THE LAW AND SCIENCE OF CLIMATE CHANGE ATTRIBUTION

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EXECUTIVE SUMMARY

The evolving field of climate change detection and attribution science helps to shape both our physical understanding of how the global climate system is changing and discussions pertaining to responsibility and accountability for the impacts of climate change. Confronted with a growing body of research linking increases in greenhouse gas emissions to specific harmful impacts, governments, courts, and private actors are addressing critical legal questions such as whether governments are doing enough to mitigate and adapt to the effects of climate change and whether corporations can be held liable for their contributions to the problem.

This Article describes how climate change detection and attribution science is now and may in the future be used in policymaking and litigation. We focus primarily on litigation, as this is one key context in which attribution science is influencing the legal discourse on "responsibility" for climate change. Some of our key findings are:

- **The existing body of detection and attribution research is sufficiently robust to support the adjudication of certain types of legal disputes. But there are also complicating factors which can make it difficult to identify a clear causal chain between a particular emission source and specific harms or impacts associated with climate change.** Ultimately, the extent to which the science can support legal claims will depend on many factors, such as the nature of the claim, the identities of the plaintiffs and defendants, and the nature of the alleged injuries.

- **Many observed physical impacts such as sea level rise, melting permafrost, and ocean acidification can be attributed to anthropogenic climate change with high confidence. Consensus confidence levels are currently lower for other impacts, such as extreme events, public health outcomes, economic losses, and ecosystem degradation.** There is a growing body of extreme event and impact attribution studies finding a causal connection between impacts such as heat-related mortality and anthropogenic influence on climate change.

- **Once an impact has been attributed to anthropogenic climate change, it can also be attributed to specific emission sources on a proportional basis**. This calculation may involve estimating the proportional contribution of the source to global greenhouse gas emissions, and using that to extrapolate the proportional contribution of the source to the impact. However, source attribution is not a purely objective quantitative exercise. There are normative questions implicated in the process of determining who is responsible for what emissions.

- **Attribution science plays an important role in lawsuits seeking to compel national governments to take action on climate change.** In several foreign cases, plaintiffs have successfully used attribution science to demonstrate that a government's failure to regulate greenhouse gas emissions at adequate levels endangered the public health and welfare of citizens within the country, and thus the government had violated its duty of care to its citizens. Attribution science is also central to the plaintiffs' claims for standing, constitutional harm and violations of the public trust doctrine in *Juliana v. United States*.

- **Lawsuits seeking to hold corporations liable for their contribution to climate change have met with jurisdictional, justiciability, and procedural obstacles, and to date have not faltered due to any limitations in the science.** For example, some U.S. courts have held that climate-related claims are either displaced by the Clean Air Act or should be handled by other branches of government based on separation of powers principles. The science may be strong enough to support a finding of liability if plaintiffs in pending and future cases overcome these initial hurdles and if judges apply traditional tort principles when evaluating the merits of these claims.

- **The scientific community can support applications of attribution research, such as the use of this research to inform loss and damage negotiations and judicial determinations of liability for climate change impacts**. Such support may involve continuing to expand and improve upon existing attribution research, including in currently underrepresented geographic regions and with regards to impacts experienced in the present; communicating findings clearly and in an accessible format; engaging with stakeholders to help them understand findings; and linking individual studies to other research that helps to flesh out the causal chain from emissions to impact. …. Policymakers, judges, and litigants can also improve their understanding of the science and expand the analytical approaches they use to evaluate the legal and normative implications of the science when making judicial or policy determinations.

Below, we summarize our analysis and findings in greater detail.

Scientific Underpinnings

Climate change detection and attribution science can be broadly defined to encompass a range of research aimed at linking human activities to observed changes in the climate system and corresponding impacts on natural and earth systems. Recognizing that these terms may be defined differently in other papers, we divide this research into several interrelated parts:

1. **Climate change attribution:** How are human activities affecting the global climate system?

2. **Extreme event attribution:** How do changes in the global climate system affect different categories and individual incidences of extreme weather-related events?

3. **Impact attribution:** How do changes in the global climate system affect other interconnected natural and human systems?

4. **Source attribution:** To what extent have different sectors, activities, and entities contributed to anthropogenic climate change?

  i. *Climate Change Attribution*

The existing body of research leaves little room for doubt that the global climate system is changing and human activities are at least partially responsible for that change (thus there is no real question as to *whether* anthropogenic climate change is occurring). As noted in the IPCC's Fifth Assessment Report (AR5):

> Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.

AR5 contained similarly conclusive findings about climate change attribution, particularly with respect to the link between human influence on climate and global warming:

> Human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system.

The report also found strong evidence that human activity had contributed to changes in other essential climate variables, such as sea level rise and the loss of sea ice, and scientists have made considerable progress towards quantifying these changes. There is still some uncertainty about total anthropogenic emissions and the relative effect of different climate forcings (e.g., GHGs, aerosols, and solar radiation) on observed changes, but overall the evidence linking observed changes in the global climate system to human activities is robust.

  ii. *Extreme Event Attribution*

Extreme event attribution is a branch of climate change attribution which seeks to understand how human-induced changes in the global climate system are affecting the frequency, severity, and other characteristics of extreme events such as abnormally hot days, heat waves, tropical cyclones, abnormally heavy rainfall events, and meteorological droughts. This can be contrasted with the climate change attribution research described above, which focuses on changes in mean variables rather than changes in extremes. Extreme event attribution is rapidly advancing due to

improved understanding of extreme events, improved modeling (including standardized sets of simulations that can be used by the community), lengthening observational datasets and re-analyses (blends of observations and models), and more robust remote sensing data sets.

Dozens of extreme event attribution studies have shown a link between anthropogenic climate change and specific extreme events, and in recent years, several studies have found that certain extreme events could not have been possible in a pre-industrial climate. Generally speaking, the confidence with which scientists have been able to attribute extreme events to climate change has been highest for events that are directly related to temperature, such as heat waves. Extreme events that are the result of more complex interactions between variables are more difficult to attribute. There is moderate confidence in the attribution of extreme precipitation events. While there is relatively low confidence about precipitation deficits alone in the context of drought, there is higher confidence in the combined impacts of higher temperature and precipitation on drought risk. For other classes of severe weather, such as tropical cyclones, mid-latitude storms, and smaller scale convective events and tornadoes, confidence is generally lower, but the findings depend on the specific event in question.

iii.   Impact Attribution

Impact attribution focuses on the consequences and outcomes of climate change. Many of the phenomena discussed above (e.g., sea level rise and changes in precipitation) can be described as "impacts" of a changing climate, but for the purpose of this Article, we focus on effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure that occur as a result of the physical impacts of climate change. Because impact attribution deals with consequences that are farther along the causal chain, it is harder to issue robust findings about the connection between anthropogenic influence on climate and specific on-the-ground impacts.

The most fundamental challenge is that researchers must account for an increasing number of non-climate and exogenous variables which complicate the attribution analysis (sometimes referred to as "confounding factors"). For example, in a study seeking to link public health impacts from a heat wave to anthropogenic forcing, researchers would need to account for land use decisions, access to cooling and other adaptations affecting public health, as well as baseline vulnerability of subsets of the population to heat impacts, in order to ascertain the extent to which anthropogenic climate change was responsible for those impacts.

Much of the research that falls under our definition of "impact attribution" is, to date, qualitative rather than quantitative. But there are examples of quantitative impact research. A study of the 2003 European heatwave found that approximately 570 of the deaths that occurred in Paris and London as a result of the heatwave were attributable to anthropogenic influence on climate change. These types of studies could potentially support litigation against governments (for failure to regulate emissions or adapt) as well as tort-based or tort-like claims against private actors that are major emitters.

iv.   Source Attribution

Source attribution studies can provide insights on how to allocate responsibility for climate change. In this context a "source" could be a particular actor (e.g., a country or a company) or an economic or industrial sector. Source attribution has been, and remains, a distinct discipline from what is commonly labelled "detection and attribution" science, but recent studies have combined detection and attribution science with source attribution in order to link specific impacts to specific emitters.

Once an impact has been observed and attributed to anthropogenic climate change, a source category or entity's contribution to that impact can in theory be expressed as a proportion of their contribution to total global greenhouse gas emissions. However, estimating this contribution requires resolving some technical uncertainties about total anthropogenic emissions and the respective emissions of the source category or entity. Determining a source's contribution also requires resolving normative questions about how "total" emissions should be calculated (e.g., whether to focus on cumulative or current emissions) and whether and which entities are legally responsible for different emissions. Physical sciences alone cannot fully answer the question of who is "responsible" for emissions because responsibility can be approportionated in many different ways – for example, governments can be held responsible for emissions from sources within their jurisdiction, the sources themselves can be held responsible, or both entities can be recognized as responsible parties. There are also different accounting methodologies – for example, one could frame national obligations based on territorial emissions, consumption emissions, or extraction emissions. The choice between these approaches is not a scientific question but rather a policy and legal question that must be answered based on ethical and pragmatic considerations.

Legal Applications

The ability to detect and attribute environmental changes to anthropogenic greenhouse gas emissions is useful for a variety of different law and policy applications. In the broadest sense, detection and attribution are the scientific tools that policy-makers and lawyers can use to show the existence, causes, and effects of climate change. This information can help inform critical policy decisions, such as the appropriate level for an emissions cap or a carbon tax. It can also help plaintiffs pursue certain types of legal actions, such as cases against government actors for failure to act on climate change. However, attribution science is not a panacea – the evidence generated by this field is not always effective at persuading or compelling policy-makers, courts, or the public to take action on climate change. This is in part due to the complexity of and limitations in the science, but there are also barriers to policy and legal action on climate change that inhere in the nature of political decision-making and legal doctrine, unrelated to the quality of detection and attribution data.

Here we summarize some of the ways in which the science has factored into lawsuits seeking to compel action on climate change as well as challenges to and the legal defense of programs and regulations aimed at reducing greenhouse gas emissions or advancing adaptation objectives. The full Article contains a more detailed analysis of the litigation as well as the role of attribution science in policy-making and planning.

i. Establishing Standing to Sue

Injury and causation are crucial elements of standing in U.S. courts. Attribution science can be used by plaintiffs to demonstrate that they have suffered an injury as a result of anthropogenic climate change and that defendants contributed to that injury as a result of their contribution to greenhouse gas emissions. Attribution data is a valuable complement to impact projections as it can be used to establish an existing injury while also lending credibility to projections of future harm.

Generally speaking, it is easier for plaintiffs with a broad scope of interests, such as states and large associations, to establish that they have suffered an injury as a result of climate change. States, in particular, are granted special solitude in the standing analysis. In addition, to link the climate-related injury to a defendant's conduct, plaintiffs must typically show that the defendant has made a "substantial" or "meaningful" contribution to global greenhouse gas emissions. Case law provides some insight on what this means, though no single threshold for significance has been established.

ii. Challenging the Failure to Regulate

Environmental and citizen groups in the United States and other jurisdictions have brought numerous challenges seeking to compel governments to take action to curtail greenhouse gas emissions. These include: (i) lawsuits challenging the government failure to implement statutory mandates with respect to air pollution control; (ii) lawsuits challenging the failure to protect public health pursuant to general legal mandates recognized in constitutions, public trust doctrines, human rights law, and other legal sources; and (iii) lawsuits involving administrative decisions undertaken within an existing regulatory scheme, typically decisions to grant or refuse an authorization for a particular activity (such as coal mining or the construction of an airport). In all three types of cases, attribution science is used to establish a link between governmental inaction and concrete harms to the injured party.

Attribution science has featured most prominently in lawsuits alleging that governments have abdicated their duties to protect public health and welfare pursuant to constitutional mandates, public trust doctrines, and human rights law. One key example is *Urgenda Foundation v. Kingdom of the Netherlands*. There, the court relied on impact attribution research for evidence of the harms incurred by Dutch people as a result of climate change, as well as source attribution research for information about the domestic emissions reductions necessary to meet the Paris Agreement's target of limiting global warming to 2° C.

Attribution science has also factored into some of the U.S. litigation brought under the Clean Air Act. However, most of the litigation surrounding regulation of greenhouse gases under the Clean Air Act has dealt with EPA's interpretation of provisions calling for the establishment of technology-based emission standards (e.g., reflecting the "best available technology" for air pollution control). Attribution science plays a less pivotal role in the judicial review of such standards because they are primarily based on considerations pertaining to statutory authority, technological feasibility, and cost.

Finally, attribution science has been used in some cases challenging individual permitting decisions and authorizations to link emissions from the authorized project or activity to specific harmful impacts, but it has not played a pivotal role in court analyses or decisions to date.

iii. Legal Defense of Climate Programs

As governments introduce an increasing number of laws, policies, and programs aimed at addressing the causes and impacts of climate change, the number of lawsuits challenging these actions will also increase. These are similar to lawsuits challenging the failure to regulate greenhouse gas emissions – the key difference being that these lawsuits involve allegations that regulations are too stringent or that other actions taken to curtail emissions (e.g., permit denials) are unjustified. In this context, attribution science can be used by government actors to defend emission standards and other programs aimed at mitigating or adapting to climate change.

iv. Lawsuits to Hold Emitters Liable for Contributions to Climate Change

In addition to suing governments for failure to regulate greenhouse gas emissions, some plaintiffs have gone directly to the source, suing major emitters, such as utilities, as well as fossil fuel companies, in an attempt to obtain an injunction against future emissions or monetary damages for adaptation costs. To date, the majority of these lawsuits have been brought in U.S. courts, and based on tort or tort-like theories such as public nuisance, private nuisance, and negligence.

Attribution science can be used to establish three key elements in tort litigation: injury, causation, and foreseeability of harm. Establishing a causal connection between an injury and the defendants' conduct is the most challenging aspect of such claims. Plaintiffs must demonstrate that:

- There was a specific change or event that was caused or exacerbated by anthropogenic climate change (e.g., sea level rise or a flooding event);
- They incurred a loss or injury as a result of that change or event (e.g., the cost of adaptation measures or residual losses that were not or could not be avoided through adaptation); and
- The defendant contributed to anthropogenic climate change, and thus to the loss or injury, as a result of its conduct (i.e., the release of greenhouse gas emissions).

Regarding the first line of causation: Proving that a specific change or event is caused by climate change will be easier for long-term changes such as mean temperature increases and sea level rise, but challenges arise even in that context. For example, plaintiffs will need to establish that flooding or saltwater inundation is caused by sea level rise even where coastal erosion and subsidence are also occurring as a result of coastal development. Linking a specific extreme weather event to climate change can be more difficult. A probabilistic approach to event attribution, whereby scientists quantify the extent to which anthropogenic climate change affected the probability of the event occurring, would likely be the best vehicle for establishing causation for the purposes of tort litigation. Some probabilistic attribution assessments have identified a relatively strong climate signal on certain events with a relatively high level of certainty. (For example, a study of the 2003 European heat wave found that climate change had increased the probability of this event at least a factor of two, more likely a factor of six.) There is precedent for courts accepting this type of statistical data as evidence of causation – for example, in U.S. tort law, plaintiffs typically must show that their individual injuries were "more likely than not" caused by the behavior question, and this requirement has been met through showings that the behavior increased the risk of the harm occurring by a factor of two.[1]

Plaintiffs must also establish the second and third lines of causation. The second causation challenge – establishing and quantifying the specific loss caused by the change or event – involves determining the extent to which the loss was caused by anthropogenic climate change as compared with other confounding factors. A probabilistic approach can also be used in impact attribution to generate this sort of information. However, to date, most impact attribution studies have not produced findings that are as quantitatively robust as studies conducted on extreme events due to the number of confounding factors that influence impacts such as public health outcomes.

The third causation challenge – defining the defendant's relative contribution to the damage – is a matter of source attribution. Importantly, even if a source's emissions are considered to be a "material", "substantial", or "significant" contribution to climate change, this does not mean that the source caused a specific impact and can therefore be held liable for all harms associated with that impact. Imposing liability in this context would be akin to imposing joint and several liability on all emitters that surpass a materiality threshold – something courts may be reluctant or even unwilling to do, given the possible ramifications of such a judicial policy. Recognizing this, some plaintiffs are now seeking to obtain monetary damages from sources that are proportional to the contribution from that source.

Generally speaking, it will be easier to establish a causal nexus between defendants' conduct and plaintiffs' injuries where plaintiffs aggregate harms from multiple types of climate change-related impacts and across multiple persons. It is easier to establish, for example, that climate

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[1] David A. Grossman, *Warming Up to a Not-So-Radical Ideas: Tort-Based Climate Change Litigation,* 28 Columbia Journal of Environmental Law 1, 23 (2003).

change (and defendants' conduct contributing to climate change) has caused injury to an entire state, city, or trade organization as opposed to an individual private plaintiff.

There have not yet been any major decisions holding private companies liable for their contribution to climate change but this is a relatively new area of litigation and there are many pending lawsuits. There have also been a number of lawsuits against emitters in the U.S. that were unsuccessful, but these were dismissed on grounds unrelated to the adequacy of the science – specifically, legislative displacement, the political question doctrine, and the doctrine of foreign affairs preemption.

    v.   Lawsuits Involving Climate Change Impacts, Disclosures, and Adaptation

Attribution science plays a role in lawsuits involving climate change impacts, adaptation, and disclosures about climate change-related risks. These include: (i) failure-to-adapt lawsuits, which involve allegations that an actor has failed to account for the effects of climate change and this resulted in an adverse outcome that would not have occurred if the actor had accounted for those effects, or else failed to develop adequate plans to prevent foreseeable adverse outcomes in the future; (ii) lawsuits involving legal defense of adaptation measures; (iii) lawsuits in which defendants seek to shield themselves from liability for climate-related harms by alleging that climate change and not their own conduct was responsible for those harms; and (iv) lawsuits involving climate change-related risk disclosures in contexts such as environmental reviews and financial statements. One critical question in such cases is whether the present or future effects of climate change are foreseeable such that a reasonable person would account for those effects in a planning decision, security disclosure, or environmental report. Attribution science can be used in conjunction with impact projections to demonstrate the foreseeability of such effects.

Future Directions in the Law and Science of Attribution

As courts and policy-makers continue to grapple with appropriate responses to the increasingly urgent climate crisis, attribution science will continue to play a critical role in shaping discussions around responsibility and liability for climate change and its impacts.

There are a variety of ways in which the scientific community could work towards supporting applications of attribution research, including the use of this research to inform judicial determinations of liability for climate change impacts. These include: (i) continuing to lead the development of scientific knowledge and understanding by advancing detection and attribution research across the board, (ii) generating attribution findings at different confidence levels to better communicate uncertainty about the "upper bound" and "lower bound" of plausible anthropogenic influence on an observed change; (iii) communicating findings clearly and in an accessible format; (iv) engaging stakeholders; and (v) linking individual studies to other research that helps to flesh out the causal chain from emissions to impact.

Judges and litigants can also seek to improve their understanding and communication of the science, and adopt analytical approaches which will provide for a more robust assessment and application of attribution science in the courtroom. This paper offers four suggestions:

1) Some courts have recognized that the questions implicated in the standing analysis are heavily fact dependent and tend to overlap with the merits of the case. But other courts have denied standing based on a cursory assessment of these scientific questions, finding without trial that the causal connection between emissions and injury is "too attenuated." Plaintiffs should not be denied their day in court based on judicial hunches about the state of the science. Standing claims involving disputed facts should be addressed after discovery, when all issues are fully briefed and all evidence is submitted.

2) Courts and litigants must select appropriate source attribution methodologies for defining a defendant's contribution to climate change vis-à-vis global greenhouse gas emissions. This is not always straightforward. Even where there is ample emissions data, there are questions about how to frame "responsibility" for emissions. For example, when framing national responsibility, litigants and courts must consider which emissions accounting approach to use (territorial, consumption-based, or extraction-based) and how to account for historical as compared with present (and possibly even future) emissions. Similarly, when framing private actor responsibility, one critical question is whether fossil fuel companies are responsible for the emissions generated by the combustion of the fuels that it produces and sells? Lawyers and judges can turn to source attribution science to understand the relative contribution of sources under different accounting methods at different temporal scales, but they must also rely on other tools to help answer these questions.

3) Litigants and courts should be aware of both the strengths and limitations of attribution science when framing and analyzing arguments. Plaintiffs may prove most successful where they base their claims on impacts which can be attributed to anthropogenic climate change with high confidence, such as sea level rise, melting snowpack, increases in average temperatures and extreme heat, and ocean acidification. Judges, meanwhile, should be mindful of the fact that there are different levels of confidence for different impacts, pay close attention to the evidence submitted, and should not dismiss claims based on generalized conclusions about the uncertainty of the science. Judges should also be aware that, when translating global or regional impacts to specific injuries, it may be necessary to accept causal inferences – for example, if plaintiffs submit evidence that anthropogenic influence on climate is driving snowpack declines throughout the Northern Hemisphere, it would be reasonable to infer that anthropogenic influence on climate is also causing observed declines in snowpack in a particular mountain range in the Northern Hemisphere even without a downscaled attribution study which definitively links the local impacts to global climate change.

4) Just as attribution science can be used to help frame responsibility for climate change, it can also be used to help frame private and governmental obligations to address climate change. Attribution science can be used to define specific obligations for national governments, such as national emission budgets, obligations pertaining to fossil fuel development and subsidies (source attribution data on extraction emissions would be particularly relevant in this context). As for private actor obligations: a critical question will be how to allocate liability and damages among multiple companies.