# 30. FUTURE CHALLENGES IN EVENT ATTRIBUTION METHODOLOGIES

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*Since these reports began five years ago, they have played an important part in the development and remarkable advancement of the science of event attribution. At the start of this endeavor, only a few events had been studied, geographical coverage was limited, and the focus had been mainly on extreme temperature events. Now, the range of events covered includes rain storms, droughts, tropical storms, and wildfires, as well as heat waves.*

The website Carbon Brief[1] has produced a graphical inventory of studies from this report along with other peer-reviewed literature. It shows a growing geographical coverage over the last five years and a developing wealth of evidence pointing to the significant effects of human-induced climate change on many extreme events. The majority of attribution studies have been published in these annual reports. This demonstrates the important role these reports have taken, thanks to the continuing engagement by the scientific community in this endeavor.

The breadth and depth of these articles demonstrate a notable developing maturity of this science. At the same time, a few important challenges still remain, and this latest report highlights three of these. They are: 1) the role of methodological choices in determining the outcome of event attribution studies; 2) the need to better assess the influence of human-induced climate change on the impacts of extreme events; and 3) the growing needs of a wider range of stakeholders to inform decision making.

First, it is becoming increasingly apparent that different methodological choices can lead to important differences in the results of event attribution studies. To take one example from this report, the study of the air pollution episode in Europe in December 2016 (Vautard et al. 2018) found different results depending on the type of climate model used. With a multimodel ensemble, a significant human-induced effect was found on the stagnant winter time conditions that prevailed over northwestern Europe during that month, but this was not found with two single-model ensembles. The record 2016 heat in Asia was found not to be possible without human-caused climate change, and the authors concluded the fraction of attributable risk (FAR) to climate change was effectively 1. This result is based on the atmospheric general circulation model (AGCM) simulations using the observed sea surface temperatures (SST). Thus, it is suggested that "the observed heat anomaly have zero probability of occurrence with the certain, observed, SST variability pattern." However, it is not clear how the FAR would be impacted if the uncertainty of the natural variability of SST were considered.

Attribution results are potentially sensitive to methodological choices. Thus, it is important to clearly communicate the methodological choices within each study and, when possible, also to explore such methodological sensitivities in the study itself. In last year's issue, we included additional information on the methods used in the summary Table 1.1 (pages S4–S5), and this year we continue with this additional contextual information. Even so, there is an ongoing debate in the scientific community about the effects of methodological choices and optimal strategies for attribution of extreme events. For example, two recent companion pieces in *Climatic Change* took alternative viewpoints about the role of statistical paradigms in event attribution studies (Mann et al. 2017; Stott et al. 2017). Further work is needed to fully understand the effects such choices are having, as summarized by the statistics in Table 1.1 of the results in this report (p. S4).

Second, clearly much more should be done to better assess any links between the impacts of extreme

[1] www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world

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events to human-induced climate change. Traditionally, those who are part of the impacts community have focused on assessing the extent to which impacts such as changes in ecosystems can be attributed to variations in climate, howsoever caused. Ultimately, however, if we wish to make statements about links between impacts and human-induced climate change we need to differentiate possible natural climatic effects from human-induced ones. This is a challenge. We have been keen to encourage contributions to this latest report that address impacts. The submissions provide important new information but also illustrate the challenges in making such links.

Brainard et al. find that coral reef and seabird communities were disrupted by the record-setting sea surface temperatures of the central equatorial Pacific during the 2015/16 El Niño. This, by linking a particular meteorological event to impacts on marine ecosystem, is in itself an important conclusion. But this conclusion by itself would not be sufficient to be included in this issue because it does not assess the link to anthropogenic climate change. However, by making a link to a companion paper in this issue by Newman et al., which shows evidence that record warm central equatorial Pacific temperatures during the 15/16 El Niño reflect an anthropogenically forced trend, Brainard et al. are able to make an indirect two-step link to human-induced climate change. Such a two-step approach as illustrated here in Brainard et al. has been recognized by IPCC as a suitable method for attributing impacts (Hegerl et al. 2009). The value of this type of information to the marine resource management community is included as a Perspectives piece co-authored by the NOAA National Marine Fisheries chief scientist (Webb and Werner 2018). The authors describe the value of attribution results that assess the different drivers impacting living marine resources when making management decisions, in particular for considering potential future impacts to resources such as fisheries stocks.

Third, as the science matures and a mounting focus builds on possible links between extreme events and climate change, with a view to better adapting and to better partitioning the costs of climate change, there is increasing interest in applying this science. In the legal field, for example, there is an argument that attribution studies can be used to help courts determine liability for climate-related harm (Marjanan et al. 2017). In the past, beyond the scientific community, these results have primarily been used with stakeholders for whom very rapid analyses may be particularly relevant, for example those engaged in building resilience in the aftermath of an extreme event, or the media and other climate change science communicators. Today, stakeholders have expanded to include those involved in the regulatory, legal, and management frameworks who increasingly may find such approaches potentially useful.

While it represents a considerable challenge to provide robust results that are clearly communicated for stakeholders to use as part of their decision-making processes, these annual reports are increasingly showing their potential to help meet such growing needs. By taking a middle road in terms of timescale of delivery—longer than the very rapid results needed by the media but shorter than many academic contributions—and by using relatively standard approaches that have been previously peer reviewed, advances being made in these reports point the way forward toward a greater use of event attribution studies in decision-making contexts.

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