Socialising attribution of climate events: Progress, myths and future outlook

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Abstract

In the past decade there has been increasing attention on the development of the science of climate attribution and the potential challenges and opportunities presented by this science. Attribution is a branch of climate science which focuses on assessing the causal links between anthropogenic and natural influences on the climate manifested in slow-onset and individual extreme weather events. In this paper we aim to give a brief progress update on event attribution science from the literature. We focus our assessment of the literature on three myths around attribution and correct the perspective on what science can and cannot do. We do this conceptually using myth analysis which has been applied to understand ideologies, ‘common sense’ and accepted truths in a range of environmental topics. Finally, we assess discursive interactions between how and where climate science and in particular attribution could expand to be more useful at the science-society interface, and how civil society could be involved to use or to shape attribution science. This final aim is the “socialising attribution” and clarifies what attribution could do.

Key words: Myths, socialising, event attribution

1. Introduction

In 2021 Western US and Canada experienced four record-breaking heat waves in a period of five weeks. The extreme heat (which set a new national record temperature of 49.6 °C in Lytton in Canada) also contributed to a season of wild fires with devastating impacts including both economic (e.g. physical homes and infrastructure) and non-economic (e.g. loss of life, mental health and displacement) losses. Climate attribution science has shown that this North America heatwave was at least 150 times more likely to have happened because of global warming – an unprecedented scale of change.

In the past decade there has been increasing attention on the development of the science of climate attribution and the potential challenges and opportunities presented by this science. Attribution is a branch of climate science which focuses on assessing the causal links between anthropogenic and natural influences on the climate manifested in slow-onset and individual extreme weather events. While the latter has been the focus of many recent studies, attribution science is certainly not limited to extremes. We draw on Sobel (2020) to define attribution science as a “usable science” – one that is oriented towards decision-making. Sobel argues that the full value of a piece of science, like that of a political action, cannot be fully measured in the moment, but may become clear only in a longer historical view (Sobel, 2020, cf. Solnit, 2018; Coen, 2020, pg.1). Attribution science is controversial in whether it is a ‘good’ or ‘bad’ science, and to what extent it will act as an engine of and justification for elevation of some methods, and erasure of diverse ‘other’ knowledges from the realm of ‘proper’ science. As social sustainability scientists and interdisciplinary climate scientists we take seriously the need to challenge assumptions underpinning linear links between climate change and human impacts and losses, and to consider the tacit role of normative values in how climate risk is constructed (Forsyth, 2021). Nevertheless, we argue that climate attribution science is usable. Attribution science is usable in the sense that it relates to the clear and urgent governmentalities of climate change (Jackson et al., 2022). It is a science ‘of our time’ and aims to provide scientific evidence on climate change with respect to weather and slow-onset events that are or have been occurring in the real world and led to concrete losses and damages. Thus, event attribution not only assesses extreme (i.e. rare) meteorological events. Rather, these studies evaluate the slow-onset and extreme hazards.

1 Note there are differences in terminology between climate attribution (linking climate change to anthropogenic drivers); impact attribution (linking impacts to climate change) and source attribution (identifying the relative contribution of various emission sources and land use changes). We speak of climate event attribution to include both slow onset and extreme hazards.
extreme hazards which result in substantial impacts, irrespective of their meteorological rarity (Philip et al., 2018).

In recent years, attribution science has been subject to critiques of assumptions that underlie this methodology. These include specific challenges associated with efforts to ascertain the effect of climate change on a particular extreme event, including methodological approaches (conditional vs. probabilistic approaches) (Otto et al., 2016), questioning the climate models’ ability to stimulate the observed events (Bellprat et al., 2016), reasoning of ‘climate centric’ perspective on disasters (Raju et al., 2020), and limitations in the application of these methods given the lack of data on drivers of climate change impacts in the Global South (Otto et al. 2020; Scown et al., 2022).

Here, we argue that attribution science is necessarily interdisciplinary (van Oldenborgh et al., 2021) and it has far reaching socio-political and legal implications. Therefore, much of the criticism it has received is linked to misunderstanding it as an exercise in pure meteorology.

1.1. A new debate on climate event attribution

Event attribution has generated debate within the Intergovernmental Panel on Climate Change IPCC (IPCC, 2022) and is considered by some as fuelling climate-change sceptics’ inexhaustible demands for further evidence instead of focusing on practical and solution-oriented science (Parmesan et al., 2011).

While these debates have been visible to a small group of climate scientists, most other scientists and stakeholders outside academia access climate science via the reports of the IPCC, which was established to assess the state of science on human induced climate change (including its implications) relevant to policy (IPCC, 2022). The IPCC’s SREX Report (2012) focused on extreme events and the Sixth Assessment Report highlighted human influence on the climate as unequivocal and clearly being experienced in all regions and all components of the climate system (IPCC, 2021). The assessments provided by the IPCC historically looked at impacts independent of the extent to which they were caused by human-made climate change or natural variability. This has made it difficult in the past to use existing IPCC assessments to evaluate losses and damages from climate change within the framework of the United Nations Framework Convention on Climate Change (UNFCCC), where “climate change” is implied to mean “human-induced climate change” (UNFCCC, 1992). This changed dramatically with the publication of the contributions of Working Groups’ 1 and 2 to IPCC AR6 in August 2021 and February 2022 respectively where impacts are now causally linked to anthropogenic climate change where such a link has been proven. However, this understanding has not reached large parts of society and in particular, in the context of intergovernmental policymaking, there are challenges in conveying that we actually know much less about the impacts of anthropogenic climate change than it might seem at first glance, (e.g. the UN World Food Programme associated the drought induced food security crisis in Madagascar with human-caused climate change which was later shown to be incorrect (Harrington et al. in rev).

Critiques of climate event attribution science are consistent with typical responses to the development of new scientific paradigms and approaches (i.e., Kuhn’s explanation of re-examination of first principles and foundational assumptions) and constitute struggles between whose arguments or stories are more persuasive. With respect to event attribution this is most clearly illustrated by arguments that the climate models used are not good enough to simulate realistically the events being studied. The same arguments would apply to climate projections but are rarely made to the same extent. While climate models for projections are generally critiqued for individual applications, the same arguments have been used as a dismissal for a whole discipline. One such critique of attribution science is given in an article by Smith et al. (2020) which deals with the predictability of the NAO, a feature irrelevant for the vast majority of attribution studies, in which the first author is quoted with the statement “[t]he missing predictability also undermines so-called event attribution” (Vossen, 2020). This exemplifies the climate centric (and also trans-Atlantic centric) debate which risks getting bogged down in technical controversies regarding specific settings in which attribution assessments may be especially challenging to conduct, and in discourses of ‘delay’ resulting in inaction or inadequate efforts on climate change (Lamb et al. 2020).
Such critiques and technical controversies at times prevent a full appreciation of the potential impacts that the acquisitions of climate attribution could exercise on the social and political spheres, beyond the circle. In particular, there is a growing interest among legal scholars and practitioners in the results provided by climate attribution, as these can constitute evidence in climate lawsuits (Burger, et al., 2020). A further underappreciated area is the use of climate attribution evidence by climate activists, especially its influence on activists’ frames and strategies. As results of climate attribution studies are increasingly picked up by the media, we call for more elaboration on the ways in which climate attribution could be socialised.

In this paper we aim to do three things. Firstly, we give a very brief progress update on event attribution science from the literature, often using extremes as an illustration as the majority of studies has been on weather events, but highlighting that the science is not limited in that way. We adopt an ‘argumentative review’ approach. Second, we aim to give critical perspective on the debate outlined above. We focus on three myths around attribution and correct the perspective on what science can and cannot do. We do this conceptually using myth analysis which has been applied to understand ideologies, ‘common sense’ and accepted truths in a range of environmental topics (Essebo, 2018). Thirdly, we examine discursive interactions between how and where climate science and in particular attribution could expand to be more useful at the science-society interface, and how civil society could be involved to use or to shape attribution science. This final aim is the “socialising attribution” and clarifies what attribution could do.

1.2 Method

We draw inspiration from Coleman’s (2017) adapted and simplified methodology for an ‘argumentative literature review’ for evaluating literature. This required us to: 1. identify a set of focused questions of interest. 2. search literature and review relevant articles on the topic of interest. 3. bring together and assess arguments used by the relevant articles of interest using our diverse expert view on the relevance of the literature and arguments. 4. assess the conclusions the authors used in supporting their arguments for or against event attribution science.

1.2.1 Focused questions

We were guided loosely by a set of questions that we had on the progress, challenges and future potential of the science, to assess the relevancy of the arguments put forward in articles, and to help to shed light on the issue under review through a lens of myth analysis (see Section 3). We looked for 1a. what is the argument basis of the authors for advancing their perspectives on climate event attribution? 1b. from arguments raised in 1a what are the claims about climate event attribution, how are the claims framed and what are the future potentials?

1.2.2. Literature search

Published articles were found and reviewed using key word searches using a combination of the words: climate event attribution, disasters, vulnerability, blame, ethics, methods, by using Google scholar and web of science. The articles selected for the review were based on their relevance using inclusion criteria: Articles in the English language on the topic of interest. Articles from approximately last ten years are included, up to February 2022; Articles familiar among the co-authors. Exclusion criteria were articles with non-related subject matter on for example specifics on how to communicate extreme event attribution, or specifics of how to determine event characteristics of interest. Articles were read and reflected upon through multiple iterative and critical discussions on recurrent issues around the myths. This was in order to ensure consistency and avoid bias. We identified a growing body of literature on extreme event attribution in the past ten years (see Section 6 Reference list). A limited number of critiques exist yet those critiques generate disproportionate attention. There is a wider set of literature that already reflects on the challenges of climate models, disasters, and limited evidence on the significant reach of event attribution science for climate action still.
2. Progress on climate event attribution science

Causally linking observed weather and slow-onset events to anthropogenic climate change is the application of attribution science (e.g., Otto, 2017; Stuart-Smith et al., 2021; Strauss et al., 2021) that has led to a shift in understanding the impacts of climate change. Event attribution has come a long way over the course of this century and developed from an emerging scientific idea to a rapidly growing field of science, assessing the role of anthropogenic climate change in heatwaves, flooding, drought, sea-level rise and other weather and climate-related events around the world (e.g. Stott et al., 2016; Otto et al., 2018, Otto et al., 2020, Herring et al., 2018, 2019) using a range of methodologies and assumptions. It has demonstrated that anthropogenic greenhouse gas emissions have contributed to many high impact events in recent years, though not to all and not always substantially. The most recent IPCC report, AR6 for the first time systematically reviewed the science and required all chapters not only to report on observed changes and projections but also on attribution.

While disasters are not new, the magnitude and frequency of the weather and climate-related events leading to disasters has changed as a result of climate change in many cases. In essence event attribution as it is mostly undertaken today helps to disentangle the drivers of hazards, by isolating the contributions of historic greenhouse gas emissions, and other climate-related drivers such as aerosols and modes of natural variability. To fully disentangle the drivers of impacts experienced by societies, we need to combine the insights from attribution science with further analyses on the root causes of vulnerabilities, and assess how climate change affects individuals’ or communities’ exposure and vulnerability to hazards as has been aimed at in the most recent developments of attribution science (Philip et al., 2020; Stone et al. 2021). These vulnerabilities have been studied for decades in disaster and development research (Stone et al. 2021; Wisner et al, 2004; Adger, 2006). Furthermore, the methodologies developed for the attribution of observed weather events can be used to provide assessments of future hazards on the spatial and temporal scales where decisions on adaptation and resilience are made (Harrington and Otto 2018, Otto et al., 2018), thereby providing the basis for risk assessment from past to present and future impacts.

Event attribution makes a critical contribution to policy making (Burger et al. 2020). Firstly, it helps to build support for action to address the causes and impacts of climate change by demonstrating the magnitude and immediacy of its impacts. Secondly, attribution contributes to the formation of more effective mitigation and adaptation policies, for example, helping decision makers to better understand costs of unabated climate change and thus informing the appropriate level of regulation (Frame et al., 2020 a,b). Thirdly, attribution science can act as a framing mechanism for highly political international negotiations, for example, helping to improve decision making about how to allocate funds for adaptation (Otto et al. 2020) and provide insight into which countries have greatest risk of vulnerability to losses and damages due to anthropogenic climate change (Boyd et al., 2021, IPCC,2022). Fourthly, attribution shows when there is no climate change signal in the hazard, i.e. when there is no change in the likelihood and intensity of the event thus pointing also to socio-political and historical drivers of losses and harms (e.g politics of uneven impacts and vulnerability) and the importance of broader actions to reduce exposure and vulnerability to minimise the impacts of its occurrence whether or not there is a climate change signal. Finally, attribution science can influence communications and messaging around climate impacts (Ettinger et al., 2021), leading to social mobilisation, driving political change and in providing evidence in climate litigation.

2.1 Development of the science of event attribution

In the early days of event attribution scientists approached analysis of impacts of anthropogenic emissions on events in two distinct ways. The methodology applied in the greatest numbers of attribution studies evaluates changes in an event’s probability or intensity, as compared with a counterfactual climate, typically without anthropogenic greenhouse-gas and aerosol emissions. This probabilistic approach focuses on the extent to which climate change has altered the likelihood of an extreme event occurring with a magnitude greater than a defined threshold, or the intensity of an event of given probability (Otto, 2017). Although most probabilistic attribution studies conducted to
date have assessed the role of climate change in physical hazards themselves, more recent studies
have extended these analyses to evaluate anthropogenic influence on the health (Mitchell et al., 2016;
Clarke et al., 2021) and economic (Frame et al., 2020a,b; Strauss et al., 2021) impacts of extreme
weather events. The other is the storyline approach which has focused on how a variety of factors
including climate change have impacted the characteristics and magnitude of an individual extreme
event in its entirety (Shepherd, 2016; Shepherd et al. 2018; Shepherd, 2019). Authors advocating for
the ‘storyline’ approach have argued that the models used in the probabilistic attribution framework
struggle to accurately represent dynamically driven extremes because of their small signal-to-noise
ratios and often uncertain nature of the forced changes. They have suggested that a different framing
is desirable, which asks why such extremes unfold the way they do (Trenberth, 2015). It has been
shown however, that the differences between both methods are fluid rather than categorical (Jezequel
et al., 2018). At a conceptual level, there is no fundamental difference between attributing extreme
events and other climate-related hazards like glacier retreat or sea-level rise.

The key critique of the probabilistic framing from storyline advocates is primarily based on climate
model limitations. By contrast, the probabilistic framing (including changes in likelihood as well as
magnitude (Philip et al., 2020)) is argued to be much more useful for real-world implementation of
event attribution assessments (Otto et al., 2016) including in legal settings as it better reflects the logic
of causal analysis in law (Stuart-Smith et al., 2021). Climate models do nevertheless have difficulties
representing extremes. For instance, recent literature has questioned models’ abilities to simulate
events strongly influenced by Atlantic modes of variability (Smith et al., 2020) and challenges in
simulating tropical climate processes. Different types of events occurring around the world result
from a variety of components of the climate system that may be better or less well represented by
climate models. These factors may include the influence of aerosols, irrigation, land use change, and
soil moisture feedback. Hence evaluating climate models with respect to their fitness for purpose for
the event in question is a key step in an attribution study (Philip et al., 2020), and can lead to the study
being abandoned if it turns out that models poorly reproduce observations, or if there are very large
uncertainties in the results (e.g. Vautard et al., 2020). All recent attribution studies recognize this and
are designed accordingly: especially as early studies in event attribution failed to adequately address
model evaluation (e.g. Peterson et al., 2012, 13…) i.e. understanding that they need to carry out very
location-specific and event class-specific climate model validation exercises and present the evidence
transparently for why they are ‘fit-for-purpose’ and thus the resulting attribution assessments are
useful (Oldenborgh et al., 2021).

Assessing and attributing losses and damages to climate change remains a challenge to science, policy
and law (Boyd et al., 2021), which is further complicated by the need to link them to pre-existing
vulnerabilities. Advances in attribution science together with other methods such as spatial data
compilation and visualisation, and accounting for losses and damages that matter to people are
emerging for policy relevant scales in accessible, integrated and globally consistent ways (Scown et
al., 2022). Science is progressing on how to assess quality of the literature on attribution (Otto et al.
2020). However, obstacles to conducting attribution assessments of climate-related events in some
countries in the Global South persist, including due to observational limitations (Harrington and Otto,
2020) and work is developing that aims to fill global-scale gaps, mainly related to vulnerability and
exposure data (Birkmann et al., 2022; CRED, 2020; Eckstein et al., 2019; Feldmeyer et al., 2021;
Garschagen et al. 2021; INFORM, 2019; ND-GAIN, 2019)). There is also relevant work on the rate of
change in vulnerability (Andrijevic et al., 2020) including in the health literature (Benmarhnia et al.,
2015). But while the components exist there has not yet been a systematic mapping in an integrated
way of attribution, loss and damage and vulnerability (Otto et al. 2020, Raju et al., 2020; Stone et al
2021). We need more coherent maps of what losses and damages we are projecting in the future
(Scown et al. 2022), and to show what these maps reflect, how are needs identified in terms of
adaptation to climate change, i.e. where, in the future, support and funding should go based on a more
realistic inventory of the impacts of climate change events.

While it was long considered impossible to directly link a singular event with external climate drivers,
the now-established science of event attribution renders it possible to attribute the fraction of risk
caused by anthropogenic climate change to particular weather events and their associated losses. Robustly linking even a small fraction of excess deaths in, for instance, a heatwave, to manmade climate change is highly significant from an ethical point of view (Thomson and Otto, 2015). This has widespread implications, e.g. for policy decisions concerning the Warsaw International Mechanism for Loss and Damage and the recognition of such losses and harms in the broader context of framing climate justice (Boyd et al. 2021).

Growing numbers of legal cases seeking remedies for the impacts of climate change continue to be filed around the world (Setzer and Byrnes, 2020). In some of these lawsuits, plaintiffs have sought relief for losses that they allege are a result of climate change through tort law or nuisance claims. The key is to present a harm that appeals to the sensibility of the court and judges while at the same time applying science to demonstrate the impacts of the conduct (emissions) of one or more defendants (Thornton and Covington, 2016). While there is huge potential in attribution science in combination with social sciences and the law, persistent myths painting the whole area of science as inherently flawed hinder a more rapid development of the field and the inclusion of a broad range of scientists from different disciplines and geographies. These myths need to be challenged in order to advance our ability to adapt our societies to a rapidly warming climate.

3. Myths

3.1. Myths

Myth analysis has been applied to understand ideologies, ‘common sense’ and accepted truths in a range of environmental topics (e.g. recently in analysis of global sustainable forest governance by Delabre et al., 2020). Myths are symbolic tales, connected to belief systems, and can be thought of in terms of structure mediating different cultural perspectives and values, and as function (Malinowski et al. 1992) in providing a framework for action. Myths have socialising effects that bring people together, exclude others (with critical or dissenting voices), or reinforce hierarchy of states and values (Essebo, 2018). Lincoln (1999:17) describes a myth as “an assertive discourse of power and authority that represents itself as something to be believed and obeyed,” thus representing “ideology in narrative form” (Lincoln, 1999: xii). As myths convey naturalised stories, they are perceived as reflecting the natural state of things, or “common sense,” rather than politically created (Essebo, 2018), even if myths shape political discourse. Understanding the nature of myths, their power and indifference to the truth, helps us to better ‘comprehend how certain discourses become locked-in, and how they are replicated by the storyteller. Creating order out of chaos, seemingly overrides ‘truth’ or facts, to allow for dominant or traditional beliefs and actions to permeate social order and change (Overing, 1997: 10, cf. Essebo). It is meaningful to look at ‘attribution claims’ as myths to break down the mythical aspects of attribution claims and challenges. By acting as the ‘bricoleurs’ in piecing together fragmented elements of knowledge (Lévi-Strauss, 1995) on the science of attribution and its role and contentions, this can help us to weave together cultural meaning and function of ‘socialising’ this new science toward action. We identify three dominant discourses in the literature surrounding attribution science. We establish that they exist through review of the literature and assessment of the key challenges associated with each of these discourses which we see frame scholarship and create dualisms (simply truths) or polarisation. One may ask why certain myths are reproduced, for example why powerful voices generate myths on attribution science and thus undermine the science? We examine the three myths surrounding event attribution science and assess whether the myth is upheld or not, and to what extent this contributes to its socialisation.

3.2 Three myths of event attribution and associated challenges

Each myth is structured as follows: The myth is presented and explained, we show reasons why the myth is unequivocally wrong or misleading, and finally we identify the challenges we still need to work on.

Myth 1. Climate models are not good enough for attribution
The myth: This myth has two parts, one relating to the interpretation of causality and the other with respect to what an individual weather event is. For example, the statement of “it is impossible to attribute any individual weather or climate-related event to a particular cause” can be interpreted to mean that human-induced climate change could never be shown to be exclusively responsible for any specific weather event, either the probability of its occurrence or its magnitude. As weather events always have multiple causes this is trivially true. However, if interpreting causality in a probabilistic sense (equivalent to “smoking causes cancer”) there is clear evidence from many studies that individual event attribution is a feasible, if challenging, undertaking (Chen et al., 2021) that can identify climate change as one driver among others and the proportional contribution climate change makes (Hannart et al., 2015).

Furthermore, it is ambiguous what a weather event is. If an extreme event is defined based on its dynamical features, it will become extremely difficult for any climate model to represent this completely faithfully. However, as many events making the class of events the exact observed one is a representation of, lead to the same or very similar impacts the exact trajectory is in many cases irrelevant. Jézéquel et al. (2018) suggests that there exists a plurality of selecting event definitions and that individual scientists disagree on which one is most useful. They further find that there is a lack of solid, empirical evidence to back up any of these motivations brought by scientists.

In the case of individual weather events, there are many different ways to define these and a common practice is to do so based on the meteorological outcome rather than its cause, e.g., a heatwave based on the temperatures reached independent of whether they are driven by a Spanish plume or Scandinavian high-pressure system, or heavy rainfall based on precipitation thresholds independent of whether a hurricane brought the rain or an atmospheric river. While such definitions still require climate models to simulate their distributions correctly, they are not dependent on skill in the model’s ability to predict the event at the right time (as required for seasonal forecasts) but only at the right frequency. Noting this, the EU’s Copernicus Climate Change Service is operationalising attribution science in Europe employing a probabilistic framework (Otto et al., 2022). Clearly, establishing a causal link between climate change and specific weather and climate events is still developing. Stott et al. (2015) note attribution science requires the continuing development of methodologies to assess the reliability of event attribution results and further work to understand the potential utility of event attribution for different stakeholder groups and decision makers. However, it can show an event that occurred with a specific magnitude would not have happened without climate change, thus climate change has caused that event.

Thus, attribution is no different to many other scientific studies that only make sense in their entirety and not without context. Hence, while the “model insufficiency” argument highlights a veritable challenge that indeed climate models are not always fit for purpose, by focusing on a very specific definition of an event and in a specific region, a myth is created (attribution is impossible because all the models are wrong) that only marginally touches on the real challenge and crucially hinders scientific development by keeping the attention focused on a very narrow question. Establishing causal links becomes more difficult when speaking about loss for certain communities. To test new causal links poses the question: What does this mean for vulnerable people? Then how to establish a causal link through all of this is a starting point of existing vulnerability methodologies. A further challenge is that the results of an event attribution study depend on how the event is defined and a “right” definition does not exist, but more or less useful characteristics of the weather event driving a disaster. This is however a challenge that can be addressed through testing the sensitivity of the results to different definitions within a study and a transparent and tested way of communicating these specifics of the framing (Otto et al. 2020; Philip et al., 2020; Vautard et al. 2019).

Myth 2. Climate-centric explanations of disasters cannot be reconciled with vulnerability-centric explanations
Myth 2 relates to the notion that the political nature of vulnerability is overlooked (e.g. Lahsen and Ribot, 2022; Raju et al., 2022; Olsson et al., 2022), and that this undermines the value of event attribution science. Attribution of disaster events to natural hazards is a political process. Climate change is a global issue that affects humanity across scales at some level – all regions are affected (IPCC 2021). Attribution can be applied worldwide and there is nothing inherent in the science that leads to focus on specific regions, however myth 1 above does focus a lot of attention of scientists away from the global South because of limited observations in some regions for model evaluation. Olsson et al. (2022) for example argue that "it is clear that the availability of data that would be necessary for event attribution is extremely variable across countries and over time. Probabilistic event attribution would incur severe injustices if promoted as a basis for compensations for losses and damages." Still their argument overlooks relevant related studies that also point to the lack of data (e.g. Harrington and Otto, 2021; Scown et al., 2022) which also implicitly argue why reject extreme event attribution for the lack of data instead of demanding more data coverage as a necessary step towards data justice? (Dencik et al., 2019).

There are scientific reasons for attribution studies being done preferentially over Europe, but they themselves are (mostly) borne out of inequalities in how the science gets to a stage of being "good enough" to evaluate: 1) Climate models are developed such that they work well in the (wealthy) regions where they were constructed, often with less attention given to other regions (James et al., 2018); 2) Unequal geographic distribution of weather observations leads to greater uncertainty in what the return period of a hazard associated with an extreme event actually was in the Global South (IPCC 2021); 3) Purely by chance, the physical processes that govern many climate extremes over Europe are easier to simulate in a coarser-resolution model, when comparing with lower-latitude locations which are typically affected by processes requiring convection-resolving (and coupled ocean-atmosphere) models; and 4) a focus on 'insured losses' in assessments of climate change impacts (e.g., Mandel et al., 2021) also contributes to a skewed / misleading focus on regions in the Global North.

It is well established in the literature the need to consider the histories and power relations that make some social groups vulnerable in the first place, instead of blaming everything on climate change. Vulnerability from climate change is a political issue, thick in history and loaded with power. Disasters are a result of a combination of social and political processes in relation to natural hazards and are matters of human rights and justice (Raju and da Costa 2018; Raju et al, 2020; Raju, Boyd and Otto, 2022). Local and national perceptions of risk also change depending on who is in power, for example, if populists are in power, they may be even less willing to consider disproportionate vulnerability by local exposure and blame the events on external actors or nations (even if there is no attribution) deflecting from bad governance issues (Pereira and Raju, 2020). A lot of climate scientists shy away from event attribution science because they see it as too political. It is well established that political and contextual concerns often eclipse perceptions and actions in response to climate extremes (Marquart-Pyatt et al. 2014; Boudet et al 2020), including national level, economic, political, and environmental factors influence our environmental concerns (Marquart-Pyatt, 2012) of event attribution and the inequalities in science more generally certainly apply to attribution too.

Natural hazard/climate centric framings of disasters and vulnerability is an old debate, as highlighted by Oreskes’ (2015) critique of incorporation of social factors into physical models and the resulting skewed knowledge claim. Oreskes argues that the incorporation of social factors into 'physical' models by scientists with limited training in humanities and social sciences creates concerns. Oreskes also notes the potentially profound epistemic and social consequences of doing so (Oreskes, 2015). There is a longstanding debate that impacts are mostly situated in hazard and climate narratives in adaptation and development research (Pelling and Garchagen, 2019) – which emphasises that disasters always have multiple social and biophysical causes and are political (Nightingale et al. 2019). A well-established argument in social sciences is framing of climate versus disaster justice, development and vulnerability, as the cause of disaster leads attention away from the role of pre-existing vulnerabilities (Lahsen and Ribot, 2021; Larssen et al., 2019, Hulme, 2014, Wisner et al., 2004). Specifically, as a number of examples (Brazil, Oldenbourgh et al., 2021; Madagascar,
Harrington et al., in review) demonstrate, using attribution science is useful as it shows where climate
deriving. The myth here is that attribution science is trying to plaster climate change on everything. For
example, the study of the 2014-15 drought in Sao Paolo, Brazil (Otto et al. 2015b) found that,
contrary to belief, anthropogenic climate change was not a major driver of water scarcity in the city
(pg.17).

This long-going debate may explain why some are concerned that event attribution science will
undermine efforts to highlight the structural and historical drivers of vulnerability. Extreme events
exacerbate existing inequalities and vulnerabilities. Moreover, debates on loss and damage now add
further layers of complexity to disaster risk reduction and adaptation debates. Journalists, NGOs and
activists also use natural hazard/climate centric framings at times to serve their interest. Governments
use climate centric framings to make governance decisions (Boyd et al., 2014) for example if
governments want to relocate communities and families, they may use climate risk as a rationale for
that and shift blame among actors in society for adaptation. Scientific understanding of global
environmental change and the process of designing public policies to face them are characterised by
their complexity as well as by epistemic and normative uncertainties. This makes it necessary to
evaluate the way in which research efforts understand the ‘social’ nature of climate change and
moreover, how these depictions are furthered by for example news media representations (e.g.Feygina
et al. 2020; Timm et al., 2020; Osaka et al, 2020). This is certainly true for attribution and a few
framings have indeed ignored the social nature of climate change impacts. The critique from Hulme et
al., (2011) further adds challenge to this debate –putting attribution models at the heart of political
decisions on adaptation - only leads to ‘scientizing’ adaptation resulting in delays in allocation of
adaptation funds. Today, advances in attribution science and the link to unequivocal nature of the
human influence in specific meteorological events (IPCC, 2021) has demonstrated quite the opposite -
which could lead to increased government attention and commitment to adaptation and mitigation,
to usable evidence in climate litigation and to novel campaigning tools for climate activists,
potentially in mutually reinforcing ways across governance, law and mobilizations.

Attributing one component of the disaster, i.e., the hazard, is not unique to climate science. As with
vulnerability assessments in risk analysis, most attribution studies leave vulnerability unchanged but
isolate the hazard component. Most studies not only do not pretend to explain the reasons for a
disaster but explicitly acknowledge the importance of vulnerability and exposure to complete the
picture (Oldenborgh et al., 2021). To combine event attribution science with interconnections with
human rights, vulnerability and legal understandings offers the opportunity to examine why current
measures to adapt or mitigate are failing the vulnerable. A way to link practically to disasters includes
a Comprehensive Risk Management approach proposed as a practical framing for national and local
policies to address loss and damage which could lead to addressing both the underlying and
cumulative development failures and risk management capacities that shape loss and damage
outcomes (Roberts and Pelling, 2019).

By framing the problem as resulting from the impacts rather than from the climate system, attribution
can help to move away from a climate-centric framing. There is a trade-off painted between climate
activists and the politics of social movements and advocacy groups, with the latter engaging less in
climate science and focusing more on localized risks, injustice and vulnerability. Yet, in recent years
there has been an escalation in the use of litigation by activists and advocacy groups (Beauregard et
al. 2021; Noonan 2018; McCammon and McGrath 2015), including as a part of the wave of climate
protests that took place in many cities around the world (de Moor et al 2020; Niehaus and Davies
2021).

Myth 3. Attribution is a blame game

Debates on attribution have raised the issue of blame at different scales and among actors.
Myth 3 is that attribution science assigns liability and responsibility. Attribution science does not aim
to establish responsibility or blame, but rather to investigate drivers of change (James et al.,2019).
Other actors or institutions, including courts, policymakers or activists may then interpret the findings of attribution science to assign responsibility to certain entities for climate change impacts.

This myth relates to politics of knowledge, politicised urgency and normative goals - who is assigned responsibility for climate change impacts and how people should be compensated for losses and damages incurred by climate impacts. Attribution science quantifies contributions made by different actors which can then be used to assign liability and responsibility, which are crucial in climate justice debates, and potentially integrating (and reinforcing) social movements and law in stirring climate action. In international climate negotiations, questions about attribution science could be associated /co-opted to support some groups to mobilise against compensation for loss and damage, and adopted by sceptics and industry to block progress on action. Among civil society attribution science could generate a potential co-option toward one type of ‘green’ activism and litigation. Rather than blame (as per the myth), attribution science evaluates the extent to which the emissions of certain actors (or anthropogenic emissions as a whole) have changed the likelihood or intensity of a given event. Political, legal and other social processes then determine the implications of this scientific assessment of contributions to harm for allocating liability, responsibility or blame.

The transnational companies most responsible for greenhouse gas emissions, especially those producing and burning fossil fuels, have long sought to muddle the science of climate change (Oreskes and Conway 2010) and delay meaningful action by governments to curb emissions (Franta, 2021). More recently, with “climate scepticism” becoming increasingly untenable, the fossil fuel industry has, in rhetoric and targets, publicly supported climate action while deploying strategies to maintain their business by opposing government climate policy (Mann 2021) and to target climate protesters (Nosek, 2020). One of these strategies has been to shift the blame for climate change from structural causes to individual consumption choices (Supran and Oreskes, 2021) and otherwise well-intentioned people then perpetuate this largely-unhelpful emphasis on individual responsibility.

Other critiques base their arguments on a single study, and thus focus on a singular instance of applying attribution science rather than its breadth and potential. E.g. Lahsen and Ribot (2021) base their arguments largely on Otto and Thompson 2015 which in such a quickly developing field is a very old study, not representing the state-of-the-art. However, there is a clear interest from outside the climate science community of the extent to which recent damaging extreme events can be linked to human-induced climate change or natural climate variability (Stott et al., 2015). In 2019 there was an escalation in the use of litigation by activists and advocacy groups, including as a part of the wave of climate protests that took place in many cities around the world (Setzer and Byrnes, 2020). Litigation cases continue to increase in number and human rights arguments are being used in an increasing number of cases (Setzer and Higham, 2021).

Climate justice organisations are becoming keenly aware of the potential to address justice through courts (Niehaus and Davies 2021). Friends of the Earth International, together with a network of grassroots organizations, demands to provide climate victims with access to justice, compensation and restoration of their livelihoods wherever crimes occur” (FOEI 2021). In a framing paper on racism and climate injustice, Abimbola et al (2021) advocate for addressing the disproportionate harms wrought by climate and environmental racism and sexism through enforcement of human rights obligations.

Questions about whether the outcomes of climate-related lawsuits have yet had substantial impacts on efforts to tackle climate change remain open (Setzer and Byrnes, 2020) and there is plenty of scope to explore these intersections. The prospects of litigation will be improved by the provision of attribution-science evidence specific to the causal claims made in climate-related lawsuits (Thorton and Covington, 2016; Betts 2021). There have been hundreds of climate-related cases of litigation filed many of which are not tort claims for damages (Setzer and Byrnes, 2020. Some cases have been highly effective in terms of legal outcomes, e.g. Urgenda, the Irish climate case, Neubauer v Germany, Demanda Generaciones Futuras v. Minambiente (Future Generations v. Ministry of the
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Environment); and the effectiveness of other cases may not be able to be measured in remedies awarded alone. Rather, they may help reframing the fossil fuel industry as criminal enterprises, drawing attention to climate change impacts, their injustice and their seriousness, and promoting political change. Litigation developments, as the risk of liability—borne either by governments or private companies—could become a source of substantial leverage for those advocating for deeper emissions cuts and fairer loss-and- damage policies’ (Verchick, 2018).

Climate science and the law is linked in various ways, including that climate science is already relevant and helpful based on the assumption that advancing attribution science will have a direct or strong influence on the policy or legal world; however also scientists often assume a high degree of problem-solving orientation and a strive for consistency between talk, decisions and action. By contrast, most policymakers and political leaders are not keen to reduce uncertainties and overcome ambiguities — these are a source of political flexibility (Hayhoe, 2018; Geden, 2018). Some would argue that current legal and policy landscape around climate change clearly shows that this is not necessarily the case - science is only one of the many factors influencing how the law develops and it does not often play a key role (Setzer and Vanhala in WIREs Climate Change (2019)- Climate change litigation: A review of research on courts and litigants in climate governance, Hayhoe, 2018). In tort litigation on climate damages, this is partly due to the fact that many of these cases have been thrown out for procedural legal reasons, at early stages of adjudication, and not because the science would not have an influence at later stages. It is not the case that the science does not matter, but rather that in many of the cases to date, other (non-science) reasons have been the immediate factor holding them back.

Policy and decision makers often have limited understanding of the sense in which extreme events can be attributed to climate change. However, policy makers do identify and discuss potential uses for event attribution at the international level and in wider policy, and there is an opportunity for advancing concepts of Loss and Damage and the role of science to support national and local policy on risk (Parker et al. 2017) and climate litigation as a tool has potential to remedy damage and inequalities caused by extreme weather events.

In summary, Myth 3 on attribution is a "blame game" identifies how the push to assign liability in fact comes from those impacted by slow-onset and extreme events exacerbated by climate change, from increasing present (and future) losses and damages, and from the politicization of climate change governance by social movements and civic engagement. Climate attribution, rather than looking for who to blame, contributes precisely to the disentangling of drivers of disasters, isolating the human-induced warming effect from other determinants of vulnerability, and therefore contributing to avoid simplifications and reductive readings. On the other hand, as methodologies for parsing the influence on specific events of emissions from different sources advance, climate attribution may have a role - in tandem with law and social mobilizations - in evaluating the responsibility of big emitters.

4.Future outlook: ‘Socialising’ event attribution

Myths like those introduced above arise when new ways of doing science are developed. They emerge from the tension of what science can and cannot do. But while building and attacking strawmen is not surprising, it is not constructive to develop the best ways to make the science as useful as possible. This tension also provides an opportunity to examine whole interactions between how and where climate science and in particular attribution should expand to be more useful at the broader science-society interface and how governance and civil society could be involved to use or to shape attribution science. Instead of focusing on the myth we can use the highlighted tensions to advance the fragmented discourses, identified through the conceptual lens of myths..Below we briefly discuss two steps towards socialising event attribution towards solutions, acknowledging that as researchers we need to balance the normative goal of ‘saving the world’ with a recognition of the moral and political reasoning behind our motivations. While we are pressed with the crisis of climate change, we are also challenged to nuance our discourse from ‘silver bullet’ solutions to reflexivity.
4.1 Interdisciplinarity and synergies

Attribution of slow onset and extreme events has been an important new line of evidence integrated into most chapters in the IPCC AR6 WG1 report, and crucially acted as an integrator between previously separate research on observations and climate projections. While attribution is also an important part of WG2, there is still a large discrepancy between chapters, methods and the two working groups. Attribution has the potential to also integrate the natural and social sciences, climate centricity is, as shown above, not inherent in the method. However, while there are now a few examples where attribution studies have integrated across disciplines (e.g. Boyd et al., 2021) this potential has not been realised in full.

Research is needed to study the strategic and operational barriers for physical and social sciences to find common solutions to the problem of climate change, including how to strengthen science-policy communications (Albris et al., 2020). Attribution science is an evolving area with potential for addressing critical connections between how societies organised around global science, regulation and sustainability, by focusing on disentangling drivers, impacts and local vulnerability. We will need to explore a range of methodologies and better understand the context of what is acceptable and for whom (see Lloyd and Oreskes, 2018). The normative nature of working on something that has norms and goals of climate justice attached is easily criticised. For example, more research is required to produce the scientific evidence needed to substantiate causal connections between specific emitters, climate change and loss and damage in climate lawsuits (Williams, 2019; Lloyd et al., 2021).

A recent manifesto for best practices for responsible mathematical modelling highlights important principles and lessons for use of mathematical models to ensure they serve society (Saltelli et al., 2020). While models play a critical role in science and society, it must be noted that models must ‘Match purpose and context’ as modelling is also a ‘social activity’ (Saltelli et al., 2020). Therefore, recognizing the value of attribution science in combination with other disciplines that explain social phenomena beyond numbers is crucial for climate policy and action. The quantification game tends to be highly political and must not camouflage complex questions of vulnerability and inequalities.

Both science, technology and social sciences, humanities, and arts disciplines can tackle intersections between climate impacts, disasters and the politics of social and economic inequalities, there is of course ample room for political science, sociology and economics.

There are those who consider event attribution science as a key tool to advance not only knowledge but also policy, public awareness and engagement, and climate action. Moreover, in order to support the leverage that law and climate litigations provide, it is important that climate attribution (in all parts of the world) remains a focus of the scientific community (Verchick, 2018).

4.2. Social mobilisation, normative and political persuasion

In seeking to better understand, and to foster, the socialisation of attribution science, interdisciplinary research could focus on how social and climate movements incorporate findings from attribution studies in their campaigns (Boyd et al., 2021).

A relevant question would be how clearer attribution of extreme weather events to climate change and to specific emitters interacts with the framings of activists and influences the emergence of novel strategies and discourses. In terms of source attribution, evidence of causal links between specific emitters and increased intensity or frequency of specific weather events could feed into campaigns that demand accountability of fossil fuel companies, complementing legal cases and activists’ campaigns against the prolonged deception - seeding doubts on climate change, hiding internal evidence demonstrating awareness of the climate effects of their products etc. - of fossil fuel companies aimed to slow down climate action and policy.
This could also be complemented by an analysis of the geographical distribution of sites of climate-induced harm, attribution research and social mobilizations, in particular by disentangling the mutual influences and connections of extreme events, research and activism as they emerge in different locations. These would trigger questions such as: how does the availability of scientific evidence linking specific extreme or slow onset events to climate change influence, or not, the political responses of communities impacted by that event? Or, how would a clarification of the contribution of specific emitters to climate change and to particular weather events influence the strategies of social movements located in the country of the emitter and of those located in the country where the event happened? This kind of multi-scalar and multi-locale research is poised to become more and more relevant, as hazards and impacts from climate change grow and as the social awareness of the causal links increases.

Likewise, such interrogation could extend to litigation in which climate change and related impacts have a central role in ascertaining how (and which) advancements in the science of attribution provide the evidence that evaluates defendants’ contribution to harm associated with climate change. These inquiries would need to be carried out empirically, in ongoing lawsuits that allow for a dynamic assessment of the relations between scientific findings and the social use of science.

Such inquiries could shed light on how activists’ campaigns trigger and support specific climate lawsuits on the basis of weather attribution science, among other sources of evidence, and especially on how activists’ campaigns make scientific findings and legal frameworks relevant for the general public beyond courts, effectively socialising science through political organising. In this regard, the scholarship on community-led lawsuit in the tradition of environmental justice could offer important insights, in combination with empirical research, on the potential to link local and global risks to redress climate injustices and harm at several scales. The findings based on an analysis of these interactions and synergies, could in turn influence attribution science itself by, for example, pointing to knowledge gaps of societal significance, specific weather events, emitters, or geographical areas, that need to be addressed by further research, potentially generating fruitful integrations.

One of such integrations could be the development of attribution science to contextualise weather forecasts and events through so-called rapid attribution. If scientific results of attribution studies could be performed during or immediately after the event itself, and translated into accessible information, such speed may enhance the influence of attribution on the social sphere, by for example allowing the incorporation of evidence of climate change influence on weather in media narratives of disasters and by providing tools for community responses and social movements’ reactions.

5. Conclusions

To conclude, a literature review of the progress, myths and challenges of event attribution and its future socialising leads us to believe that there is a burgeoning interest in this useable science. And like other climate science -as useable -also has potential to be meaningful (Sheperd and Lloyd, 2021). It is likely to continue to develop. As this area develops there is a unique opportunity to advance both blue skies knowledge and if usable and meaningful lift action on climate change, and to advance understanding science of event attribution and societal and governance challenges. Nevertheless, further work is required as demonstrated by the myths the critiques help to make a more useful science overall to create a coherent and robust future for socialised attribution science in combination across disciplines, protocols and networks of scholars, practitioners, civil society, private actors, policy makers, lawyers and journalists.

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