

## Stakeholder Perspectives on the Attribution of Extreme Weather Events: An Explorative Enquiry

SEBASTIAN SIPPEL,\* PETER WALTON, AND FRIEDERIKE E. L. OTTO

*Environmental Change Institute, University of Oxford, Oxford, United Kingdom*

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### ABSTRACT

Recent extreme weather events and their impacts on societies have highlighted the need for timely adaptation to the changing odds of their occurrence. Such measures require appropriate information about likely changes in event frequency and magnitude on relevant spatiotemporal scales. However, to support robust climate information for decision-making, an effective communication between scientists and stakeholders is crucial. In this context, weather event attribution studies are increasingly raising attention beyond academic circles, although the understanding of how to take it beyond academia is still evolving. This paper presents the results of a study that involved in-depth interviews with stakeholders from a range of sectors about potential applications and the general usefulness of event attribution studies. A case study of the hot and dry summer 2012 in southeast Europe is used as a concrete example, with a focus on the applicability of attribution results across sectors. An analysis of the interviews reveals an abundant interest among the interviewed stakeholders and highlights the need for information on the causes and odds of extreme events, in particular on regional scales. From this data key aspects of stakeholder engagement are emerging, which could productively feed back into how probabilistic event attribution studies are designed and communicated to ensure practical relevance and usefulness for the stakeholder community.

### 1. Introduction

Changing extreme weather events are likely to be among the most notable consequences of anthropogenic climate change with potentially highly significant impacts on societies (Seneviratne et al. 2012; Barriopedro et al. 2011; Rahmstorf and Coumou 2011; Huntingford et al. 2014). A number of recent extreme events with considerable adverse impacts have raised questions as to whether and to what extent those events might be linked to climate change (Rahmstorf and Coumou 2011; Coumou and Rahmstorf 2012). These have included droughts in the Horn of Africa (Funk et al. 2013; Lott et al. 2013); flooding in Pakistan (Christidis et al. 2013),

Bosnia and Serbia (van Oldenborgh 2014) and Thailand (van Oldenborgh et al. 2012); and exceptionally hot and dry summers in Russia, southeast Europe (Christidis et al. 2013; Otto et al. 2012; Sippel and Otto 2014), and California (Swain et al. 2014; Funk et al. 2014), among others.

Although the frequency and magnitude of some extreme events such as heat waves have increased in recent years (Donat et al. 2013; Seneviratne et al. 2012), the question of causality (i.e., whether the odds of occurrence of any particular extreme event have changed due to anthropogenic climate change) remains largely unanswered (Stott et al. 2013). Over the last decade, however, scientists have started to use and explore the prospects of probabilistic event attribution (PEA) as a way to make probabilistic statements about the links between climate change and particular extreme events (Allen et al. 2007). After the method had been initially described (Allen 2003; Stone

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\* Current affiliation: Max Planck Institute for Biogeochemistry, Hans-Knöll-Str. 10, 07745 Jena, Germany.

Corresponding author address: Sebastian Sippel, Environmental Change Institute, South Parks Road, Oxford OX1 3QY, United Kingdom.  
E-mail: ssippel@bgc-jena.mpg.de

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and Allen 2005), scientists attributed large-scale heat events, such as the European heat wave 2003, and found that human influence on the climate “has at least doubled the risk of a heat wave exceeding this threshold magnitude” in a European summer (Stott et al. 2004, p. 610). Subsequently, PEA was extended to smaller spatial scales and more directly impact-relevant variables, such as floods (Pall et al. 2011; van Oldenborgh et al. 2012) or dryness (Sippel and Otto 2014). Since 2012, an annual report has been published by the American Meteorological Society that aims to investigate extreme weather events within a wider climatic context (Peterson et al. 2012, 2013; Herring et al. 2014), which has received large interest both within the scientific community and beyond. Currently, a near-real-time quasi-operational attribution service is being discussed (Stott et al. 2013; Nature 2012) and the prospects are explored within the recently launched European Union (EU)-funded project European Climate and Weather Events: Interpretation and Attribution (EUCLEIA 2014; <http://eucleia.eu>). It is anticipated that this would allow a preliminary answer to the question whether or not anthropogenic climate change played a role with respect to an extreme event while the event is happening or shortly after, but crucially “while the world is listening.” The real-time opportunities that attribution scientists are striving to achieve could provide a wide range of applications (Stott and Walton 2013). However, even with the current time lag in the attribution process a number of roles for the science have already been established, for example, by offering a long-term perspective on extreme weather events and, in doing so, addressing the public’s demand for rigorous climate information (Schiermeier 2011; Stott et al. 2013). This would potentially contribute to closing communication gaps in media and public discourse in how daily weather is influenced by long-term climate. Furthermore, it has been suggested that on regional levels, attribution information could assist government authorities, nongovernmental organizations (NGOs), and businesses in adaptation planning (Pall et al. 2011; Schiermeier 2011; Hoegh-Guldberg et al. 2011; Stott et al. 2013), emphasizing changes in extremes that are not only projected for the future but are already under way. Further potential applications of event attribution lie in legal claims (Grossman 2003; Lord et al. 2012) or in the loss and damage agenda under the United Nations Framework on Climate Change (UNFCCC; Huggel et al. 2013; James et al. 2014), where under the adaptation program the Warsaw International Mechanism for Loss and Damage (UNFCCC 2013) has been established to address impacts of climate change we cannot adapt against (Thompson and Otto 2015).

However, a more general use of event attribution science will present a number of challenges. Hulme et al.

(2011) and Hulme (2014) suggest that the attribution of extreme weather events could be counterproductive by emphasizing the uncertainty and possibly subjective outcomes of these studies, and also that there can be a discrepancy between the (meteorological) hazard (which is being attributed) and the (real) risk of the event, including vulnerability and exposure. The latter point also involves other complex and interacting drivers, for example in assessments of biological impacts (Parmesan et al. 2011).

While it is recognized that there is a compelling case to better understand the impacts of a changing climate and the potential change in risk from extreme weather events (Moss et al. 2013), these impacts have not yet been universally adopted by stakeholders (Schiermeier 2011; Stott and Walton 2013). Nonetheless, it has been shown that robust decision-relevant climate science is more likely to emerge from extended scientist–stakeholder dialogues, including active learning, support and feedback loops, rather than from “predict-then-act” types of scientist–stakeholder communication (Weaver et al. 2013). The latter places the expert climate change scientist at the top of an information chain feeding knowledge down to the nonexpert, passive stakeholder (Burns et al. 2003; Young and Matthews 2007). This process does not provide a mechanism for the decision-maker to communicate back to the scientist any concerns, misunderstanding, relevance, or timeliness of the issues. In contrast, the contextual model underlying recent stakeholder engagement efforts defines communication as a process of dialogue between an expert and nonexpert where information is socially contextualized (Weaver et al. 2013). That is, the information is not communicated in a social vacuum, but rather all parties will have their own cultural values, norms, heritage, political perspectives, and so on that will influence how the information is received, processed, and applied (Kahan et al. 2012). Dialogue between the parties, therefore, not only allows the science to be framed within one context, but also helps to situate the science in a range of contexts, providing parties with an equal stake in the knowledge construction (Sarewitz and Pielke 2007; Weaver et al. 2013). Using this approach the stakeholder becomes a central part of the research process (O’Riordan 1994; Harrison et al. 2004; Sarewitz and Pielke 2007) by a mutual exchange of information that can support decision-makers’ understanding and develop trust in the process (Wagner 2007; Krauss et al. 2012). The development of trust is a key aspect of the communication and engagement process as highlighted by Cash et al. (2003) and Kahan et al. (2012) as a way to develop credibility, saliency, and legitimacy of the research and researcher. Here, “credibility” refers to the adequacy of the scientific methodologies deployed, which ideally generates

knowledge relevant to the stakeholder (salience) without compromising potentially opposing values and beliefs of the stakeholder or other relevant groups in its production (legitimacy; see [Cash et al. 2003](#)).

Within the context of climate change, extensive stakeholder dialogues have been conducted for certain climate information products, such as the UK Climate Projections 2009 (UKCP09; [Street et al. 2009](#)), to assess the relevance, usefulness, and uptake across the stakeholder community. Notably, [Tang and Dessai \(2012\)](#) found that while these forecasts were mostly considered as legitimate and credible, the practical uptake for specific decisions was limited due to, but not limited to, the complexity and information richness provided by probabilistic forecasts that are generally not incorporated into adaptation decisions.

Although it is not as developed as other climate services, there is expected to be a high degree of stakeholder engagement within event attribution, which is currently being tested in recent projects. However, at present extensive dialogues or platforms for dialogue have not been developed or institutionalized more broadly ([Stott and Walton 2013](#)). Moreover, the literature on practical exercises that assess how this could be applied within attribution science is still sparse ([Stott and Walton 2013](#)). A possible reason for such limited stakeholder engagement with attribution science could center on the issue that, even compared to other climate science problems, it is both a complex issue and a relatively new subject, sometimes even compounded by a range of apparently conflicting attribution statements ([Otto et al. 2012](#); [James et al. 2014](#)).

While there are gaps between the state of the science and the possibility of its application, the potential for its use is slowly being realized. Although the growing attribution scientific community can in principle assess the attributable risk of a wide range of extreme weather events and their impacts ([Stott et al. 2013](#)), the needs of potential users of such data are largely unexplored. Failure to adequately communicate and contextualize the science of event attribution would potentially present a missed opportunity ([Sarewitz and Pielke 2007](#)) in terms of improving or optimizing climate-related decisions on various temporal and spatial scales.

This explorative study explores the gap between stakeholder needs and the scientific potential of probabilistic event attribution and considers the design principles necessary for meaningful engagement and application.

## 2. Methodology

Our study involved a series of in-depth interviews with stakeholders to identify their perspectives on

TABLE 1. Key interview questions.

- 1) How do you use climate science information in your work (and in your sector more broadly)?
- 2) What are relevant and useful applications of probabilistic attribution services in your sector?
- 3) What are the potential implications of the attribution study for southeast European climate adaptation planning?
- 4) What are potentially adverse outcomes of event attribution (see [Hulme et al. 2011](#))?
- 5) In what respect would the information have to be different to be more useful?

attribution science in relation to their capacity as decision-makers to determine what kind of attribution information might be relevant and useful. The interview data were gathered to help identify potential improvements and shortcomings of the PEA methodology, in particular whether the current attribution research is relevant to stakeholders. For this study the term “probabilistic event attribution” is defined as the detection of changes in the probabilities of extreme events, and the subsequent establishment of causes, following [Christidis et al. \(2013\)](#) and [Bindoff et al. \(2013\)](#).

The sample population for the study was drawn from sectors already engaged in climate policy and/or adaptation. This population was selected to represent the stakeholder community who would potentially make use of the data presented to them, in particular with respect to extreme weather events of drought and heat.

As the study was designed as an explorative enquiry involving focused participant selection criteria, a small sample size was recruited ( $N = 14$ ). Hence, with the qualitative analysis of the data it is not possible to extrapolate results to a wider population. However, the study has been able to identify key principles that can be tested as part of a future larger research study. [Table A1](#) in the [appendix](#) shows the breakdown of the sectors and participants, including further details of each (anonymized) interview.

The semistructured interviews lasted approximately 1 h and were based on the following protocol: First, stakeholders were shown an analysis of an extreme seasonal heat and drought event that had occurred over southeast Europe in summer 2012. Preliminary results of the attribution study ([Sippel and Otto 2014](#)) were shown, explained, and discussed in detail (see below for further information on that study). Second, the interviews continued with a series of key questions ([Table 1](#)). Those questions were chosen to elicit sector-specific information relevant to event attribution (e.g., current level of use of climate services, anticipated applications, etc.), to identify potential methodological shortcomings and to discuss possible improvements. During the questioning, the interviewer and participant were able to explore other related issues dependent on

the responses. Last, the interviews finished with a freely evolving dialogue based on further issues or comments brought up by the participants that had not been addressed during the predetermined structure. The interviews were recorded on electronic media based upon approval by the participants, and were subsequently transcribed.

A free-coding analysis (Flick 2009) of the interviews identified a range of emerging themes that could be considered as important issues for users of event attribution information. Consideration needs to be given to the relatively small sample size, which could lead to potential biases, along with the semistructured nature of the interviews and coding process. However, the qualitative methodology was not intended to provide a comprehensive, unbiased reflection of (potential) users of, or perspectives on, event attribution science, but to offer the opportunity to elucidate broad cross-sectoral insights into stakeholder perspectives. A selection of relevant statements from the interviews is detailed in the appendix tables.

The interviews were primed with an exemplary illustration of an event attribution study of an exceptional season of heat and drought in southeast Europe, which two of the authors had previously conducted (Sippel and Otto 2014). This was used to demonstrate what attribution information could look like and provide a focus for discussion. The event was chosen because it had significant impacts on agriculture and human health (G. Simic 2013, personal communication) and occurred in a region where no event attribution study had previously been conducted. Therefore, the choice of event, regional focus, and its extent and magnitude might have influenced the interview process and the interest of participants in the issues.

The study region seen in Fig. 1 encompasses mostly states on the Balkan Peninsula and the Pannonian Plain and is often considered as a region particularly vulnerable to the impacts of climate change; thus, appropriate adaptation and planning measures are of high interest in a range of sectors of the regional economy (Whitlock 2012). In addition, southeast Europe was considered a good case study to present to participants as it has seen a number of extreme events in recent years, most notably a severe drought and heat wave in the summer in 2012 (Hydrometeorological Service of Serbia 2012), with mean summer temperatures up to 5°C above the average and lower than normal precipitation (Fig. 1). Based on extensive climate model ensemble simulations, Sippel and Otto (2014) found pronounced changes in the probability of 5-day summer heat waves compared to an earlier decade (1960s; Fig. 1). For example, the frequency of a

100-yr monthly heat extreme in July or August in the 1960s now occurs around once in a decade and hence the frequency has increased by more than an order of magnitude, which might have profound implications for climate adaptation planning in the region.

### 3. Results and discussion

The coding analysis of the interview data identified a range of themes that emerged from the stakeholders' perceptions of how PEA could be applied in practical decision-making processes, including in support of climate adaptation decisions, as tools for communication, and for the allocation of funds and liability within international negotiations. In addition, we construct and discuss some guidelines that could be used by scientists to develop meaningful stakeholder engagement.

#### a. Stakeholder perspectives on event attribution

In initially establishing whether event attribution research has a role to play in decision-making it was stated by *all interviewed stakeholders* that the presented methodology is potentially of high practical relevance to their work (Table A1). Although the perceived usefulness of PEA varied between “it is certainly interesting” and “this is absolutely a step forward,” we interpret these statements as indicating that a close engagement with the stakeholder community could yield very productive results (Table A2). A central aspect of those claims was that “event attribution” answers the question of how changes in the climate impact current weather, which is not answered by projections (Table A2). However, various sector-specific reasons might have additionally motivated these statements, and are discussed below.

Initially, the PEA framework had been motivated by its potential applicability in the insurance and risk sectors (Allen 2003). This view was corroborated by an insurance expert, who emphasized that the availability of attribution insights would help to determine the additional risk of extreme events imposed by climate change—the “delta” (participant N; Table A2). The interviewee further suggested applications in which smallholder farmers in vulnerable regions could potentially be reimbursed for the risk premium due to climate change, justifying public or donor subsidies (keeping in mind that meteorological risk is only one contributing factor to disaster risk; see, e.g., IPCC 2012). Moreover, there was agreement that investment decisions are often decisively influenced by risk assessments—an area where any better description of

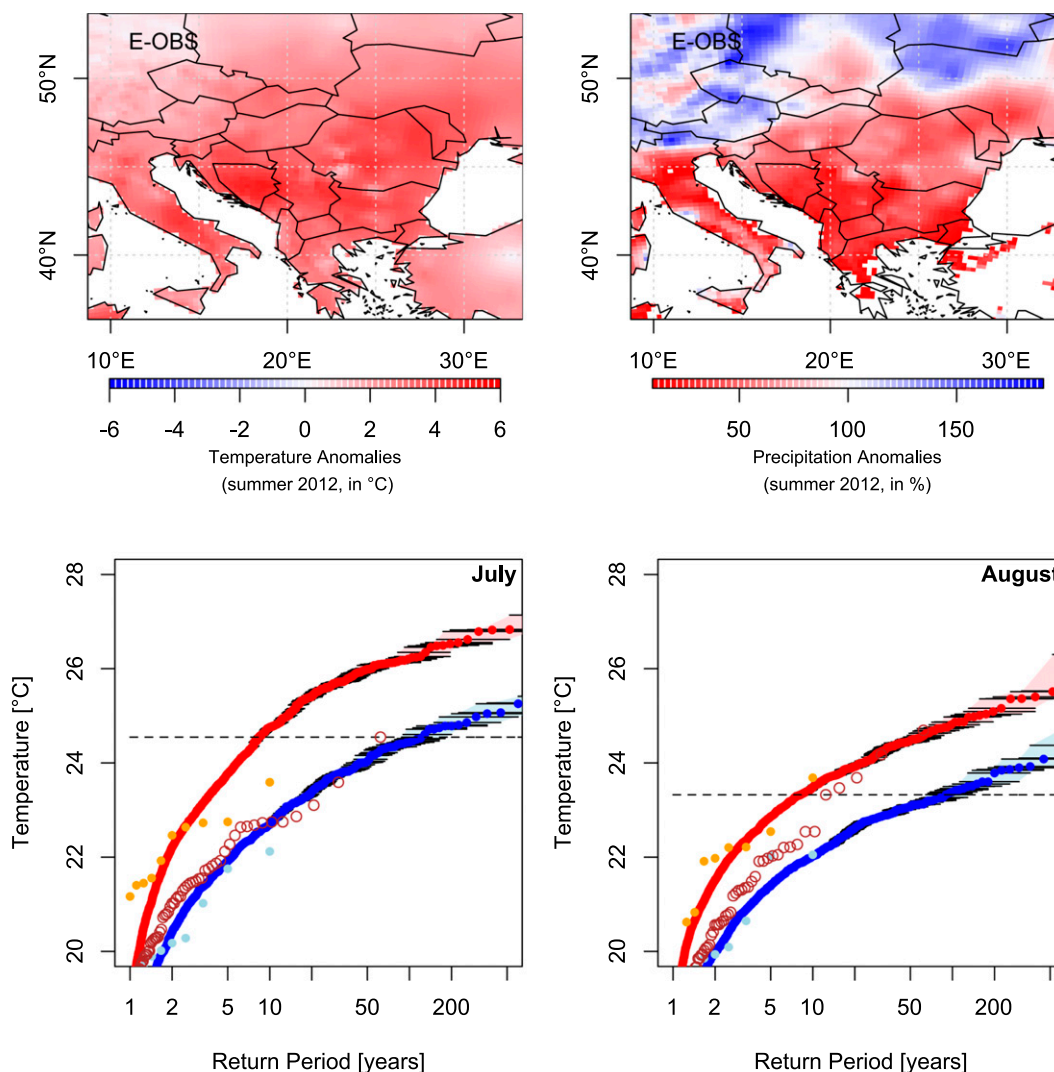


FIG. 1. Southeast European attribution study results that were presented to stakeholders and explained accordingly. (top left) Temperature and (top right) precipitation anomalies in summer 2012 in southeast Europe with reference to the period 1960–90. (bottom) Changes in return periods of July and August monthly heat extremes between two different decades (blue: 1960s, red: 2000s) according to climate model simulations (figure modified from Sippel and Otto 2014).

how the different risk components are changing would constitute an improvement (Table A2). However, this is not to say that changes in climate necessarily exert major influence on the integrated risk: “I get the impression that in developed countries, too few emphasis [sic] is put on the increasing value of assets and their vulnerability, because it’s easy to blame the climate. [...] But this does not mean that one does not need to understand how climate has changed” (participant A).

Regardless of those general statements, however, stakeholders that are actively engaged in southeast Europe recognized the importance of attribution

information on regional scales, particularly where detailed climate information products are scarcely available (Table A2). A public health expert explained that in this region the development of early warning and adaptation tools (e.g., the development of national “Heat-Health Action Plans”; WHO 2011) has made use of probabilistic climate predictions and aims to reduce heat impacts among the most vulnerable population. Here, participant H emphasized that an additional layer of information that targets the current state of the climate would enhance those activities, as it would unambiguously highlight the relevance for addressing and reducing public health related risks now,



not only in a somewhat distant future. Furthermore, PEA information could assist to illustrate the complexity and interconnectedness of the impacts of extreme events. In the case of southeast Europe these have resulted by a combination of heat *and* drought affecting both animal and human health through various pathways (participant K).

Stakeholders who engage with communication activities stated that attribution results could help raise awareness of climate change impacts, which previously has been achieved only through using anecdotal experiences. However, the latter had led to accusations of being selective in their choice of events, which would possibly undermine the message. This highlights the need of a comprehensive approach to PEA aspired by projects like EUCLEIA. Participant J noted that “One has to see the wood [climate change] for the trees [single weather events]. I think the wood becomes much clearer to see. However, it is still important to better recognize single trees in order to accurately determine the problem.” The interviewee further explained that studies with clear statements about changes in the odds of specific extreme events would enter and influence political debates and potentially raise awareness among politicians and policy-makers by increasing the “signal-to-noise ratio” and would therefore help to shape common norms.

However, many stakeholders were keen to stress that any consideration of event attribution information would be in addition to the climate information they are currently using (often on a very detailed level; Table A2). It is therefore important to recognize that any attribution statement would not be presented in isolation, but rather would need to be presented in such a way as to complement the existing information, making it as simple as possible for the stakeholder to assimilate this new information (Table A2). Importantly, this would preclude neither low-regret adaptation strategies (Wilby and Keenan 2012) nor a general build-up of capacity to deal with disaster risk (Hulme et al. 2011).

While the limited sample size and the explorative nature of this study does not allow us to derive definitive conclusions, we still can infer from the interviews that stakeholders across different sectors would welcome the availability of information regarding the attribution of extreme events. The statements also reveal different sector-specific information needs, which corroborates previous findings in the context of probabilistic climate projections (Street et al. 2009; Gawith et al. 2009). Hence, a future development of sector-specific dialogues seems to be promising in this context. Besides, these dialogues

could tackle questions that remain currently unanswered, namely whether some of the anticipated applications prove mutually exclusive or whether there is a risk that certain groups within sectors could be marginalized by PEA-related activities.

As previously mentioned, the question of whether probabilistic event attribution could have a role to play in allocating funds or liability in international negotiations is currently under debate (Hulme 2014; James et al. 2014), which was reflected in the participants’ responses during the interviews.

Some stakeholders argued that there might be a role for scientific evidence taken from event attribution in the allocation of adaptation funds or in the emerging loss and damage agenda [e.g., a “compensation mechanism with a scientific element to it” (participant L)], although a more integrated risk assessment framework would be needed (Huggel et al. 2013). It was also pointed out that an attribution of cost estimates (e.g., by using empirical damage databases; see Bouwer et al. 2007) would be an important prerequisite for the allocation of funds or liability, which could be a relevant extension to attribution studies but would necessarily have much higher uncertainties attached: “I think the holy grail is to pin the costs of particular extreme weather events to hold some parties liable for those costs. [...] As I understand it the holy grail of being able to attribute the costs of a particular event to a particular party is difficult to envisage, but I think that there could be some particular use in determining uses of global funds for climate adaptation, for example” (participant H).

Yet, other participants expressed the opinion that the allocation of climate funds will remain *fully* within a political process (both proponents and opponents of this idea were actively engaged in international climate negotiations). This implies that the issue of compensation would not be linked to any scientific risk analysis, as summarized by participant J: “Particular studies that have come up with a framework [to allocate funds] have not been taken up by the [UNFCCC] process, because in the end it is a political negotiation process, which involves normative decisions. [...] I believe that in the future the process will be that attribution informs decision-makers, which will then determine allocation decisions in a political process.” Thus, scientific (case) studies of event attribution could contribute to clarify the overall picture, but would not directly influence normative decisions. A similar view is also conveyed by Hulme (2014), who argues that in a political context “it seems unlikely that there will be a role for the sort of forensic science being offered by extreme weather attribution science” (p. 9).

Nonetheless, we found agreement among stakeholders that the issue of compensation, closely connected to individual parties' liabilities, is still widely tabooed within climate negotiations (which had been stated before; see, e.g., Müller 2004), even if a scientifically unambiguous probabilistic attribution of a damaging weather event were possible. While this seems true in the emerging negotiations around loss and damage where parties so far are not yet discussing a definition of the term (James et al. 2014), an indirect influence of scientific evidence gathered in event attribution studies seems plausible as the UNFCCC secretariat actively requests background information on the topic.

Hence, the mixed views of our stakeholders seem to mirror the academic debate on event attribution (Table A3). While clearly indicating a potential demand for event attribution assessments we emphasize that further qualitative studies, and in particular a broader dialogue with relevant stakeholders, are needed to explore in more detail whether and how probabilistic event attribution studies could be designed. An example would be addressing how PEA could help to base instruments like the Warsaw mechanism on scientific evidence, beyond providing a clearer overall picture by exemplarily assessing the risk of extreme weather events attributable to greenhouse gas emissions as is currently done (e.g., Peterson et al. 2013; Herring et al. 2014).

#### *b. Designing attribution studies that are relevant beyond academia*

The interviewed stakeholders saw probabilistic event attribution as potentially having a positive impact on decision-making (Table A2). However, during the interviews it became evident that it is not just the information that is important but also how the information is constructed and communicated. Here, we highlight design criteria for event attribution studies that were considered important by the participants. The following presentation and discussion is structured along the three central themes that frequently lie between knowledge and action: credibility, legitimacy, and salience (Cash et al. 2003).

It was emphasized that in order to use an event attribution result for adaptation policies or to include in science-based NGO campaigns, a high level of *credibility* is crucial (see also Wagner 2007; Cash et al. 2003). It was stated that scientific credibility in a policy context includes the reputation of individual researchers and their institutions, a wide acceptance of the applied methodologies by the scientific community, and the publication of studies in peer-reviewed scientific

journals (participant L; Table A4). However, credibility goes beyond any single researcher, institution, or journal. For instance, event attribution studies that are being carried out remotely would gain credibility if local or regional researchers were involved, for example through a collaborative study design or evaluation of results as shown earlier (O'Riordan 1994; Harrison et al. 2004).

Further, most stakeholders emphasized that studies *legitimately* addressing policy-makers or the public must show "a great deal of confidence" and "have to be careful to communicate fully the uncertainty that comes with that" (Table A4). Those statements might raise concerns about whether there is a tension between the need for relevant/robust information and methodologically inherent uncertainties. However, participants further stressed that uncertainty in a modeling study as such does not impede its usefulness, as long as it is clearly illustrated, because "politicians and decision-makers all over the world make very important and far-reaching decisions on much less certainty. [...] The fact that we are dealing with decision-making under uncertainty is a fact, and it doesn't mean we should only do it in economics and not in climate change" (participant B).

The need to clearly define terminology and methodological limitations is of particular importance when it comes to attribution studies, since the risk that is being attributed (which is meteorological hazard in many, but not all cases) might differ from risk perceptions in the stakeholder community (Hulme et al. 2011).

However, as a result of our study we found that the participants were well aware that "hazard is a central component of risk, but not the only one," which was reinforced by several similar statements from stakeholders across sectors (Table A4). It was emphasized that there could not be one single dataset or methodology that provides for the full range of risk or that determines political decisions (see also Stirling 2010; Huggel et al. 2013), but a methodology dedicated to identify changes in the hazard component was nevertheless regarded as highly useful (Table A4). For example, an insurance expert stated that "[Poor discrimination between hazard and risk] is not my problem, because I wish that science could answer the question how hazard probabilities have changed. Of course vulnerability changes as well and I include this into my calculations [...]. But the question I wish to be answered is about causality and changes in the hazard component" (participant N). However, we note that the interviewed stakeholders were (high level) experts in their respective fields, and hence we argue for caution in extrapolating those statements and awareness illustrated here into the

wider stakeholder community where understanding of the role of risk may not be so developed.

Nonetheless, while assessments of uncertainty and a clear definition of a study's limitations and terminology are a crucial part of scientifically credible methodologies, an open discussion and illustration of an attribution study's limitations might simultaneously enhance its legitimacy among the stakeholder community.

From our interviews as well as previous research (Stott and Walton 2013; Stott et al. 2013; James et al. 2014) one might conclude that *salience* of attribution statements strongly depends on the particular sector involved. In addition, however, we find that the eligibility of the results as well as the consideration of spatial and temporal scales (and the variables that are being attributed) seems to determine a large part of the perceived usefulness to many stakeholders. For instance, it was stated that precise, understandable communication of scientific results is crucial if attribution statements are to be included in public education or policy campaigns (Table A4). According to an interviewee, this includes a clear labeling of figures and graphs and the availability of short captions that clearly portray the message; "if there's also [easily understandable] information with it, for example a blog in addition to a peer-reviewed publication, that is very powerful" (participant F). In addition, it was suggested that numerical data are often hard to contextualize especially among the general public, citing the 2°C global warming target as an example: "It's warmer, fine. [...] But for the rest of the population it means absolutely nothing. But in terms of mortality, flood risks, and all sorts of things, that [attribution] is very important, because it means something to the public" (participant B). Hence, the communication of tangible climatic impacts such as changes in extreme events might be one of the key advantages of event attribution, if adequately contextualized. Further, several participants suggested that attribution scientists should think carefully about the geographical scope of their studies, particularly since PEA studies generally involve the calculation of regional averages that can mask nuanced information *within* a region. For example, studies relevant for public health would have to consider the local topography in a mountainous environment as the majority of the population live in the valleys and not on the mountains with very different climatic conditions (participant F). Similarly, studies that are meant to be relevant for decision-makers would have to incorporate political and economic realities and state boundaries, particularly in a highly fragmented region such as southeast Europe (participant M). In this regard, the possibility to "zoom in" was suggested in order to distinguish between different regions, which could further

increase the usefulness of probabilistic information to regional stakeholders. However, it would require very detailed model simulations and might come at the cost of larger uncertainties. An extension of the geographical scope to regions with highly vulnerable populations and where climate information is often scarce (e.g., sub-Saharan Africa) was considered as a potential hot spot for the usefulness of event attribution assessments (Table A4).

The themes outlined here could serve as a starting point to develop suitable design principles for stakeholder-relevant attribution studies. We note that future in-depth assessments of these and related criteria in relation to the application of event attribution in the wider stakeholder community would constitute a highly topical research activity. In particular, potential trade-offs or tensions between these themes and within specific sectors will have to be explored, as it has been shown that such trade-offs are often present in science advising and assessment, for instance between credibility, salience, and legitimacy (Cash et al. 2003).

Nonetheless, the design ideas for pragmatically relevant event attribution studies presented and discussed in this paper could be readily taken up by attribution scientists as a feedback from the explorative stakeholder dialogue.

#### 4. Conclusions

The engagement with potential users of attribution information from various sectors has shown a variety of different perspectives on event attribution. The most intriguing result of our scoping study was that, regardless of their backgrounds, all interviewed stakeholders found the presented findings of an event attribution study in southeast Europe interesting, and most argued that results of this kind could potentially be usefully applied in their daily work.

This finding is notable because it suggests that results of attribution studies are relevant beyond pointing the finger about who is to blame for climate change. Our results indicate that this kind of research might become a useful tool in the day-to-day work of adaptation planners or to bolster investment decisions. However, future enquiries are needed to investigate in detail how those applications could be tailored more specifically, for example in the water, agriculture, or health sector. Further, an objective communication of the links between climatic changes and the impacts of extreme events was suggested by participants as another key advantage of the PEA method. This would add an additional layer of information to current discourses about extreme events, where at present some people are quick



TABLE A1. Stakeholders and sectors that were included in the interviews.

Participant	Type of organization	Sector	Primary country of work and working language	Language and date of interview	Number of words	Specific comments
A	Foundation	Disaster risk reduction	Switzerland, English and German	English, 1 Jul 2013	1191	Infrastructure risk assessments in Europe
B	Governmental research institution	Climate finance consultancy	United Kingdom, English	English, 15 Jun 2013	1484	—
C	Government agency	Public health	Macedonia, English and Macedonian	English, 17 Jul 2013	2186	Specializes in heat wave protection
D	International organization	Disaster risk reduction	Belgium, English	English, 18 Jul 2013	1881	Involved in risk reduction and planning in southeast Europe
E	International organization	Public health	Germany and Macedonia, English	English, 17 Jul 2013	2186	Regional-scale public health in Macedonia
F	NGO	Science communication	United States, English	English, 19 Jun 2013	2155	Specialized in communication of climatic extremes
G	NGO	Poverty reduction	United Kingdom, English	English, 21 Jun 2013	1043	Participant is designing climate awareness campaigns
H	NGO	Public policy	Sweden, English	English, 30 Jul 2013	1489	—
I	NGO	Climate justice/litigation	Germany, English and German	German, 29 Jul 2013	2084	—
J	NGO	Public policy	Germany, English and German	German, 25 Jun 2013	1773	Consultancy in climate negotiations and climate communication
K	NGO	Environmental monitoring and vulnerability assessments	Serbia, Serbian and English	English, 15 Jul 2013	1015	—
L	Nongovernmental research institution	Public policy	United Kingdom and Bangladesh, English	English, 28 Jun 2013	1160	International negotiations: adaptation and UNFCCC consultancy
M	Private business	Agricultural finance	United Kingdom, English	English, 25 Jun 2013	1927	Investing in agricultural assets in southeast Europe
N	Private business	Insurance	Zambia, Kenya and Germany, English	German, 6 Jul 2013	1133	Agricultural (micro)insurance against extreme weather

TABLE A2. Broad themes at the science-stakeholder interface that relate to event attribution.

Key theme	Statements (all direct quotations)
Current use of climate science information	<p>We are in the risk assessment sector for natural hazards of different kinds. Hence, for us the question is how has the risk changed—in terms of intensity and frequency of temperature and precipitation. (participant A)</p> <p>We absorb climate science that goes from extremely general problem identification to very specific risk associated with particular assets. (participant M)</p> <p>Not explicitly a lot. [...] I use expanded IPCC figures (participant B)</p> <p>Three things: First, we use climate information for insurance purposes [...], second we distribute weather and climate information to smallholder farmers, and third we have our own network of weather stations in sub-Saharan Africa. (participant N)</p> <p>As a lawyer I have to incorporate the impacts of climate change in long-term infrastructure decisions [...], there is a need for finescale climate decision tools. [...]</p> <p>Thus I use climate information on a relatively detailed level. (participant I)</p> <p>Understanding from the climate models which are present and future risks. From a scientific point of view, we merge the information that comes from people working on climate models with the work we do on risk assessment, meaning that we push for building at the national and local level hybrid models, in which we basically use probabilistic assessment, based on models like yours; both on specific aspects and multiple hazards. (participant E)</p> <p>One has to see the wood [climate change] for the trees [single weather events]. I think the wood becomes much clearer to see. However, it is still important to better recognize single trees in order to accurately determine the problem. [...] An ensemble of scientific studies influences the formation of international norms and one important perspective is one, which shows a practical impact of climate change. (participant J)</p> <p>Absolutely [is attribution a step forward] [...]. There are severely significant issues for economies that are not that robust, if you look on former Yugoslavia or Romania, where politics are not exactly stable. So, those kind of patterns [meteorological hazard of drought and heat], if there's an attribution, you can see how there's a strong connection between how we run our economies, the risk that's being run by fossil fuels and near neighbors that are experiencing consequences. (participant M)</p> <p>Causality is extremely relevant for insurance applications. For instance it's about farmers that have to make a risk-management decision, and have to handle this new risk. [...] If now it became clear that climate change is in part to blame for those extreme events, this means it is clearly relevant. If causality is established one could make the next step and ask the polluter to pay for the "delta" in insurance premiums, the increased risk. (participant N)</p> <p>It's definitely a step forward. The more we can be confident about the links between emissions, climate change and particular events and the costs of those events, that strengthens our case, both for emissions reductions and for climate finance to support adaptation and potentially other forms of compensation for loss and damage in developing countries. (participant H)</p> <p>We are doing risk analysis for critical infrastructure. Hence, it is very important to know how the intensity and frequency of such events is changing to evaluate the risk as the product of hazard, exposure and vulnerability. [...] Hazard is one important component of risk. However, if I talk about risk, I mean the product of hazard, exposure and vulnerability. Each of them is important, and any better description of any of those components is an improvement. (participant A)</p> <p>The science is getting to a level of saying that types of events that were rare before are now more likely because of heat-trapping emissions in the past if very important for the public to understand and for policy-makers to understand that, because you can go forward in time for preparing populations so there health is not compromised. So that's why [these studies] are important to raise awareness in the U.S., because we have not had that level of loss of life as has happened in Russia and Europe and the scale of the problem, because people do not think heat is a threat in summer and so we have the risk of losing more lives, because we don't make that connection. (participant F)</p> <p>For the Balkans the aspect that is different from the UK or Germany is that this information is also relevant for regional and international organizations, because these are countries with fiscal constraints. It means that they have not much liquidity or capability to invest and they need the financial support. (participant D)</p> <p>As a following problem [of the 2012 summer], corn that was hit by drought then developed aflatoxins [mold fungus toxins], and with this corn the cows were fed, so [...] became from an agricultural economic problem to an animal health problem and shifted toward a public health problem, [...] so it's all connected. (participant K)</p> <p>It is very important for us to use results [of probabilistic climate studies]. [...] We can build for example the "Heat Wave Action Plan" in Macedonia, because we are aware that in the coming years the frequency and intensity of heat waves will be higher. (participant C)</p>
Perspectives on "attributing causality"	
Implications of attribution results for southeast Europe	

TABLE A3. Perspectives on the allocation of funds and liability.

Key theme	Statements (all direct quotations)
Allocation of funds and liability	<p>I think the holy grail is to pin the costs of particular extreme weather events to hold some parties liable for those costs. [...] As I understand it the holy grail of being able to attribute the costs of a particular event to a particular party is difficult to envisage, but I think that there could be some particular use in determining uses of global funds for climate adaptation, for example. (participant H)</p> <p>Particular studies that have come up with a framework [to allocate funds] have not been taken up by the [UNFCCC] process, because in the end it is a political negotiation process, which involves normative decisions. [...] I believe that in the future the process will be that attribution informs decision-makers, which will then determine allocation decisions in a political process. (participant J)</p> <p>Attribution will be necessary in order of this issue [allocation of adaptation funds] to be taken forward in terms of the next step, which is liability, [...] which are the difficult bits that the Annex I countries do not want to talk about. (participant B)</p> <p>I have become a realist in this regard. I think it was and will remain only a political process, and in that sense commitments are only marginally fulfilled. This has aggravated in recent years due to the financial crisis in Europe and elsewhere. (participant A)</p> <p>If you think about where the \$100 billion number came from, which was the number in the Copenhagen agreement and since has been reinforced in subsequent agreements, of course it was in the end a political decision. But in setting the parameters, of where that political negotiation and that final agreement might come from, we had to base estimates on something, albeit imperfect. So we do need inputs, even if they are imperfect that help us qualify the scale of damages and the costs that might be associated with them. And the more closely we can attribute those particularly to climate change, the better. So these are useful inputs for sure, but all of us working in this space have to be careful to communicate fully the uncertainty that comes with that and use them to inform the kinds of political decisions, rather than to determine them. (participant H)</p> <p>This is a very relevant question. <a href="#">Hulme et al. (2011)</a> have answered them that one shouldn't do those studies, because they are sending the wrong political signals and because there are no definitive answers, and one should instead focus on risk reduction and risk management. I would not subscribe to that. [...] In my opinion, an "attribution," in the sense that "there is a fundamental risk X, of which an important fraction is due to climate change," is useful. It pushes the political discussion forward, and helps to develop concrete supporting mechanisms and instruments. (participant I)</p>

to blame climate change for the bulk of extreme events, or conversely for none of them.

Nevertheless, stakeholders' needs with respect to attribution information were not found to be uniform across sectors but they were by no means contradictory, corroborating earlier results ([Gawith et al. 2009](#); [Street et al. 2009](#)). The identified themes at the interface between science and its application indicate that detailed and fine-tuned attribution studies, with careful consideration of spatiotemporal scales as well as local meteorological peculiarities, and the (hydro) meteorological variables that are being attributed could add to the range of climate science products that are currently used by stakeholders in various sectors and regions and could provide more objective estimates for meteorological hazard and its changes. Those products should be accompanied with a clear communication of the full range of methodological uncertainties, and would presumably offer a higher credibility if peer-reviewed research papers are produced in collaboration with local scientists.

Moreover, research into how probabilistic estimates of meteorological hazard, as generated by PEA studies,

could be made more impact-relevant, for instance through the combination with different (observational) datasets or impact models, seems currently to be highly topical among stakeholders. This being said, we emphasize that these studies should be conducted without claiming to determine political decisions, but to better inform stakeholders, decision-makers, and the public, for the feasibility of which we presented qualitative evidence in this paper.

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## APPENDIX

### Extended Interview Data

Interviewed stakeholders and their sectors ([Table A1](#)) and stakeholder responses ([Tables A2–A4](#)).

TABLE A4. Stakeholders' statements relating to the design of event attribution studies.

Key theme	Statements (all direct quotations)
Uncertainty	<p>We need to have those uncertainty bands (or shading) on the temperature to show that if they're overlapping. (participant F)</p> <p>There are two curves and if standard deviations are visible, one could show if they're overlapping. If that's not the case, one can assume that changes have taken place that one can account for quantitatively [...]. So less black-and-white, but to make the gray area visible. (participant A)</p> <p>We need the scientific community to tell the laypersons and policy-makers that we can now with a great deal of confidence say that these events are man-made or there's a contribution of human GHGs in there that cannot be denied any more. (participant L)</p> <p>Politicians and decision-makers all over the world make very important and far-reaching decisions on much less certainty. [...] So the idea that it would be too uncertain to be used is just nonsense. The fact that we are dealing with decision-making under uncertainty is a fact, and it doesn't mean we should only do it in economics and not in climate change. It's a bit of hypocrisy among people. (participant B)</p>
Credibility	<p>Another thing that is critical for us as stakeholders is that we have to see these graphs in their full scientific journal. So if they are not peer-reviewed published we cannot use them, so that's really critical. (participant F)</p> <p>We would like a credible scientific level of attribution [...], and thereby I mean:</p> <ol style="list-style-type: none"> <li>1) who is saying it;</li> <li>2) based on reasonable scientific methodologies, which the scientific community in general would accept as being sound;</li> <li>3) published in a good peer-reviewed journal gives a credibility as well. (participant L)</li> </ol> <p>If you want to convince a policy-maker about what you are saying, you need to bring him credible evidence. So the role of science and the credibility of the institutions that do this kind of forecast is crucial, because to advise on how to invest public money, [...] we need this kind of information it's the backbone of our work. (participant D)</p>
Communication	<p>We are working on the public communication of this and people do not understand these graphs (i.e., return plots). [...] I think that there is a translation step for the public. [...] we test our figures against other folks in our organization who are specialists in public communication or specialists in the policy or other aspects, outreach. (participant F)</p> <p>People are only able to take in a very simple message, and then they begin to think what does that mean for me and my community and how we do things. It's got to be kept clear, but not oversimple. (participant G)</p> <p>One of the big problems in terms of getting public buy-in [...] is the whole focus on two degrees [i.e., 2°C]. It's a nonsense in terms of the public. It's warmer, fine. [...] But for the rest of the population it means absolutely nothing. But in terms of mortality, flood risks, and all sorts of things, that [attribution] is very important, because it means something to the public. (participant B)</p>
Geographical scope	<p>My concern is to extent this [attribution] approach to sub-Saharan Africa. I'm interested in the hazard of drought and floods events. [...] Thus a geographical extension would be very useful and would indeed make a difference. (participant N)</p> <p>Having the data is actually very useful, for example to do our own averaging in a certain region (that is politically interesting for particular politicians for instance). To be able to zoom in and out could thus be very helpful, [...] people are living in the valleys, so you want to actually get the valley temperature and not the mountain temperature. (participant F)</p> <p>[Regarding] the political economy, I think about where this might go. Because it makes a big difference whether you're talking about Austria and Hungary as opposed to Serbia and Albania. (participant M)</p>
Discrimination between hazard and risk (see critique by <a href="#">Hulme et al. (2011)</a> )	<p>[Poor discrimination between hazard and risk] is not my problem, because I wish that science could answer the question how hazard probabilities have changed. Of course vulnerability changes as well and I include this into my calculations [...]. But the question I wish to be answered is about causality and changes in the hazard component. (participant B)</p> <p>You cannot expect a particular dataset to give you all the answers of what the response should be, and it doesn't tell you all sorts of other factors, including social vulnerability or mobility questions. (participant M)</p> <p>I fully agree on the fact that Disaster Risk Reduction Strategies should be based on multihazard risk assessment without saying that one risk is more or less relevant. [...] But in the same time I think that you're research is really relevant for policy-makers that want to in any case undertake a multihazard risk reduction approach, in which climate adaptation is one of the elements that are to be integrated into a disaster risk management. (participant D)</p>

TABLE A4. (Continued)

Key theme	Statements (all direct quotations)
	I think that's about the presentation. Most or all of the challenges are about how this science is used and how it's presented. So one risk is, sort of what you identify there, is that it will be used in such ways to suggest that risk or vulnerability is determined purely by exposure to events or the frequency that has been increased by GHG emissions. There are many other factors determining vulnerability, which is a challenge for all of us working in this sector, being careful about how we portray the science. I think, similarly, we have to be extremely careful in suggesting that we can be too confident in one way or another, that any particular study determines once and for all that an event is caused by climate change. (participant H)
	Often, assets are increasing faster than meteorological hazard. [...] I get the impression that in developed countries, too few emphasis [sic] is put on the increasing value of assets and their vulnerability, because it's easy to blame the climate. [...] But this does not mean that one does not need to understand how climate has changed. (participant A)

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