol and reliability of the results from a scientific point of view has been very successful. For the purpose of scientific appropriateness, the attribution protocol advocating the multi-model approach and improving on transparency is a currently available approach to event attribution that can be readily implemented in an operational process. Toward the future development of operationalizing event attribution, a conscious decision on where the service stands between risking overstating the role of climate change and underestimating it by issuing too conservative statements needs to be undertaken, taking new research on communication into account when possible. Furthermore a service needs to be clear on whether only the hazard or also vulnerability and exposure as well are included in the assessment. In the evolution of the service these decisions need to be taken into account when developing communication strategies.

References

- Bellprat, O., and F. Doblas-Reyes, 2016: Attribution of extreme weather and climate events overestimated by unreliable climate simulations. *Geophys. Res. Lett.*, **43**, 2158–2164, <https://doi.org/10.1002/2015GL067189>.
- Christidis, N., P.A. Stott, and F.W. Zwiers, 2015: Fast-track attribution assessments based on pre-computed estimates of changes in the odds of warm extremes. *Climate Dyn.*, **45**, 1547–1564, <https://doi.org/10.1007/s00382-014-2408-x>.
- Diffenbaugh, N. S., 2020: Verification of extreme event attribution: Using out-of-sample observations to assess changes in probabilities of unprecedented events. *Sci. Adv.*, **6**, eaay2368, <https://doi.org/10.1126/sciadv.aay2368>.
- Harrington, L. J., and F. E. Otto, 2018: Adapting attribution science to the climate extremes of tomorrow. *Environ. Res. Lett.*, **13**, 123006, <https://doi.org/10.1088/1748-9326/aaf4cc>.
- Lahsen, M., and J. Ribot, 2021: Politics of attributing extreme events and disasters to climate change. *Wiley Interdiscip. Rev.: Climate Change*, **13**, e750, <https://doi.org/10.1002/wcc.750>.
- Leach, N., S. Li, S. Sparrow, G. J. van Oldenborgh, F. C. Lott, A. Weisheimer, and M. R. Allen, 2020: Anthropogenic influence on the 2018 summer warm spell in Europe: The impact of different spatio-temporal scales [in “Explaining Extreme Events of 2018 from a Climate Perspective”]. *Bull. Amer. Meteor. Soc.*, **101** (1), S41–S46, <https://doi.org/10.1175/BAMS-D-19-0201.1>.
- Lloyd, E. A., and N. Oreskes, 2018: Climate change attribution: When is it appropriate to accept new methods? *Earth's Future*, **6**, 311–325, <https://doi.org/10.1002/2017EF000665>.
- , and T. G. Shepherd, 2020: Environmental catastrophes, climate change, and attribution. *Ann. N. Y. Acad. Sci.*, **1469**, 105–124, <https://doi.org/10.1111/nyas.14308>.
- Mann, M. E., E. A. Lloyd, and N. Oreskes, 2017: Assessing climate change impacts on extreme weather events: The case for an alternative (Bayesian) approach. *Climatic Change*, **144**, 131–142, <https://doi.org/10.1007/s10584-017-2048-3>.
- National Academies of Sciences, Engineering, and Medicine, 2016: *Attribution of Extreme Weather Events in the Context of Climate Change*. National Academies Press, 187 pp.
- Otto, F. E. L., and Coauthors, 2015: Water shortage in southeast Brazil [in “Explaining Extreme Events of 2014 from a Climate Perspective”]. *Bull. Amer. Meteor. Soc.*, **96**, 35–44, <https://doi.org/10.1175/BAMS-D-15-00120.1>.
- Philip, S., and Coauthors, 2020: A protocol for probabilistic extreme event attribution analyses. *Adv. Stat. Climatol. Meteor. Oceanogr.*, **6**, 177–203, <https://doi.org/10.5194/ascmo-6-177-2020>.
- Schaller, N., F. E. L. Otto, G. J. van Oldenborgh, N. R. Massey, S. Sparrow, and M. R. Allen, 2014: The heavy precipitation event of May–June 2013 in the upper Danube and Elbe basins [in “Explaining Extreme Events of 2013 from a Climate Perspective”]. *Bull. Amer. Meteor. Soc.*, **95** (9), S69–S72, <https://doi.org/10.1175/1520-0477-95.9.S1.1>.
- Shepherd, T. G., 2019: Storyline approach to the construction of regional climate change information. *Proc. Roy. Soc.*, **475A**, 20190013, <https://doi.org/10.1098/rspa.2019.0013>.
- , 2021: Bringing physical reasoning into statistical practice in climate-change science. *Climatic Change*, **169**, 2, <https://doi.org/10.1007/s10584-021-03226-6>.
- Stone, D. A., S. M. Rosier, and D. J. Frame, 2021: The question of life, the universe and event attribution. *Nat. Climate Change*, **11**, 276–278, <https://doi.org/10.1038/s41558-021-01012-x>.
- van Oldenborgh, G. J., and Coauthors, 2018: Extreme heat in India and anthropogenic climate change. *Nat. Hazards Earth Syst. Sci.*, **18**, 365–381, <https://doi.org/10.5194/nhess-18-365-2018>.
- , and Coauthors, 2021: Pathways and pitfalls in extreme event attribution. *Climatic Change*, **166**, 13, <https://doi.org/10.1007/s10584-021-03071-7>.
- Vautard, R., and Coauthors, 2019: Human influence on European winter wind storms such as those of January 2018. *Earth Syst. Dyn.*, **10**, 271–286, <https://doi.org/10.5194/esd-10-271-2019>.