"In Science We Trust": Evidence-Based Judicial Innovation in Climate-Related Litigation

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ABSTRACT: This article investigates the epistemic role of science in shaping judicial reasoning on states' environmental and climate obligations. It argues that scientific knowledge functions not merely as auxiliary evidence but as an epistemic infrastructure through which courts construct, interpret and enforce climate-related duties. By examining jurisprudence from the Inter-American and European human rights systems, alongside landmark national and international precedents, the study argues that courts progressively embed scientific consensus into legal argumentation. This process enables them to translate empirical findings – particularly those consolidated by the IPCC – into normative benchmarks for assessing state responsibility in environmental and climate matters.

KEYWORDS: climate litigation; scientific evidence; epistemic authority; state responsibility; human rights and climate change

1. Introduction

Science occupies a pivotal role in climate change litigation.[1] Courts increasingly confront the challenge of interpreting complex scientific data to determine whether governments or corporations have failed to protect individuals from the harmful effects of climate change.

To this end, judges use climate science to "identify victims, determine guard rails for states' legal obligations to mitigate and adapt to climate change, and prescribe remedies".[2]

Yet, the integration of science into adjudication presents methodological challenges. Climate science typically operates on a global scale, quantifying general human influence on temperature rise. Standard

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[1] See, for a broader discussion of climate change litigation and the evolving role of science – although only marginally addressed – A.V. RYDBERG, *Climate Change Litigation: General Perspectives and Emerging Trends*, in *International Community Law Review*, 26(4), 2024.

[2] N.J. SCHULDT, R.F. STUART-SMITH, T. WETZER, *Strategies for navigating competing climate science in human rights courts*, in *PLOS Climate*, 3(8), 2024, 1.

detection-and-attribution studies, such as those used by the Intergovernmental Panel on Climate Change (IPCC), are adequate to establish general causation on a large scale but rarely suffice to prove that a specific defendant's emissions caused a specific harm. Thus, courts struggle to connect diffuse, cumulative emissions to localised injuries. Compounding this difficulty, judges possess limited technical expertise for scientific appraisal, which can lead to misinterpretation or overreliance on expert testimony.[3] Moreover, natural science evolves continuously, and litigants may advance competing interpretations of the same environmental data.[4] Additionally, unequal access to expert resources can affect procedural fairness, as claimants and defendants may not be equally equipped to substantiate their argument scientifically.[5]

Nevertheless, the Paris Agreement, the legally binding international treaty on climate change, instructs Parties to ground climate action on the *best available science* (BAS).[6] This mandate raises foundational questions: how does an extra-legal criterion such as BAS acquire normative authority in adjudication? Do courts autonomously identify it, or do they defer to institutional syntheses such as the IPCC's Assessment Reports? While a comprehensive exploration exceeds the scope of this study,[7] these questions frame the broader inquiry into science as the epistemic infrastructure of judicial reasoning.

Accordingly, this research explores how courts use scientific findings to delineate the contours of states' environmental and climate obligations. The central argument is that scientific evidence has evolved into the principal epistemic infrastructure of judicial reasoning in climate litigation. Judges treat scientific consensus not as contextual information, rather as an authoritative framework for defining the scope, content, and enforceability of environmental and climate duties. To substantiate such claim, the study analyses key case-law, mostly involving decisions at the regional level – precisely, within the Inter-

[3] See S. JASANOFF, *Science, Common Sense & Judicial Power in U.S. Courts*, in *Daedalus*, 147(4), 2018. Doctrinal proposals to address the issue of courts specialisation in the field of environmental law include the establishment of environmental courts or dedicated environmental divisions within administrative or general courts ("environmental benches"); the recruitment of in-house scientific expertise; the courts hybrid composition of both legally trained judges and technical experts, as exemplified by Sweden. See *infra*, notes 4 and 5.

[4] See M. SCHULTZ, *Scientific evidence in Swedish courts: the use of technical judges for better integration of scientific data in environmental decision-making*, in L. SQUINTANI, J. DARPÖ, L. LAVRYSEN, P. STOLL (Eds.), *Managing Facts and Feelings in Environmental Governance*, Cheltenham, 2019.

[5] J. DARPÖ, *Understanding the Nuts and Bolts – Scientific and Technical Knowledge in Environmental Litigation: National Solutions, EU Requirements and Current Challenges*, in L. SQUINTANI, J. DARPÖ, L. LAVRYSEN, P. STOLL (Eds.), *Managing Facts and Feelings in Environmental Governance*, Cheltenham, 2019.

[6] Paris Agreement to the United Nations Framework Convention on Climate Change, Paris, 12 December 2015, United Nations, Treaty Series, vol. 3156, p.79 T.I.A.S. No. 16-1104, Artt. 4 and 7. As for the notion of BAS, the absence of a formal legal definition raises several interpretative questions. For a comprehensive discussion on whether BAS should be understood through legal criteria or as a factual concept; whether its application should vary according to the differing levels of scientific development across states; and, more generally, how such standard has been operationalised in practice, see C. RAGNI, *Scienza, diritto e giustizia internazionale*, Milano, 2020.

[7] For a more detailed treatment on the choice of scientific targets and their implications see, *inter alia*, R. KNUTTI, J. ROGELJ, J. SEDLÁČEK, E.M. FISCHER, *A Scientific Critique of the Two-Degree Climate Change Target*, in *Nature Geoscience*, 9, 2016; S. MARJANAC, L. PATTON, *Extreme Weather Event Attribution Science and Climate Change Litigation: an Essential Step in the Causal Chain?*, in *Journal of Energy and Natural Resources Law*, 36(3), 2018. The authors note that the widely used proxy for international climate change law, Global Mean Surface Temperature (GMST), vary significantly in different regions around the world: a global warming of 2°C could correspond to temperature increases of up to six degrees in some areas.

American and European human rights systems – to trace how courts incorporate scientific findings into normative reasoning. Further insights are also drawn from leading national and international judgments.

2. Science as a Foundation for Individuals' Claims

Scientific knowledge provides the evidentiary and conceptual foundation for asserting rights in environmental and climate-related claims. Yet, translating complex scientific data into legally actionable arguments remains one of the greatest challenges in environmental adjudication. The difficulty lies not in proving general causation – the accepted scientific fact that human greenhouse gas (GHG) emissions drive global warming, as documented in IPCC reports, which "synthesise the scientific community's consensus understanding of climate change" and constitute "an assessment of the state of the science that is accepted by all governments and are therefore considered authoritative in court".[8]

Rather, the problem concerns specific causation: linking a particular emitter's conduct to a claimant's concrete harm. The multiplicity of emitters, the fungibility of GHGs, the often-minor contribution of any single defendant to global emissions, and scientific uncertainty complicate the task of establishing causation. Traditional legal tests are ill-suited for cumulative and transboundary phenomena and tend to strain under the probabilistic nature of climate causation. What science presents as confidence intervals and probability distributions, the law must translate into binary determinations of liability.

Advances in the science of attribution, however, have begun to bridge this evidentiary gap.[9] Attribution studies can now trace the full causal chain from the GHG emissions of individual entities to the resulting societal impacts. The IPCC'S Sixth Assessment Report confirms that it is possible to delineate causal links between individual state (in)actions and particular environmental harms.[10]

Once an impact is attributed to anthropogenic climate change, emissions can be further allocated to specific sources by calculating their proportional contribution to global totals.[11]

Building on these methodologies, plaintiffs in several jurisdictions have successfully used attribution evidence to demonstrate sufficiently particularised injuries for standing purposes.[12]

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[8] R.F. STUART-SMITH, F.E. OTTO, T. WETZER, *Liability for climate change impacts: the role of climate attribution science*, in E. DE JONG, (eds). *Corporate Accountability and Liability for Climate Change*, Cheltenham, 2024, 218.

[9] For a more detailed discussion on the notion of 'attribution science' see S. MARJANAC, L. PATTON, *op. cit.*; S. MCCLUSKEY, *Calibrating states' emissions reduction due diligence obligations with reference to the right to life*, in *Review of European, Comparative & International Environmental Law*, 31(3), 2022.

[10] IPCC: 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 [V. MASSON-DELMOTTE, P. ZHAI, A. PIRANI, S.L. CONNORS, C. PÉAN, S. BERGER, N. CAUD, Y. CHEN, L. GOLDFARB, M.I. GOMIS, M. HUANG, K. LEITZELL, E. LONNOY, J.B.R. MATTHEWS, T.K. MAYCOCK, T. WATERFIELD, O. YELEKÇI, R. YU, B. ZHOU (eds.)], United Kingdom and New York, 2021, 3-32.

[11] See, among others, F.E. OTTO, R.B. SKEIE, J. FUGLESTVEDT, T. BERNTSEN, M.R. ALLEN, *Assigning historic responsibility for extreme weather events*, in *Nature Climate Change*, 7, 2017; B. EKWURZEL, J. BONEHAM, M.W. DALTON, R. HEEDE, R.J. MERA, M.R. ALLEN, P.C. FRUMHOFF, *The rise in global atmospheric CO_2, surface temperature, and sea level from emissions traced to major carbon producers*, in *Climatic Change*, 144, 2017; R. LICKER, B. EKWURZEL, S.C. DONEY, S.R. COOLEY, I.D. LIMA, R. HEEDE, P.C. FRUMHOFF, *Attributing ocean acidification to major carbon producers*, in *Environmental Research Letters*, 14(12), 2019.

[12] See, *ex multis*, M. BURGER, J. WENTZ, R. HORTON, *The Law and Science of Climate Change Attribution*, in *Colombia Journal of Environmental Law*, 45(1), 2021.

Importantly, courts worldwide have increasingly rejected the 'drop-in-the-ocean' defence, under which defendants argue that their emissions are too insignificant to meaningfully affect global outcomes.[13] In the *Urgenda* case (see *infra*, para. 3.2), the Dutch Supreme Court found that despite the global nature of climate change, the state must fulfil "its part" to bring down the level of global GHGs concentration and to counter therefore the threat of climate change.[14] In the *KlimaSeniorinnen* case (see *infra*, para. 2.2), the European Court of Human Rights (ECtHR) underscored that even minimal emissions are legally significant when the state had the capacity, through reasonable measures, to avert them.[15]

The Committee on the Right of the Child (CRC) in *Sacchi v. Argentina*, while dismissing the case on procedural grounds, similarly found that "the collective nature of the causation of climate change does not absolve the State party of its individual responsibility that may derive from the harm that the emissions originating within its territory may cause".[16]

The International Court of Justice (ICJ), in its recent Advisory Opinion (see *infra*, para. 3.1), recognised that attribution science could assist in establishing a "sufficiently direct and certain causal nexus between the wrongful act […] and the injury suffered", required for responsibility in relation to reparation obligations under the customary duty to prevent environmental harm (or climatic harm, as part of 'environment' legal concept).[17] The ICJ observed that "while climate change is caused by cumulative GHG emissions, it is scientifically possible to determine each State's total contribution to global emissions, taking into account both historical and current emissions".[18] While acknowledging that this nexus is "more tenuous than in the case of local sources of pollution",[19] the Court affirmed that causation should be assessed contextually, evaluating whether a state's conduct constitutes material contribution to climate change and attribution science could be useful in this regard.[20]

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[13] See N. Nedeski, A. Nollkaemper, *A guide to tackling the collective causation problem in international climate change litigation*, in *EJIL:Talk! Blog of the European Journal of International Law*, 2022, www.ejiltalk.org (last visited: 04/12/2025). The authors contest the 'drop-in-the-ocean' argument, since obligations to prevent climate-related harm are shared obligations that oblige individual states to do their part in a collective effort.

[14] Supreme Court of the Netherlands (Hoge Raad), *Urgenda Foundation v the State of The Netherlands* (*Ministry of Infrastructure and Environment*), Case No. 19/00135 (20 December 2019), C/09/456689/HA ZA 13–1396, ECLI:NL:HR:2019:2006, para. 5.8, ECLI:NL:HR:2019:2007. See also A. Nollkaemper, J. d'Aspremont, C. Ahlborn, B. Boutin, N. Nedeski, I. Plakokefalos, D. Jacobs, *Guiding Principles on Shared Responsibility in International Law*, in *European Journal of International Law*, 31(1), 2020, 58.

[15] ECtHR, case of *Verein KlimaSeniorinnen Schweiz and Others v. Switzerland* (9 April 2024), App. No. 53600/20, ECLI:CE:ECHR:2024:0409JUD005360020, para. 444.

[16] Committee on the Right of the Child (CRC), *Chiara Sacchi et al. v. Argentina*, No. CRC/C/88/D/104/2019 (22 September 2021), para. 10.10.

[17] International Court of Justice, Advisory Opinion, *Obligations of States in Respect of Climate Change* (July 23, 2025), para. 436.

[18] *Ibid.*, para. 429. However, see Judge Nolte's critical declaration, www.icj-cij.org (last visited: 04/12/2025).

[19] *Ibid.*, para. 438.

[20] See M. Colli Vignarelli, *Ripartire con le idee chiare: il contributo della Corte internazionale di giustizia all'azione per il clima*, in *SIDIBlog*, 2025, www.sidiblog.org (last visited: 04/12/2025).

3. Human Rights Courts: Integrating Science into the Protection of Fundamental Rights from Environmental and Climate Harm

Climate litigation intersects with human rights litigation, as courts around the world recognise that state inaction on climate change can endanger fundamental rights. Therefore, there is growing reliance on human rights frameworks to articulate and enforce climate obligations, as they provide claimants with a legally compelling foundation for their cases. Human rights law thus strengthens climate litigation by supplying both a normative framework and a procedural avenue through which individuals and communities can demand accountability for states and corporations.[21] Within this human rights turn, science acquires a central role, as scientific findings underpin both the factual basis of rights claims and the normative definition of state obligations.[22] The following section examines the most significant cases in the jurisprudence of the Inter-American Court of Human Rights (IACtHR) and the ECtHR which vividly illustrate the intersection between science, rights, and judicial reasoning.[23]

3.1. Inter-American Court of Human Rights

Within the Inter-American system, scientific evidence plays a constitutive role in determining state responsibility for environmental harm that threatens human rights.[24]

The IACtHR has consistently emphasised that environmental harm – particularly transboundary harm – cannot be evaluated without reference to empirical data.

This trajectory can be traced back to *Saramaka People v. Suriname,* where expert testimony on ecological damage informed the Court's valuation of the harm to Indigenous land and it therefore recognised a causal link between state-authorised logging and the community's loss of traditional territory.[25]

In its landmark Advisory Opinion OC 23-17, the Court expanded this logic, holding that states may be held accountable for transboundary environmental harm when activities originating in their territory or under

[21] For a broader discussion on human rights-based climate litigation see, *inter alia*, A. SAVARESI, J. AUZ, *Climate Change Litigation and Human Rights: Pushing the Boundaries*, in *Climate Law*, 9(3), 2019; L. SERYON, *Human Rights and Climate Litigation: Trends, Challenges, and Implications*, in *The Korean Journal of International and Comparative Law*, 13(1), 2025.

[22] For a discussion of the challenges involved in applying the human rights framework to science, particularly in the context of climate litigation, see N. SILBERT, *In search of impact: climate litigation impact through a human rights litigation framework*, in *Journal of Human Rights and the Environment*, 13(1), 2022. As the author points out, the human rights framework is primarily designed to consider direct and individually experienced harms on individuals and communities, whereas climate science often deals with complex, probabilistic, and long-term phenomena that resist straightforward translation into rights-based categories (see *supra*, para. 1). The present study seeks to explore how human rights courts have nonetheless integrated scientific knowledge into climate-related adjudication.

[23] It should also be mentioned that, on 2 May 2025, the African Court on Human and People's Rights was requested to deliver an Advisory Opinion on the human rights obligations of African states in the climate crisis context. The initiative, led by the Pan African Lawyers Union (PALU) with the support of multiple civil society organisations, can be further investigated in N.O. AFOGO, M.A. TIGRE, A. ROCHA, M. COHEN, *Defining Climate Justice in the African Human Rights System: On the Climate Advisory Opinion Request to the African Court on Human and Peoples' Rights*, in *Verfassungsblog,* 2025, www.verfassungsblog.de (last visited: 04/12/2025).

[24] For further understanding, see K. SULYOK, *Science and Judicial Reasoning: The Legitimacy of International Environmental Adjudication*, Cambridge, 2020.

[25] IACtHR, *Saramaka People v. Suriname*, Preliminary Objections, Merits, Reparations, and Costs. Judgement of November 28, 2007. Serie C No. 172, paras. 151 and 199.

their effective control or authority, cause violations of human rights outside their borders.[26] Establishing the causal link between the activities on that state's territory and the impairment of human rights abroad is a highly science-intensive matter.[27]

Among an ever-growing number of cases concerning environmental degradation and exposure to various toxic agents released by industrial activities, in which applicants refer to scientific studies to support their claim, we find *La Oroya v. Peru.* The IACtHR ruled that Peru was responsible for the violation of several human rights – including right to life, physical integrity, and to a healthy environment, enshrined in Articles 4.1, 5, 26 of the American Convention on Human Rights (ACHR)[28] – of eighty inhabitants of the small city of La Oroya, by failing to comply with its obligations to regulate and monitor the activities of a highly pollutant plant operating there.[29] The Court maintained that states should design their air and water quality standards in accordance with BAS.[30] Additionally, based on expert reports, the Court

> notes that there is scientific evidence that mere exposure to high levels of pollutants – such as those produced by the CMLO's activities – pose a risk to human health, even after such exposure to pollution has ceased and there are no traces of contamination in people's bodies due to the passage of time […] For this reason, the Court considers that the alleged victims in this case faced significant risks to their health given the many years of exposure to high levels of heavy metals and environmental pollution in La Oroya. Furthermore, there is no doubt that the main source of contamination in La Oroya was the CMLO's mining and metallurgical operations, and that the State failed in its duty to prevent high levels of pollution in the air, soil and water.[31]

The IACtHR also found Peru responsible for the breach of Articles 13 (Freedom of Thought and Expression) and 23 (Right to Participate in Government) ACHR for failing to provide the inhabitants with sufficient scientific information on the risks to which they were exposed and to involve them in decision-making processes on the matter, which aggravated their vulnerability in the face of the mining company's activities.[32]

The IACtHR's recent Advisory Opinion No. 32/25, marks a decisive evolution in this jurisprudence.[33] Extensively relying on IPCC's findings and building on its prior recognition of a right to a healthy

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[26] IACtHR, Advisory Opinion OC-23/17 of November 15, 2017 Requested by the Republic of Colombia: *The Environment and Human Rights*, *(State obligations in relation to the environment in the context of the protection and guarantee of the rights to life and to personal integrity: interpretation and scope of articles 4(1) and 5(1) in relation to articles 1(1) and 2 of the American convention on human rights)*, Series A No. 23/17 (15 November 2017), paras. 102-104.

[27] K. Sulyok, *op. cit.*, 164.

[28] Organization of American States (OAS), American Convention on Human Rights, "Pact of San Jose", Costa Rica, 22 November 1969.

[29] IACtHR, Case of *The Inhabitants of La Oroya v. Peru*. Preliminary Objections, Merits, Reparations and Costs. Judgment of November 27, 2023. Series C No. 511, para. 266.

[30] *Ibid.*, paras. 120-1.

[31] *Ibid.*, para. 205. In this regard, even before the case reached the Court, the Inter-American Commission's scientific fact-finding relied on the World Health Organisation (WHO) air-quality guidelines to determine the admissibility of the claim under Article 4 and 5 of ACHR, in Inter-American Commission on Human Rights, *the Community of La Oroya v. Peru*, Admissibility Decision, Report No. 76/09.

[32] *Ibid.*, paras. 255 and 261.

[33] IACtHR, *The Climate Emergency and Human Rights (Interpretation and scope of Articles 1(1), 2, 4(1), 5(1), 8, 11(2), 13, 17(1), 19, 21, 22, 23, 25 and 26 of the American Convention on Human Rights; 1, 2, 3, 6, 7, 9, 10, 11, 12, 13, 14,*

environment,[34] the Court articulated a distinct human right to a healthy climate.[35] The corresponding duty compels governments to proactively protect the global climate system and prevent human rights violations resulting from its disruption, by adopting science-guided measures to guarantee the protection, restoration, and regeneration of ecosystems, which should be compatible with BAS.[36]

The Court further linked this obligation to the right to science – falling within the scope of socio-economic rights protected under Article 26 ACHR – affirming that states must, *inter alia*, integrate scientific knowledge into environmental public policy to safeguard human rights effectively.[37] The IACtHR reconceptualised environmental and climate protection duties (mitigation, adaptation, equitable funding, etc.) as corollaries of the scientific consensus on climate change.

3.2. European Court of Human Rights

As it is well known, the ECtHR has progressively derived environmental safeguards from the European Convention on Human Rights (ECHR),[38] despite the absence of explicit environmental rights. Through dynamic interpretation of primarily Articles 2 (Right to life), 8 (Right to respect for private and family life), 6 (Right to a fair trial), 10 (Freedom of expression), it has held states accountable for environmental degradation.[39]

Causality and evidentiary standards have been pivotal in this evolution. Early jurisprudence, including *Fadeyeva v. Russia* and *Ledyayeva a.o. v. Russia*, illustrates the Court's use of expert reports and environmental monitoring data to infer state responsibility for hazardous pollution. In the former, the applicant submitted an expert report which specifically linked the plant's activities to increased adverse health conditions of persons residing nearby. The Court found that the medical evidence did not establish

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15, 16, 17 and 18 of the Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social and Cultural Rights "Protocol of San Salvador" and I, II, IV, V, VI, VII, VIII, XI, XII, XIII, XIV, XVI, XVIII, XX, XXIII, and XXVII, of the American Declaration of the Rights and Duties of Man). Advisory Opinion AO-32/25, Series A No. 32 (May 29, 2025).

[34] For further information, see L. D'APOTE, *Diritto a un Ambiente Salubre e Democrazia Ambientale: Il Caso La Oroya tra Dimensione Locale e Globale*, in *SIDIBlog*, 2025, www.sidiblog.org (last visited: 04/14/2025). To further investigate the extent to which the right to a healthy environment contributes to improved implementation and enforcement of climate laws, see P. DE VILCHEZ, A. SAVARESI, *The Right to a Healthy Environment and Climate Litigation: A Game Changer?*, in *Yearbook of International Environmental Law*, 32(1), 2021.

[35] Advisory Opinion AO-32/25, para. 297.

[36] *Ibid*. paras. 293 and 363.

[37] *Ibid.*, para. 485. As appropriately pointed out by some scholars, such right requires States to meaningfully include Indigenous and local knowledge in public decision-making and recognise them as equally valid alongside other scientific sources. See A. DO AMARAL JUNIOR, I. SOARES BICALHO, *Epistemic Authority and the Right to Science in AO-32/25: Legal Foundations for the Integration of Traditional Knowledge in the Inter-American System*, in *Verfassungsblog*, 2025, www.verfassungsblog.de (last visited: 04/12/2025).

[38] Council of Europe, European Convention for the Protection of Human Rights and Fundamental Freedoms, as amended by Protocols Nos. 11 and 14, 4 November 1950, ETS 5.

[39] Most notably, ECtHR, *Case of López Ostra v. Spain* (9 December 1994), Appl. No. 16798/90, ECLI:CE:ECHR:1994:1209JUD001679890; ECtHR; *Case of Guerra and Others v. Italy* (19 February 1998) Appl. No. 14967/89, ECLI:CE:ECHR:1998:0219JUD001496789; ECtHR, *Case of Taşkin and Others v. Turkey* (10 November 2004), Appl. No. 46117/99, ECLI:CE:ECHR:2004:1110JUD004611799; ECtHR, Case of *Öneryildiz v. Turkey* (30 November 2004), Appl. No. 48939/99, ECLI:CE:ECHR:2004:1130JUD004893999; ECtHR, *Case of Okyay and Others v. Turkey* (12 October 2005), Appl. No. 36220/97, ECLI:CE:ECHR:2005:0712JUD003622097.

a causal link between the pollution at her residence and her illnesses but accepted that the evidence was clear about the unsafe excessive pollution and the unfavourable climate around her home.[40] Likewise, in the latter, the Court noted that while individual health effects could not be properly quantified, scientific evidence confirmed the serious industrial pollution consequences on public health in general.[41]

Despite the fact that some scholars have observed that the inquiry of the ECtHR to assess environmental violations in science-intensive cases — governed by non-scientific proxies such as proximity to pollution sources, duration and intensity of the nuisance, domestic lawfulness of the polluting activity, or prior incidents occurred in the area — grants the Court considerable flexibility in crafting its legal reasoning, it also often led to less precise judgments and potential inconsistencies and controversial results (and different outcomes for similar facts and scientifically comparable harm, i.e. *Giacomelli v. Italy* and *Atanasov v. Bulgaria*).[42]

Notwithstanding, there are numerous examples in which the Court concluded that a defendant state had violated applicants' human rights, in particular under Art. 8, considerably referring to scientific findings.[43] The Court's engagement with climate science has become explicit in *KlimaSeniorinnen a.o. v. Switzerland*.[44] The Grand Chamber ruled that Switzerland's inadequate climate policy violated the state's positive obligations under Article 8 of the ECHR,[45] which the judges found encompassing a right for individuals and a duty for state authorities to effective protection from serious adverse effects of climate change on people's life and health.[46] Central to this reasoning was the Court's particular emphasis on the IPCC reports, requiring the state to effectively align its emissions with the 1.5°C limit set out in the Paris Agreement, noting that failure to do so would indeed breach human rights.[47] The Court ultimately translated these facts into law: it created a new right for individuals to effective protection from climate harm and a corresponding duty on states to adopt mitigation measures based on BAS. The Court also limited states' margin of appreciation in the climate context: when the nature and gravity of climate risks are scientifically established, governments' discretion in setting climate objectives must narrow. In other words, where science indicates severe risk, judicial deference to political discretion diminishes and judges will scrutinise state action more tightly.[48]

Other cases resolved before the ECtHR similarly hinged on science. In *Duarte a.o. v. Portugal a.o.*, six Portuguese youths challenged 33 governments for failing to curb emissions in line with the 1.5°C goal,

[40] ECtHR, *Case of Fadeyeva v. Russia* (9 June 2005), Appl. No. 55723/00, ECLI:CE:ECHR:2005:0609JUD005572300, para. 45.

[41] ECtHR, *Case of Ledyayeva, Dobrokhotova, Zolotareva and Romashina v. Russia* (26 October 2006), Appl. Nos. 53157/99, 53247/99, 53695/00 and 56850/00, ECLI:CE:ECHR:2006:1026JUD005315799, para. 90.

[42] K. SULYOK, *op. cit.*

[43] ECtHR, *Affaire Tătar c. Roumanie* (27 January 2009), Appl. No. 67021/01, ECLI:CE:ECHR:2009:0127JUD006702101, paras. 25, 31-2, 95. For further details, see D.L. SHELTON, *Developing Substantive Environmental Rights*, in *Journal of Human Rights and the Environment*, 1(1), 2010.

[44] *Supra*, note 15. For a general examination of the case, see A. HÖSLI, M. REHMANN, *Verein KlimaSeniorinnen Schweiz and Others v. Switzerland: the European Court of Human Rights' Answer to Climate Change*, in *Climate Law*, 14(3-4), 2024.

[45] *Ibid.*, paras. 573-4.

[46] *Ibid.*, para. 519.

[47] *Ibid.*, paras. 429 and 436.

[48] *Ibid.*, para. 543.

reiterating the arguments made in the application form and further relied on the more recent reports of the IPCC, and other scientific reports including, *inter alia*, the UN Environment Programme, 'Emissions Gap Report 2022'.[49] Interveners, including the Centre for Climate Repair and Oxfam, have urged tribunals to rely on "the most up-to-date and best available scientific evidence", particularly regarding children's disproportionate vulnerability to climate-related health harms emphasizing that children face disproportional harms under warming scenarios.[50] Although dismissed on procedural grounds, the proceedings demonstrate a by now consolidated consensus among litigants and interveners that IPCC assessments constitute the baseline for determining state responsibility. The applicants and respondent states alike framed their arguments in scientific terms – despite debating methodologies and emissions accounting – illustrating how climate science structures the argumentative space of climate litigation.

4. Beyond Human Rights: The Judicial Uses of Science Across Jurisdictions

4.1. International Interpretations of the Normative Function of Science

On the international stage, two other recent advisory opinions signal a maturation of BAS as the evidentiary foundation and normative benchmark for defining states' duties of prevention, mitigation, and adaptation.

Firstly, the Advisory Opinion that the International Tribunal of the Law of the Sea (ITLOS) released back in May 2024, constitutes a milestone in the judicial recognition of scientific authority. Responding to a request by the Commission of Small Island States (COSIS), the Tribunal examined how obligations under the United Nations Convention on the Law of the Sea (UNCLOS)[51] apply to anthropogenic GHG emissions.[52] In a section explicitly titled "Scientific aspects", ITLOS acknowledged scientific expertise centrality, recalling that the UN General Assembly, in Resolution 43/53 (1988), endorsed the joint action of the WMO and UNEP in establishing IPCC.[53] The Tribunal further notes that such body, now comprising 195 member countries, enjoys broad institutional legitimacy,[54] and that most participants in the proceeding explicitly relied on IPCC reports as authoritative assessments of climate science, without questioning their evidentiary value.[55]

[49] ECtHR, case of *Duarte Agostinho and Others against Portugal and 32 Others* (9 April 2024), App. No 39371/20, ECLI:CE:ECHR:2024:0409DEC003937120, para. 25.
[50] *Ibid.*, para. 157.
[51] UN General Assembly, Convention on the Law of the Sea, 10 December 1982.
[52] Request Submitted to the Tribunal by the Commission of Small Island States on Climate Change and International Law, Advisory Opinion (21 May 2024) [2024] ITLOS Rep, www.itlos.org (last visited: 04/12/2025). For more detailed analyses see K. BARTENSTEIN, *The "Integrative Approach" in the ITLOS Climate Change Advisory Opinion: An Essay in Honor of Aldo Chircop*, in *Ocean Yearbook Online*, 39(1), 2025; A. LONGO, *Passing on the baton: a few reflections on the applicable law in the ITLOS Advisory Opinion on climate change and ocean acidification*, in *SIDIBlog*, 2024, www.sidiblog.org (last visited: 04/12/2025).
[53] General Assembly Resolution 43/53, Protection of Global Climate for Present and Future Generations of Mankind, A/RES/43/53 (6 December 1988).
[54] *Supra*, note 52, para. 47.
[55] *Ibid*., para. 51.

Building on such consensus, in this case regarding climate change and ocean acidification, ITLOS identified the duty, framed as due diligence obligation,[56] to prevent and protect the marine environment from anthropogenic GHG emissions under Articles 192 and 194(1) UNCLOS.[57] Clearly, science becomes the essential basis for defining the measures states must take to counter marine pollution from anthropogenic GHG emissions.[58]

However, the Tribunal refrained from defining BAS substantively, instead equating it with the IPCC's collective assessments and reflecting blind and unquestioning trust in the IPCC's authority, assuming its findings as uncontested fact.

Reflecting ITLOS' approach, the ICJ grounded its reasoning in IPCC's findings in its long-awaited 2025 Advisory Opinion, especially following consultations with IPCC experts, whom it described as providing "the best available science on the causes, nature and consequences of climate change".[59]

Throughout the opinion, the ICJ framed *due-diligence* standard in scientific terms, holding that states are required to take preventive action even amid scientific uncertainty and undertake thorough risk and impact assessments for proposed activities within their jurisdiction that may contribute to climate harm, based on BAS.[60] It emphasised that inaction, or failure to meet Paris-based plans, "may constitute an internationally wrongful act" because it violates the duty of care derived from scientific knowledge.[61]

For mitigation obligations stemming from the Paris Agreement, the standard is stringent as IPCC findings prove that climate risks escalate with each increment of warming (IPCC, 2023 *Summary for Policymakers*, p. 14, Statement B.2).[62]

For adaptation obligations, the ICJ held that Article 7 of the Paris Agreement must be implemented through measures that reinforce adaptive capacity and reduce vulnerability to climate change in accordance with BAS.[63] Moreover, under the no-harm rule in customary international law, the judges reaffirmed that due diligence standard "may also become more demanding in the light of new scientific or technological knowledge. The Court is aware that scientific research on climate change is well

[56] *Ibid.*, paras. 441(3)(c) and 441(4)(c). As to the nature of the obligations established, critiques have been advanced: see, among others, D. DIMITRAKOS, *The ITLOS Advisory Opinion on Climate Change: A Brief Review*, in *American Society of International Law*, 29(5), 2025, www.asil.org (last visited: 04/12/2025).

[57] *Ibid.*, para. 189. Such duty must be informed by a range of factors, among which BAS plays a crucial role (para. 243).

[58] *Ibid*. paras. 207-9. See also M. TORRE-SCHAUB, *Why Climate Science Matters for International Law*, in *Verfassungsblog*, 2024, www.verfassungsblog.de (last visited: 04/12/2025).

[59] *Supra*, note 17, paras. 33 and 74. In a dedicated section on "General Context and Scientific Aspects" (paras. 50-87), the Court reiterated that the UN GA Resolution 43/53 had endorsed the creation of the IPCC which currently consists of 195 member countries as a sign of universal legitimacy (paras. 58-60). Also, in para. 278, the Court added that "The determination of 'significant harm to the climate system and other parts of the environment' must take into account the best available science, which is currently to be found in the reports of the IPCC."

[60] This approach, however, is not new in the ICJ jurisprudence, particularly in the early articulation of the duty of prevention. Reference can be made to the *Trail Smelter Arbitration* (United States v. Canada), which highlights the role of science as the tool through which the existence of a risk arising from a given activity is first established, thereby giving rise to the state's obligation to adopt preventive measures aimed at avoiding its occurrence. For a detailed analysis, see C. RAGNI, *op. cit.*, 68.

[61] *Supra*, note 17, paras. 281-299.

[62] *Ibid.*, para. 254.

[63] *Ibid*., para. 258.

developed" recognising IPCC reports as "comprehensive and authoritative restatements of the best available science".[64]

Perhaps most notably, the ICJ joined the Inter-American Court in formally recognising the right to a healthy environment as a universal human right, "an essential prerequisite for the enjoyment of all human rights" and affirmed that states' obligations to protect the climate system stem from fundamental rights protections.[65] In doing so, the Court positioned science as the factual precondition for rights protection: empirical data on temperature and sea-level rise, and biodiversity loss provide the basis for identifying violations.

While the Court's engagement with scientific data represents a significant step toward integrating empirical reasoning into international law, methodological criticalities remain.[66]

These two Advisory Opinions reveal both the normative centrality and the epistemic vulnerability of science in international environmental law. On the one hand, they solidify the function of BAS as a source of interpretative authority in international adjudication, shaping both the definition and evolution of legal obligations. On the other, the judicial bodies did not articulate criteria for identifying BAS beyond reference to IPCC assessments.

By contrast, the IACtHR provided a more dynamic interpretation in its Opinion. While equally recognising the IPCC as the current benchmark for authoritative science, the Court went further by listing the aspects constituting the concept of BAS.[67]

Collectively, the three opinions converge on the argument that due diligence in climate governance is no longer a purely legal standard, but a science-informed duty of care. Yet, while ITLOS and ICJ have used BAS primarily as a parameter for assessing the legality of state conduct, IACHR also articulated an interpretative framework for identifying what counts as BAS, acknowledging science as a living and self-correcting process that requires states – and judges – to continually reassess their obligations in light of new evidence.

4.2. Insights from Domestic Adjudication

Landmark domestic decisions, particularly from the Netherlands and Germany, mark a shift from judicial deference to evidence-based intervention.[68]

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[64] *Ibid*., para. 284.

[65] *Ibid.*, para. 393.

[66] See, *ex multis*, L.C. LIMA, *The Evidential Weight of Experts before the ICJ: Reflections on the Whaling in the Antarctic Case*, in *Journal of International Dispute Settlement*, 6(3), 2015; L. BOISSON DE CHAZOURNES, M.M. MBENGUE, R. DAS, G. GROS, *One Size does not Fit All—Uses of Experts before International Courts and Tribunals: An Insight into the Practice*, in *Journal of International Dispute Settlement*, 9(3), 2018; C. RAGNI, *op. cit*.; K. SULYOK, *op. cit*.

[67] *Supra*, note 33, para. 486. Among the criteria set forth, there are being the most up-to-date, verifiable and reproducible science, based on peer-reviewed methodologies, practices and internationally recognised scientific standards; undergoing review processes by high quality peers or equivalent organizations; clearly communicating the uncertainties is through the publication of the non-confidential data and models used to reach its conclusions; accurately presenting its sources of information.

[68] Also, the *Juliana v. United States* case exemplifies the heavy reliance on expert testimony grounded in IPCC data, "since the assessment reports from the Intergovernmental Panel on Climate Change (IPCC) had been accepted by the US Government, its findings were taken as true. The question was then how to reason from those general findings to the specific case at issue". Indeed, plaintiffs faced the challenge in establishing a causal connection to

In the seminal *Urgenda* case, defined as a striking example of "courts borrowing the epistemic authority of external norms",[69] the Dutch Supreme Court famously compelled the Netherlands to cut emissions by 25% below 1990 levels by 2020.[70]

From the outset, the judiciary incorporated climate science, specifically citing IPCC reports and the consensus that Annex I countries of the United Nations Framework Convention on Climate Change needed to achieve 25% to 40% emissions reductions to keep global warming below 2°C.[71]

Drawing on these reports, the Court quantified the gap between the government's target and the scientifically required goal to prevent dangerous climate change, finding the former insufficient to meet the state's contribution toward the UN goal.[72]

Urgenda powerfully shows how policy recommendations embedded in scientific literature can carry normative weight in legal proceedings.

Similarly, in *Neubauer v. Germany*, the German Federal Constitutional Court grounded the right to climate protection directly in scientific metrics.[73] The Court agreed with plaintiffs that the 2030 target set in the Federal Climate Protection Act (KSG) was insufficient to comply with the Paris Agreement goal and adopted a carbon-budget approach, a scientific metric quantifying allowable CO_2 emissions. It held that Article 20a of the Basic Law (*Grundgesetz* – GG) read in conjunction with fundamental rights of life and human dignity, required the legislature to distribute the remaining carbon budget fairly over time and generations. In powerful terms, the Court stated that "one generation must not be allowed to consume large portions of the CO2 budget (…) if this would involve leaving subsequent generations with a drastic reduction burden".[74] The German court thus struck down parts of the 2019 climate law for lacking clear paths after 2030, invoking intergenerational equity grounded in CO_2 budget science.[75]

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individual injuries, as they argued that federal fossil-fuel policies violated their constitutional rights by contributing to dangerous climate change. Although dismissed on procedural grounds, "the Court accepts the factual allegations in the complaint as true. Plaintiffs have alleged that defendants helped create the current climate crisis, that defendants acted with full knowledge of the consequences of their actions, and that defendants have failed to correct or mitigate the harms they helped create in deliberate indifference to the injuries caused by climate change. Plaintiffs may therefore proceed with their substantive due process challenge to defendants' failure to adequately regulate CO2 emissions and defendants' motion to dismiss is denied as to this issue.", United States District Court, District of Oregon, *Juliana v. United States*, Case No. 6:15-cv-01517-AA (29 December 2023), 44. On September 23, 2025, the plaintiffs filed a petition to the Inter-American Commission on Human Rights against the United States government for climate-related human rights violations. For a more targeted discussion of U.S. litigation, see M.L. BANDA, *Climate Science in the Courts: A Review of U.S. and International Judicial Pronouncements*, in *Environmental Law Institute*, 2020.

[69] M. LEE, *The Sources and Challenges of Norm Generation in Tort Law*, in *European Journal of Risk Regulation*, 9(1), 2018, 40. In general, reference should be made to this source to understand the courts engagement with scientific and technical expertise as material to legally construct the content of a duty.

[70] *Supra*, note 14.

[71] *Supra*, note 14 paras. 7.2.1-7.2.11.

[72] *Ibid.*, para. 7.5.

[73] Bundesverfassungsgericht (BVerfG) (Federal Constitutional Court), *Neubauer et al. v. Germany*, (24 March 2021), BvR 2656/18/1, BvR 78/20/1, BvR 96/20/1, BvR 288/20/1. English version in www.climatecasechart.com (last visited: 04/12/2025).

[74] *Ibid.*, para. 192.

[75] For the partially different conclusions the two judicial bodies reached see J. DE AUGUSTINIS, *Judicial approaches to science and the procedural legitimacy of climate rulings: Comparative insights from the Netherlands and Germany*, in *European Law Journal*, 29(3-6), 2024. In particular, whereas the Dutch court proactively used scientific evidence

A more recent decision highlights the challenge of translating collective scientific knowledge into specific legal duties for diverse actors. Building on *Urgenda,* the *Milieudefensie v. Shell* case saw several associations extend the argument – anchored to Paris Agreement's goals and scientific evidence – that Dutch government's inadequate action on climate change violated a duty of care to its citizens to private actors, which in the case at hand was Shell, having a duty of care to take action to reduce its GHG emissions too.[76] While the Hague District Court ordered Shell a 45% emissions cut by 2030, as compared to 2019 levels, the Court of Appeal found that Shell could not be subjected to such a specific reduction requirement.

Even though it found that companies contributing to climate change actually bear a duty to limit their emissions, even without explicit (public law) regulations,[77] there is insufficient scientific consensus on a precise reduction rate for individual companies. Scientific reports indeed indicate that global cuts – especially in oil and gas combustion – are necessary to limit warming to 1.5°C, but they assume an average global reduction in all sectors, rather than one specific company alone. The Court found businesses retaining discretion in selecting emission-reduction strategies, provided these are consistent with the objectives of the Paris Agreement.[78]

This case, although still pending before the Dutch Supreme Court, shows that while science provides the irrefutable foundation of corporate responsibility, successfully establishing the existence of a legal duty (to act to cut emissions), it cannot yet supply the precise quantitative standards for judicial enforcement. Translating collective global targets into differentiated legal duties for diverse actors remains the defining challenge for climate-related litigation.

5. Discussion and Concluding Remarks

The analysis reveals a progressive evolution in the judicial use of science across human rights, international, and domestic fora.

Human rights bodies, such as the IACtHR and the ECtHR, increasingly use scientific evidence evaluatively, as a normative benchmark for assessing state's compliance with their obligations. In the IACtHR's 2025 Advisory Opinion, BAS is framed as essential for interpreting states' positive obligations to prevent foreseeable human rights harms, recognising science as the foundation of rights protection. In the ECtHR's *KlimaSeniorinnen* ruling, the Court relied on IPCC findings to define the scientific parameters of effective climate action and narrowed the state's margin of appreciation in determining appropriate measures to

to compel the government to implement specific mitigation targets, the German Constitutional Court adopted a more cautious approach, affording policymakers a margin of discretion to autonomously define reduction trajectories through 2030.

[76] Court of Appeal (Gerechtshof Den Haag), Case No. 200.302.332/01 (12 November 2024), C/09/571932 / HA ZA 19-379, ECLI:NL:GHDHA:2024:2099, ECLI:NL:GHDHA:2024:2100. Plaintiffs' arguments are based, once again, on science – UNEP and IEA reports (paras. 3.10 and 3.11) – to substantiate that climate scientists agree that large-scale investments in new oil and gas fields are neither desirable nor necessary to meet the demand for oil and gas in a scenario where warming is limited to well below 2°C, as agreed in the Paris Agreement.

[77] *Ibid.*, para. 7.27. Such responsibility is informed is informed by the standard of care under Dutch law, Articles 2 and 8 ECHR and soft law principles such as the UN Guiding Principles on Business and Human Rights and the OECD Guidelines for Multinational Enterprises on Responsible Business Conduct, which Shell adhere to, paras. 7.19-7.22

[78] *Ibid*., para. 7.111.

combat climate change. The Court transformed scientific empirical knowledge into a criterion for evaluating the opportunity and proportionality of state action to the seriousness of climate risks.

While they may derive rights differently – the IACtHR extrapolating a right to a healthy environment from Article 26 ACHR, and then an autonomous right to a stable climate in 2025 Advisory Opinion, versus the ECHR still largely framing climate harms under Articles 8 or 2 ECHR – both use empirical findings to delineate the scope of state duties, identify victims, and highlight procedural safeguards.

International judicial bodies have employed science in a more constructive and systemic manner. Scientific reports and expert submissions inform the definition or evolution of normative principles, thus embedding scientific rationality into the formation of international environmental law itself. In its 2024 Advisory Opinion, ITLOS refrained from substantively defining BAS but equated it with the IPCC's assessments, making science the essential basis for defining measures to counter marine pollution from anthropogenic GHG emissions under UNCLOS. Likewise, the ICJ's 2025 Advisory Opinion described IPCC experts as providing BAS and emphasised that inaction failing to meet Paris-based goals may constitute an internationally wrongful act, violating a duty of care derived from scientific knowledge.

At the domestic level, courts have used science in a more operational way. Domestic courts borrow scientific benchmarks – carbon budgets, emission pathways, risk probabilities – as normative yardsticks for assessing whether governments have fulfilled their constitutional or statutory obligations.

In *Urgenda*, the Dutch Supreme Court used IPCC reports to quantify the gap between the government's reduction target and the scientifically required goal and to compel national authorities to stricter emissions cuts. In *Neubauer*, the German Federal Constitutional Court relied on IPCC pathways and carbon budgets to recalibrate emission-reduction quotas, ordering the legislature to set clear provisions for reduction targets from 2031 onward. Science here functions as quantitative tool, enabling courts to translate broad constitutional or statutory duties into concrete mitigation benchmarks. In other words, we could say that domestic courts employ science to define *how much* states must do; human rights courts to determine *how well* states must act; and international tribunals to construct *what* constitutes lawful conduct.

However, this judicial reliance on science is not absolute, especially regarding corporations. In *Milieudefensie v. Shell*, the Dutch Court of Appeal showed greater caution. While recognising a corporate duty of care aligned with the Paris Agreement, it also acknowledge the current absence of scientific consensus on company-specific reduction benchmarks.

In any case, this development is not without controversy. Courts frequently lack in-house scientific expertise and must rely on external scientific assessments, which are themselves products of politically mediated processes: "the politicization of the science and the socio-political construction of scientific consensus in the climate area render any attempt to rule impartially on the key scientific disputes futile and suspect".[79]

Consensus does not necessarily equal truth and certainly does not exhaust science. "In politics, consensus is required to achieve results and progress. In science, however, the debate is never closed, although it

[79] See J. SETZER, L.C. VANHALA, *Climate change litigation: A review of research on courts and litigants in climate governance*, in *WIREs Climate Change*, 10(3), 2019. To quote Bailey, climate science is "the most politicized science of our time". R. BAILEY, *End of Doom*, New York, 2015, 7-8.

may be dormant for some time. Even a widely accepted scientific theory can be falsified at any point in time".[80]

Furthermore, climate science operates through probabilities and uncertainty at various levels of the causal chain. Science and law have different standards when it comes to cause-effect relation: scientific reasoning may infer causation from correlation or probabilistic attribution, but courts apply stricter evidentiary requirements. This epistemic mismatch explains why judicial outcomes may diverge even when based on identical factual and scientific premises.

Despite these limitations, the review of case law confirms that from the Hague to Strasbourg, from San José to Hamburg, judges have been integrating empirical knowledge directly into the definition of legal duties.

Looking ahead, the growing judicial reliance on scientific expertise calls for a more structured approach to BAS. Procedurally, judges should interpret due diligence as encompassing an obligation to actively engage with scientific evidence. States, and corporations by extension, must regularly update their policies in accordance with evolving scientific knowledge, while courts, in turn, should verify whether scientific assessments have been duly considered in the environmental decision-making process, including the disclosure of any evidence underpinning deviations from established findings and the possibility for affected communities to access and contest scientific data. From an internal technical perspective, judges should develop clear legal standards and methodologies for discerning BAS, weighing competing scientific evidence, and translating probabilistic scientific attribution into legal determinations of liability.

The recent ITLOS and ICJ's advisory opinions expose the risk of a quasi-mechanical use of scientific consensus – which, it is worth repeating, is politically shaped – that overlooks the evolving and inherent contestable nature of scientific knowledge. Substantively, BAS informs the very content of the duty of care. States are expected not merely to avoid harm but to adopt the level of precaution and mitigation that science deems necessary to prevent foreseeable climate risks. Yet, as science progresses, so too must the stringency of this standard evolve. Therefore, when scientific evidence demonstrates a serious threat to fundamental rights posed by climate impacts, judicial deference to political discretion must diminish proportionally. Courts need not to replace policy judgements with scientific determinism, but they must ensure that the margin of appreciation does not extend to disregard of credible science. In this sense, the judicial task is to ensure that the normative response to climate change remains anchored in reasoned engagement with the evolution of knowledge.

[80] L. BERGKAMP, *Adjudicating scientific disputes in climate science: the limits of judicial competence and the risks of taking sides*, in *Environmental Liability, Law, Policy and Practice*, 2015, 90.