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Regional decision-makers as potential users of Extreme Weather Event Attribution - Case studies from the German Baltic Sea coast and the Greater Paris area

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A B S T R A C T

Extreme Event Attribution has raised increasing attention in climate science in the last years. It means to judge the extent to which certain weather-related extreme events have changed due to human influences on climate with probabilistic statements. Extreme Event Attribution is often anticipated to spur more than just scientific ambition. It is able to provide answers to a commonly asked questions after extreme events, namely, 'can we blame it on climate change' and is assumed to support decision-making of various actors engaged in climate change mitigation and adaptation. More in-depth research is widely lacking about who these actors are; in which context they can make use of it; and what requirements they have, to be able to actually apply Extreme Event Attribution. We have therefore addressed these questions with two empirical case studies looking at regional decision-makers who deal with storm surge risks in the German Baltic Sea region and heat waves in the Greater Paris area. Stakeholder interviews and workshops reveal that fields of application and requirements are diverse, difficult to explicitly identify, and often clearly associated with stakeholders' specific mandate, the hazard background, and the regional socio-economic setting. Among the considered stakeholders in the Baltic Sea region, Extreme Event Attribution is perceived to be most useful to awareness-raising, in particular for climate change mitigation. They emphasised the importance of receiving understandable information - and that, rather later, but with smaller uncertainties than faster, but with higher uncertainties. In the *Paris* case, we typically talked to people engaged in adaptation with expertise in terms of climate science, but narrowly defined mandates which is typical for the Paris-centred political system with highly specialised public experts. The interviewees claimed that Extreme Event Attribution is most useful to political leverage and public discourses. If novel information like this is not sorted out a priori, it needs to be clearly linked to impacts, preferably as monetary values lost. These examples underline the significance of conducting case-specific stakeholder mappings and consultation. Overall, our studies can thereby provide methods and exemplary empirical evidence to support developing useful services from Extreme Event Attribution for targeted groups of users.

1. Introduction and background

In 2007, the IPCC addressed for the first time general attribution studies, i.e. the evaluation of the relative contribution of anthropogenic greenhouse gas emissions to climate change. The report states that more than 50% of the observed increased global average temperatures since mid of last century are very likely to be caused by the emission of anthropogenic greenhouse gases. This trend attribution shows whether climate change is generally linked to anthropogenic greenhouse gases. Nevertheless, it does not show whether and in how far specific extreme events are attributable to anthropogenic climate change. This is a question which is often posed after extreme events, but which has rarely been answered to date (Stott et al., 2016; Hulme, 2014; James et al., 2014). The World Climate Research Programme declared that answers to this question are essential for 'Understanding and Predicting Weather and Climate Extremes' and identified it therefore as part of the six grand challenges of climate research (World Climate Research Programme, 2013; Seneviratne Zwiers, 2015). In the last two decades, a range of scientists have aimed at meeting this challenge by continuously advancing the science of Extreme Event Attribution. This field of research is meant to judge the extent to which certain weather-related extreme events have changed due to human influences on climate with probabilistic statements (Hegerl et al., 2010). Extreme event attribution tries to overcome the problem of rarity regarding extreme events by simulating tens of thousands of times the occurrence of extreme weather events in two virtual worlds. One world where our atmosphere and climate is reproduced as it is today and another world which simulates a pre-industrial-like world without anthropogenic greenhouse gas emissions. These two worlds are then compared with each other (see e.g. Solow, 2015).

It is often argued that scientists, media, and practitioners are interested in rising to this "grand challenge" for different reasons (see e.g.

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Hulme, 2014; Hegerl et al., 2010; James et al., 2014; Sippel et al., 2015). Scientists seem to be spurred by scientific ambition to master the methodological complexities; the media hopes to answer one of the most commonly asked questions after extreme events, i.e. who is to blame for it; and decision-makers fondly hope to get justification, funding and a better knowledge base for managing climate-related risks. Overall, it seems to be anticipated that Extreme Event Attribution may make anthropogenic climate change more visible or unvisible if no link is found. Negative consequences of climatic conditions in general and climate change become most apparent through extreme events. Extreme Event Attribution quantifies whether these extremes are linked to anthropogenic greenhouse gases. It does thereby not argue on an abstract level of long-term climate changes which can hardly be experienced by individuals over a lifetime. Extreme Event Attribution is able to demonstrate the imminent perils of climate change at a vivid example of recent extreme events and may reveal that climate change is or is not real already today. Research which goes beyond the understanding that Extreme Event Attribution is important for stakeholders and which empirically identifies potential groups of users or maps possible needs of different sectors, institutions and agents is still rare (Stott and Walton, 2013). Also a more detailed empirical analysis of these stakeholders' needs, for instance, against the background of context-, hazard- or region-specific factors, or with respect to their implications for climate change-related decision-making has not been undertaken, so far.

This paper therefore aims at answering the questions of who could be potential user groups at the regional level, whether their interests coincides with what is often assumed to interest them, and what requirements may exist in different fields of their work. These questions are addressed using the example of stakeholders engaged in managing the risks of climate change, storm surges at the German Baltic Sea coast, and heat waves in the Greater Paris area. We answered the above mentioned questions with a qualitative empirical case study and analysed them in light of concepts which link science and practice. This has revealed that is important to be aware of the mandate, background and needs of different stakeholder groups. It became apparent that there is not one set of potential users, but that they are different depending on the region and hazard under consideration. In the test cases, we found that Extreme Event Attribution products should be understandable, trustworthy, and tailored to stakeholders' specific concerns. In the end, this study shall provide a basis to effectively communicate and frame attribution studies and create useful services from Extreme Event Attribution.

In this paper, a literature review about Extreme Event Attribution research and its relevance to stakeholders will be presented first. Subsequently, we will introduce the materials, methods and concepts used in the two case studies. The results will be outlined and discussed in the next section. In the end, general conclusions will be drawn.

2. Existing research on Extreme Event Attribution and its assumed relevance to stakeholders

Extreme Event Attribution information may serve an already long-lasting public interest in the so called 'extreme weather blame' question, i.e. who is responsible for extreme weather. He further states that in the past, this question has commonly been answered by blaming god, evil spirits or witches (Hulme, 2014). In recent decades, man-made greenhouse gas emissions are often made responsible for extreme weather events. Several authors therefore argue that Extreme Event Attribution information could increase scientific rigour in the debate and add probabilities to such assumptions. In addition, it could ease the frustration with and the argument about the invisibility of climate change because extreme events are more visible than creeping climate changes (Stott and Walton, 2013; Sippel et al., 2015; Bray and von Storch, 2016).

There is a growing number of studies which have judged the contribution of climate change to particular events. These are based on various methodologies and models (for an extensive overview of Extreme Event Attribution approaches see Stott et al., 2016). Some of the studies found that climate change is responsible for the intensity and frequency of extreme events considered, e.g. in case of the heat wave in Europe in 2003 (Stott et al., 2004a,b), the floods in the UK in autumn 2000 (Pall et al., 2011), the cold spell in the US (Wolter et al., 2015); others detected no significant anthropogenic influence on climate, like in case of Storm Christian in 2013 (von Storch et al., 2014) and Hurricane Gonzalo (Feser et al., 2015). For the latter, there have, however, also been contradictory results presented indicating an anthropogenic contribution (Rahmstorf and Coumou, 2011).

Since 2011, yearly collections of attribution studies of events from the previous calendar year have been published as Special Issue of the Bulletin of the American Meteorological Society (BAMS). An analysis of all events assessed in the 2011–2014 BAMS reports shows that most BAMS studies have looked at heat, precipitation and drought. Storm surges or winter storms have been assessed only once. These reports present case studies of event attribution of the recent past (Herring, 2015). They support the visibility of attribution studies also beyond the scientific community. More recently, event attribution scholars have further demonstrated that Extreme Event Attribution can be done in near-real time (see e.g. van Oldenborgh et al., 2015; van Oldenborgh et al., 2016). Climate Central, a non-profit environmental news organization, has published a near real-time example of "weather attribution" in July 2015. Building on weather forecasts and later on the observed temperatures during the July 2015 heat wave in Europe, they found that, for example, a 3-day period as hot as experienced in Mannheim is now roughly 8 times more likely than it was in the 1930s. This was published only a couple of days after the event (Climate Central, 2015). Attribution scientists predict that within a decade from now attribution methods may become an operational product like local weather forecasts (Stott et al., 2016; Zastrow, 2015). Extreme Event Attribution studies have, however, been criticised for having a too hazard-centred view on risk (see e.g. Hulme, 2014). They only look at the causes of hazard changes, but do not look at what drives vulnerabilities and exposure. Challenging this critique, there are already some examples of event attribution studies which link the meteorological causation to infrastructure, ecosystem, or hydrological analyses (see e.g. Pall et al., 2011; Sippel and Otto, 2014; Mitchell et al., 2016; Schaller et al., 2016).

Despite of these advances, many stakeholders and the public seem to think that it is not possible to attribute a single event to anthropogenic climate change (Hegerl et al., 2010; Thompson and Otto, 2015). Bray and von Storch (2016) reveal that many scientists share this opinion. In their survey of climate scientists, nearly one third believes that Extreme Event Attribution efforts have not provided robust evidence of attributing events to climate change at all or only to a minor degree (Bray and von Storch, 2016: 83). Extreme weather can be generated by natural variability also without climate change. Another point of criticism, in this respect, is that extreme events are too rare to attribute a single event to climate change. Extreme Event Attribution, however, builds on ensembles of simulations of climate models and can therefore overcome this challenge (IDAG, 2005; James et al., 2014).

There is a key argument which can hardly be overcome and limits the confidence in event attribution results. This is the assumption that a given climate model, or a given family of climate models, is really describing the full range of phenomena in terms of intensity and frequency. In many cases, this may be the case, but in others the contemporary models will have their limitations. One case refers to a model-set-up used in event attribution and its performance in simulating weather conditions which lead to storm surges in the Baltic Sea (Klehmet et al., 2016). Thus, when scientists speak about changing probabilities, they talk about estimates of probabilities which may, in fact, be systematically over- or underestimated; and different models may generate different statistics of extreme events and their change. Accordingly, the confidence in the event attribution depends critically on the confidence of the used models to generate extreme events correctly in terms of the locations, seasonal timing, frequency, intensity etc. (von Storch, and Bray, 2017).

Some authors argue that Extreme Event Attribution statements