The Role of Attribution Science in Legal Action on Loss and Damage

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Union of Concerned Scientists

The Role of Attribution Science in Legal Action on Loss and Damage

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I. Executive Summary

Climate change is one of the defining issues of our time. As its impacts grow increasingly severe, communities—particularly in the Global South—have begun to experience loss and damage caused by climate change. Loss and damage, a term that emerged from international climate negotiations, refers to harms caused by climate change, including future harms that cannot be avoided through adaptation or mitigation.[1] These harms can be economic, such as property damage, or non-economic, such as the loss of biodiversity or cultural heritage.

Broadly speaking, attribution science involves separating out a given variable—such as human-induced warming or a specific source of emissions—to estimate that variable's influence on natural and human systems. By excluding this variable, scientists are able to simulate counterfactual worlds which they can compare to the world as it is.

For decades, advocates and governments have demanded that wealthy, high-emitter countries and corporations address the loss and damage that their emissions caused. In 2022, wealthy industrialized nations finally agreed to create the United Nations Loss and Damage Fund, which will provide funding to vulnerable developing countries.[2] Notably, numerous impacted communities have filed over 50 cases worldwide seeking remedies for loss and damage.[3] Governments have also begun adopting local laws and policies aimed at addressing these mounting losses. Attending to loss and damage is a matter of justice, as it disproportionately impacts those who have contributed the least to climate change.

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1 Karen E. McNamara & Guy Jackson, *Loss and Damage: A Review of the Literature and Directions for Future Research*, 10(2) WIREs Climate Change e564 (2018).

2 UNFCCC Conference of the Parties, *Report of the Conference of the Parties on its twenty-seventh session, held in Sharm el-Sheikh from 6 to 20 November 2022. Addendum. Part two: Action taken by the Conference of the Parties at its twenty-seventh session*, U.N. Doc. FCCC/CP/2022/10/Add.1 (Mar. 12, 2023).

3 Climate Law Accelerator (CLX) Database of Loss and Damage Climate Cases, https://docs.google.com/spreadsheets/d/1kjr-GfCk9o-Ldaiz-UDlLR3Kgy_3SVcHZt1V9pE6M7w/edit?usp=sharing (last visited Sep. 30, 2024).

Flooding caused by Hurricane Florence.
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Attribution science, which identifies and quantifies the contribution of climate change to global phenomena, is informing each of these areas of loss and damage law. This emerging scientific discipline can provide the causal link between climate change and slow-onset trends, extreme weather events, impacts on humans and nature, and specific sources of emissions. In doing so, attribution science allows courts, governments, and advocates to draw causal inferences about the impacts of climate change. These inferences have numerous applications in the law, from establishing standing and causation in lawsuits to guiding legislation and policy.

Attribution science has four distinct subfields, each exploring a different dimension of climate change causation. Trend attribution (sometimes referred to as "climate change attribution"[4]) allows scientists to measure the degree to which anthropogenic climate change contributed to large-scale trends, such as sea-level rise. Event attribution allows scientists to assess the degree to which climate change contributed to the frequency, intensity, or likelihood of extreme weather events. Impact attribution allows scientists to quantify the impacts of climate change on other interconnected natural and human systems (health, infrastructure, etc.). Lastly, source attribution allows scientists to assess the degree to which specific emissions contributed to climate change. Scientists conduct attribution research by comparing the world as it is to a counterfactual world without climate change or a specific source of emissions. They generally do this by generating climate models based on long-term data and simulating counterfactual scenarios. Drawing on observational data, a scientific understanding of physical properties and processes, and statistical analysis, scientists can estimate the role of human activities on climate change and its attendant impacts.[5]

[4] Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 77 (2020).

[5] *Id.* at 69–73.

Treating attribution science as the only form of causal evidence could undercut efforts to achieve climate justice by setting a standard that the communities most vulnerable to loss and damage may not be able to meet.

This science can inform legal efforts in myriad ways. Litigants may use attribution studies as causal evidence, supporting various elements of their case, including standing, causation, injury, liability, and damages.[6] In international negotiations, parties can use attribution science to guide the design and operationalization of the Loss and Damage Fund. Attribution research can also support the identification and quantification of losses, assessment of funding needs, and place pressure on governments to donate to the Fund. Similarly, attribution science has inspired legislative efforts to recover loss and damage costs from fossil fuel companies by quantifying their contribution to climate change.[7] Studies may also justify government action on loss and damage and help guide government assistance.

Nevertheless, loss and damage law should not rely too heavily on attribution science. The discipline cannot establish every causal link in the context of climate change. Other forms of evidence may help to establish the connection between climate change and specific harms, particularly for loss and damage experienced by communities in the Global South where fewer attribution studies are available. Treating attribution science as the only form of causal evidence could undercut efforts to achieve climate justice by setting a standard that the communities most vulnerable to loss and damage may not be able to meet. With this in mind, this white paper seeks to elucidate the role attribution science can play in legal action relating to climate change–induced loss and damage.

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6 Aisha I. Saad, *Attribution for Climate Torts*, 64(4) B.C L. Rev. 867, 886–901 (2023).

7 Martin Lockman & Emma Shumway, *State "Climate Superfund" Bills: What You Need to Know*, Climate L. (Mar. 14, 2024), https://blogs.law.columbia.edu/climatechange/2024/03/14/state-climate-superfund-bills-what-you-need-to-know/.

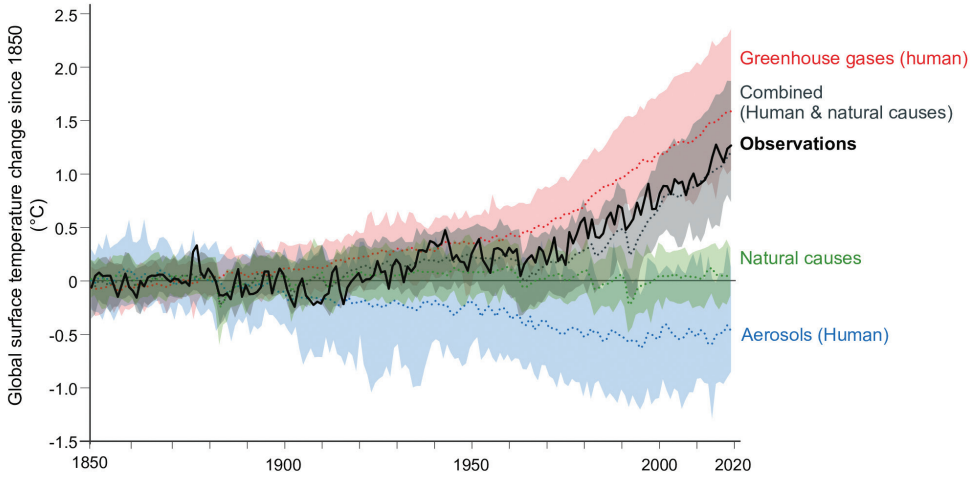
II. Overview of Attribution Science

The Intergovernmental Panel on Climate Change (IPCC), established in 1988 by the United Nations Environment Program and World Meteorological Organization, is an international body that provides decision-makers across the world with objective, scientific information about climate change. They produce comprehensive assessment reports every five to seven years that synthesize research from scientists worldwide who focus on the physical science basis of climate change (Working Group I (WG1)), climate change impacts, adaptation and vulnerability (Working Group II (WG2)), and mitigation of climate change (Working Group III (WG3)).

Figure 1.

How do we know humans are causing climate change?

Observed warming (1850–2019) is only reproduced in simulations including human influence.



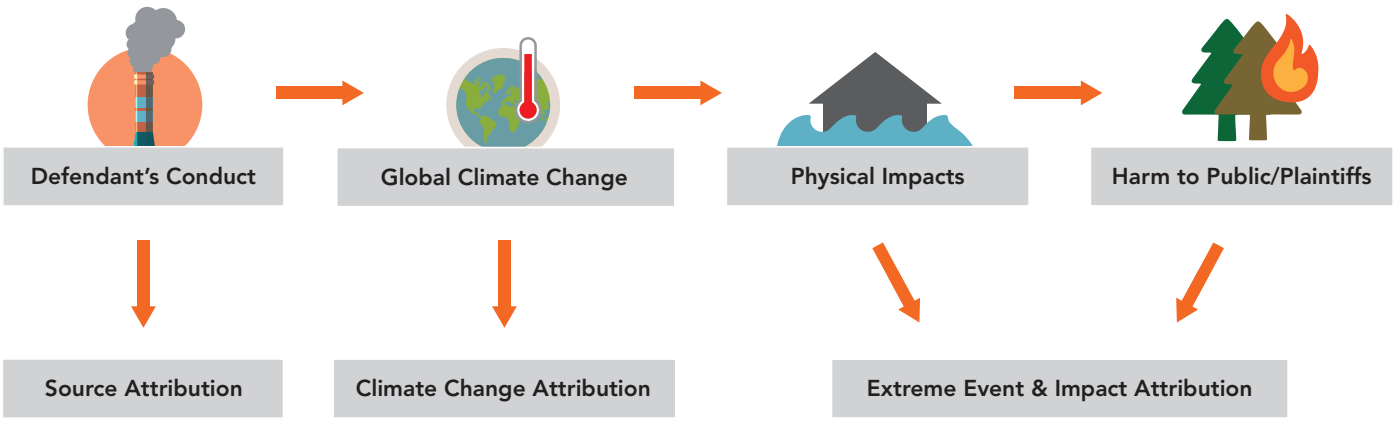
FAQ 3.1, Figure 1. IPCC, *2021: Chapter 3, in* Climate Change 2021: The Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 6 (Eyring, V., et al. eds.).

Attribution science has been a key line of evidence throughout the last 30 years of authoritative reports released by the IPCC, highlighting its rigor and scientific reputability. While detection and attribution science (sometimes referred to as fingerprinting) can be found throughout these IPCC reports, it plays a particularly prominent role in reports from the most recent assessment cycle (AR6), released from 2021 to 2023. These reports unequivocally attribute 1.1C° of global surface temperature warming to human emissions of greenhouse gasses (GHGs)[8] and note that

> [h]uman-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heat waves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since [assessment report] 5.[9]

Attribution science can be organized into four categories—trend, event, source, and impact—each of which considers different dimensions of climate change's causes and effects.

Figure 2.
Climate change detection and attribution



[8] IPCC, *Summary for Policymakers*, Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 3–32 (V. Masson-Delmotte et al. eds., 2021).

[9] *Id.*

1. Trend attribution

Trend attribution science identifies and quantifies the link between human-caused changes to the climate system and large-scale trends. Trend attribution studies often focus on indicators like average surface temperature,[10] sea level, drought, ocean acidification, and sea ice loss, among others.[11] Research in this field provided the basis for our scientific understanding of climate change,[12] and its methodology and conclusions have provided the foundation for and catalyzed other types of attribution science. Trend attribution uses historical, observational data combined with the output of climate models[13] with and without anthropogenic warming to disentangle the impact of human-caused climate change from other factors. These methods allow scientists to conclude, for example, that human-driven emissions have increased global average surface temperatures by 1.07°C (0.8°C–1.3°C) and reduced September Arctic sea ice area by 40% since the 1980s.[14] Further, anthropogenic climate change was also the primary force behind a 0.2m (0.15m to 0.25m) increase in global mean sea level between 1901 and 2018.[15]

Trend attribution has allowed scientists to conclude that anthropogenic climate change was the primary force behind a 0.2m (ranging from 0.15m to 0.25m) increase in global mean sea level between 1901 and 2018.

Trend attribution science can also explain regional trends, such as the attribution of drought in California, showing that climate change has roughly doubled the likelihood that precipitation deficits lead to drought conditions, with implications for water availability and wildfire risk.[16] Relatedly, climate change nearly doubled the area burned by wildfires in forests of western North America between 1984 and 2015, with an additional 4.2 million acres burned due to climate change.[17]

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10 Simon F. B. Tett et al., *Causes of Twentieth-Century Temperature Change Near the Earth's Surface*, 399 Nature 569 (1999).

11 V. Eyring et al., *Human Influence on the Climate System*, Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 423 (V. Masson-Delmotte et al. eds., 2021).

12 Gabriele C. Hegerl et al., *Climate Change Detection and Attribution: Beyond Mean Temperature Signals*, 19 J. Climate 5058 (2006).

13 Currently from the sixth iteration of the Coupled Model Intercomparison Project (CMIP6).

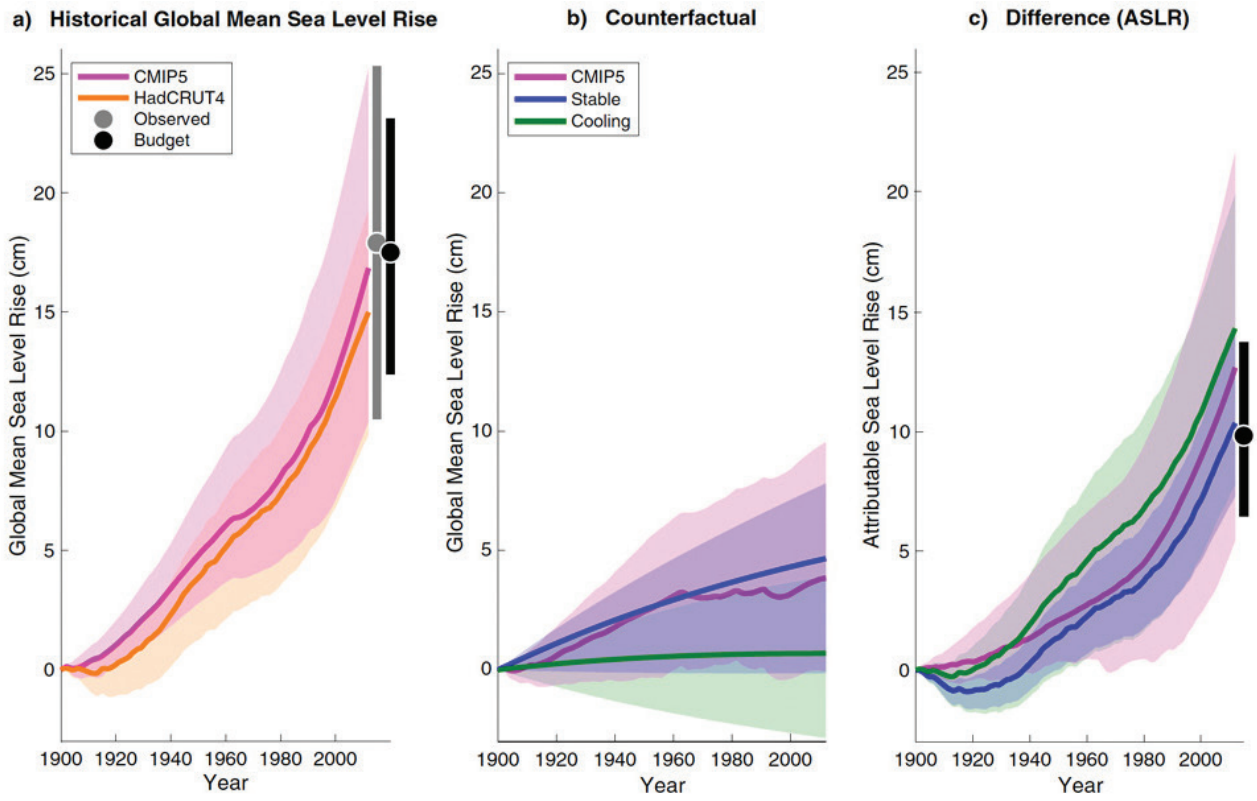
14 IPCC, *Summary for Policymakers*, Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 3–32 (V. Masson-Delmotte et al. eds., 2021).

15 *Id.*

16 Noah S. Diffenbaugh, Daniel L. Swain & Danielle Touma, *Anthropogenic Warming Has Increased Drought Risk in California*, 112 Proc. Natl. Acad. Sci. U.S.A. 3931 (2015).

17 John T. Abatzoglou & A. Park Williams, *Impact of Anthropogenic Climate Change on Wildfire across Western US Forests*, 113 Proceedings of the National Academy of Sciences 11770 (2016).

Figure 3.
Climate change detection and attribution



Historical, counterfactual, and climate change-driven changes in global mean sea level between 1900 and 2012. Benjamin H. Strauss et al., *Economic damages from Hurricane Sandy attributable to sea level rise caused by anthropogenic climate change*, 12(2720) Nature Communications 1, 6 (May 18, 2021).

2. Event attribution

Event attribution, a relatively young field of research and one that has become synonymous with 'attribution science' for many audiences, quantifies the contribution of climate change to the frequency, intensity, or likelihood of extreme weather events.[18] Studies in this field can now show how climate change makes a heatwave hotter or a hurricane-related downpour more intense than it would have otherwise been.[19] This type of research uses two principal methodologies: 'probabilistic' event attribution employs quantitative, statistical

[18] Friederike E. L. Otto, *Attribution of Extreme Events to Climate Change*, 48 Annu. Rev. Environ. Resour. 813 (2023).

[19] Friederike E. L. Otto, *Attribution of Weather and Climate Events*, 42 Annu. Rev. Environ. Resour. 627 (2017).

Typhoon Haiyan in the city of Tacloban, Philippines
© Henry Donati, Department for International Development

analyses to assess the likelihood and intensity of an event with and without human influence on the climate, whereas 'storyline' event attribution focuses on the atmospheric dynamics that led to an event, addressing how an event would develop with and without human-induced climate change.[20]

While event attribution research continues to expand, studies have primarily focused on heat and cold waves, storms, heavy rainfall, flooding, droughts, and wildfires due to their clear links to climate change, data availability, and policy relevance.[21] For example, climate change made Argentina's December 2013 heatwave five times more likely than in a climate without human influence.[22] In addition, a study of drought in the southern Horn of Africa from 2020 to 2022 showed that climate change has doubled the likelihood of low rainfall events, which, when considered alongside the event's extreme temperatures, has made the record-breaking drought 100 times more likely.[23] For complex weather events like tropical cyclones, scientists have not investigated the role of climate change in the development or intensity of storms; however, they have identified how climate change may modify storm surges and extreme precipitation as part of these events. Indeed, climate change increased storm surge height during Typhoon Haiyah in 2013 by 20%,[24] a finding that is transferable to

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20 Friederike E. L. Otto, *Attribution of Extreme Events to Climate Change*, 48 Annu. Rev. Environ. Resour. 813 (2023); Ben Clarke et al., *Extreme Weather Impacts of Climate Change: An Attribution Perspective*, 1 Environ. Res.: Climate 012001 (2022). For further information on the advantages and disadvantages of these two methodologies, see Jonathan D. Haskett, Cong. Rsch. Serv. R47583, Is That Climate Change? The Science of Extreme Event Attribution 5–9 (2023).

21 Ben Clarke et al., *Extreme Weather Impacts of Climate Change: An Attribution Perspective*, 1 Environ. Res.: Climate 012001 (2022).

22 A. Hannart et al., *9. Causal Influence of Anthropogenic Forcings on the Argentinian Heat Wave of December 2013*, 96 Bulletin of the American Meteorological Society S41 (2015).

23 *See generally* Joyce Kimutai et al., World Weather Attribution, Human-induced climate change increased drought severity in Horn of Africa (2023).

24 Izuru Takayabu et al., *Climate Change Effects on the Worst-Case Storm Surge: A Case Study of Typhoon Haiyan*, 10 Environ. Res. Lett. 064011 (2015).

similar events due to the role of sea-level rise. Together, the available range of event attribution studies provides critical quantitative information that can be used to project future risk, understand vulnerabilities, and build resilience in the face of increasingly severe climate impacts.

3. Source attribution

Source attribution research quantifies how emissions from specific sources, like the fossil fuel industry or a high-emitting country like the United States, contribute to climate warming and its impacts. Like other attribution research, source attribution studies compare climate models with and without emissions from specific sources to understand the relative proportion of an impact attributable to those emissions. Richard Heede's "Carbon Majors" study, which finds that nearly two-thirds of cumulative CO_2 and methane emissions between 1854 and 2010 can be traced to 90 fossil fuel and cement producers, has served as an important dataset for source attribution studies.[25] Leveraging this dataset, scientists have attributed the Carbon Majors' contribution to specific global and regional trends. For example, scientists have found that approximately 42–50% of the rise in global mean surface temperature and approximately 26–32% of global sea-level rise between 1880 and 2010 are attributable to emissions from the Carbon Majors.[26] They have also found that 88 Carbon Majors (down from 90 due to mergers and acquisitions) contributed roughly 55% of the increase in ocean acidification between 1880 and 2010.[27]

Scientists published the first regional source attribution study in 2023, finding that more than one-third of the total burned forest area in the Western United States and Southwestern Canada between 1986 and 2021 is attributable to emissions from the Carbon Majors.

Scientists published the first regional source attribution study in 2023, finding that more than one-third of the total burned forest area in the Western United States and Southwestern Canada between 1986 and 2021—and roughly half of the increase in wildfire-prone conditions since 1901—is attributable to emissions from the Carbon Majors.[28] These source attribution studies provide further evidence of the historical and ongoing contributions of major carbon producers, specifically in the fossil fuel and cement manufacturing industries, to climate change.

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25 Richard Heede, *Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010*, 122 Climatic Change 229 (2014).

26 B. Ekwurzel et al., *The Rise in Global Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers*, 144 Climatic Change 579 (2017).

27 R. Licker et al., *Attributing Ocean Acidification to Major Carbon Producers*, 14 Environ. Res. Lett. 124060 (2019).

28 Kristina A. Dahl et al., *Quantifying the Contribution of Major Carbon Producers to Increases in Vapor Pressure Deficit and Burned Area in Western US and Southwestern Canadian Forests*, 18 Environ. Res. Lett. 064011 (2023).

Flooding from Hurricane Sandy
© National Guard of the United States

4. Impact attribution

The leading edge of attribution science is impact attribution research, which expands on event and trend attribution findings to quantify climate change's impacts on other interconnected natural and human systems, such as the economy and health.[29] As a relatively young field, scientists continue to debate the merits of different methodologies, as well as potential pitfalls and guardrails around using this type of research.[30] Despite this ongoing discussion, impact attribution provides key insights into the toll of climate change on society and ecosystems. Recent research in this field explored the economic impacts of Hurricane Sandy, which struck the East Coast of the United States in 2012, finding that $8 billion of the storm's $60 billion of damages were attributable to "climate-mediated anthropogenic sea-level rise."[31] On a global scale, a 2021 study found that, across 43 countries, 37% (20.5%-76.3%) of warm-season, heat-related deaths are attributable to anthropogenic climate change.[32]

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29 Friederike E. L. Otto, *The Art of Attribution*, 6 Nature Climate Change 342 (2016).

30 S. E. Perkins-Kirkpatrick et al., *On the Attribution of the Impacts of Extreme Weather Events to Anthropogenic Climate Change*, 17 Environ. Res. Lett. 024009 (2022).

31 Benjamin H. Strauss et al., *Economic Damages from Hurricane Sandy Attributable to Sea Level Rise Caused by Anthropogenic Climate Change*, 12 Nat Commun 2720 (2021).

32 A. M. Vicedo-Cabrera et al., *The Burden of Heat-Related Mortality Attributable to Recent Human-Induced Climate Change*, 11 Nature Climate Chang. 492 (2021).

III. Attribution Methodology

Broadly speaking, attribution science involves separating out a given variable—such as human-induced warming or a specific source of emissions—to estimate that variable's influence on natural and human systems. By excluding this variable, scientists are able to simulate counterfactual worlds which they can compare to the world as it is. Scientists create these climate model simulations with powerful supercomputers, and the data inputs, methodologies, and timelines required for each study depend on the specific research question.

Long-term data is a key input for all types of attribution research as it allows scientists to construct a historical baseline for comparison.[33] The geographic scale and type of research question determine the required granularity of the data, meaning that the data inputs for a local study on sea-level rise in a single community would vary considerably from the data inputs for a continental study of an extreme heat wave. Many studies combine data from observations, satellites, and climate model simulations. Observation data varies widely in its starting point, while satellite data and data from climate simulations, like the Coupled Model Intercomparison Project (CMIP6), began around 1950 and 1850, respectively.[34]

Running climate models is computationally and resource-intensive, which has led scientists to develop alternative methods that rely on existing climate model data. While increased computing power would allow scientists to answer additional attribution research questions, computational constraints are likely to continue into the foreseeable future.

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[33] Friederike E. L. Otto et al., *Challenges to Understanding Extreme Weather Changes in Lower Income Countries* BAMS E1851 (2020).

[34] Veronika Eyring et al., *Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) Experimental Design and Organization*, 9 Geoscientific Model Development 1937 (2016); Sjoukje Philip et al., *A Protocol for Probabilistic Extreme Event Attribution Analyses*, 6(2) Advances in Statistical Climatology, Meteorology and Oceanography 177 (2020).

Figure 3.

Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850–1900

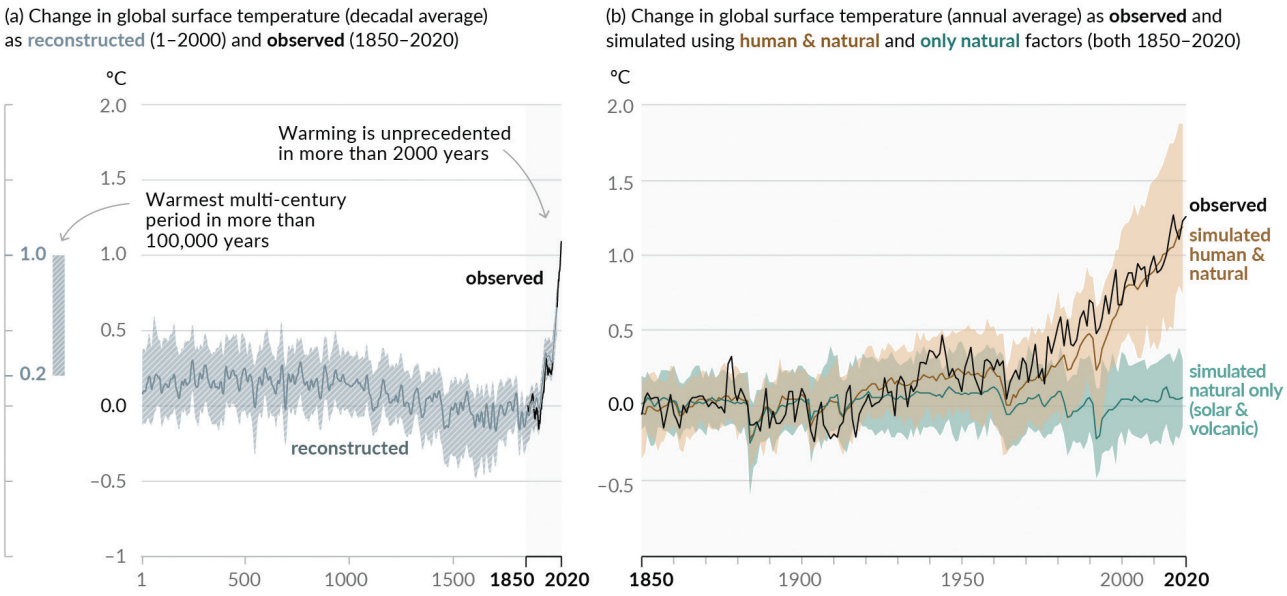

Figure SPM.1. IPCC, *2021: Summary for Policymakers, in* Climate Change 2021: The Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 6 (Masson-Delmotte, V., et al. eds.).

Attribution research is more advanced for physical processes closely related to temperature, such as heatwaves, than complex processes where factors beyond the climate contribute to the intensity, frequency, and likelihood of a given event.[35] Wildfires provide a clear example of this: trend attribution research has shown that dryness,[36] heat,[37] and extreme fire weather conditions have significantly worsened wildfire seasons across the world.[38] However, determining the role of climate change in an individual wildfire event is far more difficult given the variability of ignition sources and forest conditions that result from human management, among other factors.

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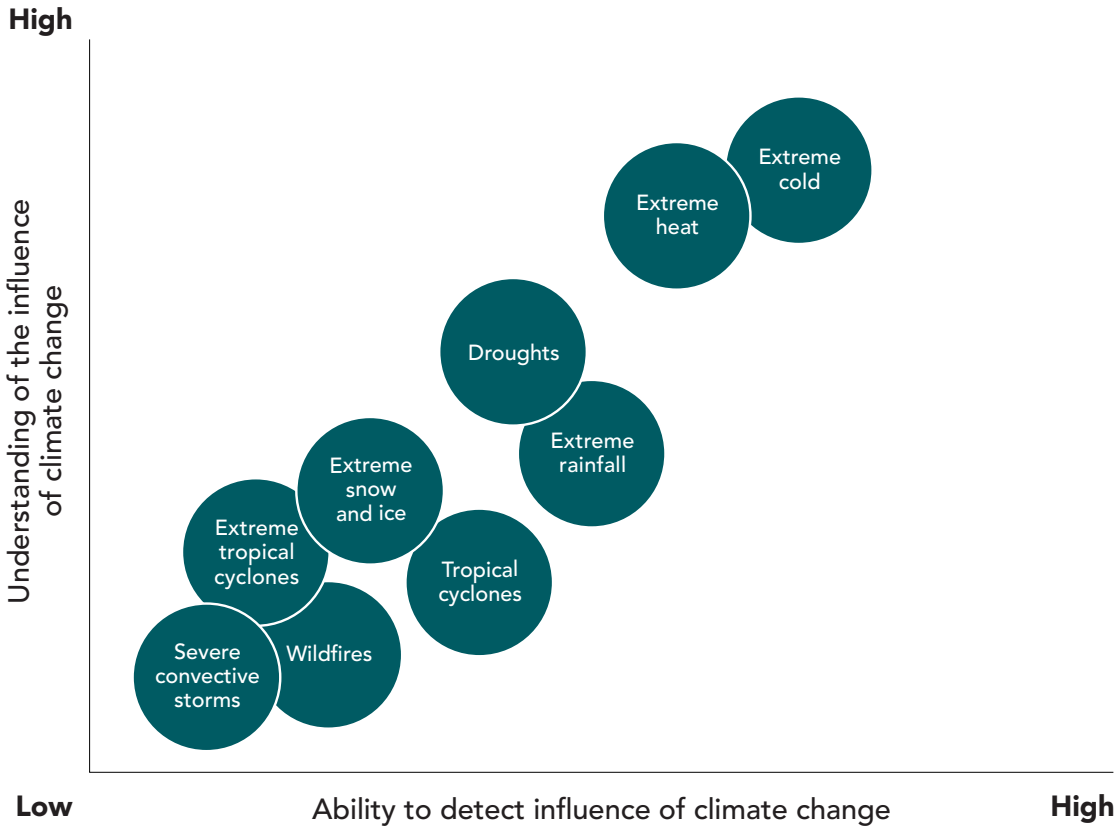
35 D. Chen et al., *Framing, Context, and Methods*, Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 147 (V. Masson-Delmotte et al. eds., 2021).

36 John T. Abatzoglou & A. Park Williams, *Impact of Anthropogenic Climate Change on Wildfire across Western US Forests*, 113 Proceedings of the National Academy of Sciences 11770 (2016).

37 M. C. Kirchmeier-Young et al., *Attribution of the Influence of Human-Induced Climate Change on an Extreme Fire Season*, 7 Earth's Future 2 (2019).

38 Ben Clarke et al., *Extreme Weather Impacts of Climate Change: An Attribution Perspective*, 1 Environ. Res.: Climate 012001 (2022).

Figure 4.
Relative confidence in attribution of different extreme events



Ayesha Tandon, *Q&A: The evolving science of 'extreme weather attribution',* Carbon Brief, https://www.carbonbrief.org/qa-the-evolving-science-of-extreme-weather-attribution/ (Nov. 18, 2024) (adapted from a graphic by the National Academy of Science).

Attribution can also be challenging for highly localized impacts, which cannot be easily captured in downscaled climate models that often express data in grid cells that may occupy multiple kilometers squared. Both of these challenges arise when discussing local sea-level rise. While robust models and projections of global sea-level rise exist, local representations of the same phenomenon become challenging due to factors beyond climate issues, like human modifications of coastlines, and questions of scale, where existing climate models cannot adequately capture small-scale differences.

Forest fire in Bitterroot National Forest in Montana
© John McColgan

Finally, timing presents an additional practical consideration for conducting attribution studies. Groups like World Weather Attribution and Climate Central have recently developed peer-reviewed methods that allow for rapid or near-real-time event attribution,[39] which have contributed greatly to the dissemination of this science. While these 'rapid attribution analyses' provide insight into how climate change is disrupting lives and livelihoods, such methods are not suitable for every type of event.[40] Novel attribution research can take months to years, depending on the question and capacity of scientists. As a result, involving scientists early on is critical to ensuring that the supporting evidence for a case or other legal action can be developed or interpreted appropriately.

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39 Geert Jan van Oldenborgh et al., *Pathways and Pitfalls in Extreme Event Attribution*, 166 Climatic Change 13 (2021); Sjoukje Philip et al., *A Protocol for Probabilistic Extreme Event Attribution Analyses*, 6(2) Advances in Statistical Climatology, Meteorology and Oceanography 177 (2020).

40 Karen A. McKinnon & Isla R. Simpson, *How Unexpected Was the 2021 Pacific Northwest Heatwave?*, 49 Geophysical Research Letters e2022GL100380 (2022); Emily Bercos-Hickey et al., *Anthropogenic Contributions to the 2021 Pacific Northwest Heatwave*, 49 Geophysical Research Letters e2022GL099396 (2022); Karen J. Heeter et al., *Unprecedented 21st Century Heat across the Pacific Northwest of North America*, 6 npj Climate Atmospheric Sci. 1 (2023); E. M. Fischer et al., *Storylines for Unprecedented Heatwaves Based on Ensemble Boosting*, 14 Nature Commc'n 4643 (2023).

IV. Informing Legal Action on Loss and Damage

Attribution science is already informing legal action on loss and damage. Conceptualizing loss and damage involves drawing a causal link between climate change and specific losses. In other words, attribution—as a general term—is inherent in the very meaning of loss and damage and central to the development of this body of law. Attribution science as a research discipline holds the potential to provide evidence of this causal link, in turn informing loss and damage litigation, international negotiations, domestic legislation, and related advocacy.

1. Evidence in litigation

Attribution science is perhaps most well-known by attorneys for its use in litigation. An increasing number of plaintiffs rely on attribution science to prove that they have experienced, are experiencing, or will likely experience climate change impacts. This evidence can be critical for establishing standing, causation, liability, and damages.[41]

Standing

Standing—which generally requires plaintiffs to show that they have a legally protected interest in the case—can pose a challenge in climate litigation. While standing rules differ by jurisdiction, many legal systems define

[41] Aisha I. Saad, *Attribution for Climate Torts*, 64(4) B.C L. Rev. 867, 886–901 (2023).

interested plaintiffs as those who have suffered a concrete and particularized injury or risk of injury.[42] Standing rules may also require plaintiffs to show that the defendant caused their injury, or risk of injury, such that the defendant can redress the harm. This threshold inquiry may differ from the substantive inquiry into whether the defendant injured the plaintiff; however, attribution science may play a similar role in both inquiries. This overlapping inquiry regarding causation is discussed in more detail in the next section.

Proving injury and causation as elements of standing can be difficult in a climate change–related case for a few reasons:

1. It may not be obvious whether climate change caused or exacerbated a given trend or event, given the variability of natural phenomena, and that non-climate-related confounding factors may have contributed to the event or injury;
2. Climate change threatens to impact nearly everyone, such that it can be interpreted as an issue for the general public rather than a particularized issue; and
3. It can be difficult to predict an imminent injury from climate change, given the complexity and unpredictability of climate change impacts.

As a result, some courts have dismissed climate cases for lack of standing.[43] Fortunately, attribution science can play a key role in overcoming these challenges.[44] Plaintiffs can establish their particularized interest in the case by showing that climate change caused or exacerbated an event, trend, or impact that directly affected them. Moreover, source attribution can demonstrate that a given defendant's cumulative GHG emissions contributed to that injury. Plaintiffs may also bolster claims regarding the possibility of future harm by demonstrating how climate change influenced past events, trends, and impacts, thereby supporting the inference that such harm could happen again.

KlimaSeniorinnen v. Switzerland demonstrates how plaintiffs can use attribution science, among other evidence, to help establish standing. In this case, a group representing senior Swiss women and several individual women sued the Swiss government for failing to take sufficient action on climate change. They argued that they had standing to sue because older women are particularly at risk from extreme heat, which is exacerbated by climate change. The Swiss courts disagreed, holding that the plaintiffs were not impacted by climate change because the alleged harm was too distant in the future, and they were no more at risk than the general public.[45] However, the European Court of Human Rights overruled the Swiss courts, finding that Swiss senior women, as a group, are directly affected by climate change. In reaching this conclusion, specifically in its consideration of standing, the Court referred to IPCC reports that relied on attribution science, as well as

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42 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 148–53 (2020).

43 *See e.g.*, *Sinnok v. State of Alaska* No. 3AN-17-09910 CI (Alaska Super. Ct. 2018).

44 Aisha I. Saad, *Attribution for Climate Torts*, 64(4) B.C L. Rev. 867, 886–892 (2023).

45 BundesverwaltungsgerichtFederal Administrative Court], Nov. 27, 2018, A-2992/2017, ¶7.4.2 (Switz.), https://climatecasechart.com/wp-content/uploads/non-us-case-documents/2018/20181127_No.-A-29922017_decision.pdf; and Bundesgericht [Federal Supreme Court], May 5, 2020, 1C_37/2019, at ¶5.4-5.5 (Switz.), https://climatecasechart.com/wp-content/uploads/non-us-case-documents/2020/20200505_No.-A-29922017_judgment.pdf.

two attribution studies provided by the applicants that attributed increased heat mortality to climate change.[46]

Causation

Proving causation can be a key hurdle in climate litigation.[47] In most cases, plaintiffs must show that the defendant's conduct caused them harm (including a risk of future harm), which involves multiple layers of causation.[48] First, the plaintiff must link the defendant's conduct to climate change. To do so, the plaintiff must establish that human activities (e.g., GHG emissions) caused climate change and that the defendant meaningfully contributed to these activities. Second, they must link climate change to a slow-onset trend or extreme weather event (e.g., sea-level rise or a cyclone). Third, they must link that event to the harm they suffered (e.g., property loss or poor health).

In *BLOOM v. TotalEnergies*, the plaintiffs cite a study that concludes climate change may have increased rainfall intensity by up to 50% during the 2022 monsoon season in Pakistan.

Attribution science can play an integral role in establishing each of these causal links.[49] A substantial body of attribution research demonstrates that humans have contributed and continue to contribute to climate change, primarily through GHG-emitting activities.[50] Emissions datasets and source attribution research then allow plaintiffs to show that a defendant's particular GHG emissions meaningfully contributed to climate change. For example, a number of loss and damage cases cite the aforementioned Carbon Majors database, which calculated each Carbon Major's specific contribution to cumulative worldwide industrial emissions between 1854 and 2010.[51] While the use of source attribution studies in pending cases is less common, we expect that as cases develop into the evidentiary stage, they may introduce such studies.[52] Depending on what impact or

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46 In setting the applicable rules for assessing standing for climate change related claims and ultimately finding that older women are at risk from climate change–induced heatwaves, the court referred to evidence submitted by the plaintiffs, including attribution studies. *See* Verein KlimaSeniorinnen Schweiz and Others v. Switzerland [GC], App. No. 53600/20, ¶509–511, 519, 529–30 (Sept. 4, 2024), https://hudoc.echr.coe.int/eng/?i=002-14304; A.M. Vicedo-Cabrera et al., *The Burden of Heat-related Mortality Attributable to Recent Human-induced Climate Change*, 11 Nature Climate Change 492 (2021); A. M. Vicedo-Cabrera et al., *The Footprint of Anthropogenic Climate Change on Heat-Related Deaths in Summer 2022 in Switzerland*, 18 Environ. Res. Lett. 074037 (2023). It is worth noting that the Court did not recognize standing for the individual applicants who had experienced heat-related injuries, finding that these injuries were not severe enough to require future protection.

47 Tobias Pfrommer et al., *Establishing Causation in Climate Litigation: Admissibility and Reliability*, 152 Climatic Change 67, 68 (2019); Aisha I. Saad, *Attribution for Climate Torts*, 64(4) B.C L. Rev. 867, 896 (2023).

48 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 205 (2020).

49 Aisha I. Saad, *Attribution for Climate Torts*, 64(4) B.C L. Rev. 867, 896–899 (2023).

50 *See generally* V. Eyring et al., *2021: Human Influence on the Climate System Supplementary Material*, *in* Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 423–552 (Masson-Delmotte et al. eds., 2021).

51 Richard Heede, *Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010*, 122 Climatic Change 229 (2014). This study is cited in *Greenpeace Italy et. al v. ENI S.p.A.* (Italy), *King County v. BP p.l.c.* (U.S.), *Rhode Island v. Chevron Corp.* (U.S.), and *Llyuvia v. RWE* (Germany), among many other cases brought against the Carbon Majors.

52 *See e.g.*, Christoph Bals, *RWE Lawsuit: First Test Case in Europe to Clarify Responsibilities of Carbon Majors for Climate Change*, Germanwatch (Nov. 8, 2018), https://www.germanwatch.org/en/15999 (noting counsel for Lluyia is "confident that [they] could do an attribution study to establish the impact of RWE's activities on the climate.").

Proving causation can be a key hurdle in climate litigation. In most cases, plaintiffs must show that the defendant's conduct caused them harm, which involves multiple layers of causation.

1. The plaintiff must link the defendant's conduct to climate change
2. They must link climate change to a slow-onset trend or extreme weather event
3. They must link that event to the harm they suffered

issue the source attribution study addresses (e.g., sea-level rise, mean surface temperatures), plaintiffs can then use extreme event attribution to connect climate change to specific events, such as hurricanes or heat waves. In *BLOOM v. TotalEnergies*, the eight individual plaintiffs point to attribution studies that connect climate change to the seven different extreme weather events that caused their injuries.[53] For example, they cite a study that found that climate change may have increased rainfall intensity by up to 50% during the 2022 monsoon season in Pakistan, which contributed to devastating floods.[54]

Finally, plaintiffs can use impact attribution to link the harm they suffered to that trend or event and, therefore, climate change. For example, as noted above, an attribution study found that climate change was responsible for approximately $8.1 billion of the damage caused by Hurricane Sandy.[55] This study was cited by New Jersey in a suit against oil and gas companies seeking compensation for climate-related damages.[56] However, as noted in the discussion of impact attribution above, this category is a new frontier in attribution science, and its methodologies remain subject to debate in the scientific community. Consequently, impact attribution may

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53 Press Release, NGOs and Climate Change Victims File Criminal Case Against TotalEnergies Board of Directors and Shareholders (May 2023) 10–12, https://climatecasechart.com/wp-content/uploads/non-us-case-documents/2024/20240521_68903_press-release-1.pdf.

54 Friederike E. L. Otto et al., *Climate Change Increased Extreme Monsoon Rainfall, Flooding Highly Vulnerable Communities in Pakistan*, 2(2) Environ. Res. Climate 025001 (2023).

55 Benjamin H. Strauss et al., *Economic Damages from Hurricane Sandy Attributable to Sea Level Rise Caused by Anthropogenic Climate Change*, 12 Nature Commc'n 2720 (2021).

56 Complaint, *Platkin v. Exxon Mobil Corp.*, at 145 fn.277 (citing Ayesha Tandon, Hurricane Sandy Caused an 'Extra $8bn' Damage Due to Human-Caused Sea-Level Rise, CarbonBrief (May 18, 2021), https://www.carbonbrief.org/hurricane-sandycaused-an-extra-8bn-damage-due-to-human-caused-sea-levelrise/#:~:text=More%20than%20%248bn%20of,%2460bn%20of%20economic%20damage, which reports the findings of the Strauss study).

not currently provide sufficiently robust evidence, and litigants may not even have access to relevant impact attribution. Nevertheless, plaintiffs may be able to prove a causal connection by supplementing impact attribution with additional evidence. For example, hospital records showing an increase in admissions during extreme heat could be paired with impact attribution on heat mortality to prove that climate change caused certain health injuries.

To establish causation, attribution research needs to meet legal standards of proof. Most legal systems apply a "bifurcated approach," where they assess whether the harm would have happened 'but for' the defendant's conduct and whether that conduct was the "legally relevant" cause.[57] This bifurcated inquiry is often called factual and legal (or proximate) causation. The precise application of these tests differs by jurisdiction. However, many courts have relaxed the strictness of 'but for' causation, recognizing causation where multiple actors contributed to harm or where the harm cannot be easily traced to an individual wrongdoer.[58] In the face of scientific uncertainties, some courts have accepted probabilistic evidence as evidence of causation.[59] Courts have found causation where statistical evidence shows that a defendant's conduct increased the likelihood of injury.[60]

Not all attribution research arrives at the same level of probability. Many studies find that an event or impact can be only partially attributed to climate change, while others have found that climate change played no role in a given event. So, while events like heatwaves are more easily attributable to climate change, others, like cyclones, can be more difficult to attribute.

However, not all attribution research arrives at the same level of probability. Many studies find that an event or impact can be only partially attributed to climate change, while others have found that climate change played no role in a given event.[61] So, while events like heatwaves are more easily attributable to climate change, others, like cyclones, can be more difficult to attribute.[62] As a result, plaintiffs may need to adapt their causation arguments to available attribution findings and consider the limitations that relevant confidence intervals may pose.

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57 Petra Minnerop & Freiderike Otto, *Climate Change and Causation: Joining Law and Climate Science on the Basis of Formal Logic*, 27(1) Buffalo Environ. L. J. 49, 55–56 (2020).

58 Petra Minnerop & Freiderike Otto, *Climate Change and Causation: Joining Law and Climate Science on the Basis of Formal Logic*, 27(1) Buffalo Environ. L. J. 49, 58–61 (2020).

59 Rupert Stuart-Smith et al., Oxford Sustainable Law Programme, Attribution science and litigation: facilitating effective legal arguments and strategies to manage climate change damages 10–11 (2021).

60 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 206 (2020).

61 Audrey Brouillet et al., World Weather Attribution, Food crisis in Central Sahel in 2022 driven by chronic vulnerability with uncertain role of climate change (2022) (finding that the food crisis in Central Sahel in 2022 was driven by chronic vulnerability with uncertain role of climate change); Linh N. Luu et al., *Attribution of Typhoon-induced Torrential Precipitation in Central Vietnam, October 2020*, 169(24) Climatic Change 1 (2021) (finding that climate change is not a major driver of present climate multi-day heavy rainfall over Central Vietnam); Clair Barnes et al., World Weather Attribution, Limited net role for climate change in heavy spring rainfall in Emilia-Romagna (2023) (finding that none of the models showed a significant change in the likelihood or intensity of heavy rainfall in the Emilia-Romagna region in spring).

62 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 100, 109 (2020).

Youth plaintiffs in the lawsuit, *Held vs. Montana*. © Our Children's Trust

Depending on the case, courts may not require the level of certainty that attribution evidence can provide for each link in the causal chain. For example, in *Held v. Montana*, the District Court drew on conclusions from attribution science to find that climate change is driving certain large-scale trends, such as the increasing frequency and intensity of wildfires.[63] The Court then inferred that the plaintiffs were injured by climate change because events like wildfires impacted them.[64] In doing so, the court did not require the plaintiffs to demonstrate that climate change caused these specific events, which had not been the subject of attribution studies.[65] This may have been possible because the case did not turn on attributing any particular event—the court only needed to find a causal link between GHG emissions and general impacts on the plaintiffs' lives.[66] Nevertheless, *Held* demonstrates how plaintiffs may depend on logical inferences to close gaps in the causal chain if they do not have access to relevant event, source, or impact attribution for their specific case.

Despite its availability, scholars have warned that many loss and damage cases do not presently rely on attribution science, thus risking dismissal for failure to prove causation.[67] While attribution science cannot provide causal connections in every instance, litigators are underutilizing this persuasive and rigorous form of evidence. Nevertheless, as will be discussed in Section V below, attribution science should not be the only accepted form of causal evidence, lest it become a barrier for plaintiffs who do not have access to such studies.

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63 *Held v. Montana*, No. CDV-2020-307 (1st Dist. Ct. Mont., Aug. 14, 2023) at 35–46.

64 *Id.* at 46–64.

65 Celina Zhao, *In Montana Lawsuit, a Climate Scientist Takes the Stand*, Science (June 20, 2023), https://www.science.org/content/article/montana-lawsuit-climate-scientist-takes-stand.

66 Petra Minnerop & Freiderike Otto, *Climate Change and Causation: Joining Law and Climate Science on the Basis of Formal Logic*, 27(1) Buffalo Environ. L. J. 49, 65 (2020).

67 Rupert Stuart-Smith et al., Oxford Sustainable Law Programme, Attribution science and litigation: facilitating effective legal arguments and strategies to manage climate change damages 11–14 (2021).

Injury, Liability, and Damages

Flowing from the foregoing analysis, attribution research can also be used to identify injuries and quantify a defendant's liability. By their very nature, loss and damage claims require proof of injury. This inquiry may be similar to the 'injury-in-fact' inquiry for standing (discussed above); however, unlike with standing, it generally requires proof of past or ongoing harm.[68] Additionally, courts tailor their remedies according to the degree of the injury and the defendant's degree of fault.[69]

As discussed above, plaintiffs can use trend, extreme event, and impact attribution to help demonstrate that they were injured by climate change. In *BLOOM v. TotalEnergies*, the complainants cite studies that connect deadly extreme weather events, such as flooding in France, to climate change.[70] This evidence, paired with testimony from relatives and witnesses, will likely be central to the issue of whether the directors of TotalEnergies are guilty of homicide.

Relatedly, source attribution and the emissions-based datasets that inform such studies can be leveraged to make claims regarding a defendant's degree of fault. Plaintiffs can use source attribution to quantify a defendant's liability by demonstrating their contribution to specific climate impacts. For example, in *Greenpeace Italy v. ENI*, the plaintiffs draw on source attribution to argue that the defendant, ENI, is responsible for between 0.0013 and 0.0037 °C of the increase in global mean land temperature, between 0.04 and 0.21 mm of global sea-level rise, and between 0.000365 and 0.000444 of the reduction in ocean pH.[71]

When source attribution studies are not readily available, plaintiffs can commission attribution studies that use emissions datasets, like Heede's, in climate models to understand how emissions traced to specific entities contribute to a climate impact.[72] It bears noting, however, that in the absence of source attribution studies, plaintiffs may still choose to put forth claims relying on datasets that trace emissions to a specific entity and request that the court infer proportional liability and damages. For example, in *Lliuya v. RWE AG*, the plaintiff is asking a German energy company to contribute €15,000 to draining an overflowing glacial lake,[73] which is

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68 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 202 (2020).

69 For example, when awarding damages for a tort, courts will consider the value of a plaintiff's losses and the degree to which the defendant bears full responsibility for them. A defendant's liability may be limited by the plaintiff's comparative fault. In criminal cases, courts generally take into account the victim's injury when sentencing a defendant. In rights-based cases, courts may craft an injunctive order or order reparations based on the seriousness of the rights violations.

70 *See generally*, Press Release, NGOs and Climate Change Victims File Criminal Case Against TotalEnergies Board of Directors and Shareholders (May 2023), https://climatecasechart.com/wp-content/uploads/non-us-case-documents/2024/20240521_68903_press-release-1.pdf.

71 Summons at 44, Greenpeace Italy v. ENI S.p.A. (It.) (citing Ekwurzel 2017 and Licker 2019).

72 *See e.g.*, B. Ekwurzel et al., *The Rise in Global Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers*, 144 Climatic Change 579 (2017); R. Licker et al., *Attributing Ocean Acidification to Major Carbon Producers*, 14 Environ. Res. Lett. 124060 (2019); Kristina A. Dahl et al., *Quantifying the Contribution of Major Carbon Producers to Increases in Vapor Pressure Deficit and Burned Area in Western US and Southwestern Canadian Forests*, 18 Environ. Res. Lett. 064011 (2023).

73 The plaintiff, Saúl Lliuya, argues that high water levels in a nearby glacial lake place his land at risk of flooding. Trend attribution shows that glacial melt, "entirely attributable" to climate change, has raised the lake's water levels. *See* Rupert F. Stuart-Smith et al., *Increased Outburst Flood Hazard from Lake Palcacocha Due to Human-induced Glacier Retreat*, 14 Nature Geosci. 85, 85 (2021).

proportional to the company's 0.47% share of global cumulative GHG emissions.[74] In other words, Lluyia argues that the defendant is liable for the costs associated with its share of the pollution that triggered climate change. While it appears that Lliuya only uses the Heede dataset in its initial filings, advocates for the plaintiff have indicated that they expect to conduct an attribution study to establish the impact of RWE's activities on the climate.[75]

Trend and extreme event studies can also help plaintiffs quantify their damages.[76] For example, in *Multnomah County v. Exxon Mobil*, the plaintiff county is demanding that fossil fuel companies compensate it for damages that stem from a 2021 heatwave.[77] In its complaint, the county cites three extreme event attribution studies that found a robust connection between the heatwave and climate change.[78] These studies attribute the heatwave's occurrence and severity to climate change, thereby providing a metric for quantifying the damages caused by climate change. In some cases, a defendant may only be responsible for the anthropogenic contribution to an event rather than its entire impact. For example, the finding that climate change increased precipitation during Hurricane Harvey by approximately 38%[79] may only support liability for the estimated impact of that additional rain.

Impact attribution studies can also provide a statistical measure of a plaintiff's damages; however, this measure may not be direct evidence of the plaintiff's damages if the study concerned a different or broader population than the plaintiff. In other words, a study on global crop yields may not provide a definitive measure of a plaintiff's individual agricultural losses. Nevertheless, such a study could serve as a guidepost for calculating the plaintiff's damages.

Caveats to Using Attribution as Evidence

Attribution science may play a pivotal role in climate litigation, but it is only one form of evidence. This body of research complements other forms of evidence, such as individual testimony; it does not, on its own, establish standing, causation, or damages in climate change cases. Like any evidence, litigants will need to wield attribution studies in support of their legal arguments alongside other forms of evidence. For example, to prove legal causation, plaintiffs may need to demonstrate that their injury was a foreseeable result of the defendant's conduct.[80] While attribution studies may help to demonstrate the foreseeability of future climate-induced injuries given past events, other forms of scientific evidence like climate modeling and legal precedent will likely also play a role in determining foreseeability.

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74 Richard Heede, *Tracing Anthropogenic Carbon Dioxide and Methane Emissions to Fossil Fuel and Cement Producers, 1854–2010*, 122 Climatic Change 229 (2014) (supplementary materials at 6).

75 Christoph Bals, *RWE Lawsuit: First Test Case in Europe to Clarify Responsibilities of Carbon Majors for Climate Change*, Germanwatch (Nov. 8, 2018), https://www.germanwatch.org/en/15999.

76 Aisha I. Saad, *Attribution for Climate Torts*, 64(4) B.C L. Rev. 867, 899–901 (2023).

77 *See generally*, Complaint, Cnty. of Multnomah v. Exxon Mobil Corp., Bottom of FormNo. 23CV25164 (Or. Cir. Ct, June 22, 2023).

78 *Id.* at 66–67.

79 Mark D. Risser & Michael F. Wehner, *Attributable Human-induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation During Hurricane Harvey*, 44(24) Geophysical Res. Lett. 12457 (2017).

80 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 201 (2020).

It is worth noting that as a scientific discipline, attribution research is not associated with a given form of advocacy or scientific outcome. Attribution studies may not always find a strong climate signal in a studied event or trend.[81] As a result, plaintiffs and advocates should be aware that commissioning an attribution study could, in theory, produce evidence that undermines arguments around standing, causation, liability, or damages, particularly if the study concludes the climate signal is not strong. For example, defendants could use studies to show that climate change was only a negligible cause of the plaintiff's injury. Before filing a case, litigants should consider whether existing attribution studies undermine their intended claims. In cases where competing attribution studies exist, courts may need to compare the methodology, data, and results of those studies, so litigants should expect to retain experts accordingly.

2. Informing negotiations

Attribution studies can also influence international climate negotiations by informing political and institutional decision-making.

Most significantly, attribution science may influence the framework and operationalization of the newly minted Loss and Damage Fund. After agreeing to create the Fund in 2022, negotiators are currently in the process of designing its structure and mechanisms.[82] In 2023, the parties approved the Fund's governing instrument; however, they have not yet determined how the Fund will distribute resources. Attribution science can play a role in shaping this nascent Fund, guiding decisions about how to design funding mechanisms, the operation of those mechanisms, and the downstream distribution of funding in developing countries.

Attribution science can help the Fund and recipient countries identify and estimate aggregate losses from climate change.

Attribution science can help the Fund and recipient countries identify and estimate aggregate losses from climate change.[83] While it would be impractical and unfeasible to require attribution research as a prerequisite for funding, studies can provide generalized insights into funding needs. For example, trend attribution studies on global sea-level rise could allow decision-makers to estimate land losses in a particular region. Similarly, impact attribution studies could provide decision-makers with a metric for estimating the aggregate costs of slow-onset trends and extreme weather. For example, one study concluded that, between 2000 and 2019,

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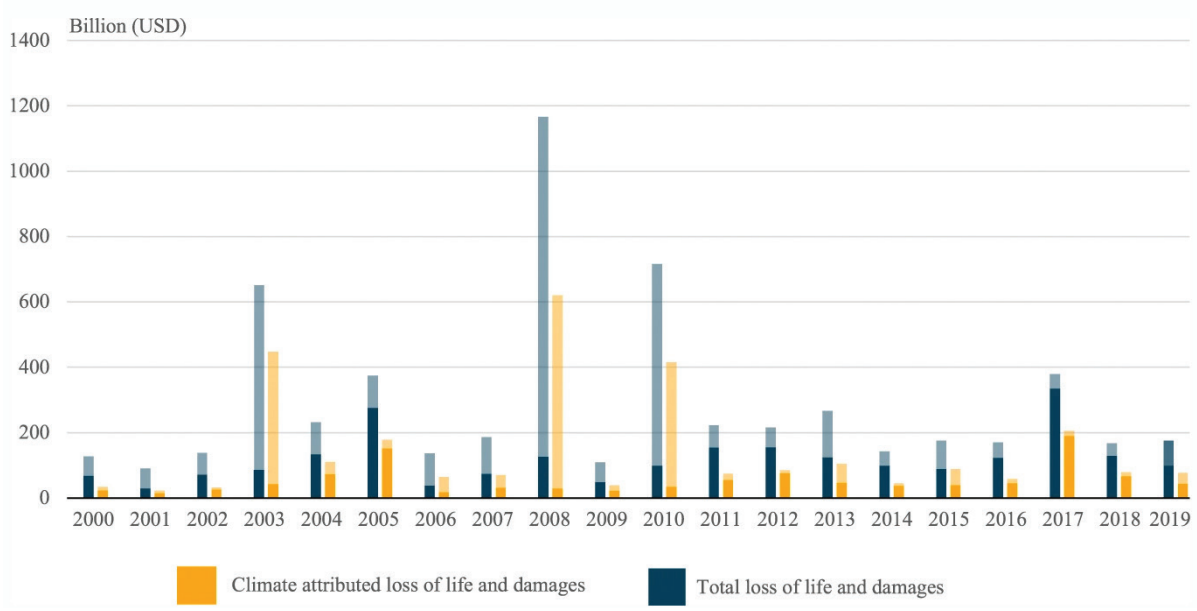
81 *See e.g.*, Joyce Kimutai et al., *Attribution of the Human Influence on Heavy Rainfall Associated with Flooding Events During the 2012, 2016, and 2018 March-April-May Seasons in Kenya*, 38 Weather & Climate Extremes 100529 (2022) (finding no significant anthropogenic climate change influence).

82 *Q&A: The Fight Over the 'Loss-and-damage Fund' for Climate Change*, Carbon Brief (July 11, 2023), https://www.carbonbrief.org/qa-the-fight-over-the-loss-and-damage-fund-for-climate-change/.

83 *See generally*, Ilan Noy et al., *Event Attribution is Ready to Inform Loss and Damage Negotiations*, 13 Nature Climate Change 1279 (2023); *see also* Lea Rahman, Attribution Science and the Loss and Damage Fund: Using Science Will Make the Fund More Fair and Effective, German Council on Foreign Relations (DGAP) 1, 4 (2023), https://www.researchgate.net/publication/369304834_Attribution_Science_and_the_Loss_and_Damage_Fund_Using_Science_Will_Make_the_Fund_More_Fair_and_Effective.

climate change was responsible for an average of $143 billion in damages from extreme weather each year.[84] In addition to providing a sense of funding needs, research like this could help the Fund determine how to distribute funds fairly without exhausting available capital.

Figure 5.
Climate change-attributed loss of life and damages from extreme weather events



Rebecca Newman & Ilan Noy, *The global costs of extreme weather that are attributable to climate change*, 14:6103 Nature Communications 1, 3 (Sept. 29, 2023).

Attribution science can also help to identify funding recipients—countries and communities that are particularly vulnerable to climate change.[85] Studies can help decision-makers assess which areas and groups are most impacted by climate change. Trend and event attribution can help to identify regions that are being impacted by climate change, while impact attribution can help to identify vulnerable groups by demonstrating that they have experienced climate change–induced loss and damage. For example, a study connecting climate change to haze pollution in eastern China in 2013 and 2015[86] suggests that climate change may increase the likelihood and frequency of the conditions that exacerbate poor air quality. Similarly, a study attributing

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[84] Rebecca Newman & Ilan Noy, *The Global Costs of Extreme Weather that Are Attributable to Climate Change*, 14 Nature Commc'n 6103 (2023).

[85] Lea Rahman, *Attribution Science and the Loss and Damage Fund: Using Science Will Make the Fund More Fair and Effective*, German Council on Foreign Relations (DGAP) (Mar. 15, 2023), https://dgap.org/en/research/publications/attribution-science-and-loss-and-damage-fund.

[86] Ke Li et al., *Attribution of Anthropogenic Influence on Atmospheric Patterns Conducive to Recent Most Severe Haze Over Eastern China*, 45 Geophysical Research Letters 2072 (2018).

heat-related deaths to climate change identified older women and urban residents as particularly at risk from increasing temperatures.[87] Impacted communities can also use attribution research to push their governments to request funding and distribute those resources to their specific communities.

Relatedly, attribution research could influence the politics of the Fund. Historically, polluting countries have benefited from the intangible and seemingly distant impacts of climate change. Attribution studies undercut this advantage by making the dangers of climate change concrete and tangible, thereby demonstrating the injustice to vulnerable communities that have contributed the least to climate change. This could increase ambition for loss and damage funding, as well as ambition for adaptation funding and mitigation.[88] While the Fund is not formally based on historical responsibility for climate change, developing countries could also use source attribution and the emissions-based datasets that inform such studies to place pressure on polluter states to donate to the Fund by quantifying their specific contribution to loss and damage.

3. Informing and catalyzing government action

Attribution science has already contributed to government action on loss and damage. Several U.S. states have advanced "climate superfund" bills that plan to rely on source attribution to identify emitters that substantially contributed to climate change and require compensation for its attendant damages.[89] For example, Vermont's Climate Superfund Act—the first to become law—only applies to companies that extracted or refined fossil fuels that are "attributable to . . . more than one billion metric tons of covered greenhouse gas emissions."[90] The law also requires the state to evaluate its expenditures associated with climate change, which might also rely on attribution science. Similar efforts are ongoing in New York, Massachusetts, and Maryland.[91] While there are currently no superfund bills at the federal level in the United States, attribution science has been cited in congressional hearings on numerous topics, including wildfires, disaster preparedness and the role of FEMA, extreme heat, and the impacts of climate change, suggesting that U.S.

Attribution science has already contributed to government action on loss and damage. Several U.S. states have advanced "climate superfund" bills that plan to rely on source attribution to identify emitters that substantially contributed to climate change and require compensation for its attendant damages.

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87 A. M. Vicedo-Cabrera et al., *The Footprint of Anthropogenic Climate Change on Heat-Related Deaths in Summer 2022 in Switzerland,* 18 Environ. Res. Lett. 074037 (2023).

88 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 143 (noting that attribution science can help increase ambition for mitigation efforts) (2020).

89 Martin Lockman & Emma Shumway, *State "Climate Superfund" Bills: What You Need to Know*, Climate L. (Mar. 14, 2024), https://blogs.law.columbia.edu/climatechange/2024/03/14/state-climate-superfund-bills-what-you-need-to-know/.

90 An Act Relating to Climate Change Cost Recovery, 2023 Vt. ALS 122, at 22, https://legislature.vermont.gov/Documents/2024/Docs/ACTS/ACT122/ACT122%20As%20Enacted.pdf.

91 Emily Pontecorvo, *A Climate Superfund Law Might Be Crazy Enough to Work*, Heatmap (Mar. 29, 2024), https://heatmap.news/climate/climate-superfund-vermont.

Flooding in Berlin, Vermont
© New Hampshire National Guard

lawmakers are considering attribution science when formulating policies.[92]

Climate change cost recovery measures are also being introduced outside of the United States. In 2023, lawmakers in the Philippines introduced the Climate Accountability Act, which would require corporations to pay for their impacts on the climate, including excessive emissions, greenwashing, and climate denialism, and would finance claims raised by survivors of loss and damage.[93] If passed, this law would draw on attribution science, among other resources, to assess the degree to which a company is liable.[94]

Attribution science may also inform government adaptation and mitigation policies, which are often intertwined with efforts to address loss and damage.[95] With regard to adaptation, governments can use attribution science to identify who and what is at risk, allowing them to increase disaster preparedness,[96]

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92 Jonathan D. Haskett, Cong. Rsch. Serv. R47583, Is That Climate Change? The Science of Extreme Event Attribution 10 (2023) (prepared for members and committees of Congress).

93 Jameela Joy Reyes, *Loss and Damage: Perspectives from Inside and Outside the UNFCCC*, Heinrich Böll Foundation (July 9, 2024), https://th.boell.org/en/2024/07/09/loss-and-damage-perspectives-inside-and-outside-unfccc.

94 Emily Bradeen, Tiffanie Chan & Catherine Higham, *Philippines Climate Accountability Bill: loss and damage in domestic legislation*, Grantham Research Institute on Climate Change and the Environment Commentary (Dec. 18, 2023), https://www.lse.ac.uk/granthaminstitute/news/philippines-climate-accountability-bill-loss-and-damage-in-domestic-legislation/.

95 For example, Vermont's Climate Superfund Act and many of the cases against the fossil fuel industry (e.g., *City of Oakland v. BP*, *King County v. BP*, *Multnomah County v. Exxon Mobil*) call for funds for adaptation projects designed to prevent future loss and damage. Climate Law Accelerator (CLX) Database of Loss and Damage Climate Cases, https://docs.google.com/spreadsheets/d/1kjr-GfCk9o-Ldaiz-UDlL-R3Kgy_3SVcHZt1V9pE6M7w/edit?usp=sharing (last visited Jan. 30, 2025). Some cases (e.g., *Asmania v. Holcim*, *Connecticut v. American Electric Power Co.*, *Greenpeace Italy v. ENI S.p.A.*, *Falys v.* TotalEnergies) also call for mitigation measures in addition to damages. *Id.*

96 Rachel A. James et al., *Attribution: How Is It Relevant for Loss*

Additional Resources

Organizations Producing or Compiling Attribution Science

World Weather Attribution

Climate Attribution Database

Climate Shift Index

Carbon Brief

Carbon Majors

prioritize adaptation projects, and direct resources to the communities most in need.[97] For example, extreme event and impact attribution can assist governments in understanding climate change's role in extreme weather events and quantify prior losses, which may inform budgeting decisions for disaster assistance. Similarly, governments can use source attribution to guide mitigation policies by tracing emissions to specific sectors or activities,[98] which may inform the policies they adopt to mitigate climate change (denying permits for new extraction, investing in clean energy, reducing fossil fuel subsidies, etc.).

Attribution science can also strengthen support for government action on climate change.[99] By connecting harmful trends, events, and impacts to climate change, studies can increase public awareness about the dangers of climate change. This, in turn, may bolster support for government efforts to remedy climate-induced losses, reduce emissions, and adapt to climate change. Even if the public supports such government efforts, vested interests and disaffected groups may still challenge them.[100] In response, governments could use attribution science as evidence in support of their decisions, thereby shielding such action from political and legal challenges.[101] For example, governments could use attribution studies to justify loss and damage assistance for particular groups, fending off discrimination and equal protection challenges. Governments could also use attribution studies to demonstrate that their decisions were deliberate and well-informed, fending off claims that government actions were arbitrary or irrational. Attribution science could play this role in the expected challenges to climate superfund laws.[102]

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and Damage Policy and Practice?, *in* Loss and Damage from Climate Change 139 (Reinhard Mechler et al. eds., 2018).

97 Joanna Spalding & Daniel Hales, *The Uses of Climate Change Attribution Science: The NGO Practitioner's View*, 51 Environ. L. Reporter 10654, 10657 (2021).

98 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 143 (2020).

99 *Id.*, at 141–42.

100 Various groups and entities have challenged mitigation and adaptation efforts. *See e.g.*, *EPA Rule to Cut Power Sector GHG Emissions Faces Legal and Political Challenges*, Davis Polk (May 29, 2024), https://www.davispolk.com/insights/client-update/epa-rule-cut-power-sector-ghg-emissions-faces-legal-and-political-challenges; Jurisich Oysters, LLC v. United States Army Corps of Eng'rs, No. 24-106, 2024 U.S. Dist. LEXIS 137081 (E.D. La. Aug. 2, 2024) (challenging a U.S. government project aimed at strengthening coastal resiliency to climate change).

101 Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45(1) Colum. J. Env't L. 57, 142 (2020).

102 Martin Lockman & Emma Shumway, *State "Climate Superfund" Bills: What You Need to Know*, Climate L. (Mar. 14, 2024), https://blogs.law.columbia.edu/climatechange/2024/03/14/state-climate-superfund-bills-what-you-need-to-know/.

V. The Limitations of Attribution Science

It is essential to recognize the limitations of attribution science and set realistic expectations about its role in the development of law. Attribution research cannot provide causal evidence for every effect of climate change, meaning that courts, governments, and practitioners should avoid relying on it exclusively. Attribution research should serve as an aid to loss and damage law rather than an arbiter of this body of law.

Wealthy countries have the greatest access to the high-quality long-term datasets that attribution studies require. These data inequities are driven by the legacy of colonialism, ongoing disparities in resources, and the consequences of armed conflict.

Legal uses of attribution science raise serious questions of equity and fairness. Wealthy countries have the greatest access to the high-quality long-term datasets that attribution studies require.[103] These data inequities are driven by the legacy of colonialism, ongoing disparities in resources, and the consequences of armed conflict.[104] Such inequities constrain the geographic location and granularity of some studies,[105] with most published attribution studies focused on the Global North.[106] Bias in climate models,

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[103] Rachel A. James et al., *Attribution: How Is It Relevant for Loss and Damage Policy and Practice?*, *in* Loss and Damage from Climate Change 142, figure 5.9 (Reinhard Mechler et al. eds., 2018).

[104] Kenneth A. Schultz & Justin S. Mankin, *Is Temperature Exogenous? The Impact of Civil Conflict on the Instrumental Climate Record in Sub-Saharan Africa*, 63(4) Am. J. Pol. Sci. 723 (2019) (finding that civil conflict leads to the loss of weather stations and that countries with higher average conflict risk tend to have poorer coverage).

[105] Joyce Kimutai et al., World Weather Attribution, Limited data prevent assessment of role of climate change in deadly floods affecting highly vulnerable communities around Lake Kivu (2023) (finding that "due to the data limitations it is not possible to assess the spatial or temporal extent of the rainfall that led to the flooding" in Rwanda and the Democratic Republic of Congo, meaning "a formal attribution study [was] not possible and the role of climate change [could not] be assessed").

[106] P. A. Arias et al., *Technical Summary*, Climate Change 2021: The Physical Science Basis. Contribution of Working

along with resource and expertise limitations (e.g., limited access to supercomputers), also contribute to the unequal distribution of attribution science.[107]

This disparity leaves some of the most vulnerable and exploited communities without attribution evidence of the climate-induced harms they suffer. Consequently, legal reliance on attribution science risks stratifying existing inequities by rewarding wealthier communities for their access to the discipline and creating barriers to entry. For example, the successful use of attribution science in litigation risks setting an evidentiary standard that other plaintiffs may not be able to meet. This disparity could even pose a problem for impacted plaintiffs in wealthy countries, given that attribution research will never provide an exhaustive assessment of climate change impacts.

An overreliance on attribution science may lead to a devaluing of other forms of relevant knowledge. As noted above, attribution science is only one form of causal evidence among many. Traditional or Indigenous knowledge, community testimony, observational and theoretical science, and logical reasoning can play crucial roles in climate attribution. For example, in *Sustaining the Wild Coast*, the South African High Court cited resident testimony on observed climate change impacts, such as an increased frequency of droughts and heavy precipitation.[108] While not all testimony is reliable, communities with long-standing connections to nature may be able to offer credible evidence of climate change impacts and the ways in which weather systems have changed. Given the gaps in attribution research and its analytical limitations, courts and governments must consider other forms of evidence.

Despite the power of attribution science, this research cannot demonstrate causal connections in every instance where those connections exist. Scientific capacity constraints and incentive structures make it unlikely that the research community will conduct an attribution study for every extreme event, and scientists have debated the merit and utility of seemingly repetitive studies.[109] However, one argument for conducting additional studies focused on well-studied phenomena is the unequal distribution of existing studies.[110] Attribution methodologies may also struggle to model complex, multi-step causal chains since those chains often involve non-climate factors, which can be more difficult to model. In the case of a hypothetical extreme rain event that is partially attributable to climate change, that event may lead to flooding, which may, in turn, lead to a landslide, which in turn may destroy part of a home. Although a proportion of the extreme rainfall event could be attributed to climate change, other conditions, like a theoretical clearcut harvest of forest that destabilized soil, increasing the risk of a landslide, make attributing the loss of that home to climate change a challenge.

Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 33–144 (V. Masson-Delmotte et al. eds., 2021); *see also* Lea Rahman, *Attribution Science and the Loss and Damage Fund: Using Science Will Make the Fund More Fair and Effective*, German Council on Foreign Relations (DGAP) (Mar. 15, 2023), https://dgap.org/en/research/publications/attribution-science-and-loss-and-damage-fund.

107 Friederike E. L. Otto et al., *Challenges to Understanding Extreme Weather Changes in Lower Income Countries* BAMS E1851, E1855 (2020).

108 Sustaining the Wild Coast NPC and Others v. Minister of Mineral Resources and Energy and Others, No. 3491/2021, ¶ 117 (Eastern Cape Div., Makhanda, 2022) (S. Afr.).

109 *See e.g.*, Ben Clarke, Friederike Otto & Richard Jones, *When Don't We Need a New Extreme Event Attribution Study?*, 176 Climatic Change 60 (2023).

110 *See generally*, Friederike E. L. Otto et al., *Challenges to Understanding Extreme Weather Changes in Lower Income Countries* BAMS E1851, E1855 (2020).

VI. Conclusion

Attribution science can inform legal action on loss and damage in a variety of ways. The discipline offers causal evidence that can help justify and shape government policies, guide the distribution of funds, and establish legal claims. In doing so, attribution science can play an important—but not indispensable—role in the development of loss and damage law, which is still nascent. Attribution research should not displace other forms of causal evidence, given that it does not, and cannot, establish every causal relationship in the realm of climate change. Nevertheless, it remains a helpful resource that legal practitioners should consider when engaging in efforts to address climate change–induced loss and damage.

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