Exhibit 1

Letter from Cooley LLP, to Rep. Jim Jordan, Chairman,
H. Comm. on the Judiciary (Mar. 20, 2026)

Cooley

Susanne Sachsman Grooms
[redacted]

CONFIDENTIAL
Via Email

March 20, 2026

The Honorable Jim Jordan
Chairman
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

The Honorable Darrell Issa
Chairman, Subcommittee on Courts,
Intellectual Property, Artificial Intelligence,
and the Internet
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

The Honorable Wesley Hunt
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

Dear Chairman Jordan, Chairman Issa, and Congressman Hunt:

My firm, Cooley LLP, and I represent the Environmental Law Institute ("ELI") in response to your letter of August 29, 2025, regarding its Climate Judiciary Project ("CJP"). Over the past several months, ELI has welcomed the opportunity to answer your questions and has worked diligently to respond to your requests.

Following ELI's September 8, 2025 production of documents, Majority staff identified a handful of priorities and requested additional information about those matters. ELI produced additional documents on October 10 and October 31, 2025. Among other things, ELI identified events where ELI reimbursed partner organizations – the Federal Judicial Center (FJC) or National Judicial College (NJC) – for judges' travel costs that had been approved and paid for by FJC or NJC. ELI also identified the speakers at those events, as requested by Majority staff. Because ELI was identifying individual speakers, whose privacy and safety could be put at risk through public release of their names, ELI respectfully requested that the Committee treat this information as confidential and not release these names outside of the Committee.

Regarding Majority staff's request that ELI list the names of judges attending these events, ELI respectfully requested that the Committee seek this information from FJC and NJC. As explained in our letter of October 31, 2025, these entities are responsible for the continuing education of judges and they, not ELI, were primarily responsible for inviting judges to these judicial education events. As a result, they are in the best position to provide accurate information about judicial participation to the Committee and to raise any equities, including any privacy or security concerns, that they might have.

Toward the end of February, and after engaging directly with FJC to request the names of judges attending its events, Majority staff renewed its request that ELI provide whatever information it has regarding which federal judges attended judicial education events, even if that information is incomplete or inaccurate. Majority staff expanded this request beyond the priority events previously identified by ELI, to demand a list of federal judges participating in any judicial education event involving CJP, which we understand to mean any event from April 1, 2019 through the date of your letter.

In response to this renewed request, we again reminded Majority staff that because ELI was not responsible for managing invitations or logistics for these events, information it has related to judicial attendance at any specific event might be incomplete or inaccurate. We also noted that the judicial education entities who organized the events are better positioned to negotiate the competing equities implicated by the request and to reach appropriate accommodation with the Committee. Majority staff took the position that, if ELI failed to confirm within the week that it would provide the requested names of federal judges, ELI would be at an impasse with the Committee that warranted further escalation.

It is our understanding that FJC considers information regarding the identities of judges who attend their education events as confidential and that FJC has refused to produce this information to the Committee to date, despite the Committee's request for it. As a charitable non-profit organization, ELI lacks the resources and bargaining power of the co-equal branches of government or the constitutional prerogative to negotiate a compromise that balances the branch's respective interests. *See*, *e.g.*, *Trump v. Mazars USA, LLP*, 591 U.S. 848 (2020) (recognizing the need for careful balancing of institutional interests when congressional requests to third parties implicate the interests and independence of a co-equal branch of government). Now facing the threat of congressional subpoena, ELI feels that it has no choice but to produce the information demanded by the Majority, and therefore is providing with this letter the names of federal judges who may have attended the pilot program events identified in our letter of October 31, 2025. We are continuing to work with ELI to identify and review materials related to additional CJP judicial education events attended by federal judges and training materials used at any such events.

While FJC remains better positioned to provide this information to the Committee, ELI nonetheless has sought in good faith to respond to the Committee's requests, and the information provided with this letter represents ELI's current understanding of the federal judges who may have attended these events based on a good-faith search for responsive information. We respectfully request that the Committee treat this information as confidential and negotiate with FJC prior to releasing these names beyond the Committee. Among other things, this will afford FJC the opportunity to raise corrections to this list as well as safety or privacy concerns and suggest potential safeguards, which are important considerations given the alarming increase in harassment, threats, and violence directed at judges over the past few years.

Along with these responses, and as part of ELI's ongoing cooperation with the Committee's requests, we are also producing with this letter the versions of the presentations used at these FJC pilot program events that are in ELI's possession at ELI-HJC-0000941 to at ELI-HJC-0001335. Because ELI was not responsible for presenting these materials at the events, ELI cannot verify whether or not these documents reflect final versions of these materials or whether these materials were actually presented at the events.

In providing documents and information in response to your requests, our client does not waive, nor does it intend to waive, any of its rights or privileges with respect to this inquiry, including any applicable attorney-client, work product, or other evidentiary privilege, or any objection to your requests. We request that you notify us prior to any public release of our client's documents or information within them to provide us with an opportunity to identify specific sensitivities and request redactions.

Sincerely,



Susanne Sachsman Grooms

Enclosures

cc: The Honorable Jamie Raskin, Ranking Member

The Honorable Henry C. "Hank" Johnson, Ranking Member, Subcommittee on Courts, Intellectual Property, Artificial Intelligence, and the Internet

March 20, 2026

FEDERAL JUDICIAL CENTER PILOT PROGRAM EVENTS

The following events comprise the five pilot programs FJC cosponsored with CJP in collaboration with the American Association for the Advancement of Science (AAAS). As FJC was responsible for inviting participants, it remains better positioned to provide the Committee with information about judicial participation in these events. ELI nonetheless has sought in good faith to respond to the Committee's requests, and the information provided with this letter represents ELI's current understanding of the federal judges who may have attended these events based on a good-faith search for responsive information. It is our understanding that FJC considers this information confidential and that FJC refused to produce it to the Committee pursuant to the Committee's request. We therefore respectfully request that the Committee treat this information as confidential and negotiate with FJC prior to releasing these names beyond the Committee, to appropriately consider the accuracy of this information, the equities of the judicial branch, and the potential safety concerns of the judges.

Following a reasonable, good-faith search of its records, ELI has also identified the presentation materials for the FJC pilot programs in its possession, as listed below. Documents identified to date are being produced with this letter at ELI-HJC-0000941 to at ELI-HJC-0001335. Because ELI was not responsible for presenting these materials at the events, ELI cannot verify that these documents reflect final versions of these materials or that these materials were actually presented at the events.

Toward a Climate Science Curriculum: Pilot Program Launch
New York, NY, June 28, 2019

Speakers:
- Dana Chipman, Federal Judicial Center
- Michael Gerard, Columbia Law School
- Radley Horton, PhD, Columbia University
- John Pendergrass, Environmental Law Institute
- Deborah Runkle, American Association for the Advancement of Science
- Sandra Nichols Thiam, Environmental Law Institute

Slides in ELI Possession:
- Michael Gerrard – "Overview of the Climate Change Litigation Landscape"
- Radley Horton – "Climate Science for Judges"

Participants:
- Hon. Frank Bailey, U.S. Bankruptcy Court, District of Massachusetts
- Hon. Mildred Caban, U.S. Bankruptcy Court, District of Puerto Rico
- Hon. Margaret Cangilos-Ruiz, U.S. District Court, Northern District of New York
- Hon. Paul Davison, U.S. District Court, Southern District of New York
- Hon. Joseph Dickson, U.S. District Court, District of New Jersey
- Hon. Richard Eaton, U.S. Court of International Trade
- Hon. Cynthia Eddy, U.S. District Court, Western District of Pennsylvania

Confidential

- Hon. Julio Fuentes, U.S. Court of Appeals for the Third Circuit
- Hon. William Garfinkle, U.S. District Court, District of Connecticut
- Hon. Nina Gershon, U.S. District Court, Eastern District of New York
- Hon. Page Kelley, U.S. District Court, District of Massachusetts
- Hon. Jerrold Poslusny, U.S. District Court, District of New Jersey
- Hon. Frederic Scullin, U.S. District Court, Northern District of New York
- Hon. D. Brooks Smith, U.S. Court of Appeals for the Third Circuit

Toward a Climate Science Curriculum: Pilot Program Launch
Washington, DC, July 12, 2019

Speakers:
- Hon. Jeremy Fogel, Berkeley Judicial Institute
- Michael Gerrard, Columbia Law School
- Robert Glicksman, George Washington University Law School
- Scott Fulton, Environmental Law Institute
- Stephen Pacala, PhD, Princeton University
- Deborah Runkle, American Association for the Advancement of Science

Slides in ELI Possession:
- Michael Gerrard – "Overview of the Climate Change Litigation Landscape"
- Stephen Pacala – "Introduction to Climate and Climate Change"

Participants:
- Hon. Joseph Anderson, Jr., U.S. District Court, District of South Carolina
- Hon. Cameron Currie, U.S. District Court, District of South Carolina
- Hon. Nancy B. Firestone, U.S. Court of Federal Claims
- Hon. Arthur Harris, U.S. District Court, District of Ohio
- Hon. Joel Hoppe, U.S. District Court, District of Virginia
- Hon. Malcolm Howard, U.S. District Court, District of North Carolina
- Hon. Pauline Newman, U.S. Court of Appeals for the Federal Circuit
- Hon. Eugene Siler, U.S. Court of Appeals for the Sixth Circuit

Toward a Climate Science Curriculum: Pilot Program Launch
Berkeley, CA, September 13, 2019

Speakers:
- Ann Carlson, UCLA School of Law
- Jordan Diamond, UC Berkeley School of Law
- Christopher Field, PhD, Stanford University
- Hon. Jeremy Fogel, Berkeley Judicial Institute
- John Pendergrass, Environmental Law Institute
- Hon. Ronald B. Robie, California Court of Appeals
- Deborah Runkle, American Association for the Advancement of Science

- Hon. Michael Wilson, Hawaii Supreme Court

Slides in ELI Possession:
- Ann Carlson – "Climate Change Litigation"
- Christopher Field – "Climate Change Science & Impacts"

Participants:
- Hon. Cynthia Bashant, U.S. District Court, Southern District of California
- Hon. Peter Carroll, U.S. District Court, Central District of California
- Hon. William Fletcher, U.S. Court of Appeals for the Ninth Circuit
- Hon. Theresa Fricke, U.S. District Court, Western District of Washington
- Hon. Michael Hegarty, U.S. District Court, District of Colorado
- Hon. Elizabeth Laporte, U.S. District Court, North District of California
- Hon. Robert Lasnik, U.S. District Court, Western District of Washington
- Hon. Ramona Manglona, U.S. District Court, District of Northern Mariana Islands
- Hon. William Orrick, U.S. District Court, Northern District of California
- Hon. Michael Seabright, U.S. District Court, District of Hawaii
- Hon. Suzanne Segal, U.S. District Court, Central District of California
- Hon. William Shubb, U.S. District Court, Eastern District of California
- Hon. Michael Simon, U.S. District Court, District of Oregon
- Hon. Deborah Smith, U.S. District Court, District of Alaska
- Hon. Nina Wang, U.S. District Court, District of Colorado
- Hon. Michael Wilner, U.S. District Court, Central District of California
- Hon. Frank Zapata, U.S. District Court, District of Arizona

Toward a Climate Science Curriculum: Pilot Program Launch
Chicago, IL, December 6, 2019

Speakers:
- David Archer, PhD, University of Chicago
- Joe Cecil, UC Berkeley School of Law
- Emily Cloyd, American Association for the Advancement of Science
- Daniel Farber, UC Berkeley School of Law
- John Pendergrass, Environmental Law Institute
- Mark Templeton, University of Chicago Law School
- Sandra Nichols Thiam, Environmental Law Institute
- Jalonne White-Newsome, PhD, The Kresge Foundation
- Donald Wuebbles, PhD, University of Illinois

Slides in ELI Possession:
- David Archer – "Global warming within the context of the Earth's natural carbon cycle"
- Jalonne White-Newsome – "Climate Science & Health for Judges"
- Don Wuebbles – "Our Changing Climate: The Science"

Participants:
- Barry Bryant, U.S. District Court, Western District of Arkansas
- Hon. Jacqueline Cox, U.S. District Court, Northern District of Illinois
- Hon. Scott Dales, U.S. District Court, Western District of Michigan
- Hon. Thomas Durkin, U.S. District Court, Northern District of Illinois
- Hon. Willie Epps, Jr., U.S. District Court, Western District of Missouri
- Hon. Brian Fenimore, U.S. District Court, Western District of Missouri
- Hon. Sheila Finnegan, U.S. District Court, Northern District of Illinois
- Hon. Gabriel Fuentes, U.S. District Court, Northern District of Illinois
- Hon. David Hamilton, U.S. Court of Appeals for the Seventh Circuit
- Hon. Jerome Kearney, U.S. District Court, Eastern District of Arkansas
- Hon. Young Kim, U.S. District Court, Northern District of Illinois
- Hon. Robert Kressel, U.S. District Court, District of Minnesota
- Hon. Thomas Lynch, U.S. District Court, Northern District of Illinois
- Hon. Ann Montgomery, U.S. District Court, District of Minnesota
- Hon. Michael Nelson, U.S. District Court, District of Nebraska
- Hon. Thomas Perkins, U.S. District Court, Central District of Illinois
- Hon. Lawrence Piersol, U.S. District Court, District of South Dakota
- Hon. Charles Rendlen, U.S. District Court, Eastern District of Missouri
- Hon. Karen Schreier, U.S. District Court, District of South Dakota

Toward a Climate Science Curriculum: Pilot Program Launch
Atlanta, GA, March 13, 2020

Speakers:
- Rafael L. Bras, PhD, Georgia Institute of Technology
- Kim Cobb, PhD, Georgia Institute of Technology
- Michael Gerard, Columbia Law School
- Karen Levy, PhD, Emory University
- John Pendergrass, Environmental Law Institute
- Deborah Runkle, American Association for the Advancement of Science
- Marshall Shepherd, PhD, University of Georgia
- Sandra Nichols Thiam, Environmental Law Institute

Slides in ELI Possession:
- Kim Cobb – "Climate change, oceans, and our coasts"
- Michael Gerrard – "Climate Change Litigation In the United States"
- Karen Levy – "Climate Change & Health"

Participants:
- Hon. Joseph Anderson, Jr., U.S. District Court, District of South Carolina
- Hon. Paul Baisier, U.S. District Court, Northern District of Georgia
- Hon. Patricia Barksdale, U.S. District Court, Middle District of Florida

- Hon. Debra Brown, U.S. District Court, Northern District of Mississippi
- Hon. Helen Burris, U.S. District Court, District of South Carolina
- Hon. Paul Byron, U.S. District Court, Middle District of Florida
- Hon. Joseph Callaway II, U.S. District Court, Eastern District of North Carolina
- Hon. Virginia Covington, U.S. District Court, Middle District of Florida
- Hon. Marina Garcia Marmolejo, U.S. District Court, Southern District of Texas
- Hon. Robert Hinkle, U.S. District Court, Northern District of Florida
- Hon. David Jones, U.S. District Court, Southern District of Texas
- Hon. Gary Jones, U.S. District Court, Northern District of Florida
- Hon. Dena Palermo, U.S. District Court, Southern District of Texas
- Hon. Sage Sigler, U.S. District Court, Northern District of Georgia
- Hon. Jerry Smith, U.S. Court of Appeals for the Fifth Circuit
- Hon. Thomas Thrash, Jr., U.S. District Court, Northern District of Georgia

Exhibit 2

Letter from Cooley LLP, to Rep. Jim Jordan, Chairman,
H. Comm. on the Judiciary (Apr. 10, 2026)

Cooley

Susanne Sachsman Grooms
[redacted]

CONFIDENTIAL
Via Email

April 10, 2026

The Honorable Jim Jordan
Chairman
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

The Honorable Darrell Issa
Chairman, Subcommittee on Courts,
Intellectual Property, Artificial Intelligence,
and the Internet
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

The Honorable Wesley Hunt
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

Dear Chairman Jordan, Chairman Issa, and Congressman Hunt:

My firm, Cooley LLP, and I represent the Environmental Law Institute ("ELI") in response to your letter of August 29, 2025, regarding its Climate Judiciary Project ("CJP"). Over the past several months, ELI has welcomed the opportunity to answer your questions and has worked diligently to respond to your requests.

As part of ELI's good-faith efforts to comply with the Majority staff's follow-up requests, we previously provided information about five pilot program judicial education events where CJP partnered with the Federal Judicial Center (FJC), including identifying federal judges who may have attended those events. The Majority staff broadened its requests beyond these FJC events, asking ELI to identify federal judges who may have participated in any other CJP judicial education events, and the training materials used at those events.

As noted previously, in all cases, it was the partnering organizations, such as FJC, who were primarily responsible for inviting judges to these events. Among other things, and as set forth in our previous correspondence, ELI was not responsible for managing invitations or logistics for these events, and information it has related to judicial attendance at any specific event might be incomplete or inaccurate. As a result, these partnering organizations remain better positioned to provide this information and to negotiate the competing equities implicated by the Majority staff's requests, including raising any privacy or security concerns they might have regarding the release of information identifying specific judges.

However, facing the threat of congressional subpoena, ELI has produced, and is continuing to produce on a rolling basis, the information demanded by the Majority staff. Accordingly, and

based on a good-faith search for responsive information, the attachment provided with this letter represents ELI's current understanding of the federal judges who may have attended the judicial education events identified in the attachment. ELI respectfully requests that the Committee treat this information as confidential and negotiate with FJC or the other partnering organizations prior to any release of these names beyond the Committee. Among other things, this will afford the entities who are responsible for the education of judges the opportunity to raise corrections to this list as well as safety or privacy concerns and suggest potential safeguards, which are important considerations given the alarming increase in harassment, threats, and violence directed at judges over the past few years.

As part of ELI's ongoing cooperation with the Committee's requests, we are also producing with this letter the versions of the presentations that are in ELI's possession from the judicial education events identified in the attachment at ELI-HJC-0001336 to at ELI-HJC-0001432. Because ELI was not responsible for presenting these materials at the events, ELI cannot verify whether or not these documents reflect final versions of these materials or whether these materials were actually presented at the events. ELI is continuing its work to gather additional information in response to the Majority staff's requests.

In providing documents and information in response to your requests, our client does not waive, nor does it intend to waive, any of its rights or privileges with respect to this inquiry, including any applicable attorney-client, work product, or other evidentiary privilege, or any objection to your requests. We request that you notify us prior to any public release of our client's documents or information within them to provide us with an opportunity to identify specific sensitivities and request redactions.

Sincerely,



Susanne Sachsman Grooms

Enclosures

cc: The Honorable Jamie Raskin, Ranking Member

The Honorable Henry C. "Hank" Johnson, Ranking Member, Subcommittee on Courts, Intellectual Property, Artificial Intelligence, and the Internet

April 10, 2026

ADDITIONAL CJP EVENTS FROM 2020 AND 2021

Further to the information provided in our letter of March 20, 2026 and following a reasonable, good-faith search of its records, ELI has identified the following events in which CJP participated from 2020 and 2021 where federal judges may have been in attendance. As the partner organizations were responsible for inviting participants, they remain better positioned to provide the Committee with information about judicial participation in these events. ELI nonetheless has sought in good faith to respond to the Committee's requests, and the information provided with this letter represents ELI's current understanding of the federal judges who may have attended these events based on a good-faith search for responsive information. It is ELI's understanding that these partner organizations consider this information confidential. We therefore respectfully request that the Committee treat this information as confidential and negotiate with the partner organizations prior to releasing these names beyond the Committee, to appropriately consider the accuracy of this information, the equities of the judicial branch, and the potential safety concerns of the judges.

Following a reasonable, good-faith search of its records, ELI has also identified the presentation materials for these programs in its possession, as listed below. Documents identified to date are being produced with this letter at ELI-HJC-0001336 to at ELI-HJC-0001432. Because ELI was not responsible for presenting these materials at the events, ELI cannot verify that these documents reflect final versions of these materials or that these materials were presented at the events.

Federal Judicial Center and the Ninth Circuit Education Committee, 2020 Mid-Winter Workshop for Judges of the Ninth Circuit
Palm Springs, CA, January 27, 2020

Speakers:
- Chris Field, PhD, Stanford University
- Michael Gerrard, Columbia Law School
- Sandra Nichols Thiam, Environmental Law Institute

Slides in ELI Possession:
- Chris Field – "Understanding Extreme Events and Disasters"
- Michael Gerrard – "Litigation Arising from Extreme Weather Events in the Ninth Circuit – Volume, Types, Issues, Resolution"

Participants:
- ELI has no record of the judges in attendance.

Confidential

National Judicial College, Climate Science for Judges: Evidentiary Issues
Webinar, May 11, 2021

Speakers:
- Hon. Tani Cantil-Sakauye, Chief Justice of California
- Paul A. Hanle, PhD, Environmental Law Institute
- Benjamin D. Santer, PhD, Lawrence Livermore National Laboratory

Slides in ELI Possession:
- Benjamin D. Santer – "Evidence for the Courts: Emerging Issues in Climate Science"

Participants:
- Hon. Audrey Fleissig, U.S. District Court, Eastern District of Missouri
- Hon. Alan Johnson, U.S. District Court, District of Wyoming
- Hon. Tana Lin, U.S. District Court, Western District of Washington
- Hon. Susan Robinson (Ret.), U.S. District Court, District of Delaware
- Hon. Michael H. Simon, U.S. District Court, District of Oregon
- Hon. Frances Tydingco-Gatewood, U.S. District Court, Guam
- Hon. Reggie B. Walton, U.S. District Court, District of the District of Columbia

Federal Judicial Center and Berkeley Judicial Institute, Science Seminar for Federal Judges
Virtual, August 30–September 1, 2021

Speakers:
- Clara J. Altman, Federal Judicial Center
- Chris Field, PhD, Stanford University
- Hany Farid, PhD, University of California, Berkeley
- Professor Henry T. Greely, Stanford Law School
- Hon. Jeremy Fogel, Berkeley Judicial Institute
- Paul A. Hanle, PhD, Environmental Law Institute
- Rebecca Kihslinger, PhD, Environmental Law Institute
- Gary Marchant, PhD, Arizona State University
- Mahasin Mujahid, PhD, UC Berkeley
- Shirely M. Tilghman, PhD, Princeton University
- Sam Wang, PhD, Princeton University

Slides in ELI Possession:
- ELI has not identified any slides from this event in its possession.

Participants:

- Hon. Marvin Aspen, U.S. District Court, Northern District of Illinois
- Hon. Patricia Barksdale, U.S. District Court, Middle District of Florida
- Hon. Danny Boggs, U.S. Court of Appeals for the Sixth Circuit
- Hon. Sarah Cave, U.S. District Court, Southern District of New York
- Hon. Maxine Chesney, U.S. District Court, Northern District of California
- Hon. Elizabeth Chestney, U.S. District Court, Western District of Texas
- Hon. Jacqueline Cox, U.S. Bankruptcy Court, Northern District of Indiana
- Hon. Albert Diaz, U.S. Court of Appeals for the Fourth Circuit
- Hon. Bernice Donald, U.S. Court of Appeals for the Sixth Circuit
- Hon. Thomas Farrish, U.S. District Court, District of Connecticut
- Hon. Elizabeth Foote, U.S. District Court, Western District of Louisiana
- Hon. Catherine Furay, U.S. Bankruptcy Court, Western District of Wisconsin
- Hon. Darrin Gayles, U.S. District Court, Southern District of Florida
- Hon. Donald Graham, U.S. District Court, Southern District of Florida
- Hon. James Hanlon, U.S. District Court, Southern District of Indiana
- Hon. Bruce Harwood, U.S. Bankruptcy Court, District of New Hampshire
- Hon. Jonathan Hawley, U.S. District Court, Central District of Illinois
- Hon. Karin Immergut, U.S. District Court, District of Oregon
- Hon. Mustafa Kasubhai, U.S. District Court, District of Oregon
- Hon. Jeremy Kernodle, U.S. District Court, Eastern District of Texas
- Hon. Steve Kim, U.S. District Court, Central District of California
- Hon. Sandra Klein, U.S. District Court, Central District of California
- Hon. Susan Lee, U.S. District Court, Eastern District of Tennessee
- Hon. Ivan Lemelle, U.S. District Court, Eastern District of Louisiana
- Hon. Bruce McGiverin, U.S. District Court, District of Puerto Rico
- Hon. Ruth Miller, U.S. District Court, District of the Virgin Islands
- Hon. Dennis Montali, U.S. Bankruptcy Court, Northern District of California
- Hon. Kevin Moore, U.S. District Court, Southern District of Florida
- Hon. Cynthia Norton, U.S. Bankruptcy Court, Western District of Missouri
- Hon. Rebecca Pallmeyer, U.S. District Court, Northern District of Illinois
- Hon. Tiiara Patton, U.S. Bankruptcy Court, Northern District of Ohio
- Hon. James Peterson, U.S. District Court, Western District of Wisconsin
- Hon. Michelle Peterson, U.S. District Court, Western District of Washington
- Hon. Anthony Porcelli, U.S. District Court, Middle District of Florida
- Hon. Jacqueline Rateau, U.S. District Court, District of Arizona
- Hon. Bruce Reinhart, U.S. District Court, Southern District of Florida
- Hon. Michael Shea, U.S. District, District of Connecticut
- Hon. Roslyn Silver, U.S. District Court, District of Arizona
- Hon. Erithe Smith, U.S. Bankruptcy Court, Central District of California
- Hon. James Smith, U.S. Bankruptcy Court, Middle District of Georgia
- Hon. Sidney Stein, U.S. District Court, Southern District of New York
- Hon. David Tatel, U.S. Court of Appeals for the D.C. Circuit

- Hon. Lori Vaughan, U.S. Bankruptcy Court, Middle District of Florida
- Hon. Mary Ellen Williams, U.S. Court of Federal Claims

Confidential

Exhibit 3

Letter from Cooley LLP, to Rep. Jim Jordan, Chairman,
H. Comm. on the Judiciary (May 8, 2026)

Cooley

Susanne Sachsman Grooms
[redacted]

CONFIDENTIAL
Via Email

May 8, 2026

The Honorable Jim Jordan
Chairman
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

The Honorable Darrell Issa
Chairman, Subcommittee on Courts,
Intellectual Property, Artificial Intelligence,
and the Internet
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

The Honorable Wesley Hunt
Committee on the Judiciary
U.S. House of Representatives
2138 Rayburn House Office Building
Washington, DC 20515-6216

Dear Chairman Jordan, Chairman Issa, and Congressman Hunt:

My firm, Cooley LLP, and I represent the Environmental Law Institute ("ELI") in response to your letters of August 29, 2025 and April 28, 2026, regarding its Climate Judiciary Project.

Founded in 1969, ELI is a nonprofit organization that is internationally recognized for its independent, non-partisan environmental research, analysis, and educational programming. Among its work, ELI has decades of experience providing highly respected educational programs for judges. Its Climate Judiciary Project ("CJP") began in 2018 in coordination with the Federal Judicial Center (FJC), the "research and education agency of the judicial branch of the United States Government."[1] With a curriculum drawn from consensus reports and authoritative sources, including the National Climate Assessment and the Intergovernmental Panel on Climate Change, CJP provides general education on climate science and how it arises in the law. CJP does not advise judges on how to rule, nor does CJP participate in litigation or coordinate with any parties related to any litigation. CJP's programs are similar to other judicial education programs that provide training on legal and scientific topics that judges voluntarily choose to attend. Suggestions that CJP's judicial educational activities are improper are without merit.

[1] *About the FJC*, Federal Judicial Center, https://www.fjc.gov/about [https://perma.cc/5VDH-F72P] (last visited May 8, 2026).

The Committee nonetheless has raised concerns that CJP seeks to "predispos[e]," "indoctrinate," or "influence" judges to rule against the fossil fuel industry in cases alleging injuries from the manufacturing, marketing, or sale of fossil fuel products.[2] To support this, the Committee asserts that ELI has "concealed the identities of the judges who have attended or participated" in its educational events; that CJP "ha[s] not been transparent about the funding sources for these events"; and that "materials presented at these sessions or conferences are largely kept from public view."[3] According to the Committee, this is a concern because "[p]arties to lawsuits thus have no way of knowing whether the judges in their cases" have (in the Committee's view) been improperly influenced and "should recuse from the[se] cases."[4]

Despite these claims, CJP's written curriculum, *Climate Science and Law for Judges*, is publicly available on its website. ***To assist the Committee, and in addition to the information already publicly available, ELI has provided a significant amount of information to address the Committee's questions, allay its concerns, and allow it to make policy recommendations***. In fact, ELI has provided information above and beyond any applicable reporting requirements.[5] Specifically, for any event that ELI has reason to believe that a federal judge attended, it has identified the presenters, topics covered, materials presented, and the federal judges who attended the relevant events.

From the outset, ELI has welcomed the opportunity to answer the Committee's questions and to explain the educational programs and materials available through CJP. At the same time, we have consistently conveyed the need to narrow requests that are overly broad, vague, and unduly burden our client's constitutionally protected rights. We have been working together with

---

[2] Letter from Chairman Jordan, et al. to Ms. Jordan Diamond (Aug. 29, 2025) at 1–2.
[3] *Id.* at 3–4.
[4] *Id.* at 4.
[5] The Judicial Conference policy for certain privately funded judicial education events requires disclosure of the following information to the Administrative Office of the U.S. Courts: sponsor and sources of support for the program; list of speakers and their presentation topics; name or title of the program; and dates and location of the program. *Judicial Conference Policy on Judges' Attendance at Privately Funded Educational Programs*, United States Courts (Sept. 19, 2006), https://www.uscourts.gov/administration-policies/privately-funded-seminars-disclosure-system/judicial-conference-policy-judges-attendance-privately-funded-educational-programs#a1 [https://perma.cc/MH63-P5CN] (last visited May 8, 2026). Judges attending the privately funded programs subject to this policy must separately report their attendance if they have accepted "travel, food, lodging, reimbursement, or anything that would be considered a gift under the Judicial Conference Ethics Reform Act Gift Regulations" with certain exceptions. *Id.* CJP has participated in one privately funded judicial education event to date subject to these disclosures with the Bolch Judicial Institute of Duke Law School and information from that event was reported by Duke to the Administrative Office of the U.S. Courts to be publicly posted on the Administrative Office's website. ELI is also providing information on that event to the Committee today. FJC, the National Judicial College, and some other entities are not subject to these same reporting requirements, but ELI has now provided information in excess of these reporting requirements for any events that it believes were attended by federal judges.

Majority staff for months to identify information that ELI can provide to assist the Committee's investigation relevant to its asserted legislative interests while also safeguarding ELI's and its associates' core constitutional rights.

Today's Production

When ELI received the Committee's April 28, 2026 letter, ELI was in the process of collecting and preparing documents and information for its third production of documents and information responsive to the Committee's most recent agreed-upon priority: namely, identifying federal judges who may have participated in CJP educational events and the corresponding materials that might have been used at those events. As a continued demonstration of its ongoing cooperation, ELI is producing additional information responsive to this request today available in the attachment to this letter and at ELI-HJC-0001433 to ELI-HJC-0001762.[6]

To the best of ELI's current understanding and knowledge, ELI has now identified all of the CJP events that a federal judge attended, identified the federal judges that it believes may have participated in each event, and produced the corresponding presentation materials that ELI was able to identify, based on a reasonable, good faith search of its records.

As noted previously, in all cases, it was the partnering organizations who were primarily responsible for inviting judges to these events. ELI was not responsible for managing invitations or logistics for these events, so information it has related to judicial attendance at any specific event might be incomplete or inaccurate. ELI respectfully requests that the Committee treat this information as confidential and negotiate with FJC or the other partnering organizations prior to any release of these names beyond the Committee. Among other things, this will afford the partnering organizations the opportunity to raise corrections to these lists as well as safety or privacy concerns and suggest potential safeguards, which are important considerations given the alarming increase in harassment, threats, and violence directed at judges over the past few years. Furthermore, and because ELI was not responsible for presenting all of the material for the events listed in the attachment, it cannot verify whether all documents reflect final versions or whether these materials were actually presented.

In addition, as we have previously explained, while CJP never directly reimbursed any federal judges for any expenses related to these events, ELI provided funding to partnering organizations to support their reimbursement or payment of judges' expenses. Based on ELI's current understanding following a reasonable, good faith search for responsive information, ELI

[6] This production includes not only those events that may be exempted from reporting requirements, but also the one event attended by federal judges for which the partner organization has already disclosed event information under the Judicial Conference policy.

has identified reimbursements paid to FJC as reimbursements for judges' travel expenses to attend five FJC events and payments made to Duke University related to judges' travel expenses arranged by Duke for one privately sponsored event in the fall 2025.[7]

Furthermore, following a reasonable, good faith search of its records, ELI is not aware of any non-public video recordings or transcripts of CJP judicial education events attended by federal judges in its custody, possession, or control.[8]

Response to Threat of Compulsory Process

As an initial matter, ELI does not believe that compulsory process is fair or warranted. ELI has worked the past several months to collect and review its records, identify the information needed to respond to the Committee's requests, and present that information in an understandable and manageable format for the Committee. This has resulted in the production of more than 1,400 pages of documents and multiple attachments. We have explained repeatedly that this work is time-consuming and resource intensive, particularly for a small nonprofit that lacks the resources to manage a demand for documents spanning a lengthy period (more than six years) and seeking an ill-defined and potentially limitless amount of information.

---

[7] To the best of ELI's current understanding, based on a reasonable, good faith search, the expenses for these six events are the following amounts:

- ELI paid FJC $8,833.84 to reimburse for the travel expenses of 10 judges and one FJC staff member related to the June 28, 2019 FJC event;
- ELI paid FJC $2,946.31 to reimburse for the travel expenses of 4 judges related to the July 12, 2019 FJC event;
- ELI paid FJC $10,750 to reimburse for the travel expenses of 14 judges related to the September 13, 2019 FJC event;
- ELI paid FJC $7,422.56 to reimburse for the travel expenses of 12 judges related to the December 6, 2019 FJC event;
- ELI paid FJC $7,605.40 to reimburse for the travel expenses of 10 judges related to the March 13, 2020 FJC event; and
- ELI paid Duke University a fixed amount related to the October 20–21, 2025 event which was attended by seven federal judges. At the time that agreement was entered into, it was anticipated that the travel expenses related to the participation of 25 faculty and judges would be $45,385 (approximately $1,815.40 per participant).

[8] As noted on our May 1, 2026 call with Majority staff, the video recordings referenced in the Committee's April 28, 2026 letter do not relate either to CJP or judicial education. CJP has a short introductory video about its project on its website, and it is aware that the Berkeley Judicial Institute webinar "Introducing the Climate Judiciary Project" is also publicly available. *See Resource Library*, Climate Judiciary Project, https://cjp.eli.org/resources [https://perma.cc/JCQ6-RTYL] (last visited May 8, 2026); *Introducing the Climate Judiciary Project*, UC Berkeley Law (May 3, 2024), https://www.law.berkeley.edu/research/bji/events/introducing-the-climate-judiciary-project/ [https://perma.cc/6Z6X-CTCT] (last visited May 8, 2026).

Unfortunately, and despite productive discussions with Majority staff and ongoing compliance with agreed-upon priority requests, the Committee has threatened to compel ELI to, among other things, produce "*all* communications *relating to* 'curricula, training, and/or presentations' and 'presentations or training materials'" dating back more than six years.[9] In essence, this request demands *everything* related to CJP's programs and materials.

These sweeping demands raise profound constitutional concerns.

Climate change—its existence, its impact on the environment and on human lives, its causes, and how our laws address these issues—are matters of profound public importance and debate.[10] ELI's speech on these "public issues occupies the highest rung of the hierarchy of First Amendment values, and is entitled to special protection."[11] This right "necessarily carries with it 'a corresponding right to associate with others.'"[12]

As the Supreme Court has consistently and recently confirmed, ELI's right to associate with scientists, academics, and lawyers in pursuit of knowledge; to compile, analyze, and curate the information gathered; and to publish its educational materials are all entitled to heightened protection under the First Amendment.[13] "Strip away the ability of individuals to work together free from governmental oversight and intrusion, and the freedom to associate may become no freedom at all—individuals deterred, groups diminished, and their protected advocacy suppressed."[14] As the Supreme Court observed last week, "officials across the political spectrum have sometimes issued subpoenas and other investigatory demands in order to secure just these results."[15]

Additionally troubling, the Committee appears to be targeting ELI based on what the Committee believes to be ELI's "specific motivating ideology," "opinion," or "perspective" on

---

[9] Letter from Chairman Jordan, et al. to Ms. Jordan Diamond (Apr. 28, 2026) (citing Letter from Chairman Jordan, et al. to Ms. Jordan Diamond (Aug. 29, 2025)) (emphasis added).
[10] Indeed, it is beyond dispute that "public debate on matters of public concern" includes "scientific matters." *McMillan v. Togus Reg'l Off., Dep't of Veteran Affs.*, 294 F. Supp. 2d 305, 316 (E.D.N.Y. 2003); *see also Eastman Chem. Co. v. Plastipure, Inc.*, 775 F.3d 230, 235 (5th Cir. 2014) (The First Amendment protects "scientific debates unfolding within the scientific community.").
[11] *Snyder v. Phelps*, 562 U.S. 443, 452 (2011) (citation omitted); *see also Consol. Edison Co. of N.Y. Inc. v. Pub. Serv. Comm'n of N.Y.*, 447 U.S. 530, 534 (1980).
[12] *First Choice Women's Res. Ctrs., Inc. v. Davenport*, 608 U.S. ___, 2026 WL 1153029, at *1 (Apr. 29, 2026).
[13] *Hurley v. Irish-American Gay, Lesbian and Bisexual Grp. of Boston, Inc.*, 515 U.S. 557, 561 (1995) (citing *Miami Herald Publ'g Co. v. Tornillo*, 418 U.S. 241, 258 (1974)).
[14] *First Choice Women's Res. Ctrs., Inc.*, 608 U.S. ___, 2026 WL 1153029, at *6.
[15] *Id.* at *8 (emphasis added and internal quotations omitted).

climate science.[16] In particular, the Committee's pursuit of ELI appears to be based on the views that CJP expresses (or that the Committee believes it expresses) in its educational materials.[17] It is notable, however, that the Committee has not taken aim at judicial education that has been reported to express a contrary view that "prioritizes American business interests and questions climate science."[18]

Indeed, there are recent reports of a "symposium for 150 judges" that is "closely aligned with the fossil fuel industry and free-market conservatives" that will give judges "healthy skepticism of the invocations of 'science' that lurk in the background of lawsuits they are hearing[.]"[19] This program (run through George Mason's Law and Economics Center) reportedly has links to ExxonMobil, a defendant in several climate lawsuits; it features speakers who have participated as counsel for amici in climate-related cases as well as "at least one lawyer who has represented fossil fuel companies in court."[20]

This asymmetry strongly suggests that the Committee is targeting CJP "because of its message, its ideas, its subject matter, or its content."[21] But "when the government seeks not just to restrict speech based on its subject matter, but also seeks to dictate what particular 'opinion or perspective' individuals may express on that subject, 'the violation of the First Amendment is all the more blatant'" and the government "must nearly always 'abstain' from it."[22]

As we have discussed with Majority staff, ELI has an unquestionable interest in safeguarding much of the information that the Committee seeks and a corresponding First Amendment right to do so. This includes protection for the identities of and communications

---

[16] *Rosenberger v. Rector & Visitors of Univ. of Va.*, 515 U.S. 819, 829 (1995); *see also Bantam Books, Inc. v. Sullivan*, 372 U.S. 58, 67 (1963) (The First Amendment comes into play whenever the government "set[s] about to achieve the suppression of [ideas].").

[17] For example, the Committee complains of a line in one CJP curricular module expressing the view that "not every scientific argument deserves to be taken seriously," which is followed by research debunking claims that the sun is responsible for global warming. Letter from Chairman Jordan, et al. to Ms. Jordan Diamond (Aug. 29, 2025) (quoting *Climate Science and Law for Judges: How Climate Science Works*, Environmental Law Institute (Jan. 2023), https://www.eli.org/sites/default/files/files-pdf/HCSW_Hanle%20Mastrandrea.pdf [https://perma.cc/8BK5-SRLW] (last visited May 8, 2026)).

[18] Abrahm Lustgarten, *Event With Links to Oil Industry Teaches Judges "Healthy Skepticism" of Climate Science*, ProPublica (May 2, 2026), https://www.propublica.org/article/climate-science-oil-gas-fossil-fuel-judges-jim-jordan [https://perma.cc/LJK3-8ZDF] (last visited May 8, 2026).

[19] *Id.*

[20] *Id.*

[21] *Otto v. City of Boca Raton*, 981 F.3d 854, 862 (11th Cir. 2020) (citing *Police Dep't of Chicago v. Mosley*, 408 U.S. 92, 96 (1972)).

[22] *Chiles v. Salazar*, 146 S. Ct. 1010, 1021 (2026) (citing *Rosenberger*, 515 U.S. at 829).

with donors,[23] as well as communications reflecting deliberative discussions or editorial decisions about the content of its educational materials.[24] While we have consistently alerted Majority staff to constitutional concerns with certain requests, we have nonetheless expressed ELI's willingness to consider whether there is relevant information that it can provide without further burdening or infringing the rights of the organization or its associates.[25]

For example, after fossil fuel companies alleged that one of the plaintiffs' lawyers in a lawsuit against them had undisclosed ties to ELI, Majority staff asked ELI to produce its communications with that lawyer (Roger Worthington). ELI agreed to look into this and, following a reasonable, good faith search of relevant custodians, informed the Committee that it did not find any communications with Mr. Worthington.[26] As another example, in February 2026, Majority staff made a specific request for ELI's communications with one of the donors (New Venture Fund) that is voluntarily listed in ELI's public annual report.[27] ELI objected (and continues to object to) to searching for and producing records with donors on First Amendment grounds but confirmed that no funder dictates the work of ELI, and more specifically told the Committee that New Venture Fund was not involved in editing or commenting on CJP curriculum materials or presentations.

As courts have long confirmed, Congress's investigative authority, while broad, is not limitless. Congress is not free to operate without regard for the procedural and substantive protections that the Constitution affords.[28] It remains unclear what legitimate legislative purpose

---

[23] *See First Choice Women's Res. Ctrs., Inc*, 608 U.S. ___, 2026 WL 1153029; *Ams. for Prosperity Found. v. Bonta*, 594 U.S. 595 (2021).

[24] *Media Matters for Am. v. Paxton*, 138 F.4th 563 (D.C. Cir. 2025); *Moody v. NetChoice, LLC*, 603 U.S. 707, 731 (2024) (an organization "'exercis[ing] editorial discretion in the selection and presentation' of content is 'engage[d] in speech activity'" protected by the First Amendment) (citation omitted).

[25] The Committee's public accusations, sweeping demands for all "documents and communications," and threats of compulsory process already have a chilling effect on ELI's protected rights to "quintessential First Amendment activities." *Media Matters for Am.*, 138 F.4th at 569, 584–85 (holding that a media organization's reporting on public issues constitutes "quintessential First Amendment activities" and affirming district court's finding of "significant evidence of ongoing adverse effects to Appellees' First Amendment rights due to the CID and investigation, including current self-censorship in their reporting.").

[26] Letter from S. Grooms to Chairman Jordan et al. (Oct. 31, 2025). In a sworn declaration to the court, Mr. Worthington made clear that he "has nothing to do with" ELI or CJP and has not written, edited, or commented on drafts of any CJP materials. *Id.* at 2.

[27] *See Building Bridges for People, Places, and the Planet: 2024 Impact Report*, Environmental Law Institute, https://www.eli.org/sites/default/files/files-pdf/Annual%20Report%202024_Web.pdf [https://perma.cc/9DF5-GV33] (last visited May 8, 2026); ELI-HJC-0000671–ELI-HJC-0000689.

[28] *See, e.g.*, *Watkins v. United States*, 354 U.S. 178, 188 (1957) ("The Bill of Rights is applicable to [congressional] investigations as to all forms of governmental action.").

is served by imposing onerous investigative demands only on ELI.[29] Yet, as it has throughout, ELI remains willing to consider paths forward that adequately safeguard its constitutional rights. We therefore respectfully request that, to the extent the Committee has a legitimate legislative need for additional information, we return to a collaborative process through which we might appropriately narrow any remaining requests.

In providing information in response to your requests, including documents produced with this letter at ELI-HJC-0001433 to ELI-HJC-0001762, our client does not waive, nor does it intend to waive, any of its rights or privileges, including any applicable attorney-client, work product, or other evidentiary privilege, or any objection to your requests, including objections on constitutional grounds. In addition, letters and documents produced by ELI may contain information it considers confidential, proprietary, or otherwise sensitive, and we ask that the Committee treat them as confidential. This is particularly important given the security and other concerns that we have raised. In the event the Committee is considering public release of any of these materials, we respectfully request notice and an opportunity to confer with you prior to any such release and to identify specific sensitivities and request redactions.

If you have any questions regarding this matter, or need any additional information, please do not hesitate to contact me.

Sincerely,



Susanne Sachsman Grooms

Enclosures

cc: The Honorable Jamie Raskin, Ranking Member

---

[29] To the extent the Committee can articulate a legitimate legislative purpose behind its continued inquiry, it still must demonstrate that its sweeping demand for all "documents and communications" related to CJP serves a compelling interest and is narrowly tailored to achieve that end. *See Chiles,* 146 S. Ct. at 1021; *First Choice Women's Res. Ctrs., Inc.*, 608 U.S. ___, 2026 WL 1153029, at *7 (citing *Ams. for Prosperity Found.*, 594 U.S. at 607, 611-619). Given ELI's production of information that exceeds current reporting requirements, this is a hurdle the Committee cannot clear.

The Honorable Henry C. "Hank" Johnson, Ranking Member, Subcommittee on Courts, Intellectual Property, Artificial Intelligence, and the Internet

May 8, 2026

ADDITIONAL CJP EVENTS ATTENDED BY FEDERAL JUDGES

Further to the information provided in our letters of March 20 and April 10, 2026 and following a reasonable, good faith search of its records, ELI has identified the following additional events in which CJP participated since 2021 to the date of this letter where federal judges were, or may have been, in attendance. At the time of this letter, and based on a reasonable, good faith search, ELI believes that the information provided in our letters of March 20, April 10, and May 8 represents the complete set of CJP events where CJP could identify that federal judges were in attendance from April 1, 2019 to the date of this letter. ELI has also provided the presentation materials that it has identified for those corresponding events that were in its custody, possession, or control based on a reasonable, good faith search as of the date of this letter.

As previously expressed to the Committee, as the partner organizations were responsible for inviting participants, they remain better positioned to provide the Committee with information about judicial participation in these events. ELI nonetheless has sought in good faith to respond to the Committee's requests, and the information provided with this letter represents ELI's current understanding of the federal judges who may have attended these events based on a good-faith search for responsive information. It is ELI's understanding that these partner organizations consider this information confidential. We therefore respectfully request that the Committee treat this information as confidential and negotiate with the partner organizations prior to releasing these names beyond the Committee, to appropriately consider the accuracy of this information, the equities of the judicial branch, and the potential safety concerns of the judges.

Following a reasonable, good faith search of its records, ELI has also identified the following information, as well as the presentation materials, for these programs in its possession, as listed below. Documents identified to date are being produced with this letter at ELI-HJC-0001433 to ELI-HJC-0001762. Because ELI was not responsible for presenting these materials at the events, ELI cannot verify that these documents reflect final versions of these materials or that these materials were presented at the events.

United States District Court Judicial Retreat
Lenox, MA, May 5, 2022

Speakers:
- Michael Gerrard, Columbia Law School
- Chief Magistrate Judge Page Kelley
- Daniel Schrag, PhD, Harvard University

Slides in ELI Possession:
- Michael Gerrard – "U.S. Climate Change Litigation and the Role of Science"

Participants:
- Hon. Jennifer Boal, U.S. District Court, District of Massachusetts
- Hon. Marianne Bowler, U.S. District Court, District of Massachusetts
- Hon. Donald Cabell, U.S. District Court, District of Massachusetts
- Hon. Denise Casper, U.S. District Court, District of Massachusetts
- Hon. Robert Collings, U.S. District Court, District of Massachusetts
- Hon. Judith Dein, U.S. District Court, District of Massachusetts
- Hon. Timothy Hillman, U.S. District Court, District of Massachusetts
- Hon. Angel Kelley, U.S. District Court, District of Massachusetts
- Hon. Kenneth Neiman, U.S. District Court, District of Massachusetts
- Hon. Katherine Robertson, U.S. District Court, District of Massachusetts
- Hon. Patti Saris, U.S. District Court, District of Massachusetts
- Hon. Denise Saylor, U.S. District Court, District of Massachusetts

Ninth Circuit Judicial Conference
Big Sky, MT, July 20, 2022

Speakers:
- Sandra Nichols Thiam, Environmental Law Institute
- Michael Oppenheimer, PhD, Princeton University

Slides in ELI Possession:
- Michael Oppenheimer – "The Basic Science of Climate Change"
- Sandra Nichols Thiam – "Trends in Climate Litigation"

Participants:
- ELI has no records of the judges in attendance.

Bolch Judicial Institute, *Climate Science and the Law*
Beaufort, NC, October 20-21, 2025

Speakers:
- Kyle Bradbury, PhD, Duke University
- Cris Diaz, Bolch Judicial Institute
- John Doherty, PhD, Environmental Law Institute
- David R. Easterling, PhD, Future Climate LLC
- Hon. Paul W. Grimm (Ret.), Bolch Judicial Institute
- Hon. Jonathan E. Hawley, U.S. District Court, Central District of Illinois
- Miyuki Hino, PhD, University of North Carolina at Chapel Hill
- Helene Krasnoff, Environmental Law Institute
- Jarryd Page, Environmental Law Institute
- Ashley Ward, PhD, Duke University
- Jonathan Wiener, Duke University School of Law

Slides in ELI Possession:

- Kyle Bradbury – "The Energy System and Climate Mitigation"
- David R. Easterling – "The Scientific Basis For Climate Change And the IPCC Process"
- David R. Easterling – "Climate Change and Detection/Attribution"
- Hon. Paul W. Grimm (ret.) – "Climate Science: Evidentiary Issues"
- Miyuki Hino – "Sea level rise: science, impacts, and adaptation"
- Jarryd Page – "Climate Litigation Coming to a Courtroom Near You"
- Ashley Ward – "Heat Policy Innovation Hub"

Participants:

- Hon. Micaela Alvarez, U.S. District Court, Southern District of Texas
- Hon. Patricia Barksdale, U.S. District Court, Middle District of Florida
- Hon. Sara Darrow, U.S. District Court, Central District of Illinois
- Hon. George Hanks, Jr., U.S. District Court, Southern District of Texas
- Hon. Jonathan Hawley, U.S. District Court, Central District of Illinois
- Hon. Daniel Irick, U.S. District Court, Middle District of Florida
- Hon. Anthony Porcelli, U.S. District Court, Middle District of Florida

Exhibit 4

Email from Paul Hanle, Founder, CJP, to Michael Wehner, Senior Scientist, Lawrence Berkeley National Laboratory (May 12, 2022)

From: [redacted]
To: [redacted]
Cc: 'Sandra Nichols Thiam' [redacted]
Subject: An important climate initiative
Date: Thu, 12 May 2022 16:19:40 +0000

Michael,

I don't believe we have met, but as president of Climate Central from 2011 to 2018, I followed your work with interest. You may recall that Climate Central, under Heidi Cullen's leadership, launched the World Weather Attribution project on extreme event attribution as the secretariat to the WWA group in 2014. After the US elections and Heidi's departure to MBARI, I stepped down from running Climate Central to start a new effort to educate judges on climate science and impacts, and how they may come to bear on court cases involving climate change. It seemed to me that without legislative or executive action to address the climate problem, real government action might still be derived from court decisions based on scientific understanding of the consequences of global warming. So I joined the Environmental Law Institute as a visiting scholar and founder of what we call the Climate Judiciary Project.

I am writing today at the recommendation of Heidi and Claudia Tebaldi to ask if I might speak with you about this timely and important project. I'd like to tell you how we are going about reaching key judges, and I have a specific idea about attribution for your consideration that could make a great difference in the final outcome of cases. My colleague and partner in the project is Sandra Nichols Thiam, Director of Judicial Education and a vice president of ELI, and with your agreement I would ask her to join us as well.

I hope you would be willing to speak with us sometime next week or the following week, at a time convenient to you. If you are willing to do this, would you please suggest a time or two. We will send you a Zoom link for the meeting.

Please let me know if I can answer any questions you might have for clarification prior to speaking.

Thanks very much for considering it.

Best regards,

Paul
Paul A. Hanle, PhD
Founder
Climate Judiciary Project
Environmental Law Institute
www.eli.org
[redacted]

Exhibit 5

Email from Sandra Nichols Thiam, Vice President for Research and Policy Programs, Environmental Law Institute, to Michael Gerrard, Founder, Sabin Center (June 20, 2019)

From: Michael Gerrard [redacted]
Sent: Tue 6/25/2019 9:27:18 AM Eastern Daylight Time
To: Sandra Nichols Thiam [redacted]
Cc: Paul Hanle [redacted]
Subject: Re: Preparations and July 12

I'd be interested in seeing the latest version of the registration list for Friday's program, if that's possible. Thanks.

On Thu, Jun 20, 2019 at 4:22 PM Sandra Nichols Thiam [redacted] wrote:

Marvelous. Thank you!

From: Michael Gerrard [redacted]
Sent: Thursday, June 20, 2019 4:16 PM
To: Sandra Nichols Thiam [redacted] Paul Hanle [redacted]
Subject: Re: Preparations and July 12

I suggest these.

https://www.arnoldporter.com/-/media/files/perspectives/publications/2011/09/what-litigation-of-a-climate-nuisance-suit-might__/files/publication/fileattachment/arnoldporterllptheyalelawjournal091311.pdf?

https://thehill.com/opinion/energy-environment/415307-the-childrens-climate-case-our-obligation-to-future-generations

https://quillette.com/2018/10/30/previously-unrecognized-rights-climate-change-lawsuits-and-the-rule-of-law/

On Thu, Jun 20, 2019 at 4:01 PM Sandra Nichols Thiam [redacted] wrote:

Will do. It's One Washington Circle, quite close to GW.

We also wanted to ask if you had ideas of anything that would be appropriate to include in a list of recommended reading that we will include in the materials that the judges will receive at the event(s). We'll be listing the Burger/Horton/Wentz paper but thought it could be good to list a few more.

Thanks!

Sandy

From: Michael Gerrard [redacted]
Sent: Thursday, June 20, 2019 2:21 PM
To: Sandra Nichols Thiam [redacted]
Subject: Re: Preparations and July 12

Yes. Thanks.

On Thu, Jun 20, 2019 at 12:22 PM Sandra Nichols Thiam [redacted] wrote:

HI Michael,

Forgot to ask – would you like a hotel room in DC on the 11th of the July the night before the GW program?

Thanks,

Sandy

From: Michael Gerrard [redacted]
Sent: Tuesday, June 11, 2019 10:08 AM
To: Paul Hanle [redacted]
Cc: Michael Gerrard [redacted] Sandra Nichols Thiam [redacted]
Subject: Re: Preparations and July 12

Paul —

Yes, I can do the DC program.

Please send me Radley's deck. Would you like to see mine? I'm currently in Paris, returning tomorrow, but I think I have it on my laptop.

Can you send me the RSVP list for the June 38 program?

Michael

Michael B. Gerrard

Sent from my iPhone

On Jun 11, 2019, at 3:54 PM, Paul Hanle [redacted] wrote:

> Michael,
>
> We are looking forward to the event at Columbia on June 28. We received a deck of slides from Radley, and will be passing them along to the AAAS for their "review" as agreed with them and the FJC. Would be happy to share them with you. I'm wondering if you need anything further to prepare your talk—just let us know if you do.
>
> We have been organizing the DC program scheduled for July 12 and have some interesting developments. That program will include a mix of leading federal and state judges, including probably from New Jersey, New York, Vermont, and maybe one or two other states. Also, I'm really pleased to tell you that Jeremy Fogel has agreed to moderate the issues discussion among the judges, Steve Pacala and our legal expert. There is also a back-channel effort to have one or more Supreme Court Justices attend. Not sure that will work out, but at the very least it will win some attention for the project at the top level. All in, the quality of this event has risen considerably since we began planning it in May.
>
> For this reason, and with apologies for the lateness, I wanted to ask if you might be willing to consider being our legal landscape expert again for this event on July 12. It would be an occasion to reach a different and important group of judges at a likely higher level, and with a different set of presenters. You could make it a day-trip if you wanted (we are starting at 10:30 to allow for a train ride that morning for a couple participants), or we would be happy to have you stay the night before at the hotel. Naturally we would cover your travel expenses. And hopefully you would have little preparation required, since you will have done it two weeks before in NY. Would you think this over and let me know?
>
> Thanks very much for all you have done to help us get this launched. I'm confident it will be very successful—and interesting.
>
> Best,
>
> Paul

Spam
Not spam
Forget previous vote

--

Michael B. Gerrard

Andrew Sabin Professor of Professional Practice

Director, Sabin Center for Climate Change Law

Columbia Law School

435 West 116th Street

New York, New York 10027

[redacted]

www.columbiaclimatelaw.com

Spam
Not spam
Forget previous vote

--

Michael B. Gerrard

Andrew Sabin Professor of Professional Practice

Director, Sabin Center for Climate Change Law

Columbia Law School

435 West 116th Street

New York, New York 10027

[redacted]

www.columbiaclimatelaw.com

Spam
Not spam
Forget previous vote

--
Michael B. Gerrard
Andrew Sabin Professor of Professional Practice
Director, Sabin Center for Climate Change Law
Columbia Law School
435 West 116th Street
New York, New York 10027

[redacted]

www.columbiaclimatelaw.com

Exhibit 6

Email from Sandra Nichols Thiam, Vice President for Research and Policy Programs, Environmental Law Institute, to Michael Gerrard, Founder, Sabin Center (Dec. 22, 2021)

Message

From: Michael Gerrard [redacted]
on behalf of Michael Gerrard [redacted]
Sent: 12/22/2021 10:53:44 PM
To: Sandra Nichols Thiam [redacted]
CC: Paul Hanle-forward [redacted] Sarah Roth [redacted]
Subject: Re: request for a review

Thanks. I'll be happy to do this. Feel free to send me the draft module as soon as it's ready; you needn't wait until after the holidays.

On Wed, Dec 22, 2021 at 4:13 PM Sandra Nichols Thiam [redacted] wrote:

> Dear Michael,
>
> I hope you are enjoying some quiet and family time as the holidays are upon us.
>
> In addition to our engagements at the COP in November, the Climate Judiciary Project has made a lot of progress with our curriculum development during the second half of this year and some of our modules are to the point of being ready for peer review.
>
> Robin Kundis Craig has written a draft of the module on procedural techniques on climate litigation. Each such piece will be reviewed anonymously by three relevant experts, including at least one member of our advisory committee. As you know, the modules have been drafted based on the course outline developed by CJP and validated by our expert advisory committee and have been formulated to fit in with our methodology for educating judges. That said, the accuracy, clarity, and opportunity to teach both climate concepts and the ways they relate to litigation are of paramount importance, and so we are asking reviewers to focus on these aspects when completing a high-level substantive review.
>
> I'm attaching the current table of contents for the whole curriculum and the author guidance for a reminder of the background and context. After the holidays, would you be able to do a review of this draft for us? If you had time to do it at some point in January, that would be great.
>
> Please let us know if you would be available to do this or if you have any questions. If you agree, my colleague Sarah will send you the draft and follow up with any further details.
>
> Thanks in advance and enjoy the holidays! I look forward to being in touch in the New Year!
>
> Best,
>
> Sandy (and Paul!)

Sandra Nichols Thiam (she/her)
Director, Judicial Education
Associate Vice President for Research and Policy

ENVIRONMENTAL LAW • INSTITUTE

Environmental Law Institute

1730 M Street NW, Suite 700 | Washington DC | 20036
Ph: [redacted] Skype: [redacted] | www.eli.org

--

Michael B. Gerrard
Andrew Sabin Professor of Professional Practice
Director, Sabin Center for Climate Change Law
Columbia Law School
435 West 116th Street
New York, New York 10027
Telephone: [redacted]
Facsimile: [redacted]
www.columbiaclimatelaw.com

Exhibit 7

Email from Paul Hanle, founder, Climate Judiciary Project, to Michael Gerrard, founder, Sabin Center (June 11, 2019)

Message

From: Michael Gerrard [redacted]
on behalf of Michael Gerrard [redacted]
Sent: 6/25/2019 1:27:18 PM
To: Sandra Nichols Thiam [redacted]
CC: Paul Hanle [redacted]
Subject: Re: Preparations and July 12

I'd be interested in seeing the latest version of the registration list for Friday's program, if that's possible. Thanks.

On Thu, Jun 20, 2019 at 4:22 PM Sandra Nichols Thiam [redacted] wrote:

> Marvelous. Thank you!
>
> **From:** Michael Gerrard [mailto: [redacted]
> **Sent:** Thursday, June 20, 2019 4:16 PM
> **To:** Sandra Nichols Thiam [redacted]; Paul Hanle [redacted]
> **Subject:** Re: Preparations and July 12
>
> I suggest these.
>
> https://www.arnoldporter.com/-/media/files/perspectives/publications/2011/09/what-litigation-of-a-climate-nuisance-suit-might__/files/publication/fileattachment/arnoldporterllptheyalelawjournal091311.pdf?
>
> https://thehill.com/opinion/energy-environment/415307-the-childrens-climate-case-our-obligation-to-future-generations
>
> https://quillette.com/2018/10/30/previously-unrecognized-rights-climate-change-lawsuits-and-the-rule-of-law/
>
> On Thu, Jun 20, 2019 at 4:01 PM Sandra Nichols Thiam <[redacted] wrote:
>
> > Will do. It's One Washington Circle, quite close to GW.
> >
> > We also wanted to ask if you had ideas of anything that would be appropriate to include in a list of recommended reading that we will include in the materials that the judges will receive at the event(s). We'll be listing the Burger/Horton/Wentz paper but thought it could be good to list a few more.
> >
> > Thanks!

Sandy

From: Michael Gerrard [redacted]
Sent: Thursday, June 20, 2019 2:21 PM
To: Sandra Nichols Thiam [redacted]
Subject: Re: Preparations and July 12

Yes. Thanks.

On Thu, Jun 20, 2019 at 12:22 PM Sandra Nichols Thiam [redacted] wrote:

HI Michael,

Forgot to ask – would you like a hotel room in DC on the 11th of the July the night before the GW program?

Thanks,

Sandy

From: Michael Gerrard [mailto: [redacted]
Sent: Tuesday, June 11, 2019 10:08 AM
To: Paul Hanle [redacted]
Cc: Michael Gerrard [redacted] Sandra Nichols Thiam [redacted]
Subject: Re: Preparations and July 12

Paul —

Yes, I can do the DC program.

Please send me Radley's deck. Would you like to see mine? I'm currently in Paris, returning tomorrow, but I think I have it on my laptop.

Can you send me the RSVP list for the June 38 program?

Michael

Michael B. Gerrard

Sent from my iPhone

On Jun 11, 2019, at 3:54 PM, Paul Hanle [redacted] wrote:

Michael,

We are looking forward to the event at Columbia on June 28. We received a deck of slides from Radley, and will be passing them along to the AAAS for their "review" as agreed with them and the FJC. Would be happy to share them with you. I'm wondering if you need anything further to prepare your talk—just let us know if you do.

We have been organizing the DC program scheduled for July 12 and have some interesting developments. That program will include a mix of leading federal and state judges, including probably from New Jersey, New York, Vermont, and maybe one or two other states. Also, I'm really pleased to tell you that Jeremy Fogel has agreed to moderate the issues discussion among the judges, Steve Pacala and our legal expert. There is also a back-channel effort to have one or more Supreme Court Justices attend. Not sure that will work out, but at the very least it will win some attention for the project at the top level. All in, the quality of this event has risen considerably since we began planning it in May.

For this reason, and with apologies for the lateness, I wanted to ask if you might be willing to consider being our legal landscape expert again for this event on July 12. It would be an occasion to reach a different and important group of judges at a likely higher level, and with a different set of presenters. You could make it a day-trip if you wanted (we are starting at 10:30 to allow for a train ride that morning for a couple participants), or we would be happy to have you stay the night before at the hotel. Naturally we would cover your travel expenses. And hopefully you would have little preparation required, since you will have done it two weeks before in NY. Would you think this over and let me know?

Thanks very much for all you have done to help us get this launched. I'm confident it will be very successful—and interesting.

Best,

Paul

Spam
Not spam
Forget previous vote

--

Michael B. Gerrard

Andrew Sabin Professor of Professional Practice

Director, Sabin Center for Climate Change Law

Columbia Law School

435 West 116th Street

New York, New York 10027

Telephone: [redacted]

Facsimile: [redacted]

Exhibit 8

Email from Michael Gerrard, founder, Sabin Center, to Radley Horton, Associate Research Professor Sabin Center (Apr. 29, 2019)

From: Paul Hanle[/O=ELI/OU=EXCHANGE ADMINISTRATIVE GROUP (FYDIBOHF23SPDLT)/CN=RECIPIENTS/CN=75D058F1DD2E4A0A9B38E84976D18FC0-PAUL HANLE]
Sent: Mon 4/29/2019 2:46:25 PM Eastern Daylight Time
To: Radley Horton [redacted]
Cc: Michael Gerrard [redacted] Sandra Nichols Thiam [redacted]
Subject: RE: Judicial conference on June 28

Thanks, Radley. Let's do 10:30 tomorrow, and we will call you at that number. Looking forward to it.
Best,
Paul

From: Radley Horton [redacted]
Sent: Monday, April 29, 2019 2:37 PM
To: Paul Hanle [redacted]
Cc: Michael Gerrard [redacted]; Sandra Nichols Thiam [redacted]
Subject: Re: Judicial conference on June 28

I neglected to mention that I will be reachable at [redacted]

Best wishes
Radley

On Mon, Apr 29, 2019 at 2:36 PM Radley Horton [redacted] wrote:
Hi Paul,

Sure. I can do a short call either at 10:30 am or 5pm ET tomorrow.

Best wishes,

Radley

On Mon, Apr 29, 2019 at 2:22 PM Paul Hanle [redacted] wrote:
Thank you for the introduction, Michael. Radley, delighted that you are interested. Perhaps it would be most efficient for you, Sandy, and me to speak about the plan by phone. Would you have some time tomorrow? If you name a time, we can likely make it.
Best regards,
Paul

Paul A. Hanle, PhD
Visiting Scholar and Project Leader
Climate Judiciary Project
Environmental Law Institute
1730 M Street NW, Suite 700
Washington, DC 20036

[redacted]

From: Radley Horton [redacted]
Sent: Monday, April 29, 2019 1:55 PM
To: Michael Gerrard [redacted]
Cc: Paul Hanle [redacted]; Sandra Nichols Thiam [redacted]
Subject: Re: Judicial conference on June 28

Hi Mike,

Sounds fascinating. I am in town that day, so I should be able to make it work.

I look forward to learning more.

Best wishes
Radley

On Mon, Apr 29, 2019 at 1:12 PM Michael Gerrard [redacted] wrote:
Radley --

The Sabin Center is working with the Environmental Law Institute on a training session about climate change for federal judges. It will be held on June 28 at the Law School. I'll be giving a presentation to the judges about climate change litigation, and Paul Hanle and Sandra Thiam of the Environmental Law Institute would like to invite you to give a scientific presentation. This note is a heads up that you'll be hearing from them with the details. It would be great if you could do htis if you'll be in town, given that the audience will have some key decision makers.

Michael

--
Michael B. Gerrard
Andrew Sabin Professor of Professional Practice
Director, Sabin Center for Climate Change Law
Columbia Law School
435 West 116th Street
New York, New York 10027
[redacted]
www.columbiaclimatelaw.com

--
Radley Horton, Ph.D.
Lamont Associate Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

[redacted]

*Because I do not receive some emails sent to my [redacted] address, I request that you please use my [redacted] mail address [redacted] instead. Thank you.

--
Radley Horton, Ph.D.
Lamont Associate Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

[redacted]

*Because I do not receive some emails sent to my [redacted] email address, I request that you please use my [redacted] email address [redacted] instead. Thank you.

--
Radley Horton, Ph.D.
Lamont Associate Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

[redacted]

*Because I do not receive some emails sent to my [redacted] email address, I request that you please use my [redacted] email address [redacted] instead. Thank you.

Exhibit 9

Email from Email from Michael Gerrard, founder, Sabin Center, to Paul Hanle, founder, Climate Judiciary Project (May 14, 2019)

From: Paul Hanle[/O=ELI/OU=EXCHANGE ADMINISTRATIVE GROUP (FYDIBOHF23SPDLT)/CN=RECIPIENTS/CN=75D058F1DD2E4A0A9B38E84976D18FC0-PAUL HANLE]
Sent: Tue 5/14/2019 4:21:27 PM Eastern Daylight Time
To: Michael Gerrard [redacted]
Cc: Sandra Nichols Thiam [redacted]
Subject: RE: Judicial conference on June 28

Michael,

Glad you asked. We have 21 federal judges who have expressed interest and expect the final number to be 17 to 20 plus Marcy. We think that is a full house. But the idea of law clerks is a really good one, and we will keep it in mind for the next sessions and future programs. The next up will be DC on July 12.

This coming Monday, I will be meeting with Radley, who has agreed to be the science expert, and am working through his big paper right now. I imagine some of it will be useful on the 28th. What do you think of the idea to offer the judges a few links to readings, including that one?

Best,
Paul

From: Michael Gerrard [redacted]
Sent: Tuesday, May 14, 2019 2:22 PM
To: Paul Hanle [redacted]
Cc: Sandra Nichols Thiam [redacted]
Subject: Re: Judicial conference on June 28

How are registrations going? If they are not yet robust, would it be possible to invite the judges' law clerks? Thanks.

On Mon, Apr 29, 2019 at 2:46 PM Paul Hanle [redacted] wrote:
Thanks, Radley. Let's do 10:30 tomorrow, and we will call you at that number. Looking forward to it.
Best,
Paul

From: Radley Horton [redacted]
Sent: Monday, April 29, 2019 2:37 PM
To: Paul Hanle [redacted]
Cc: Michael Gerrard [redacted] Sandra Nichols Thiam [redacted]
Subject: Re: Judicial conference on June 28

I neglected to mention that I will be reachable at [redacted]

Best wishes
Radley

On Mon, Apr 29, 2019 at 2:36 PM Radley Horton [redacted] wrote:
Hi Paul,

Sure. I can do a short call either at 10:30 am or 5pm ET tomorrow.

Best wishes,

Radley

On Mon, Apr 29, 2019 at 2:22 PM Paul Hanle [redacted] wrote:
Thank you for the introduction, Michael. Radley, delighted that you are interested. Perhaps it would be most efficient for you, Sandy, and me to speak about the plan by phone. Would you have some time tomorrow? If you name a time, we can likely make it.
Best regards,
Paul

Paul A. Hanle, PhD
Visiting Scholar and Project Leader
Climate Judiciary Project
Environmental Law Institute
1730 M Street NW, Suite 700
Washington, DC 20036
[redacted]

From: Radley Horton [redacted]
Sent: Monday, April 29, 2019 1:55 PM
To: Michael Gerrard [redacted]
Cc: Paul Hanle [redacted] Sandra Nichols Thiam [redacted]
Subject: Re: Judicial conference on June 28

Hi Mike,

Sounds fascinating. I am in town that day, so I should be able to make it work.

I look forward to learning more.

Best wishes
Radley

On Mon, Apr 29, 2019 at 1:12 PM Michael Gerrard [redacted] wrote:

Radley --

The Sabin Center is working with the Environmental Law Institute on a training session about climate change for federal judges. It will be held on June 28 at the Law School. I'll be giving a presentation to the judges about climate change litigation, and Paul Hanle and Sandra Thiam of the Environmental Law Institute would like to invite you to give a scientific presentation. This note is a heads up that you'll be hearing from them with the details. It would be great if you could do htis if you'll be in town, given that the audience will have some key decision makers.

Michael

--
Michael B. Gerrard
Andrew Sabin Professor of Professional Practice
Director, Sabin Center for Climate Change Law
Columbia Law School
435 West 116th Street
New York, New York 10027
[redacted]
www.columbiaclimatelaw.com

--
Radley Horton, Ph.D.
Lamont Associate Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

[redacted]

*Because I do not receive some emails sent to my giss.nasa email address, I request that you please use my columbia email address [redacted] instead. Thank you.

--
Radley Horton, Ph.D.
Lamont Associate Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

[redacted]

*Because I do not receive some emails sent to my giss.nasa email address, I request that you please use my columbia email address [redacted] instead. Thank you.

--

Radley Horton, Ph.D.
Lamont Associate Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

[redacted]

*Because I do not receive some emails sent to my giss.nasa email address, I request that you please use my columbia email address [redacted] instead. Thank you.

Spam
Not spam
Forget previous vote

--
Michael B. Gerrard
Andrew Sabin Professor of Professional Practice
Director, Sabin Center for Climate Change Law
Columbia Law School
435 West 116th Street
New York, New York 10027
[redacted]
www.columbiaclimatelaw.com

Exhibit 10

Climate Judiciary – New York City Participants

Climate Judiciary Seminar – New York City

Presented by the Environmental Law Institute

Participants

Hon. Frank Bailey	US Bankruptcy Court for the District of Massachusetts
Hon. Mildred Caban	US Bankruptcy Court for the District of Puerto Rico
Hon. Margaret Cangilos-Ruiz	US District Court for the Northern District of New York
Hon. Paul Davison	US District Court for the Southern District of New York
Hon. Joseph Dickson	US District Court for the District of New Jersey
Hon. Richard Eaton	US Court of International Trade
Hon. Cynthia Eddy	US District Court for the Western District of Pennsylvania
Hon. Julio Fuentes	US Court of Appeals for the 3rd Circuit
Hon. William Garfinkel	US District Court for the District of Connecticut
Hon. Nina Gershon	US District Court for the Eastern District of New York
Hon. Curtis Gomez	District Court of the Virgin Islands
Hon. Marcy Kahn	New York Supreme Court
Hon. Page Kelley	US District Court for the District of Massachusetts
Hon. Jack McConnell	US District Court for the District of Rhode Island
Hon. Bruce McGiverin	US District Court for the District of Puerto Rico
Hon. Jerrold Poslusny	US District Court for the District of New Jersey
Hon. Vera Scanlon	US District Court for the Eastern District of New York
Hon. Frederick Scullin	US District Court for the Northern District of New York
Hon. Brooks Smith	US Court of Appeals for the 3rd Circuit

Speakers and Partners

Prof. Michael Gerrard	Columbia Law School
Prof. Radley Horton	Columbia University
Sandra Thiam	Environmental Law Institute
Merideth Wright	Environmental Law Institute
John A. Pendergrass	Environmental Law Institute
Paul Hanle	Environmental Law Institute
Emily Cloyd	American Association for the Advancement of Science
Deborah Runkel	American Association for the Advancement of Science
Dana Chipman	Federal Judicial Center
David VanHoogstraten	Peace Corps

Exhibit 11

Climate Science for Judges-Towards a Climate Science Curriculum: Pilot Program Launch (June 28, 2019)

CLIMATE SCIENCE FOR JUDGES

TOWARDS A CLIMATE SCIENCE CURRICULUM: PILOT PROGRAM LAUNCH

A Program of the Environmental Law Institute's Climate Judiciary Project
in collaboration with
The American Association for the Advancement of Science

Cosponsored by the Federal Judicial Center

Sabin Center for Climate Change Law
Columbia University
William and June Warren Hall Room 417
1125 Amsterdam Avenue (at 115th Street)
New York City

June 28, 2019

CLIMATE JUDICIARY PROJECT

PURPOSE

To meet judges' need for a basic familiarity with current climate science to keep pace with the climate issues emerging in courtrooms and the law.

OBJECTIVES

- Gain an overview of how climate science issues may arise in litigation, including in environmental permitting and land use cases, and property damage and insurance cases, as well as litigation directly addressing climate change.
- Acquire a working knowledge of basic concepts, methods, and terminology of climate science.
- Learn about current research and issues in the science of climate-change attribution, and how it arises in litigation involving human activity and climate impacts.
- Discuss with other judges how climate science concepts, methods and terminology may come into play in various kinds of climate-related cases.
- Contribute to building the capacity of judges on these issues by informing the development of future climate-science judicial education sessions.

CLIMATE SCIENCE FOR JUDGES

AGENDA

8:30 am – 9:00 am	**Registration (light breakfast)**
9:00 am – 9:10 am	**Welcome and Opening Remarks** *Mr. John Pendergrass, ELI* *Ms. Deborah Runkle, AAAS* *Mr. Dana Chipman, FJC*
9:10 am – 9:40 am	**Overview of Climate Litigation Landscape** *Prof. Michael Gerrard, Sabin Center*
9:40 am – 11:00 am	**Climate Science for Judges** *Prof. Radley Horton, Lamont Doherty Earth Observatory*
	Questions and Answers
11:00 am – 11:15 am	**Coffee Break**
11:15 am – 12:15 pm	**Nexus of Climate Science & Litigation**
	Facilitated Discussion *Ms. Sandra Nichols Thiam, ELI* **Discussants** *Prof. Michael Gerrard, Sabin Center* *Prof. Radley Horton, Lamont Doherty Earth Observatory*
12:15 pm – 12:30 pm	**Feedback for Developing Climate Science Seminars and a Curriculum for Judges**
	Facilitated Discussion *Ms. Sandra Nichols Thiam, ELI*
12:30 pm – 1:30 pm	**Working Lunch**

SPEAKER BIOGRAPHIES

Prof. Michael B. Gerrard

Michael B. Gerrard is Andrew Sabin Professor of Professional Practice at Columbia Law School, where he teaches courses on environmental and energy law and founded and directs the Sabin Center for Climate Change Law. He has also chaired the Faculty of Columbia's Earth Institute. Before joining the Columbia faculty in January 2009, he was partner in charge of the 110-lawyer New York office of Arnold & Porter; he is now Senior Counsel to the firm. He practiced environmental law in New York City full time from 1979 to 2008 and tried numerous cases and argued many appeals in federal and state courts and administrative tribunals. He was the 2004-2005 chair of the American Bar Association's 10,000-member Section of Environment, Energy and Resources. He has also chaired the Executive Committee of the New York City Bar Association, and the Environmental Law Section of the New York State Bar Association. He has served as a member of the executive committees of the boards of the Environmental Law Institute and the American College of Environmental Lawyers.

Gerrard is author or editor of thirteen books, two of which were named Best Law Book of the Year by the Association of American Publishers. Among his books are Global Climate Change and U.S. Law (with Jody Freeman) (2d ed. 2014); Legal Pathways to Deep Decarbonization in the United States (with John Dernbach) (2019); Threatened Island Nations: Legal Implications of Rising Seas and a Changing Climate (with Gregory E. Wannier) (2013); and Climate Engineering and the Law: Governance and Liability for Solar Radiation Management and Carbon Dioxide Removal (with Tracy Hester) (2018).

Legal Media Group's Guide to the World's Leading Environment Lawyers, based on 4,000 questionnaires, reported in 2005 and again in 2007 that Gerrard "received more personal nominations for this guide than any other lawyer in the world."

He received his B.A. from Columbia University and his J.D. from New York University Law School, where he was a Root Tilden Scholar.

Prof. Radley Horton

Radley Horton is a Lamont Associate Research Professor at Columbia University's Lamont-Doherty Earth Observatory. His research focuses on climate extremes, tail risks, climate impacts, and adaptation. Horton was a Convening Lead Author for the Third National Climate Assessment. He currently Co-Chairs Columbia's Adaptation Initiative, and is Principal Investigator for the NOAA-Regional Integrated Sciences and Assessments-funded Consortium for Climate Risk in the Urban Northeast. He has drafted numerous articles, including The Law and Science of Climate Change Attribution (Forthcoming, Columbia Journal of Environmental Law (January 2020). He is also the Columbia University lead for the Department of Interior-funded Northeast Climate Science Center, and is a PI on an NSF-funded Climate Change Education Partnership Project.

Horton has been a Co-leader in the development of a global research agenda in support of the United Nations Environmental Program's Programme on Vulnerability, Impacts, and Adaptation (PROVIA) initiative. He recently testified to the House Subcommittee on the Environment, a subcommittee of the House Science, Space and Technology Committee, on Sea Change: Impacts of Climate Change on Our Oceans and Coasts and to the Senate's Subcommittee on Science, Oceans, Fisheries, and Weather, on Atmospheric Science Research and Forecasting Innovation. He serves on numerous national and international task forces and committees, including the Climate Scenarios Task Force in support of the 2018 National Climate Assessment, and frequently appears on national and international television, radio, and in print. Horton teaches in Columbia University's Sustainable Development department.

PARTICIPANTS

The Honorable Frank Bailey
U.S. Bankruptcy Court
District of Massachusetts

The Honorable Mildred Caban
U.S. Bankruptcy Court
District of Puerto Rico

The Honorable Margaret Cangilos-Ruiz
U.S. District Court
Northern District of New York

The Honorable Paul Davison
U.S. District Court
Southern District of New York

The Honorable Joseph Dickson
U.S. District Court
District of New Jersey

The Honorable Richard Eaton
U.S. Court of International Trade

The Honorable Cynthia Eddy
U.S. District Court
Western District of Pennsylvania

The Honorable Julio Fuentes
U.S. Court of Appeals
3rd Circuit

The Honorable William Garfinkel
U.S. District Court
District of Connecticut

The Honorable Nina Gershon
U.S. District Court
Eastern District of New York

The Honorable Marcy Kahn
New York Supreme Court
Appellate Division

The Honorable Page Kelley
U.S. District Court
District of Massachusetts

The Honorable Juanita Bing Newton
New York Judicial Institute

The Honorable Jerrold Poslusny
U.S. District Court
District of New Jersey

The Honorable Frederic Scullin
U.S. District Court
Northern District of New York

The Honorable D. Brooks Smith
U.S. Court of Appeals
3rd Circuit

SPEAKERS AND PARTNERS

Mr. Dana Chipman
Federal Judicial Center

Ms. Emily Cloyd
American Association for the Advancement of Science

Professor Michael Gerrard
Columbia Law School

Dr. Paul Hanle
Environmental Law Institute

Mr. David Van Hoogstraten
Advisor

Professor Radley Horton
Columbia University

Mr. John A. Pendergrass
Environmental Law Institute

Ms. Deborah Runkle
American Association for the Advancement of Science

Ms. Sandra Nichols Thiam
Environmental Law Institute

Judge Merideth Wright
Environmental Law Institute

Judge Benes Aldana
National Judicial College

SUPPLEMENTAL READING

Burger, Michael and Horton, Radley and Wentz, Jessica, The Law and Science of Climate Change Attribution (April 5, 2019). Forthcoming, Columbia Journal of Environmental Law (January 2020). Available at SSRN: https://ssrn.com/abstract=3051178

Gerrard, Michael B. *What Litigation of a Climate Nuisance Lawsuit Might Look Like,* 121 Yale L.J. Online, 135 (2011). Available at: https://www.arnoldporter.com/-/media/files/perspectives/publications/2011/09/what-litigation-of-a-climate-nuisance-suit-might__/files/publication/fileattachment/arnoldporterllptheyalelawjournal091311.pdf?

Schwartz, John. "Judges Give Both Sides a Grilling in Youth Climate Case Against the Government." New York Times, 4 June 2019. Available at: https://www.nytimes.com/2019/06/04/climate/climate-lawsuit-juliana.html

HISTORY OF THE PROJECT

In 2018, two climate and energy leaders—Paul Hanle, the former president of Climate Central, and David van Hoogstraten, a former BP senior executive—conceived the Climate Judiciary Project to provide neutral, objective information to judges about the science of climate change. The partners brought the project to the preeminent center for environmental law and judicial education, the Environmental Law Institute, where it was launched this spring. Inspired by earlier efforts in scientific judicial education including in biotechnology, information technology, and neuroscience, we focus on the science relevant to issues emerging in climate cases. The project offers information about what is and is not known about climate science, the range of uncertainty for that which is known, degrees of acceptance of various scientific conclusions within the expert community, areas at the forefront of research, and other topics that are or will be of practical interest to judges presiding over these cases. Our purpose is not to influence outcomes of specific court cases. The project is solely in aid of science-informed decision-making and intended to contribute to sound judicial processes and therefore good governance.

Environmental Law Institute
1730 M St NW, Suite 700
Washington, DC 20036
(202) 939-3800
eli.org



Exhibit 12

Climate Science for Judges-Towards a Climate Science Curriculum: Pilot Program Launch (July 12, 2019)

CLIMATE SCIENCE FOR JUDGES

TOWARDS A CLIMATE SCIENCE CURRICULUM: PILOT PROGRAM LAUNCH

A Program of the Environmental Law Institute's Climate Judiciary Project
in collaboration with
The American Association for the Advancement of Science

Cosponsored by the Federal Judicial Center

Jacob Burns Moot Court Room
Lerner Hall
George Washington University Law School
2000 H Street, NW 20052
Washington, DC

July 12, 2019

CJP0000946

CLIMATE JUDICIARY PROJECT

PURPOSE

To meet judges' need for a basic familiarity with current climate science to keep pace with the climate issues emerging in courtrooms and the law.

OBJECTIVES

- Gain an overview of how climate science issues may arise in litigation, including in environmental permitting and land use cases, and property damage and insurance cases, as well as litigation directly addressing climate change.
- Acquire a working knowledge of basic concepts, methods, and terminology of climate science.
- Learn about current research and issues in the science of climate-change attribution, and how it arises in litigation involving human activity and climate impacts.
- Discuss with other judges how climate science concepts, methods and terminology may come into play in various kinds of climate-related cases.
- Contribute to building the capacity of judges on these issues by informing the development of future climate-science judicial education sessions.

CLIMATE SCIENCE FOR JUDGES

AGENDA

10:00 am – 10:30 am	**Registration (light breakfast)**
10:30 am – 10:40 am	**Welcome and Opening Remarks** *Prof. Robert Glicksman,* *George Washington University Law School* *Mr. Scott Fulton, ELI* *Ms. Deborah Runkle, AAAS*
10:40 am – 11:10 am	**Overview of Climate Litigation Landscape** *Prof. Michael Gerrard, Sabin Center*
11:10 am – 12:45 pm	**Climate Science for Judges** *Prof. Stephen W. Pacala, Princeton University* **Questions and Answers**
12:45 pm – 1:45 pm	**Lunch**
1:45 pm – 2:30 pm	**Nexus of Climate Science & Litigation** **Facilitated Discussion** *Judge Jeremy Fogel, Berkeley Judicial Institute* **Discussants** *Prof. Michael Gerrard, Sabin Center* *Prof. Stephen W. Pacala, Princeton University*
2:30 pm – 2:50 pm	**Feedback for Developing Climate Science Seminars and a Curriculum for Judges** **Facilitated Discussion**
2:50 pm	**Adjourn**

SPEAKER BIOGRAPHIES

Prof. Michael B. Gerrard

Michael B. Gerrard is Andrew Sabin Professor of Professional Practice at Columbia Law School, where he teaches courses on environmental and energy law and founded and directs the Sabin Center for Climate Change Law. He has also chaired the Faculty of Columbia's Earth Institute. Before joining the Columbia faculty in January 2009, he was partner in charge of the 110-lawyer New York office of Arnold & Porter; he is now Senior Counsel to the firm. He practiced environmental law in New York City full time from 1979 to 2008 and tried numerous cases and argued many appeals in federal and state courts and administrative tribunals. He was the 2004-2005 chair of the American Bar Association's 10,000-member Section of Environment, Energy and Resources. He has also chaired the Executive Committee of the New York City Bar Association, and the Environmental Law Section of the New York State Bar Association. He has served as a member of the executive committees of the boards of the Environmental Law Institute and the American College of Environmental Lawyers.

Gerrard is author or editor of thirteen books, two of which were named Best Law Book of the Year by the Association of American Publishers. Among his books are Global Climate Change and U.S. Law (with Jody Freeman) (2d ed. 2014); Legal Pathways to Deep Decarbonization in the United States (with John Dernbach) (2019); Threatened Island Nations: Legal Implications of Rising Seas and a Changing Climate (with Gregory E. Wannier) (2013); and Climate Engineering and the Law: Governance and Liability for Solar Radiation Management and Carbon Dioxide Removal (with Tracy Hester) (2018).

Legal Media Group's Guide to the World's Leading Environment Lawyers, based on 4,000 questionnaires, reported in 2005 and again in 2007 that Gerrard "received more personal nominations for this guide than any other lawyer in the world."

He received his B.A. from Columbia University and his J.D. from New York University Law School, where he was a Root Tilden Scholar.

Prof. Stephen W. Pacala

Stephen W. Pacala is the Frederick D. Petrie Professor of Ecology and Evolutionary Biology at Princeton University. He co-directs the Carbon Mitigation Initiative, an effort to develop solutions to the greenhouse warming problem. Steve is also on the Board of the Environmental Defense Fund, and is a founder and Chairman of the Board of Climate Central, a nonprofit media organization focusing on climate change. He chaired the National Academy of

Sciences Committee on Carbon Dioxide Removal and Sequestration, which just released its report last October.

Professor Pacala has researched a wide variety of ecological and mathematical topics. At Princeton, his work focuses on problems of global change with an emphasis on interactions among the biosphere, greenhouse gases and climate. He also researches solutions to the climate problem, the dynamics of forests, and the relationship between biodiversity and ecosystem function.

Professor Pacala completed an undergraduate degree at Dartmouth College and a Ph.D. in Biology at Stanford University. His honors include the David Starr Jordan Prize, the George Mercer and Robert MacArthur Awards of the Ecological Society of America, and the Presidential Award of the American Society of Naturalists. He is a lifetime Fellow of the Ecological Society of America and Fellow of the American Association for the Advancement of Science. He holds an honorary membership to the British Ecological Society, and membership to the American Academy of Arts and Sciences and the U.S. National Academy of Sciences.

The Honorable Jeremy Fogel (Ret.)

On September 17, 2018, Judge Jeremy Fogel became the first Executive Director of the Berkeley Judicial Institute, a center at Berkeley Law School whose mission is to build bridges between judges and academics and to promote an ethical, resilient and independent judiciary. Prior to his appointment at Berkeley, he served as Director of the Federal Judicial Center in Washington, DC (2011-2018), as a United States District Judge for the Northern District of California (1998-2011), and as a judge of the Santa Clara County Superior (1986-1998) and Municipal (1981-1986) Courts. He was the founding Directing Attorney of the Mental Health Advocacy Project from 1978 to 1981.

Judge Fogel has served as a faculty member for the Federal Judicial Center since 2002 and was a lecturer at Stanford Law School from 2003 until his relocation to Washington. He taught for the California Continuing Judicial Studies Program and California Judicial College from 1987 to 2010 and has served as a faculty member for legal exchanges in more than a dozen foreign countries.

He received his B.A. from Stanford University in 1971 and his J.D. from Harvard Law School in 1974. Judge Fogel has received numerous accolades, including the President's Award for Outstanding Service to the California Judiciary from the California Judges Association and the Vanguard Award for notable contributions to intellectual property law from the State Bar of California. In 2002, he received special recognition from the Santa Clara County Bar Association for exemplifying the highest standards of professionalism in the judiciary.

PARTICIPANTS

The Honorable Joseph Anderson, Jr.
U.S. District Court
District of South Carolina

The Honorable Philip Carchman
New Jersey Superior Court

The Honorable Cameron Currie
U.S. District Court
District of South Carolina

The Honorable Nancy B. Firestone
U.S Court of Federal Claims

The Honorable Arthur Harris
U.S. District Court
Northern District of Ohio

The Honorable Joel Hoppe
U.S. District Court
Western District of Virginia

The Honorable Malcolm Howard
U.S. District Court
Eastern District of North Carolina

The Honorable Pauline Newman
U.S. Court of Appeals
Federal Circuit

The Honorable Jenny Rivera
New York State Court of Appeals

The Honorable Eugene Siler
U.S. Court of Appeals
Sixth Circuit

The Honorable TBD
New Jersey Superior Court

SPEAKERS AND PARTNERS

Ms. Emily Cloyd
American Association for the Advancement of Science

Judge Jeremy Fogel
Berkeley Judicial Institute

Professor Michael Gerrard
Columbia Law School

Dr. Paul Hanle
Environmental Law Institute

Mr. David Van Hoogstraten
Advisor

Professor Stephen Pacala
Princeton University

Mr. John A. Pendergrass
Environmental Law Institute

Ms. Deborah Runkle
American Association for the Advancement of Science

Ms. Sandra Nichols Thiam
Environmental Law Institute

Judge Merideth Wright
Environmental Law Institute

SUPPLEMENTAL READING

Burger, Michael and Horton, Radley and Wentz, Jessica, The Law and Science of Climate Change Attribution (April 5, 2019). Forthcoming, Columbia Journal of Environmental Law (January 2020). Available at SSRN: https://bit.ly/2X332oG

Gerrard, Michael B. *What Litigation of a Climate Nuisance Lawsuit Might Look Like,* 121 Yale L.J. Online, 135 (2011). Available at: https://bit.ly/31TDb67

Schwartz, John. "Judges Give Both Sides a Grilling in Youth Climate Case Against the Government." New York Times, 4 June 2019. Available at: https://nyti.ms/2HZdObu

HISTORY OF THE PROJECT

In 2018, two climate and energy leaders—Paul Hanle, the former president of Climate Central, and David van Hoogstraten, a former BP senior executive—conceived the Climate Judiciary Project to provide neutral, objective information to judges about the science of climate change. The partners brought the project to the preeminent center for environmental law and judicial education, the Environmental Law Institute, and we approached the American Association for the Advancement of Science, the leading organization of scientists, and the Federal Judicial Center, the agency responsible for federal judicial education, to join the Project as partners. Inspired by earlier efforts in scientific judicial education including in biotechnology, information technology, and neuroscience, we focus on the science relevant to issues emerging in climate cases. The project offers information about what is and is not known about climate science, the range of uncertainty for that which is known, degrees of acceptance of various scientific conclusions within the expert community, areas at the forefront of research, and other topics that are or will be of practical interest to judges presiding over these cases. Our purpose is not to influence outcomes of specific court cases. The project is solely in aid of science-informed decision-making and intended to contribute to sound judicial processes and therefore good governance.

Environmental Law Institute
1730 M St NW, Suite 700
Washington, DC 20036
(202) 939-3800
eli.org



Exhibit 13

Federal Judicial Center, Environmental Law Institute, and the American Association for the Advancement of Science Present: Climate Justiciary Project Seminar, Participant List (Sept. 13, 2019)

Federal Judicial Center
Environmental Law Institute
and the
American Association for the Advancement of Science
Present
Climate Judiciary Project Seminar
Hosted by Berkeley Law School
Berkeley, CA
September 13, 2019
Participant List

Honorable Cynthia Bashant	Southern District of California
Honorable Peter Carroll	Central District of California
Honorable Miranda Du	District of Nevada
Honorable William Fletcher	U.S. Court of Appeals for the Ninth Circuit
Honorable Theresa Fricke	Western District of Washington
Honorable Michael Hegarty	District of Colorado
Honorable Elizabeth Laporte	Northern District of California
Honorable Robert Lasnik	Western District of Washington
Honorable Jeremiah Lynch	District of Montana
Honorable Ramona Manglona	District of Northern Mariana Islands
Honorable William Orrick	Northern District of California
Honorable Michael Seabright	District of Hawaii
Honorable Suzanne Segal	Central District of California
Honorable William Shubb	Eastern District of California
Honorable Roslyn Silver	District of Arizona

Honorable Michael Simon	District of Oregon
Honorable Deborah Smith	District of Alaska
Honorable Nina Wang	District of Colorado
Honorable Eileen Willett	District of Arizona
Honorable Michael Wilner	Central District of California
Honorable Frank Zapata	District of Arizona

Exhibit 14

Email from Paul Hanle, Founder, CJP, to Kristie Ebi, Advisory Committee Member, CJP (June 28, 2022)

From: Kristie Ebi [redacted]
To: [redacted]
Cc: Sandra Nichols Thiam [redacted]
Subject: Re: speaker for Woods Hole September 12 or 13
Date: Tue, 28 Jun 2022 15:43:56 -0700
Importance: Normal

Dear Paul:

Excellent to hear of the progress you have been making. I would be honored to join the discussion for a day, if that is an option. I am working with climate scientists in the UK on detection and attribution who are also engaged in court cases on attribution of extreme events to climate change. If so, then the 12th would be best for me.

The other person you could consider is Prof Pat Kinney at Boston University. He mostly works on climate-related health impacts of air pollution and heat.

Best wishes,

Kris

On Jun 28, 2022, at 12:45 PM, [redacted] wrote:

Hi Kris,

I hope you are well. We are making good progress with our climate science curriculum, and at some point soon I'd like to brief you on it. In the meantime, however, I have a short report and a request.

Among the many threads of the project is a year-long course for select state judges in collaboration with the National Judicial College. We engaged NJC to reach out to the Chief Justices of every state and ask each to nominate one judge to be a "Judicial Leader in Climate Science." 21 states and Puerto Rico decided to participate, and we were very pleased that all but one of our target states (where cases were being brought) opted in. The program develops both their leadership skills and their knowledge of climate science, and it then explicitly charges them to become ambassadors to their judicial colleagues in the states. This coming September, the second of two multi-day courses for these JLCS judges will be held in Woods Hole, where we are delivering talks, conversations, and interactive activities focusing mostly on climate science.

We believe it is vital that these judges have a working knowledge of health impacts of climate change. And so we have scheduled a portion of the program for an expert to speak to the topic and lead a discussion of how these impacts might come to bear in court cases they or their colleagues may hear. We are hoping to attract a leading scholar who might be willing to come for a day in mid-September to this beautiful location and important center for scientific research to engage with the judges on health impacts. So, I want to ask if you might have any suggestions for potential speakers on the topic. We will, of course, cover their travel expenses. We are trying to favor people from the Northeast, to make it easier for all concerned, but we would also entertain inviting someone from a greater distance if necessary, and we have funds to cover this option.

With thanks for any suggestions you might have.

Best regards,
Paul

From: Kristie Ebi [redacted]
To: [redacted]
Cc: Sandra Nichols Thiam [redacted] Sarah Roth [redacted]
Subject: Re: speaker for Woods Hole September 12 or 13
Date: Thu, 30 Jun 2022 19:06:05 -0700
Importance: Normal

Dear Paul:

All sounds good. I look forward to hearing more.

I am working with Fredi Otto and her former Ph.D. student Rupert Stuart-Smith.

Happy 4th.

Best,

Kris

On Jun 29, 2022, at 1:46 PM, [redacted] wrote:

Kris,
We would be delighted to have you speak to our judges, and September 12 is perfect. Thank you so much for offering! We will be working up a memo on logistical information for speakers and judges in a few weeks, but please let us know if you need more information sooner. (The airports in Boston and Providence are the nearest, with more flights of course to BOS. We'll get back about ground trans and accommodations.)

We should speak about the scope of your talk in early August.

Again, thank you so much for doing this.

Best,
Paul

PS, is that our friend Myles Allen you are working with in the UK?

From: Kristie L Ebi [redacted]
Sent: Tuesday, June 28, 2022 6:44 PM
To: [redacted]
Cc: Sandra Nichols Thiam [redacted]
Subject: Re: speaker for Woods Hole September 12 or 13

Dear Paul:

Excellent to hear of the progress you have been making. I would be honored to join the discussion for a day, if that is an option. I am working with climate scientists in the UK on detection and attribution who are also engaged in court cases on attribution of extreme events to climate change. If so, then the 12th would be best for me.

Exhibit 15

Email from Jarryd Page, Staff Attorney, ELI, to Helene Kransoff, Director, CJP et al, (Mar. 11, 2025)

Message

From: Jarryd Page (he/him) [redacted]
on behalf of Jarryd Page (he/him) [redacted]
Sent: 3/11/2025 6:51:45 PM
To: Jarryd Page (he/him) [redacted]
CC: Helene Krasnoff (she/her) [redacted] Sandra Nichols Thiam [redacted] Paul Hanle [redacted] John Doherty [redacted] Jared Mummert he/him [redacted] Tom Lutken (He/Him) [redacted]
Subject: Re: JUNE MEETING for the Climate Judiciary Project Advisory Committee

This Message Is From an External Sender

This message came from outside your organization.

Dear Committee Members,

With apologies for any confusion, this meeting will be **virtual** and scheduled for **90 minutes**.

Thank you again for filling out your availability with this tool: CJP Curriculum Advisory Committee Meeting - June 2025 - When2meet.

Best wishes,

Jarryd

From: Jarryd Page (he/him) [redacted]
Sent: Tuesday, March 11, 2025 2:00 PM
To: Jarryd Page (he/him) [redacted]
Cc: Helene Krasnoff (she/her) [redacted] Sandra Nichols Thiam [redacted] Paul Hanle [redacted] John Doherty [redacted]; Jared Mummert he/him [redacted]; Tom Lutken (He/Him) [redacted]
Subject: JUNE MEETING for the Climate Judiciary Project Advisory Committee

Dear CJP Curriculum Advisory Committee,

I hope all is well. It is hard to believe that it has been almost a year since we convened last summer! With all that's going on with our project, the broader legal landscape, and the uncertainty around the near-term role that climate science might play in federal policy, we wanted to reconvene to update you on the project's continued success and get your feedback on emerging issues. We know you all are busy, but we very much value your input and expertise and look forward to your participation.

We will follow up with a detailed agenda in advance, but we wanted to get a time on your calendars now. Please fill out your availability using the following tool: CJP Curriculum Advisory Committee Meeting - June 2025 - When2meet.

We sincerely hope you will join us for this important and lively discussion! Please reach out with any questions.

Kindly,

Jarryd

Members of the CJP Curriculum Advisory Committee:

Professor Jonathan H. Adler, Case Western Reserve University

Professor Donald Boesch, University of Maryland

Professor Kristie L. Ebi, University of Washington

Professor Christopher B. Field, Stanford University

Judge Jeremy Fogel (ret.), former Director, Federal Judicial Center

Professor Inez Fung, UC Berkeley

Professor Michael Gerrard, Columbia University

Professor Geoffrey M. Heal, Columbia University

Professor Barry E. Hill, University of Vermont

Professor Michael Oppenheimer, Princeton University

Professor Stephen Pacala, Princeton University

Justice Ron Robie, Court of Appeal, State of California

Judge Michael Simon, United States District Court, Oregon

Judge David Tatel (ret.), US Court of Appeals, DC Circuit

Exhibit 16

Email from Michael Wehner, Senior Scientist, Lawrence Berkeley National Laboratory, to Roger Worthington, attorney, Worthington & Caron (June 1, 2023)

From: Michael Wehner [redacted]>
To: [redacted]"[redacted]
Subject: Re: Multnomah County vs Fossil Fuel Majors, et al
Date: Thu, 1 Jun 2023 10:29:28 -0700

This was the thing for judges that I sent earlier. The final version is being prepared now for the ELI module.
ELI Environmental Law Institute

Michael

On Jun 1, 2023, at 9:25 AM, [redacted] wrote:

Good Morning. ELI piece? I cant find. Can you please resend?

Appreciate your valuable insights.

Worthington & Caron, PC
Toll free: [redacted]
San Pedro Office: [redacted]
Fax: [redacted]
Cell: [redacted]
[redacted]com

PastedGraphic-6.tiff

On May 31, 2023, at 4:42 PM, Michael Wehner [redacted] wrote:

Roger
The lab's attorneys need to talk to me anyway next week about the ELI piece that I sent you. I will bring it up then.
Michael

On May 31, 2023, at 4:34 PM, [redacted] wrote:

Hello Michael:

Good news! Multnomah County has retained my team to bring a civil suit for damages in Oregon state court against various shareholder owned, vertically integrated Fossil Fuel companies, and other parties, who bear major responsibility for the recent climate change exacerbated heat domes, wildfires, droughts, etc.

We appreciate the vital insights you provided us during the "due diligence" phase of our investigation. Your published work has helped us reach the opinion that we can establish a prima facie under various legal theories. We intend to file towards the end of the month.

As mentioned before, we would like to discuss retaining your services as a consulting expert witness at the appropriate time. We can and will enumerate the scope of your anticipated testimony. I understand that the terms of your employment may prohibit you from testifying as an expert; however, we would be interested in consulting with you (without the need to appear for depositions or trial). As you know, in view of the

ongoing jurisdictional battles, we likely will not have a discovery and trial schedule in state court for several months, perhaps even several years.

We look forward to working with you, and learning from you.

Cheers!

Roger

Worthington & Caron, PC
Toll free: [redacted]
San Pedro Office: [redacted]
Fax: [redacted]
Cell: [redacted]
[redacted]

PastedGraphic-6.tiff

Exhibit 17

Email from Michael Wehner, Senior Scientist, Lawrence Berkeley National Laboratory, to Roger Worthington, attorney, Worthington & Caron (June 2, 2023)

From: Michael Wehner [redacted]
To: Roger Worthington [redacted]
Subject: Re: Multnomah County vs Fossil Fuel Majors, et al
Date: Fri, 2 Jun 2023 15:11:34 -0700

Roger
I spoke with Berkeley Lab attorneys today. The module for the Environment Law Institute triggered a longer discussion. In view of that, I must decline your offer of being a paid consultant, at least for now.

Given the length of the schedule, it is likely that my employment status could change during the process as I am past retirement age. I am not ready to retire at this time however.

Regards
Michael

On May 31, 2023, at 4:34 PM, [redacted] wrote:

Hello Michael:

Good news! Multnomah County has retained my team to bring a civil suit for damages in Oregon state court against various shareholder owned, vertically integrated Fossil Fuel companies, and other parties, who bear major responsibility for the recent climate change exacerbated heat domes, wildfires, droughts, etc.

We appreciate the vital insights you provided us during the "due diligence" phase of our investigation. Your published work has helped us reach the opinion that we can establish a prima facie under various legal theories. We intend to file towards the end of the month.

As mentioned before, we would like to discuss retaining your services as a consulting expert witness at the appropriate time. We can and will enumerate the scope of your anticipated testimony. I understand that the terms of your employment may prohibit you from testifying as an expert; however, we would be interested in consulting with you (without the need to appear for depositions or trial). As you know, in view of the ongoing jurisdictional battles, we likely will not have a discovery and trial schedule in state court for several months, perhaps even several years.

We look forward to working with you, and learning from you.

Cheers!

Roger

Worthington & Caron, PC
Toll free: [redacted]
San Pedro Office: [redacted]

PastedGraphic-6.tiff

Exhibit 18

Email from Paul Hanle, Founder, CJP, to Kristie Ebi, Committee Member, CJP (Sept. 22, 2022)

From: "Green, Fergus" [redacted]
Subject: [CSSN] New database to support litigation against fossil fuel projects
Date: November 6, 2023 at 12:01:51 PM PST
To: [redacted]
Cc: "Pye, Steve" [redacted]

Dear CSSNers,

I'm excited to promote a new database, Redline—Research Database for Litigation Against New Fossil Fuel Extraction. The purpose of Redline is to help environmental NGOs and public-interest lawyers address questions of fact that commonly arise in legal challenges against new fossil fuel projects. The database will also be a useful resource for journalists and researchers working on fossil fuel-related issues in the context of the climate crisis.

Redline contains key scholarly research papers and reports relevant to these issues. Each article/report has its own page with an easily digestible summary that also highlights potential applications of the research in fossil fuel litigation. On the platform, the articles and summaries are organised into browsable categories covering factual issues commonly arising in fossil fuel-related litigation. Each category has its own landing page describing the issue and introducing the relevant articles in the database.

Redline is the product of a project I co-led with my UCL colleague, Dr Steve Pye (UCL Energy Institute), and funded by UCL Grand Challenges. We are grateful for the support of our project partners: EarthJustice; Friends of the Earth UK; Uplift; and the Climate Litigation Network.

We very much welcome any feedback and suggestions you may have.

Kind regards,

Fergus

Dr Fergus Green
Lecturer in Political Theory & Public Policy
Department of Political Science and School of Public Policy
University College London
[redacted]
--

From: [redacted]
To: 'Kristie L Ebi' [redacted]
Cc: 'Sandra Nichols Tham' [redacted]
Subject: Thank you!
Date: Thu, 22 Sep 2022 21:01:47 +0000
Importance: Normal

Dear Kris,

Sandy and I want to express our gratitude to you for taking the time and effort to present to ELI's Judicial Leaders in Climate Science in Woods Hole last week. We received many comments from the judges about the quality of the presentations, and especially on your excellent session on the impacts of climate change on human health. One judge let us know that he had begun as a skeptic about the effects on health but was turned around by your presentation. What a great validation of your presentation...and the project!

We know how busy you are and sincerely appreciate your willingness to give our program priority over the many other demands that are placed on you. The work you are doing is of vital importance to the future of humanity and the planet, and so we are extremely grateful that you would allow us to share it with this influential audience. I know I speak for all of the judges in saying thank you with deepest appreciation.

With best wishes,

Paul and Sandy

Exhibit 19

Email from Michael Wehner, Senior Scientist, Lawrence Berkeley National Laboratory, to Roger Worthington, attorney, Worthington & Caron (Mar. 16, 2023)

From: Roger Worthington [redacted]
To: Michael Wehner [redacted]
Cc: "Philip, Sjoukje (KNMI)" [redacted], "Shreedhar R. Patel" [redacted] John Caron [redacted]>
Subject: Re: PNW Heat Dome Attribution
Date: Thu, 16 Mar 2023 16:36:40 -0700
Attachments: PastedGraphic-6.tiff;
Attribution_Version_2_track_changes_bluebooked2_MFW_changesaccepted.docx

---

Fantastic.

Let me review and I will ping you back for a mutually convenient time to discuss.

Cheers!

Roger

Worthington & Caron, PC
[redacted]
www.worthingtoncaron.com
[redacted]

On Mar 16, 2023, at 4:33 PM, Michael Wehner [redacted] wrote:

Roger et al.
You may find this draft module on attribution of climate change useful.
It was prepared for the Environmental Law Institute. I have not received the final version or comments back from them yet.
Michael

On Mar 16, 2023, at 8:45 AM, Roger Worthington [redacted] wrote:

Thank you.

Can you please provide Michael Wehner's contact info?

Cheers

Roger

Worthington & Caron, PC
[redacted]
www.worthingtoncaron.com
[redacted]

PastedGraphic-6.tiff

On Mar 16, 2023, at 2:05 AM, Philip, Sjoukje (KNMI) [redacted] wrote:

Dear Roger,

Michael Wehner (in cc), one of the co-authors of this article, is willing to speak with you.

Kind regards,
Sjoukje

On 14 Mar 2023, at 16:32, Roger Worthington [redacted] > wrote:

Good Morning Sjoukje - Thank you for your reply. Can you please recommend another co-author from you PNW Heat Dome article with whom I can speak? Thank you, Roger

Worthington & Caron, PC
[redacted]
www.worthingtoncaron.com<http://ww.worthingtoncaron.com>
[redacted]

<PastedGraphic-6.tiff>

On Mar 14, 2023, at 7:05 AM, Philip, Sjoukje (KNMI) [redacted] wrote:

Dear Roger Worthington,

Thank you for your interest in my paper. I do however not deal with legal matters, so I can not speak about this matter by phone.

Kind regards,
Sjoukje Philip

On 13 Mar 2023, at 20:09, Roger Worthington [redacted] wrote:

Hello Dr. Philip:

I am an attorney who's been asked by a county in the state of Oregon (USA) to evaluate the scientific and legal merits of a potential claim against the FF companies who may be liable for damages arising from the 2021 PNW heat dome, and beyond.

I have read your Dec 2022 article. Most impressive.

Are you available to speak with me on the phone?

Thank you for your critical, impressive and timely work.

Thank you,

Roger Worthington, Esq.

Worthington & Caron, PC
[redacted]
www.worthingtoncaron.com<http://www.worthingtoncaron.com/>
<http://ww.worthingtoncaron.com<http://ww.worthingtoncaron.com/>>
[redacted]

<PastedGraphic-6.tiff>

Exhibit 20

Letter from Hon. John B. McCuskey, Attorney General, West Virginia (et. al), to Hon. Robin L. Rosenberg, Director, Federal Judicial Center (Jan. 29, 2026)

State of West Virginia
Office of the Attorney General
John B. McCuskey
Attorney General

January 29, 2026

The Honorable Robin L. Rosenberg
Director of the Federal Judicial Center
Thurgood Marshall Federal Judiciary Building
One Columbus Circle NE
Washington, DC 20002

Dear Judge Rosenberg:

For decades, litigants and judges alike have used the Federal Judicial Center's *Reference Manual on Scientific Evidence*. The U.S. Supreme Court has cited it more than once to explain foundational principles in science and math.[1] And that Court isn't alone. The *Manual* "has been provided to more than 3,000 federal judges and even more state court judges and others and has been cited in over 1,700 opinions."[2] So accuracy and impartiality in the *Manual* is vital.

At least up to this point, the Center has been careful to stress that the *Manual* merely "describes basic principles of major scientific fields."[3] It was "not intended to instruct judges concerning what evidence should be admissible or establish minimum standards for acceptable scientific testimony."[4] Rather, the Center chiefly intended that the *Manual* would "open legal institutional channels."[5]

Whatever one might say about past editions, the recently issued Fourth Edition cannot claim such restraint. It does more than address undisputed scientific principles. Instead, the Fourth Edition places the judiciary firmly on one side of some of the most hotly disputed questions in current litigation: climate-related science and "attribution." Such work undermines the judiciary's impartiality and places a thumb on one side of the scale. It does so even as these issues are pending before the Supreme Court and other parts of the federal judiciary.

---

[1] *See, e.g., Brnovich v. Democratic Nat'l Comm.*, 594 U.S. 647, 677 n.17 (2021).

[2] Michael Green, *The Education of the Judiciary: The Sciences Addressing Disease Causation*, 49 SW. L. REV. 492, 499 (2021).

[3] FED. JUD. CTR., REFERENCE MANUAL ON SCIENTIFIC EVIDENCE xv (3d ed. 2011).

[4] *Id.*

[5] *Id.* at 9.

We ask that the Center immediately withdraw the inappropriate "Reference Manual on Climate Science" included in the Fourth Edition. Judges should resolve these issues through the ordinary processes of litigation—not by way of a judicially driven, committee-led, quasi-amicus brief.

The problems in the climate reference section seem to have started in selecting its authors. Jessica Wentz and Radley Horton are both connected with climate studies programs at Columbia University. And Columbia and its research partners have long viewed lawsuits against States, traditional energy producers,[6] and others as "opportunities" to "resolve" what they see as "the pressing dangers created by climate change."[7] Wentz and Horton themselves have applauded litigation as a tool to advance their preferred political objectives, complaining that the "political sphere in the United States continues to be clouded with false debates over the validity of climate change."[8] As they see it, the courtroom provides a better venue.[9]

Wentz and Horton's work in the *Manual*'s Fourth Edition seems intended to ensure that the judiciary will continue to accept their views uncritically. As best we can tell, Wentz and Horton did not consult any experts who might take a view inconsistent with Wentz and Horton's conception of "consensus." They do not cite, for instance, any of the leading experts from the Department of Energy's recent report on climate change.[10] Instead, they endorse a select group of "authoritative science bodies," such as the Intergovernmental Panel on Climate Change.[11] They even suggest that an expert's consistency with the IPCC should be integrated as a part of the standard *Daubert* analysis.[12] At the same time, they do not acknowledge the significant criticisms that experts have levied against the IPCC's purportedly "authoritative" work.[13] Thus, one side's

[6] Even in the research notes in the *Manual*, the authors bemoan research "funded by fossil fuel interests or other industry actors." FED. JUD. CTR., REFERENCE MANUAL ON SCIENTIFIC EVIDENCE 1652 (4th ed. 2025). The authors express no similar skepticism towards those who fund research with an aim to advance plaintiff-side climate-related litigation.

[7] UNITED NATIONS ENV'T PROGRAMME, GLOBAL CLIMATE LITIGATION REPORT: 2023 STATUS REVIEW 74 (2023).

[8] Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 45 COLUM. J. ENV'T L. 57, 239 (2020). Michael Burger is counsel for the City of Honolulu in ongoing litigation against energy companies related to climate change. *See* Br. for Resps., *Sunoco LP v. City & Cnty. of Honolulu*, 145 S. Ct. 1111 (2025) (23-947), 2024 WL 1995228. Burger also wrote an amicus brief opposing the State of West Virginia in *West Virginia v. EPA*, 597 U.S. 697 (2022).

[9] Burger, Wentz & Horton, *supra* note 8, at 239. Wentz has even written about how Plaintiffs should bring such suits. *See generally, e.g.*, Jessica Wentz & Benjamin Franta, *Liability for Public Deception: Linking Fossil Fuel Disinformation to Climate Damages*, 52 ENV'T L. REP. (ELI) 10,995 (2022). And our concerns extend beyond the named authors. *See, e.g.*, Michael A. Fragoso, *Why is Congress Funding the Judiciary's Support for Climate Plaintiffs?*, NAT'L REV. (Jan. 15, 2026, 1:52 PM), https://tinyurl.com/d5h8w2k9 (cataloguing the many plaintiffs' experts who were involved in developing the report).

[10] *See generally* U.S. DEP'T OF ENERGY, CLIMATE WORKING GRP., A CRITICAL REVIEW OF IMPACTS OF GREENHOUSE GAS EMISSIONS ON U.S. CLIMATE (2025).

[11] *See* FED. JUD. CTR., *supra* note 6, at 1581-82 ("The IPCC is widely considered to be the leading scientific body for the assessment and synthesis of research on climate change.").

[12] *Id.* at 1585.

[13] *See, e.g.*, Jason S. Johnston, *Reliance on Climate Change Data From IPCC Is Badly Misplaced*, FRASER INST. (Sept. 13, 2022), https://tinyurl.com/yc34f22u ("The IPCC is not and has never been an objective science assessment

view becomes the baseline for all future judicial decisions on the subject. In fact, the *Manual*'s committee-based resolution of scientific issues is more consistent with the *European* approach to adjudication.[14]

Flawed conclusions then follow from this flawed sourcing.

In one discussion of potential expert testimony in climate- and energy-related cases, for example, the authors offer a cursory defense of "novel" attribution methods—sweepingly reassuring judges that these methods "[i]n many cases" are not "novel" at all.[15] Later, in canvassing so-called attribution science, the authors declare that certain aspects of that evolving field are actually "unequivocally" established—leaving a litigant who dares to take a different view effectively doomed from the start.[16] Among other things, the *Manual* states that human activities have "unequivocally warmed the climate," that it is "extremely likely" human influence drives ocean warming, and that researchers are "virtually certain" about ocean acidification—all treating contested litigation positions as settled fact.

Elsewhere, the authors opine that "it is possible to quantify the contribution of anthropogenic forcing to specific damages, harms, and economic and noneconomic losses"[17]—the ultimate remedy question at issue in a variety of litigation currently pending before federal courts. Unsurprisingly, then, the authors race to embrace a controversial study that ties specific harms to emissions from specific "major" sources.[18] And the authors conceive of climate-related impacts in the broadest possible terms—which would in turn support the most substantial findings of liability for climate-driven plaintiffs.[19]

Aside from their tendency to offer conclusive opinions on matters of serious dispute, the authors also canvass *legal* issues divorced from the scientific considerations that the *Manual* is meant to address. In these sections, they turn their conclusions into a litigation playbook. In one case, the *Manual* provides a three-part causation test for judges to apply when determining whether defendants' emissions contributed to plaintiffs' injuries. This is not neutral education, but rather a decision tree for resolving the central contested issue in climate tort litigation.[20] Elsewhere, after surveying various cases implicating climate and environmental issues (some of which we brought), the authors again explain how "climate science may factor into the resolution of [these] climate

organization. It was created by and has always been controlled by the governments of countries that perceive political benefits from international regulatory action to reduce greenhouse gas emissions.").

[14] Mingzhe Zhu & Liyuan Fan, *A Comparative Study of the Judicial Construction of Scientific Credibility in Climate Litigation*, 33 REV. OF EUR., COMP. & INT'L ENV'T L. 250, 261-62 (2023).

[15] *See* FEDERAL JUDICIAL CENTER, *supra note* 6, at 1585.

[16] *Id.* at 1594-98.

[17] *Id.* at 1609.

[18] *Id.* at 1622-23.

[19] *Id.* at 1604-14.

[20] *Id.* at 1584.

lawsuits."[21] Among other things, the *Manual* explicitly frames itself as helping resolve the exact causation questions at issue in pending cases.[22]

In other words, the authors offer unsolicited, *ex parte* expert opinions on matters that they recognize are directly at issue in ongoing suits. In several places, for instance, the authors dismiss any suggestion that climate science is too speculative or uncertain to justify relief.[23] They do so even though those concerns present one of the central problems in climate-related cases (and even though certainty is an essential element of expert admissibility standards).[24]

In short, the climate-related section of the *Manual* is rife with methodology issues.

But placing the judiciary's stamp of approval on this work elevates it from problematic to affirmatively destructive. "Article III, § 1[] [of the U.S. Constitution] guarantee[s] … an independent and impartial adjudication by the federal judiciary of matters within the judicial power of the United States."[25] Nothing is "independent" or "impartial" in issuing a document on behalf of America's judges declaring that only one preferred view is "within the boundaries of scientifically sound knowledge."[26] Even more so when active litigation raising those exact issues is pending before federal courts—including before the Supreme Court.[27] That kind of judicial predetermination is anathema to our system of justice.

And the problem only grows considering how many climate-related cases involve questions of state regulatory authority and state common law. By predetermining scientific underpinnings, the *Manual* effectively prejudges federalism questions that should be resolved through litigation. That sounds nothing like a "dispassionate guide."[28] Nor does it seem consistent with the Center's mandate "to further the development and adoption of improved judicial administration in the courts of the United States."[29] And ultimately, "[i]n politically contentious debates over matters shrouded in scientific uncertainty, courts should not assume that self-described experts are correct."[30]

Really, this issue transcends climate policy. If the Center can predetermine scientific questions in climate cases, what prevents it from doing the same for pharmaceutical liability, election disputes, or Second Amendment cases? The precedent is dangerous regardless of one's views on climate change. Given those consequences, we anticipate sharing this letter with congressional leadership

[21] *Id.* at 1631.

[22] *Id.* at 1564.

[23] *See, e.g.*, *id.* at 1636, 1639.

[24] *McClain v. Metabolife Int'l, Inc.*, 401 F.3d 1233, 1237 (11th Cir. 2005) ("*Daubert* requires the trial court to act as a gatekeeper to insure that speculative and unreliable opinions do not reach the jury.").

[25] *Peretz v. United States*, 501 U.S. 923, 929 n.6 (1991) (citation omitted).

[26] *See* FED. JUD. CTR., *supra note* 6, at xvii.

[27] *See, e.g., Cnty. Comm'rs of Boulder Cnty. v. Suncor Energy USA, Inc.*, 2025 CO 21, *cert. pet. filed*, 25-170 (Aug. 8, 2025); *see also, e.g.*, Compl., *West Virginia v. James*, 1:25-cv-00168-BKS-DJS (S.D.N.Y. Feb. 6, 2025).

[28] *See* FEDERAL JUDICIAL CENTER, *supra note* 6, at xiii.

[29] 28 U.S.C. § 620.

[30] *United States v. Skrmetti*, 605 U.S. 495, 547 (2025) (Thomas, J., concurring).

so that they may examine whether the Center has exceeded its statutory mandate or otherwise overstepped.

Article III guarantees every litigant—whether a State, an energy company, or an environmental group—the right to an independent and impartial tribunal. When the judiciary's own research arm predetermines contested questions in active litigation, that guarantee becomes meaningless. The Center should withdraw this chapter immediately, not out of political expedience, but out of fidelity to the Constitution it serves. The Center should also establish procedures to prevent similar advocacy-based chapters in future editions. We would appreciate a response indicating whether the Center plans to take these steps by February 6, 2026.

Sincerely,



John B. McCuskey
West Virginia Attorney General



Steve Marshall
Alabama Attorney General



Stephen J. Cox
Alaska Attorney General



Tim Griffin
Arkansas Attorney General



James Uthmeier
Florida Attorney General



Christopher M. Carr
Georgia Attorney General



Raúl Labrador
Idaho Attorney General



Todd Rokita
Indiana Attorney General



Brenna Bird
Iowa Attorney General



Kris W. Kobach
Kansas Attorney General



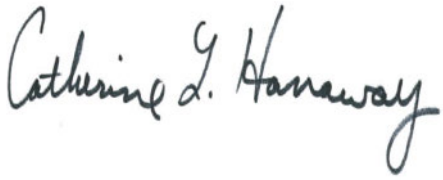
Russell Coleman
Kentucky Attorney General



Liz Murrill
Louisiana Attorney General



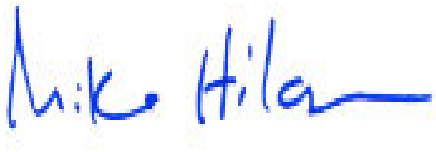
Lynn Fitch
Mississippi Attorney General



Catherine L. Hanaway
Missouri Attorney General



Austin Knudsen
Montana Attorney General



Mike Hilgers
Nebraska Attorney General



John M. Formella
New Hampshire Attorney General



Drew Wrigley
North Dakota Attorney General



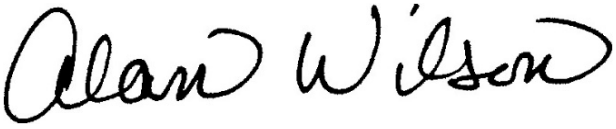
Dave Yost
Ohio Attorney General



Gentner Drummond
Oklahoma Attorney General



Dave Sunday
Pennsylvania Attorney General



Alan Wilson
South Carolina Attorney General



Marty J. Jackley
South Dakota Attorney General



Jonathan Skrmetti
Tennessee Attorney General and Reporter



Ken Paxton
Texas Attorney General



Derek Brown
Utah Attorney General



Keith Kautz
Wyoming Attorney General

cc: Chief Justice John G. Roberts, Jr., Supreme Court of the United States
Judge Kathleen Cardone, U.S. District Court for the Western District of Texas
Judge R. Guy Cole, Jr., U.S. Court of Appeals for the Sixth Circuit
Judge Sara L. Ellis, U.S. District Court for the Northern District of Illinois
Judge Ralph R. Erickson, U.S. Court of Appeals for the Eighth Circuit
Judge Michelle M. Harner, U.S. Bankruptcy Court for the District of Maryland
Judge Suzanne Mitchell, U.S. District Court for the Western District of Oklahoma
Judge Lynn Winmill, U.S. District Court for the District of Idaho
Judge Robert J. Conrad, Jr., Director of the Administrative Office of the U.S. Courts

Exhibit 21

Letter from Hon. Robin L. Rosenberg, Director, Federal Judicial Center, to Hon. John B. McCuskey, Attorney General, West Virginia (Feb. 6, 2026)

THE FEDERAL JUDICIAL CENTER
THURGOOD MARSHALL FEDERAL JUDICIARY BUILDING
ONE COLUMBUS CIRCLE, N.E.
WASHINGTON, DC 20002-8003

HONORABLE ROBIN L. ROSENBERG
DIRECTOR

[redacted]

February 6, 2026

The Honorable John B. McCuskey
Attorney General
1900 Kanawha Blvd. E.
Building 1, Room E-26
Charleston, WV 25305

Dear Attorney General McCuskey,

In response to your letter dated January 29, 2026, I write to inform you that the Federal Judicial Center has omitted the climate science chapter from the *Reference Manual on Scientific Evidence, Fourth Edition* (RMSE): https://www.fjc.gov/content/396456/reference-manual-scientific-evidence-fourth-edition

Sincerely,

Robin L. Rosenberg

Judge Robin L. Rosenberg
Director, Federal Judicial Center

Exhibit 22

Email from Michael Burger, Executive Director, Sabin Center to Joe Cecil, Senior Advisor, NASEM (Dec. 30, 2022)

From: Michael Burger <[redacted]
Sent: Friday, December 30, 2022 11:03 AM
To: Cecil, Joe <[redacted]
Cc: Mazza, Anne-Marie <[redacted]>; Beth Wiggins <[redacted]
Subject: Re: Invitation to Prepare a Climate Science Chapter for the Reference Manual on Scientific Evidence

Joe,

Happy New Year, and thank you for the invitation to contribute to this important project. The short answer is yes, I will be honored to write this chapter. If it is acceptable to you and the editorial team I would like to include Jessica Wentz and Radley Horton, my co-authors, as well. I think the combination of the three of us will only enhance the quality and authority of the chapter. Please let me know what you think.

All best,

Mike

On Dec 29, 2022, at 10:13 PM, Cecil, Joe <[redacted]> wrote:

Dear Professor Berger:

I am writing to ask whether you, perhaps along with scholars you are working with, might be interested in writing a new chapter on climate science for the fourth edition of the *Reference Manual on Scientific Evidence*, which is the primary reference source on scientific methodology for the federal judiciary.

The Federal Judicial Center and National Academies of Sciences, Engineering, and Medicine, with support from the National Science Foundation and the Gordon and Betty Moore Foundation, are currently developing a new fourth edition of the *Reference Manual*. The National Academies has convened a committee of distinguished judges and scientists to oversee the development of the new edition of the Reference Manual. The committee is seeking to develop a new chapter on climate science that will be responsive to the issues that arise when judges must consider such evidence in the context of litigation. I have attached a number of documents that will provide more information about our project.

We believe that much of the information for the proposed chapter is included in your 2020 co-authored law review article, *The Law and Science of Climate Change Attribution.* The chapter we seek will focus on climate science methodologies and the legal contexts in which such issues may arise. However, this chapter is unlike a law review article in that it should not instruct judges how the merits of such cases should be resolved.

If you are interested in this opportunity, please let me know and we can discuss next steps. Author teams will receive a total of $8,000.00 for delivery of a final manuscript that is responsive to external reviewer comments. We are on a tight schedule and will need a final draft that has undergone both committee and peer review by April 3 2023. We expect to publish the new edition of the *Reference Manual* in early 2024.

[redacted]

I hope we can collaborate in strengthening judges understanding of the process of scientific inquiry into climate-related issues. I look forward to hearing from you.

[redacted]

Regards,

Joe

[redacted]

Joe S. Cecil, Ph.D., J.D.

Senior Advisor

Committee on Science, Technology, and Law

The National Academies of Sciences, Engineering, and Medicine

[redacted]

--

Radley Horton, Ph.D. (*he/him/his*)
Lamont Research Professor

Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS

Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

Office
Cell: [redacted]
Fax:

Twitter: [redacted]

*Because I do not receive some emails sent to my [redacted], I request that you please use my [redacted] email address [redacted] instead. Thank you.

Exhibit 23

Email from Beth Wiggins, Director of the Research Division, FJC, to Michael Burger, Executive Director, Sabin Center (Mar. 6, 2023)

Michael Burger
Executive Director
Sabin Center for Climate Change Law
Senior Research Scholar and Lecturer-in-Law
Columbia Law School
[redacted]
Pronouns: *he, him, his*

The information contained in this email message may be privileged, confidential and protected from disclosure. If you are not the intended recipient, any dissemination, distribution or copying is strictly prohibited. If you think that you have received this email message in error, please notify the sender by reply email and delete the message and any attachments.

---------- Forwarded message ---------
From: **Beth Wiggins** [redacted]
Date: Mon, Mar 6, 2023 at 9:30 PM
Subject: RE: Invitation to Prepare a Climate Science Chapter for the Reference Manual on Scientific Evidence
To: Jessica Wentz [redacted]
Cc: Michael Burger [redacted], Cecil, Joe [redacted] Mazza, Anne-Marie [redacted], Radley M. Horton [redacted] Alexis Allegra [redacted]

Dear Mike, Jessica, and Radley,

Thank you very much for the outline of a chapter on climate science for the Reference Manual on Scientific Evidence. During its last meeting, the committee of judges and scientists overseeing the manual revision discussed the outline and the potential conflict Mike raised due to his representation of several state and local governments in lawsuits against fossil fuel companies.

With respect to the conflict:

The committee highly appreciated Mike's candor about his involvement in climate-related litigation and his recognition that his involvement might affect perceptions of the chapter's objectivity. Recognizing that the climate science chapter is likely to draw particular attention and critique, the committee decided that it would be inadvisable for Mike to author it. The committee is hopeful that Jessica and Radley would be comfortable authoring the chapter alone, and Mike would be comfortable stepping aside to allow them to do that. Please let us know if this would be agreeable to you.

With respect to the outline:

The committee thinks your outline shows promise of a chapter that would be suitable for the manual and is very interested in seeing a draft. They also had some crucial comments about how to modify it for the manual.

- Importantly, the chapter should be framed to ensure climate science is, in your words, "approached through a neutral lens." The introduction, rather than focusing on anthropogenic

climate change, should describe in general terms the full discipline of climate science. What are the major questions with which the science has concerned itself (in addition to modern climate change)? What are the scientific backgrounds of the scientists? Or, perhaps, in other words, how does climate science relate to other scientific disciplines and subfields? And generally, what are its methods? In Part V of your outline, you discuss the mistaken perception that climate science is uniquely novel/uncertain – framing the chapter as suggested will help show that climate science is an established field with established methods and will help judges when they are assessing whether someone qualifies as an expert on climate science (an issue you cover in greater detail in II.C.)

- One member suggested that Part II.C. might be moved before II.B to describe the leading, credible sources and authorities on climate science, an important topic for judges.

- In Part II, the committee would like: (i) an explanation of the carbon cycle including both natural and anthropogenic sources of imbalances to the cycle, and (ii) a discussion of natural variations in climate patterns over time. You may have already anticipated including this information under the first and second bullets under II.A.

- The committee had significant discussion about the difficulty of scientifically attributing climate change and its impacts to specific sources and wanted to be sure the chapter reflected this difficulty. This discussion highlighted the critical importance of the attribution discussion acknowledging both advances and limitations of science. Attribution issues are ones likely to be debated in court.

- As we discussed on our call, the committee emphasized that judges read the manual for the science not the law, which will be well-briefed and with which they are familiar. It is also the place where bias toward various legal positions might inadvertently surface. They suggested streamlining Section IV, perhaps only describing the primary ways climate science might come up in litigation. Some members suggested that state-only issues need not be covered, except perhaps in footnotes, though others noted that some issues are not squarely in one type of court or another, and state judges also use the manual.

Thank you again for your outline. Please let us know if you have any questions, and we are, of course, happy to have a conversation about the authorship issue, as well as the comments on the outline. Could you please let us know if you would like to move forward as soon as you are able? We are still hoping to have the first draft in hand mid-to-late April.

Best,
Beth

From: Jessica Wentz [redacted]
Sent: Friday, February 3, 2023 4:16 PM
To: Beth Wiggins <[redacted]
Cc: Michael Burger [redacted]; Cecil, Joe [redacted]; Mazza, Anne-Marie [redacted]; Radley M. Horton [redacted] Alexis Allegra [redacted]

Exhibit 24

Email from Michael Burger, Executive Director, Sabin Center, to Jessica Wentz, non-resident senior fellow, Sabin Center, et al. (Mar. 7, 2023)

Message

From: Radley Horton [redacted]
on behalf of Radley Horton [redacted]
Sent: 3/7/2023 5:07:28 PM
To: Jessica Wentz [redacted]
CC: Michael Burger [redacted]
Subject: Re: Invitation to Prepare a Climate Science Chapter for the Reference Manual on Scientific Evidence

Hi Jessica,

Perfect. And yes, we can have calls and iterate whenever might be helpful in the process.

Radley

On Tue, Mar 7, 2023 at 11:37 AM Jessica Wentz [redacted] wrote:
Hi Mike and Radley,

I am also disappointed but I also think this is a very important project and would like to proceed as they suggested. Fortunately the deadline is now mid/late April rather than early April.

Radley, I am so happy that you can engage more on this project. I am going to really hustle and try to get a draft ready for your review in a few weeks. And I'll probably be checking in with you periodically to ensure that I'm characterizing the science properly.

I'll reply to Beth now.

Best,

Jessica

On Tue, Mar 7, 2023 at 8:12 AM Radley Horton [redacted] wrote:
Hi Both,

[redacted]

This is disappointing, but if you are OK with it Mike, I agree the best path is to move forward as they/you suggest.

[redacted]

Jessica, if you agree, I commit to engage much more than I have previously to help lessen the burden on you.

[redacted]

Best wishes,
Radley

On Tue, Mar 7, 2023 at 7:05 AM Michael Burger [redacted] wrote:
I have no problem stepping aside for this, and think it is an extremely important contribution to the field. I will be happy to contribute behind the scenes. Jessica - this means it will really fall to you, though Radley I do think your close review and inputs will be critical and will provide the Committee and the chapter with even greater authority.

Exhibit 25

Email from Jessica Wentz, Non-resident Senior Fellow, Sabin Center, to Radley Horton, Associate Research Professor Sabin Center (Apr. 26, 2023)

Message

From: Jessica Wentz [redacted]
on behalf of Jessica Wentz [redacted]
Sent: 4/26/2023 7:38:49 PM
To: Radley Horton [redacted]
Subject: Re: Comments on Climate Science chapter - possible to send me what you have by 2 pm eastern today?
Attachments: Reference Guide on Climate Science - Draft 4-19-23 merged.mb.jw.docx

Thanks Radley. These edits are super helpful. If you can send me whatever else you finish this afternoon, that would be great.

Also -- after you send me the next round of edits, can you start working on the attached version of the Chapter? This is an updated version that includes Mike's edits (and my responses), the full text of Part IV, and the glossary.

On Wed, Apr 26, 2023 at 11:01 AM Radley Horton [redacted] wrote:

> Hi Jessica,
>
> Here is a new file, now with my edits for pages 26-40 based on the roman numeral numbering at the bottom of the page. (The first 25 pages are identical to what I sent you earlier.)
>
> I will keep working for the next two hours, which could get me close to page 60.
>
> Excellent, excellent work.
>
> radley
>
> On Wed, Apr 26, 2023 at 11:02 AM Radley Horton [redacted] wrote:
>
> > Hi Jessica,
> >
> > Yes--i will send you my latest at 2pm ET.
> >
> > My edits continue to be minor, along the lines of the types of comments i had sent earlier on the first 26 pages.
> >
> > It is an extremely impressive, effort, well-done!
> >
> > On Wed, Apr 26, 2023 at 10:59 AM Jessica Wentz [redacted] wrote:
> >
> > > Hi Radley,
> > >
> > > Could you send me your additional comments on the Climate Science chapter by 2 pm eastern / 11 am pacific today? Even if you haven't finished reviewing the chapter -- I have time to work on it this afternoon and I'd like to get as much done on the revisions as possible because Thursday/Friday are going to be busy. Thanks!
> > >
> > > Best,

Jessica

--
Radley Horton, Ph.D. (*he/him/his*)
Lamont Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

Office: [redacted]
Cell: [redacted]
Fax: [redacted]
Twitter: [redacted]

*Because I do not receive some emails sent to my [redacted] email address, I request that you please use my [redacted] email address [redacted] instead. Thank you.

--
Radley Horton, Ph.D. (*he/him/his*)
Lamont Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

Office: [redacted]
Cell: [redacted]
Fax: [redacted]
Twitter: [redacted]

*Because I do not receive some emails sent to my [redacted] email address, I request that you please use my [redacted] email address ([redacted]) instead. Thank you.

Exhibit 26

Draft climate chapter (Apr. 19, 2023)

REFERENCE MANUAL ON SCIENTIFIC EVIDENCE: THIRD EDITION

Reference Guide on Climate Science

Jessica Wentz[1] and Radley Horton[2]

Table of Contents

I. Introduction 1
II. Foundational Components of Climate Science 4
A. Core Concepts and Terminology 4
B. Physical Understanding of the Climate System 4
1. The Greenhouse Effect and Radiative Forcing 6
2. Biogeochemical Cycles 6
3. Atmospheric and Ocean Circulation and the Hydrological Cycle 8
4. Feedback Loops, Tipping Points, and Cascading Impacts in the Climate System 8
5. Natural Variability 9
C. Climate Datasets 10
D. Statistical Techniques and Climate Models 11
E. Communicating Uncertainty 13
F. Sources of Climate Research 14
1. World Meteorological Organization (WMO) 15
2. Intergovernmental Panel on Climate Change (IPCC) 15
3. Other Major Scientific Organizations 17
4. Government Agencies 18
5. Other Non-Governmental Organizations 20
6. Peer-Reviewed Research 20
III. Research on Anthropogenic Climate Change 21
A. Climate Change Detection and Attribution 22
1. General Methods and Parameters 23
a. Detection of Change 23
b. Attribution to Anthropogenic Climate Change 24

[1] Non-Resident Senior Fellow, Sabin Center for Climate Change Law, Columbia Law School.
[2] Research Professor, Lamont-Doherty Earth Observatory, Columbia University.

CJP0005445

c. Detection Without Attribution 25
d. Special Considerations for Extreme Event and Impact Attribution 26
2. Global Climate Change Detection and Attribution 27
a. Methods and Parameters 27
b. Status of Research 29
i. Chemical Composition of Global Climate System 29
ii. Atmospheric and Surface Temperature 30
iii. Ocean Warming, Acidification, and Sea Level Rise 32
iv. Cryosphere 33
v. Atmospheric and Ocean Circulation 34
vi. Hydrological Cycle and Precipitation 34
3. Extreme Event Detection and Attribution 36
a. Methods and Parameters 37
b. Status of Research 41
i. Extreme Heat 41
ii. Drought and Aridity 42
iii. Extreme Precipitation 43
iv. Tropical and Extratropical Cyclones 44
v. Compound Extremes 46
4. Impact Detection and Attribution 47
a. Methods and Parameters 47
b. Key Findings 48
i. Ecosystems, Species, and Ecological Indicators 49
ii. Extreme Events and Physical Hazards 51
iii. Food and Water Security 52
iv. Public Health and Well-Being 54
v. Cities, Settlements, and Infrastructure 55
vi. Socioeconomic Impacts 57
B. Source Attribution 58
1. Methods and Parameters 58
2. Research Findings 62
a. National Contributions 62
b. Corporate Contributions 65
C. Predictions of Future Climate Change 66

1. Methods and Parameters 66
2. Key Findings 69
a. Large-Scale Changes in the Climate System 69
b. Climate Extremes 70
c. Impacts on Humans and Natural Systems 72
d. Tipping Points 73
D. Carbon Budgeting and GHG Mitigation 73
1. Methods and Parameters 73
2. Research Findings 75
IV. Judicial Engagement With Climate Science 78
A. Overview of Climate Litigation 78
B. Legal Applications of Climate Science 80
1. Causation 81
2. Foreseeability 85
3. Legal Obligations and Authorities 86
C. Engaging with Scientific Evidence and Expert Testimony 88
V. Acknowledgments 92
VI. Glossary 92
VII. References 95

I. Introduction

Climate science examines the structure and dynamics of the Earth's climate system and how that system is influenced by human and natural processes.[1] The climate system actually consists of five interacting systems: the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere.[2] Thus, climate science spans multiple disciplines, including atmospheric science, physical geography, oceanography, and others. It also encompasses research on the interactions between the global climate system and other natural and human systems, which implicates fields such as biology, economics, and social sciences. Due to the complexity and pervasiveness of the climate system, it is difficult to establish precise boundaries for this field – but for the purposes of this chapter, we focus on the physical science aspects of climate science.[3]

Climate scientists use observational data, physical understanding, statistical analysis, and climate models to understand and characterize the complex interactions between different components of the climate system. One key focus of this research is to understand the mechanisms of observed climate change, and to characterize how humans are affecting the global climate system through greenhouse gas (GHG) emissions and other climate forcers.[4] However, climate science is not limited to the study of anthropogenic climate change – to the contrary, there is a significant body of research that focuses more broadly on fundamental questions about the climate system and how it works.[5] This foundational research informs the study of anthropogenic climate change.

Climate science is not a new discipline. Humans have been studying the climate for thousands of years,[6] and the invention of ~~the~~ thermometers and barometers allowed for systematic recordkeeping of climate conditions as early as the 1600s. However, up until the nineteenth century, the field of climatology was primary concerned with documenting climate conditions over time and describing regional climates. In the early 1800s, scientists began to develop theories and conduct experiments to explain the underlying physical processes that explain climate conditions. The study of climate has flourished in the 200 years since due to improvements in the observational record as well as advances in statistical analysis and climate modeling. Scientists now have a highly sophisticated understanding of the Earth's climate system and how that system is changing in response to natural and anthropogenic drivers.

Commented [1]:
We could provide an example here, such as how the configuration of the continents, on the spin rate of the earth, influence things like surface temperature and winds.

---

[1] For a more detailed definition, *see Climate Science*, in STANFORD ENCYCLOPEDIA OF PHILOSOPHY (first published May 11, 2018), *available at* https://plato.stanford.edu/entries/climate-science/.

[2] "Climate" describes average weather conditions averaged over a period of time, typically decades or more.

[3] Although our focus is on physical climate science, ~~but~~ it is necessary to discuss the interactions between physical climate science and other fields when discussing certain areas of the science. *See, e.g.*, § XX-III(A)(4) (impact attribution), § XX-III(B) (source attribution), § XX-III(D) (carbon budgeting).

[4] A "climate forcer" is any substance that affects the flow of energy coming into or out of the global climate system, thus affecting the amount of heat retained within the system. Anthropogenic climate forcers include GHGs, aerosols, and changes in land use that make land reflect more or less solar energy. There are also natural climate forcers, such as solar radiation and the particulate matter from volcanic eruptions.

[5] For example, research may focus on how aspects of the climate system are influenced by factors such as the configuration of the continents and the spin rate of the earth.

[6] Matthias Heymann, *The Evolution of Climate Ideas and Knowledge,* 1(4) WILEY INTERDISCIPLINARY REVIEWS: CLIMATE CHANGE 581 (2010).

As climate science has advanced, so too has evidence of pervasive anthropogenic influence on the global climate system. The Intergovernmental Panel on Climate Change (IPCC)[7] found in its most recent assessment report that: "[i]t is unequivocal that human influence has warmed the atmosphere, ocean and land" and this has caused "[w]idespread changes in the atmosphere, ocean, cryosphere, and biosphere."[8] The global warming attributable to human activities is unprecedented in the last 2000 years,[9] and "is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes."[10] These impacts of climate change will become more severe and pervasive as humans continue to release more GHGs into the atmosphere.

The increasing severity of anthropogenic climate change has contributed to growth in climate change-related litigation~~awsuits~~ in the U.S. and other jurisdictions. ~~Many~~ Much of ~~these~~ this ~~lawsuits~~ litigation seeks to establish legal obligations on the part of governments to control GHG emissions, prepare for the effects of climate change, and disclose climate change-related risks in government documents; some litigation seeks the opposite. Although the vast majority of climate lawsuits involve government defendants, there has been a recent uptick in litigation against corporate actors, ~~particularly fossil fuel companies,~~ with lawsuits seeking to hold companies accountable for their contributions to climate change, their failure to adapt the climate change impacts, and climate-related impact or risk assessment and disclosure, as well as climate-related marketing.

There are several ways in which climate science may factor into the resolution of climate-related~~such~~ lawsuits. First, climate science can be used to assess **causation** – ~~specifically~~e.g., whether and to what extent a defendant has caused or contributed to climate change-related risks or injuries. Second, climate science can be used to assess whether climate-related risks or harms were **foreseeable** and should have therefore been accounted for by the defendant. Third, climate science can be used to determine the scope of a defendant's **legal obligations and authorities** – for example, whether the defendant has an obligation to reduce its greenhouse gas (GHG) emissions, take measures to prepare for the impacts of climate change, or provide compensation or climate damages.

With many climate lawsuits, and many different kinds of climate lawsuits, now being filed in federal and state courts, it is increasingly likely that judges will confront legal and factual disputes implicating climate science. The purpose of this chapter is to help judges navigate these disputes by providing insights on the fundamentals of climate science, the current status of research on anthropogenic climate change, and how the science factors into the resolution of different legal claims. The chapter will also highlight considerations for judges engaging with different types of

Commented [2]: Could this include impacts/failure to adapt, or are you referring to the emissions side only here?

Commented [MB3R2]: I agree with Radley - I think the goal here should be to cast a wide net, rather than focus specifically on the small number of cases involving corporate accountability for emissions. Making the edits I suggest in the above paragraph may make the scope of this paragraph more clear - that it encompasses mitigation and adaptation.

Commented [JW4R2]: Yes I think those edits are helpful. I also revised this to "e.g." to clarify that this is just one example of a causation issue.

In adaptation lawsuits, the science is used to show that impacts are occurring as a result of climate change – so that does deal with scientific causation -- but from a legal perspective, I think of this as falling under the element of "foreseeability".

[7] For more information about the IPCC and its assessment methodology, see *infra* § ~~XX~~II(F)(2).
[8] IPCC, CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE SIXTH ASSESSMENT REPORT OF THE IPCC 4 (Valérie Masson-Delmotte et al. eds., Cambridge University Press 2021) [hereinafter IPCC AR6 WGI]. Other scientific bodies have also found unequivocal evidence of anthropogenic climate change. *See* NATIONAL RESEARCH COUNCIL (NRC), CLIMATE CHANGE: EVIDENCE AND CAUSES: UPDATE 2020 (National Academies Press 2020); U.S. GLOBAL CHANGE RESEARCH PROGRAM (USGCRP), FOURTH NATIONAL CLIMATE ASSESSMENT, VOL 1: CLIMATE SCIENCE SPECIAL REPORT (2017) [hereinafter NCA4 Vol. I].
[9] IPCC AR6 WGI at 6.
[10] IPCC AR6 WGI at 10.

scientific resources and data, with an eye towards helping judges assess the admissibility, credibility, and probative value of expert testimony and scientific evidence.

Part II introduces the core concepts and methods used in climate science. It describes the data and methodologies used to study the Earth's climate system, specifically elaborating on how scientists use physical understanding, climate datasets, statistical analysis, and climate models to study and characterize the climate. It also provides context on different sources of climate research – for example, discussing the work of the World Meteorological Organization (WMO) and IPCC to synthesize research within this field.

Part III focuses on the science of anthropogenic climate change. It describes research methodologies as well as key scientific findings across four disciplines: (i) climate change detection and attribution research, which examines whether observed changes in natural and human systems can be attributed to human influence on climate; (ii) source attribution research, which examines the relative contributions of different entities to anthropogenic climate change; (iii) predictive research, which provides insights on ~~the~~ future climate change and its impacts ~~of climate change~~ under different emissions trajectories and warming scenarios; and (iv) carbon budget research, which involves estimating the total amount of GHG emissions that can be released into the atmosphere without exceeding certain temperature thresholds (e.g., 1.5 or 2.0° C of warming) and allocating that budget across different jurisdictions, sectors, and/or corporate entities.[11]

Part IV discusses judicial engagement with climate science. It provides a brief overview of the types of legal claims that implicate climate science, focusing on federal claims, and describes how different areas of climate research may factor into judicial assessments of causation, foreseeability, and legal obligations and authorities. It also highlights considerations that may be relevant when evaluating the admissibility, probative value, and weight of scientific evidence and expert testimony on matters related to climate science.

One key point, which we seek to illustrate through this chapter, is that there is nothing uniquely uncertain or novel about climate science as compared with other scientific disciplines.[12] Climate researchers apply the same methods and principles that are used across all realms of scientific research. This includes the treatment of uncertainty in scientific analysis, an issue which has been misrepresented and misunderstood in the context of climate change. Climate scientists use standard quantitative techniques for measuring and communicating uncertainty (e.g., confidence intervals and p-values) and climate studies typically present findings at a 95% confidence level, consistent with standard scientific practice.[13] This scientific standard of proof is much higher than the

Commented [5]: Does this require definition for this audience?

Commented [MB6R5]: No, as the audience are judges.

Commented [7]: Within 3, could we change the current clause to 'future climate change and its impacts' ?

Also, there is some overlap between iii and iv. It might be good to briefly note that somewhere early in Part III

Commented [JW8R7]: I added a FN mentioning this overlap between the two fields.

Commented [MB9]: It seems that it would be worth flagging the issue of uncertainty in this intro. For instance, you might say here "...al realms of scientific research. This includes the role of uncertainty in scientific analysis, an issue which has been misrepresented and misunderstood in the context of climate change." Or something to that effect. And then make sure to address it in more detail elsewhere.

[11] There is a significant area of overlap between predictive research and carbon budget research, as carbon budgets are based on predictions of future warming under different emission trajectories.

[12] See *infra* §§ XX-II(E), IV(C).

[13] The confidence level reflects the probability that a finding is accurate. More specifically, the confidence level reflects the probability that the true value of a studied parameter falls within a specified range of values known as the "confidence interval". For example, a study may find with 95% confidence that anthropogenic climate forcing

standard of proof applied in civil litigation ("more likely than not", i.e., >50%). Moreover, the evidence of human influence on climate is unequivocal ~~and there is clear scientific consensus on the fact of anthropogenic climate change.~~ , and s~~S~~cientists can ~~also~~ detect, attribute, and predict many of the trends and impacts caused by climate change with a high level of certainty. But there are still ~~many~~ some contexts where judges may confront genuine scientific questions and areas of uncertainty in this field – for example, when tasked with determining whether a specific plaintiff's injuries were caused by climate change, and whether and to what extent a specific defendant contributed to those injuries. This chapter seeks to provide the scientific context necessary for answering such questions, while also recognizing the numerous normative, ethical, and legal considerations that will factor into this type of analysis.

II. Foundational Components of Climate Science

A. Core Concepts and Terminology

The Earth's climate system is enormous and complex, consisting of many nested and interlinked subsystems. It consists of five major components: the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere. The interactions between these components produce the conditions known as "climate", i.e., weather conditions averaged over a period of time, typically decades or longer. Although the climate system is global, climate is typically characterized in reference to a particular region or locale due to spatial variations in climatological conditions.

Climate science is the field of study aimed at characterizing the climate system and understanding the physical processes and parameters that ultimately determine climate conditions. The foundational components of climate science are:

- **Physical understanding of the climate system**, including the different component systems and interactions between those systems, as well as the effect of exogenous variables on the system.
- **Climate datasets**, which include direct observations of climate variables, paleoclimate reconstructions, and reanalysis datasets.
- **Statistical techniques** and **climate models,** which are used to evaluate patterns, trends, ~~and projections (?) cause-and-effect~~causal relationships ~~processes~~, variability, and uncertainty within the climate system, and to develop projections of future climate change.

These components are interconnected and mutually reinforcing – for example, physical understanding of the climate system is based on observations and statistical analysis, and climate models incorporate a combination of physical understanding, observational evidence, and statistical techniques in order to derive insights on how changes in a particular input to the climate

Commented [10]: Should we give an example at some point?

Commented [JW11R10]: I think it's fine to keep things general here, as we get into detail below. I know there are some examples of exogenous variables in the attribution section. I'll see if there are other examples that should be noted below.

increased the likelihood of a specific extreme event by a factor of 4 ± 1 (with 4x being the mean estimate, and 3-5x being the confidence interval). *See infra* § II(E).

system can affect other variables within the system. The sections below provide more detailed explanations of each component and its role in climate research.

B. Physical Understanding of the Climate System

In the early 1800s, physicists and other scientists began conducting experiments and developing theories to explain the physical mechanisms behind global and regional climate conditions. It was hypothesized that the earth had undergone significant climate changes in the past based on observations of the natural world, but the mechanism behind these changes had yet to be discovered.[14] In the 1820s, the physicist Joseph Fourier developed an early theory of what would eventually be recognized as the "greenhouse effect". Fourier had calculated that an object that is the same size as the Earth and same distance fromof the sun would be considerably colder than the Earth if it were heated by incoming solar radiation alone. Fourier hypothesized that the Earth's atmosphere trapped incoming solar radiation in the form of heat, thus causing the planet to be warmer than would otherwise be the case.[15] Several decades later, scientists such as Eunice Foote and John Tyndall recognized that atmospheric gases, particularly carbon dioxide (CO_2) and water vapor, may be responsible for this warming effect. They correctly hypothesized that these gases absorbed incoming solar radiation – preventing it from being re-emitted to space – thus increasing the energy and heat content of the Earth's atmosphere. These scientists were also able to demonstrate and measure the greenhouse effect of CO_2 through lab experiments in the 1850s and 1860s.[16] Subsequently, in the late nineteenth century, the Swedish chemist Svante Arrhenius hypothesized that human-caused GHG emissions from fossil fuel use and other combustion sources were large enough to cause global warming.[17]

Since those early experiments, scientific knowledge of the climate has advanced dramatically. The latest IPCC assessment (AR6) found that physical understanding of the fundamental features of the climate system is "robust and well established" and there are multiple lines of evidence all pointing to the central role of human activity in climate change.[18] These include increasingly strong observational data sets, paleoclimate data, physical understanding of the Earth's climate system, and complex climate models that can simulate climatological conditions with and without human influence on climate. Drawing on these different evidentiary sources, scientists can explain many of the core processes that determine climate conditions. This knowledge supports the

Commented [12]: This is the best description of this topic that I have ever seen

[14] For example, in the early 1800s, Jean-Pierre Perraudin hypothesized that glaciers might be responsible for giant boulders seen in alpine valleys, and Luis Agassiz subsequently hypothesized that glaciers had covered much of Europe and North America during what he referred to as an "Ice Age." *See* E.P. Evans, *The Authorship of the Glacial Theory*, 145(368) NORTH AMERICAN REVIEW (1887).

[15] ~~Fourier never~~ Thomas R. Anderson et al., CO_2, The Greenhouse Effect, and Global Warming: From the Pioneering Work of Arrhenius and Callendar to Today's Earth System Models, 40(3) Endeavour 178 (2016).

Formatted: Subscript

[16] JOHN TYNDALL, CONTRIBUTIONS OF MOLECULAR PHYSICS IN THE DOMAIN OF RADIANT HEAT (Longmans, Green, and Co. 1872); Eunice Foote, *Circumstances Affecting the Heat of the Sun's Rays*, AMERICAN JOURNAL OF SCIENCE AND ARTS (1856).

[17] Svante Arrhenius, *On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground,* 41 THE LONDON, EDINBURGH, AND DUBLIN PHILOSOPHICAL MAGAZINE AND JOURNAL OF SCIENCE 237 (1896).

[18] IPCC AR6 WGI at 44, 150.

scientific consensus that global warming and other aspects of climate change are "unequivocally" caused by human activities.[19]

Some key areas of physical understanding that are integral to climate research include: (i) the greenhouse effect and radiative forcing; (ii) the carbon cycle and other biogeochemical cycles that govern the movement of chemical elements among different parts of the climate system and connected systems; (iii) the mechanisms of atmospheric and ocean circulation and their relationship to the hydrological cycle; (iv) the role of feedback loops, tipping points, and cascading impacts in the climate system; and (v) natural variability in the system ~~and how this intersects with uncertainty in climate research~~.

Commented [13]:
I like this list. It would certainly be more conventional to flip iv and v, but for our purposes you might not need to.

Also, calling out uncertainty in the context of natural variability only doesn't seem quite right, since there is uncertainty in all five elements. Maybe your point is that for those focusing on climate change rather than climate variability, climate variability is still important given its influence on uncertainty in climate change projections?

If it were me, I would just remove the last 9 words of the paragraph

Commented [JW14R13]: Good point. Natural variability isn't the only source of uncertainty. I deleted the unnecessary text. Also edited the section on natural variability to avoid overstating the extent of uncertainty w/ regards to variability.

I left the order as-is – I like concluding with "natural variability" b/c it is such a cross-cutting issue in climate research.

1. The Greenhouse Effect and Radiative Forcing

The greenhouse effect plays a fundamental role in shaping climate conditions as it ultimately determines the amount of incoming solar energy that is retained within the system. The heat-trapping properties of GHGs are now well-understood and can be quantified over different time horizons. Water vapor is the most abundant naturally-occurring GHG in the atmosphere and is responsible for approximately half of the Earth's natural greenhouse effect. Other common GHGs in the atmosphere include CO_2, methane (CH_4), and nitrous oxide (N_2O). As discussed in Part III, the large increases in GHG concentrations due to human emissions ~~of GHGs~~ are the dominant cause of observed global warming and climate change.[20]

The effects of anthropogenic GHG emissions on the atmosphere are an example of *radiative forcing* – a change in the energy flux within the Earth's atmosphere. Positive radiative forcing occurs when the Earth receives more incoming energy from sunlight than it radiates into space, and this net gain of energy causes warming. There are a number of natural processes that can affect net radiative forcing – these include changes in the percentage of incoming solar radiation absorbed by the earth, volcanic activity, orbital cycles, and changes in global biochemical cycles (discussed below). There are also other human drivers that can affect atmospheric energy flux – for example, land use changes can have positive or negative effects on radiative forcing, and aerosol emissions have negative radiative forcing and thus contribute to cooling of the climate system.

Commented [15]:
This is a clunky edit admittedly, but it helps differentiate from your 'orbital cycles' later in the sentence

[19] For example, scientific research has shown that the spatial pattern of observed warming generally matches our theoretical understanding and model projections of how anthropogenic GHGs would affect the climate system; specifically, high latitude regions are warming faster than the tropics, and the lower stratosphere is cooling. The spatial pattern, or fingerprint, of the warming is thus consistent with increases in GHG concentrations, not alternative explanations such as volcanoes, incoming solar radiation, or internal climate variability. Gabriele Hegerl, Francis Zwiers & Claudia Tebaldi, *Patterns of Change: Whose Fingerprint Is Seen in Global Warming?*, 6 ENVIRONMENTAL RESEARCH LETTERS 4 (2011).

[20] Observations have demonstrated that atmospheric moisture content (water vapor) is increasing along with other GHGs, and this amplifies to the greenhouse effect. However, the increase in atmospheric moisture content is directly attributable to human-induced global warming (from GHG emissions). In other words: increased water vapor is a consequence of anthropogenic climate forcing; it is not an indicator of "natural" climate change as some climate skeptics have argued. Were these other GHG concentrations to somehow drop to pre-industrial levels, water vapor would almost instantaneously return to pre-industrial levels as well.

Scientists have been systematically studying the interactions between both human and natural forcing since the early 20th century.[21] Although the heat-trapping properties of specific substances are fairly well-understood, there is still some uncertainty about the effect of certain processes (e.g., land use changes) on climate forcing, as well as the relative contributions of different forcing agents to observed climate changes, especially at regional scales Nonetheless, physical understanding of radiative forcing is sufficiently robust to support assessments and projections~~edictions~~ of global warming, as evinced by the fact that past projections of global temperature change in response to radiative forcing have been broadly consistent with subsequent observations.[22]

Commented [16]: How would you feel about using 'projections' more consistently/as your dominant term over predictions? Climate scientists certainly prefer that, but I know we have multiple audiences

Commented [JW17R16]: Great suggestion. "Projections" makes more sense given that we're talking about hypothetical future conditions that may change depending on emission scenarios. I've updated the language throughout.

2. Biogeochemical Cycles

Biogeochemical cycles govern the transfer of chemicals among different components of the climate system and other Earth systems. Some of the cycles which are integral to the study of climate include the carbon cycle, nitrogen cycle, water cycle, and phosphorus cycle. Here we focus on the carbon cycle due to the dominant role of CO_2 in global climate change. The water (or hydrological) cycle is also integral to the study of climate, as discussed in various contexts below.

The carbon cycle describes how carbon moves between the atmosphere, hydrosphere, biosphere, cryosphere, and lithosphere.[23] Most of the carbon on the planet is stored in the lithosphere as fossil fuels and sedimentary rock deposits. Carbon is also stored in the atmosphere (as CO_2),[24] in the oceans (as dissolved atmospheric carbon), and in the biosphere (as organic molecules in organisms and soil). In climate science, oceans and terrestrial systems are generally characterized as "sinks" or "reservoirs" of carbon because they absorb more carbon than they release into the atmosphere.

The primary pathways through which carbon is released into the atmosphere include human combustion of fossil fuels, wildfires, volcanic eruptions, biological respiration, and decomposition. Once CO_2 enters the atmosphere, it can remain there for a very long time – potentially thousands of years or more – but there is significant variation in the atmospheric lifetime of individual CO_2 molecules.[25] A large proportion (20-30%) of the CO_2 that enters the atmosphere is absorbed by the oceans where it dissolves into seawater and forms carbonic acid (resulting in ocean acidification). The initial process of ocean absorption can occur within a relatively short timeframe (e.g., within 5 years) but much of that carbon is circulated back into the atmosphere on a short timeframe as well (e.g., within 10 years or less).[26] Thus, carbon is constantly cycling between the oceans and atmosphere.

---

[21] IPCC AR6 WGI at 150.
[22] IPCC AR6 WGI at 150.
[23] For a more detailed overview of the carbon cycle and how it is influenced by human activities, see USGCRP, SECOND STATE OF THE CARBON CYCLE REPORT (N. Cavallaro et al. eds., 2018), *available at* https://carbon2018.globalchange.gov/downloads/SOCCR2_2018_Full_Report.pdf.
[24] Atmospheric carbon also comes from methane (CH_4), which is converted into CO_2 as it combines with oxygen.
[25] Due to variation, the IPCC does not recognize a specific lifetime for CO_2 molecules. See IPCC AR6 WGI at 302.
[26] Mason Inman, *Carbon is Forever*, 1 NATURE CLIMATE CHANGE 156 (2008).

Carbon is also constantly cycling between the atmosphere and biological systems (i.e., forests, grasslands, and other ecosystems). The amount of carbon stored in the terrestrial sinks is largely based on the carbon uptake of vegetation through photosynthesis, with large interannual variability due to natural changes in vegetation as well as human land uses. There are some instances in which terrestrial sinks may become carbon sources – specifically, when the amount of carbon that is released is greater than the amount of carbon that is absorbed. This may occur, for example, as a consequence of wildfire or ecosystem degradation.[27]

Human activities, including land use changes and the burning of fossil fuels, have disturbed the natural carbon cycle, releasing more than a trillion tons of CO_2 and methane (CH_4) into the atmosphere. Only a fraction of those emissions remains in the atmosphere; the remainder is absorbed by ocean and terrestrial sinks. The "airborne" fraction of carbon emissions has remained constant at nearly at approximately 44% over the past six decades,[28] but the capacity of ocean and terrestrial sinks to absorb carbon is expected to decline as the CO_2 concentrations increase.[29]

3. Atmospheric and Ocean Circulation and the Hydrological Cycle

The movement of air, water, and heat in the climate system plays an integral role in shaping regional climate conditions, including regional temperature, precipitation, humidity, and aridity, as well as extreme weather events. In particular, regional climate is influenced by atmospheric circulation (the large-scale movement of air and heat in the atmosphere), ocean circulation (the large-scale movement of water in oceans), and the hydrological cycle (the circulation of water between different Earth systems), in addition to other factors.[30] Understanding the mechanisms and relationships between these large-scale processes is key to understanding the climate system and climate change.[31]

These circulatory processes are governed by thermodynamics as well as other physical processes (e.g., gravity, surface friction, planetary rotation).[32] Thermodynamic processes are those that involve the exchange of heat, work, temperature, and energy. There is strong theoretical understanding of how thermodynamics influence certain aspects of the climate system, which contributes to high confidence findings for certain trends and impacts, particularly those that are directly attributable to temperature changes.[33] Radiative forcing is an example of a thermodynamic process that is well-understood. Dynamic processes are those that deal with the movement of

Commented [18]:
I feel like this paragraph and its title overemphasize circulation a bit, but overall I would not change anything since there are bound to be oversimplifications.
My thinking is that aspects mentioned/alluded to in the second paragraph like radiation and cloud cover are as fundamental to the atmosphere for example as circulation is. And mapping the global circulation vs. thermodynamics to the attribution of local variables like temperature vs. winds isn't a perfect mapping due to how interconnected the global system is.
But again, I wouldn't change anything. I just wanted to flag almost more from a dialogue/discussion as a reader perspective some of my thoughts as I go through your material. You could write an excellent climate science textbook…seriously.

Commented [JW19R18]: Thanks! I actually did make one edit based on this comment – just acknowledging other factors that shape regional climate (see FN).

[27] *See, e.g.,* S. Wang et al., *Potential shift from a carbon sink to a source in Amazonian peatlands under a changing climate,* 115(49) PNAS 12407 (2018).
[28] IPCC AR6 WG1 at 676.
[29] IPCC AR6 WG1 at 677.
[30] Some of the other factors that shape regional climate include the amount of sunlight the area receives (which depends, in large part, on latitude); altitude, topographical features, and the shape of the land (i.e., "relief"); and proximity to oceans and large water bodies.
[31] "Coupled" models have been developed to simulate the interactions between atmospheric and ocean circulation and other components of the climate system. *See infra* § XX.II(D).
[32] The hydrological cycle is also influenced by chemical and biological interactions, which is why it is characterized as a biogeochemical process.
[33] IPCC AR6 WG1 at 430.

bodies in response to physical forces (e.g., the physical transport of temperature and moisture).[34] As noted by Screen et al. (2018), the dynamic manifestations of climate change are not as well understood as thermodynamic aspects but the knowledge gap is narrowing due to recent research unpacking the causal mechanisms behind observed changes in circulation patterns.[35] More limited understanding of dynamic processes contributes to uncertainty about certain aspects of climate and climate change, including uncertainty about the relationship between increasing GHG concentrations and changes in hydrological processes.[36]

4. Feedback Loops, Tipping Points, and Cascading Impacts in the Climate System

Understanding the climate system and anthropogenic influence on that system requires understanding of feedback loops, cascading impacts, and tipping points. "Feedback loops" are ~~cause-and-effect~~causal processes that occur when outputs of a system are routed back as inputs, resulting in acceleration of a process or change (positive feedback) or deceleration (negative feedback).[37] One key example of a feedback loop in the climate system is water-vapor feedback: warmer temperatures increase water vapor in the atmosphere, and the water vapor, which is a GHG, traps additional heat. Researchers believe that this may play an important role in current and future warming trends.[38] Another important feedback loop is the ice-albedo feedback loop, whereby warmer temperatures result in the melting of ice caps, glaciers, and sea ice (all of which have high albedo, i.e., they reflect more sunlight back to space), thus increasing the albedo of land and ocean surfaces, and accelerating the warming process.

The term "tipping point" describes a threshold that, when surpassed, will result in large and typically irreversible changes.[39] Tipping points are common throughout the climate system as well as other systems that are affected by climate change. Key examples of important tipping points within the climate system are the melting of the Greenland ice sheet (an essentially irreversible process that would ultimately trigger meters of ~~trigger significant~~ sea level rise as well as changes in atmospheric and ocean dynamics), the collapse of Arctic winter sea ice, the dieback of the Amazon rainforest, the loss of mountain glaciers, and the collapse of boreal permafrost. Some critical tipping point thresholds may have already been surpassed, although the full effects have not yet manifested due to time lags and/or incomplete understanding.[40] This highlights an important aspect of tipping points: thresholds can be "locked in" before the actual event occurs

Commented [20]:
'ultimately trigger meters of' ?

[34] The term "dynamic" is also used in climate science to describe systems that are characterized by change and complexity. Here, we specifically refer to dynamics as a subdivision of physical mechanics.
[35] J.A. Screen et al., *Polar Climate Change as Manifest in Atmospheric Circulation*, 4 CURRENT CLIMATE CHANGE REPORTS 383 (2018).
[36] *See, e.g.,* Eilat Elbaum et al., *Uncertainty in Projected Changes in Precipitation Minus Evaporation: Dominant role of Dynamic Circulation Changes and Weak Role for Thermodynamic Changes*, 49(12) GEOPHYSICAL RESEARCH LETTERS e2022GL097725 (2022).
[37] Dennis L. Hartmann, *Climate Sensitivity and Feedback Mechanisms*, in GLOBAL PHYSICAL CLIMATOLOGY (2nd Ed. 2016).
[38] A.E. Dessler et al., *Stratospheric Water Vapor Feedback*, 110(45) PNAS 18087 (2013).
[39] The IPCC defines a tipping point as a "critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly". IPCC AR6 WG1 at 95.
[40] David Armstrong McKay et al., *Exceeding 1.5° Global Warming Could Trigger Multiple Climate Tipping Points*, 377(6611) SCIENCE eabn7950 (2022).

(e.g., the melting of the Greenland ice sheet may already be inevitable due to existing warming).[41] Although much is unknown about the timing and potential consequences of climate tipping points, there are significant risks associated with surpassing these thresholds, since consequences can be so large.[42]

"Cascading impacts" are a related concept. These can be conceptualized as a series of impacts which occur together due to interdependencies within a system, flowing out to other domains, and potentially amplifying risks and hazards.[43] Cascading impacts can occur as a result of feedback loops and surpassing tipping points. Cascading impacts are a particular concern when evaluating the effects of climate change on human and natural systems. For example, changes in bioclimatic conditions caused by global warming can result in a cascade of ecosystem alterations (e.g., extinctions lead to alterations in food webs that have cascading effects on other species, potentially even triggering further extinctions).

5. Natural Variability

"Natural variability" in the climate system refers to the variations in climate that are caused by processes other than human influence. It includes variability that is internally generated within the system, like the El Niño Southern Oscillation (ENSO),[44] as well as variability driven by natural external factors, such as variations in solar activity and volcanic eruptions. Natural variability can play a prominent role in explaining changes in climate over various timespans (years, months, days) but the influence of natural variability tends to be small when evaluating trends over periods of multiple decades or longer.[45] ~~Although there have been tremendous advances in physical understanding of the climate system, there is still significant uncertainty about the physical processes governing natural variability within the climate system (i.e., the variation in climate conditions that is caused by non-human forces). This affects~~Understanding natural variability is important for climate change attribution and ~~prediction~~projections, insofar as it ~~can be difficult~~is necessary to ascertain whether an observed trend, impact, or event is a consequence of anthropogenic forcing rather than natural variability within the system. Some patterns of natural variability, like ENSO may themselves be impacted by anthropogenic warming.

Although there is still some uncertainty about the physical drivers of natural climate variability, researchers have developed techniques for reproducing many aspects of variability in climate models based on physical understanding of the climate system.[46] The effects of natural variability are sometimes quantified using a "signal-to-noise" ratio, which compares the strength of an

---

[41] Niklas Boers & Martin Rypdal, *Critical Slowing Down Suggests that the Western Greenland Ice Sheet is Close to a Tipping Point,* 118(21) PNAS e2024192118 (2021) (finding that the Greenland Ice Sheet melt tipping point is between 0.8°C and 3.2°C of warming above pre-industrial levels).
[42] Timothy M. Lenton et al., *Climate Tipping Points – Too Risky to Bet Against,* 575(7784) NATURE 592 (2019).
[43] *See* Judy Lawrence et al., *Cascading Climate Change Impacts and Implications,* 29 CLIMATE RISK MANAGEMENT 1000234 (2020).
[44] ENSO is an interaction between the tropical Pacific atmosphere and ocean that produces roughly year-long global impacts approximately every 5-7 years.
[45] *See* IPCC AR6 WGI, Ch. 3.
[46] *See, e.g.,* Feng Zhu et al., *Climate Models Can Correctly Simulate the Continuum of Global-Average Temperature Variability,* 116(18) PNAS 8728.

anthropogenic climate change signal against natural variability noise. The challenge of distinguishing the anthropogenic signal is more pronounced in regional climate assessments, because natural variability plays a larger role in shaping regional climates (i.e., there is a smaller signal-to-noise ratio). The accuracy with which scientists can distinguish anthropogenic signals from natural variability noise also depends on the type of impact being studied, and the temporal boundaries of the study. ~~Important examples of natural variability include the El Niño Southern Oscillation (ENSO), an interaction between the tropical Pacific atmosphere and ocean that produces roughly year-long global impacts approximately every 5-7 years. Furthermore, some patterns of natural variability, like ENSO may themselves be impacted by anthropogenic warming.~~

C. Climate Datasets

In order to study climate and climate change, scientists need to be able to characterize past and present climate conditions across different geographic and temporal scales. They rely on climate datasets which provide quantitative information for various climate variables (e.g., sea surface temperature) over a given period. These datasets serve multiple purposes: they are used to develop and assess physical understanding of the climate system, to establish a baseline for evaluating changes in the climate system, and to develop, refine, and calibrate climate models.

Observational data is data which can be observed and measured. Much of the observational data used in climate research comes from *instrumental records* of climate variables. Examples include ground measurements of CO_2 concentrations, surface temperatures, and sea levels; satellite measurements of sea surface temperature, water vapor, precipitation, and sea ice; and aircraft measurements of cyclone wind speed.[47] Instrumental records are somewhat limited in terms of temporal and geographic coverage. The first quasi-global instrumental datasets for land and sea surface temperature can be traced back to the mid-1800s (when national and colonial weather services built networks of surface stations and began maintaining standardized weather logs).[48] Since then, the instrumental record has grown significantly due to the expansion of ground measurement stations as well as the advent of satellite remote sensing of climate variables in the 1980s. The instrumental record of current climate variables is now fairly comprehensive, but there are still spatial and temporal gaps in the instrumental record, particularly with regards to historical climate conditions.

To fill the remaining gaps, scientists can use *re-analysis datasets* – these datasets are generated by combining available observations with statistical analyses and climate models to infer climate conditions where direct observational data is not available. Reanalysis datasets can be used to

[47] Instrumental records are sometimes described as "direct" measurements of climate variables, but the directness of the measurement depends on the instrument being used. E.g., surface thermometers provide relatively direct measurements of temperatures, whereas satellite microwave sensors record microwave emissions from which scientists can derive measurements of climate variables such as temperature and columnar water vapor. It is also important to keep in mind that instrumental records are not "perfect" – they may be subject to errors (e.g., due to calibration errors, sources of bias in the instrument, or interpretation techniques). However, scientists use calibration, validation, and verification techniques, often involving cross-comparison between different datasets, to ensure the accuracy of instrumental records.

[48] IPCC AR6 WG1 at 175.

create "a coherent, long-term record of past ~~record~~ weather by compensating for the inherent biases of the different instruments used to take measurements at different points in the history of weather observation."[49]

Paleoclimate reconstructions are also used to ~~fill~~overcome temporal gaps in instrumental records. Paleoclimate research uses geological and biological evidence to reconstruct historical climate conditions for which direct measurements are not available. Paleoclimate researchers can obtain data on past climate conditions (e.g., precipitation and temperature) from sediments, rocks, tree rings, corals, ice sheets, and other physical formations. Paleoclimate reconstructions provide insights on baseline climate conditions and natural variability in those conditions before humans began influencing the atmosphere or using instruments to measure different climate variables.

D. Statistical Techniques and Climate Models

Statistical analysis refers to the mathematical formulas and techniques that are used in empirical analysis of data. For example, statistical interpolation can be used to estimate unknown climate variables based on available data and thus plays a key role in data reanalysis.[50] Statistical analysis is also used in conjunction with observational data and climate models to detect changes in the climate system and other interconnected systems and to determine whether these are attributable to human influence ("detection and attribution" research),[51] and to predict future changes based on different warming trajectories.[52]

Climate models use quantitative methods, including predictive equations and statistical techniques, to simulate interactions within the climate system. Scientists can set up different model experiments to evaluate the effect of one or more climate drivers (e.g., GHGs, aerosols, and solar flux) on one or more variables. As with statistical analysis, climate models can be used for the purposes of climate change detection and attribution as well as the ~~prediction~~ projections of future climate change. Generally speaking, climate models are based on "well-established physical principles and have been demonstrated to reproduce observed features of recent climate… and past climate changes" and scientists are confident that they can simulate many aspects of climate change with a fair degree of accuracy, particularly at continental and global scales.[53] However, due to the complexity of the climate systems, there are still limitations in the ability of models to accurately and precisely simulate causal ~~cause-and-effect~~ relationships and processes in the climate system.

---

[49] NOAA National Centers for Environmental Information, *Reanalysis*, https://www.ncei.noaa.gov/products/weather-climate-models/reanalysis (last visited Feb. 14, 2023).

[50] Statistical interpolation involves estimating an unknown value based on related known values. There are many interpolation techniques, but the simplest example is linear interpolation – i.e., if observations show a linear increase in a variable over time, scientists can infer the value of that variable at a specific point in time even without a direct measurement.

[51] *See infra* §II~~B~~A(1) ("Detection and Attribution").

[52] *See infra* §II~~B~~C(~~2~~1) ("Predicting Future Climate Change").

[53] D.A. Randall et al., *Climate Models and their Evaluation, in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (S. Solomon et al. eds. 2007).

Commented [21]: Possible extra word here?

There are several types of climate models with different applications, including: global circulation models (GCMs), which simulate general circulation of the Earth's atmosphere and oceans; energy balance models (EBMs) which simulate changes in temperature based on the balance between incoming and outgoing solar radiation; Earth system models (ESMs), which simulate the interactions of the atmosphere, hydrosphere, geosphere, biosphere, and cryosphere to assess how changes in climate (e.g., warmer temperatures) affect and are affected by other interconnected systems such as changes in vegetation; and regional climate models (RCMs), which simulate the interactions between the climate and other Earth systems at a finer resolution than ESMs. "Coupled" GCM and ESM models use understanding of thermodynamics, fluid motion, and other physical processes to simulate interactions between multiple components of the climate system, including atmospheric and ocean circulation. The Coupled Model Intercomparison Project (CMIP) of the World Climate Research Programme is an international initiative that combines, synthesizes, and compares different climate models in order to develop more accurate climate simulations. The CMIP model ensembles are updated periodically – the latest IPCC assessment uses results from CMIP Phase 6 (CMIP6) models, which "include new and better representations of physical, chemical, and biological processes, as well as higher resolution" compared to past climate models.[54]

Commented [22]:
This sentence is a bit awkward here, since you have already noted the coupling inherent in ESMs but not the coupling inherent in GCMs. But I would keep the sentence here anyway. It reinforces the notion of coupling introduced earlier, and notes (with my edits) that it is more relevant for some types of models than others

Generally speaking, model-based approaches can support more robust findings than the use of observational data and statistical analysis alone. However, models have limitations that should be kept in mind when evaluating their results. The usefulness and accuracy of a model depends on how well the model can reproduce patterns associated with each climate forcing, and there are uncertainties in our knowledge about how individual climate forcings affect different aspects of the climate system. Comparing model results to observations can help assess the accuracy of the model, but observations cannot tell us all we need to know for several reasons. First, there is still uncertainty in observational measurements for reasons discussed above. Second, internal climate variability, unrelated to climate forcing, is difficult to disentangle from climate forcing. Third, because multiple anthropogenic and natural forcings have occurred simultaneously in the past, unpacking the relative contribution of each forcing is nontrivial.

The above challenges exist to a certain degree even for variables like global average temperature where the relationship between rising GHG concentrations and average temperatures is fairly direct. Inevitably, there will be some degree of uncertainty and room for error in model results due to the complexity of the physical systems being modelled. But this does not mean that model results are unsound. To the contrary, uncertainty is prevalent across many scientific disciplines, and scientists have tools for managing and communicating uncertainty.[55] Scientists are also constantly refining the techniques used to reduce uncertainty in their analyses, such as through additional and lengthened observational datasets, improvements to models, new analytical

[54] According to the IPCC, the use of CMIP6 "has improved the simulation of the recent mean state of most large-scale indicators of climate change and many other aspects across the climate system." However, there are still some differences between CMIP6 model results and observations, particularly with regards to regional precipitation. IPCC AR6 WGI at 12.

[55] *See infra* §II(E) ("Managing and ~~Managing~~ Communicating Uncertainty ~~and Ensuring Valid Results~~").

Formatted: Not Highlight

methods, and expert judgment. For example, new statistical approaches are being used to better account for internal climate variability and uncertainties in models and observations.[56]

Another limitation to GCMs and other large-scale models is that they produce results at large spatial scales and thus cannot simulate local climate features and their impacts with precision. To address this issue, researchers are developing dynamical and statistical downscaling techniques which can be used to transform climate model outputs into more localized data products for regional or local climate impact assessments, although these approaches can run up against inherent uncertainties at fine spatial scales.[57]

E. Managing and Communicating Uncertainty

Due to the complexity of the climate system, researchers inevitably confront uncertainty when evaluating ~~cause-and-effect~~causal relationships and processes within the system. This is not unique to the field of climate science: uncertainty exists across all scientific disciplines, and managing uncertainty is part of the scientific process.~~Uncertainty typically arises due to limitations in physical understanding, climate observations, and other datasets. Fortunately, t~~Climate scientists use~~here are~~ standard techniques and practices for ~~managing~~managing and communicating uncertainty and ensuring the validity of ~~results~~ research findings~~even in the face of uncertainty~~. These include statistical- and model-based approaches that actually reduce uncertainty in research findings,[58] as well as methods of framing and communicating uncertainty along with findings.

The IPCC, for example, uses probabilistic language to describe the assessed likelihood of an outcome or result as well as other language to communicate confidence and level of agreement in findings.[59] In individual studies, uncertainty is typically managed using similar statements about probabilities as well as confidence levels and intervals. For example, a study may conclude with 95% confidence that climate change made an extreme event at least twice as likely to occur. Such statements of confidence are based on the use of *confidence intervals*, which reflect the range of possible true values for the parameter being studied. Confidence intervals are typically expressed as the mean estimate of the parameter ± variation in the estimate at a designated confidence level (typically 95%, although 90% and 99% are also used). The *confidence level* reflects the likelihood that the parameter will fall within the upper and lower bounds of the confidence interval. Some

Commented [23]: I might cut the use of this clause in most applications. All the complexity and non-linearities, and feedbacks make us wary about the phrase 'cause and effect'. Clearly we need to use it occasionally in the paper, but I would limit it to where it is most on point

Commented [JW24R23]: Noted. I've replaced "cause-and-effect" with "causal" throughout the chapter (I think that has less of a linear implication).

Commented [MB25]: Important here to relate this back to the idea I noted at the beginning - that managing uncertainty is a part of the scientific process, with regard to climate change and elsewhere. It is not a unique aspect of climate science. And there is, inevitably, some irreduceable amount of uncertainty that remains. (Thus 99% confidence, not 100%.)

[56] IPCC AR6 WGI at 205. *See also id.* at § 3.2.

[57] "Dynamical downscaling refers to the use of high-resolution regional simulations to dynamically extrapolate the effects of large-scale climate processes to regional or local scales of interest. Statistical downscaling encompasses the use of various statistics-based techniques to determine relationships between large-scale climate patterns resolved by global climate models and observed local climate responses." NOAA Geophysical Fluid Dynamics Library, *Climate Model Downscaling,* https://www.gfdl.noaa.gov/climate-model-downscaling/ (last visited April 4, 2022)

[58] See, e.g., Flavio Lehner et al., *The Potential to Reduce Uncertainty in Regional Runoff Projections from Climate Models,* 9 NATURE CLIMATE CHANGE 926 (2019).

[59] *See infra* §~~XX~~ II(F)(1) ("Intergovernmental Panel on Climate Change").

Formatted: Not Highlight

studies will present findings at lower bounds to provide additional insights on likely or probable findings (e.g., a 66% confidence level, corresponding with a "likely" finding).[60]

Scientific studies also typically include information about Type I (false positive) and Type II (false negative) errors. If Type I errors are high, then the study may have produced a spurious association between anthropogenic forcing and an observed trend. Conversely, if Type II errors are high, then the study may be underestimating or wholly missing the effects of anthropogenic forcing on an observed trend. Climate researchers tend to be more concerned with avoiding Type I errors to ensure that they do not overstate the magnitude of anthropogenic climate change, but the downside to this approach is that researchers may be overly conservative in their estimates of climate change and its effects.[61]

A metric known as the *p-value* provides further insights on the validity of climate studies. The p-value measures the probability that an observed result would occur under the null hypothesis. In climate science, the null hypothesis is typically framed as a counterfactual world in which human activities have had no influence on the climate system. Thus, the p-value measures the probability that an observed trend such as global warming would occur in the absence of any anthropogenic climate forcing. A *p-value* of 5% or less is commonly used as a threshold of validity in climate studies and other areas of natural science.[62]

The most robust approaches to climate science combine good observations, physical understanding, rigorous statistical analysis, and detailed models to generate findings, along with clear communication and transparency with respect to research parameters, assumptions made, confidence in findings, and potential areas of uncertainty or bias. Studies that combine sound science with clear communication can generate findings that are sufficiently robust to support a wide variety of applications, but the confidence in and precision of those findings depends on the nature of the change, event, or impact being studied.

F. Sources of Climate Research

There are several major scientific organizations involved in the production, synthesis, and communication of climate research. These include the IPCC, the WMO, and the American Meteorological Society (AMS), the American Geophysical Union (AGU), and the National Academies of Sciences, Engineering, and Medicine (National Academies). The U.S. federal government also funds research and publishes reports on climate science. In addition, there are thousands of individual researchers, academic institutions, and NGOs contributing to this field.

---

[60] *See, e.g.*, Mark Risser & Michael Wehner, *Attributable Human-Induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation during Hurricane Harvey*, 44 GEOPHYSICAL RESEARCH LETTERS 12,457 (2017).

[61] William R. L. Anderegg et al., *Awareness of Both Type I and 2 Errors in Climate Science and Assessment,* AMS BAMS (2014).

[62] A p-value less than or equal to 5% is often describe as the threshold for "statistical significance", but this does not relate to the magnitude of impact but rather the probability that the test hypothesis is true (i.e., that anthropogenic forcing did influence some climate-related variable). If the p-value of a climate study is > 5%, then there is a reasonable probability that an observed trend is due to natural variability.

This section provides context on different sources of climate research and highlights some considerations to help judges assess the credibility, weight, and admissibility of research depending on the source.

1. World Meteorological Organization (WMO)

The WMO is a United Nations (UN) agency responsible for coordinating and advancing climatological and meteorological research around the world.[63] One key goal of the WMO is to promote the "free and unrestricted" exchange of data, information, and research between the 193 countries and territories that are signatories to the WMO convention.[64] The WMO is governed by the World Meteorological Congress, which is composed of member states.

Although the WMO is a political organization, it is recognized as an authoritative source of climatological and meteorological data. It provides standardized data products for climate research, most notably the "Climatological Standard Normals" which provide information on typical climate conditions averaged over thirty-year periods for thousands of locations across the world.[65] The WMO also publishes an annual *State of the Global Climate Report* which summarizes the latest observations and findings for various "global climate indicators" including greenhouse gases, global temperature, ocean heat content, sea level, marine heatwaves, the cryosphere, ~~(sea ice, glaciers, ice sheets),~~ and precipitation.[66] The report also discusses natural phenomena that are important drivers of year-to-year variability in weather patterns, such as the El Niño Southern Oscillation, and explains how these have influenced recent weather observations.

Commented [26]:
I think this is not the first use of the term

2. Intergovernmental Panel on Climate Change (IPCC)

The IPCC is widely considered to be the leading scientific body for the assessment and synthesis of research on climate change. It was established in 1988 by the United Nations Environment Programme (UNEP) and the WMO as an intergovernmental body of the UN. Its primary mandate is to provide governmental bodies and the public with regular assessments of the scientific basis for climate change, its impacts and future risks, and options for mitigation and adaptation.[67] It is governed by 195 member states.[68] There are also nearly two hundred observer

[63] The WMO originated from the International Meteorological Organization (IMO), which was a non-governmental organization founded in the late 1800s in order to promote the exchange of meteorological research. The WMO was subsequently established as a direct successor of the IMO through an agreement of UN member states in 1950.
[64] WMO, *Who We Are,* https://public.wmo.int/en/about-us/who-we-are.
[65] See WMO, *WMO Climatological Normals*, https://community.wmo.int/en/wmo-climatological-normals.
[66] See, e.g., WMO, PROVISIONAL STATE OF THE GLOBAL CLIMATE 2022 (Nov. 2022), available at https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate.
[67] *See* IPCC, History of the IPCC, https://www.ipcc.ch/about/history/.
[68] Representatives of IPCC member governments meet one or more times a year in plenary sessions. The member states elect a Bureau of Scientists to guide technical activities for each assessment cycle. They also review and approve draft assessments. IPCC, Structure of the IPCC, https://www.ipcc.ch/about/structure/.

organizations that participate in IPCC activities – for example, by nominating scientists to serve as report authors, and by reviewing draft reports.[69]

The IPCC publishes periodic assessments of the state of the scientific knowledge on anthropogenic climate change. The IPCC does not conduct its own research; rather, it conducts systematic reviews of relevant scientific publications and then synthesizes key findings from the literature in its assessments. It does so with the assistance of thousands of scientists with diverse expertise across the field of climate research.[70] There are three IPCC Working Groups involved in the assessment process: Working Group I synthesizes research on ~~The reports synthesize research on: (i)~~ the physical science basis for anthropogenic climate change, including research on the changes that are already underway as well as ~~predictions~~ projections of future climate change; ~~(ii)~~ Working Group II synthesizes research on the physical, social, and economic impacts of climate change; and ~~(iii)~~Working Group III synthesizes research on potential pathways for mitigating and adapting to climate change.[71] The experts involved in these Working Groups are selected by IPCC member governments, observer organizations, and the IPCC Bureau.

The IPCC conducts a comprehensive assessment of climate science every 6-7 years. During this process, each Working Group prepares a full "assessment report" that contains a detailed technical discussion of its respective topic.[72] Each draft report undergoes an initial review by a team of scientific and technical experts and then a second review by both governments and experts. A selection of scientists within each Working Group then produces a "Summary for Policymakers" (SPM), which is intended to help policymakers and non-scientists understand key findings from each report. The IPCC member states conduct a detailed review of each SPM, in consultation with scientists, and they must approve the SPM line-by-line. The IPCC member states also approve the full reports, but that approval process is less detailed and government inputs are more limited (as compared with the SPMs). At the end of the assessment process, the IPCC also prepares a "Synthesis Report" that combines findings from all three Working Groups. The Synthesis Report goes through the same type of review process as other reports, with an SPM subject to detailed review by member states.

Commented [MB27]: Given the reference to critiques below I think it would be good to differentiate between the reports issued by the Working Groups and the Summary for Policymakers and Executive Summary. My understanding is that the WG papers are scientific assessment reports which governments do not have control over, but that the other documents are far more politicized. It would be helpful to explain these key differences to the judges so they are not overly swayed by the critiques, and so that the critiques themselves are more properly targeted.

[69] Any non-profit body or agency with relevant expertise may apply to become an IPCC observer organization. The current list of observer organizations includes UN bodies and organizations, intergovernmental organizations, government agencies, universities, scientific research organizations, environmental NGOs, and industry NGOs. Representatives of observer organizations may attend sessions of the IPCC and the plenary sessions of the IPCC Working Groups. They are also invited to encourage experts to review draft IPCC reports. *See* IPCC, Structure of the IPCC, https://www.ipcc.ch/about/structure/; IPCC Observer Organizations, https://www.ipcc.ch/apps/contact/interface/organizationall.php.

[70] The scientists involved in the assessments are selected through a nomination process. Prior to initiating an assessment, the IPCC issues a call to governments and IPCC observer organizations for nominations; the authors are then selected by the Bureau of Scientists on the basis of their expertise. The IPCC seeks to build author teams that reflect a range of scientific, technical, and socioeconomic expertise. See IPCC Factsheet: How Does the IPCC Select Its Authors? (2021), *available at* https://www.ipcc.ch/site/assets/uploads/2021/07/AR6_FS_select.pdf.

[71] The IPCC has established three working groups to assess and synthesize research on these topics. Working Group I (WGI) focuses on the physical science basis for climate change, Working Group II (WGII) focuses on climate change impacts, adaptation, and vulnerability, and Working Group III (WGIII) focuses on mitigation.

[72] For a complete explanation of the process governing IPCC assessments, *see* IPCC, PRINCIPLES GOVERNING IPCC WORK, THE PROCEDURES FOR THE PREPARATION, REVIEW, ACCEPTANCE, ADOPTION, APPROVAL, AND PUBLICATION OF IPCC REPORTS (2018).

Formatted: Font: Italic

The IPCC also publishes methodology reports, technical papers, and other special reports in response to requests for scientific and technical information from the United Nations Framework Convention on Climate Change (UNFCCC), governments and international organizations. For example, in 2018, the IPCC issued a special report evaluating the impacts of climate change if anthropogenic emissions caused global warming at or in excess of 1.5°C.[73]

The IPCC has developed standardized language to communicate uncertainty and confidence in research findings. Specifically, it uses: (i) probabilistic language to describe the assessed likelihood of an outcome or result (very likely, likely, etc.);[74] (ii) language to describe the availability of evidence to support particular findings (limited, medium, robust); (iii) language to describe the level of agreement about findings (low, medium, high); and (iv) language describing scientific confidence in the findings (very low, low, medium, high, very high). The use of such calibrated uncertainty language can make scientific findings more accessible to scientists and non-scientists alike. Other entities, such as the U.S. Global Change Research Program (described below) have drawn on the IPCC guidance in order to characterize uncertainty and reliability in climate science findings.[75]

As noted above, the IPCC is generally considered to be~~by~~ a global authority on climate science. However, the IPCC has been critiqued on the grounds that it is a political institution subject to the governance of member states. Concerns have also been raised about the inclusion of experts with potential bias in the assessment process (e.g., representatives from renewable energy industry associations or, conversely, from fossil fuel industry associations).[76] While no organization is "perfect", an argument can be made that the structure of the IPCC actually contributes to institutional legitimacy and helps mitigate individual bias on the part of report authors and government representatives.[77] The assessments are prepared with the help of a large number of contributors, including the report authors (which include physical scientists as well as researchers with other expertise), governmental representatives, and observer organization representatives, and they reflect the consensus on the part of both scientific experts and governments.[78] The assessments have also received criticism from both sides of the climate change debate (some arguing that they overestimate the severity of anthropogenic climate change, others arguing that

Commented [MB28]: See comment above about making sure critiques are clearly identified with different parts of the IPCC reports and process.

[73] IPCC, GLOBAL WARMING OF 1.5°C. AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5°C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS 5 (Valérie Masson-Delmotte et al. eds., Cambridge University Press 2018) [hereinafter IPCC 1.5°C REPORT].

[74] The full list of terms used to communicate likelihood in the most recent IPCC report is as follows: virtually certain 99-100% probability; very likely 90-100%; likely 66-100%; about as likely as not 33-66%; unlikely 0-33%; very unlikely 0-10%; and exceptionally unlikely, 0-1%. Additional terms (extremely likely 95-100%, more likely than not >50-100%, and extremely unlikely 0-5%; are also used when appropriate. IPCC AR6 WG1 at 4.

[75] *See infra* Part II(B)(4).

[76] See, e.g., *Evolving the IPCC*, 1 NATURE CLIMATE CHANGE 227 (2011).

[77] See, e.g., Eric Paglia & Charles Parker, *The Intergovernmental Panel on Climate Change: Guardian of Climate Science*, in GUARDIANS OF PUBLIC VALUE (A. BOIN ET AL. EDS. 2021).

[78] ~~Each draft assessment undergoes an initial review by a team of scientific/technical experts and then a second review by both governments and experts. The assessments are then approved by IPCC member states before being published.~~

Formatted: Not Highlight

they underestimate the severity).[79] This suggests that there is not a pervasive industry or environmental bias within the IPCC.

Finally, for the purposes of U.S. litigation, it is important to recognize that the U.S. Supreme Court and federal appellate courts have embraced the IPCC as an authoritative and credible source of climate science.[80] In most legal contexts, it makes sense to defer to IPCC findings unless there is more recent and highly credible scientific research which calls those findings into question.[81]

3. Other Major Scientific Organizations

There are several U.S.-based organizations that play a key role in the dissemination of climate research. These include the American Meteorological Society (AMS), the American Geophysical Union (AGU), and the National Academies of Sciences, Engineering, and Medicine (National Academies). All three are viewed as highly credible sources of climate science.

The National Academies were established by the federal government in 1863, with a specific mandate of providing scientific assessments to help support government decision-making. Although the National Academies 'mandate is to assist the federal government, they are fully independent from the government.[82] Like the IPCC, the National Academies do not conduct independent research; rather they assess and synthesize existing research in order to provide objective scientific advice. They periodically publish reports on scientific matters of national significance. They have published numerous reports on the topic of climate change, ~~the most recent report being a 2020 update to their publication on~~including recent reports on *Climate Change: Evidence and Causes*,[83] and *Attribution of Extreme Weather Events in the Context of Climate Change*.[84] The National Academies also maintain peer-reviewed scientific journals, most notably the *Proceedings of the National Academies of Sciences* (PNAS), and they are involved in reviewing the *National Climate Assessments* prepared by the federal government (discussed below). For many years, the National Research Council (NRC) was the operating arm of the National Academies (e.g., the NRC published many scientific reports); but the NRC has since been reorganized into seven program units with different thematic focuses.[85]

Formatted: Font: Not Italic

Formatted: Font: Not Italic

Commented [29]:
Is it worth adding their earlier report on attribution of extremes?

The AMS is a professional membership organization involved in the dissemination of atmospheric, oceanic, and hydrologic sciences. It was founded in 1919 with the mission of

[79] *See, e.g.,* Naomi Oreskes, *Climate Change Will Cost Us Even More Than We Think*, THE NEW YORK TIMES (Oct. 23, 2019).
[80] *See* Massachusetts v. E.P.A., 549 U.S. 497 (2007); Coalition for Responsible Regulation v. EPA, 684 F.3d 102 (D.C. Cir. 2012); Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1189 (9th Cir. 2008); Dine Citizens Against Ruining Our Env't v. Haaland, 59 F.4th 1016 (10th Cir. 2023).
[81] By "more recent" research, we mean research that was published after information was collected for the latest IPCC assessment (and therefore could not have been incorporated into the assessment).
[82] National Academies, *About Us,* https://www.nationalacademies.org/about.
[83] NRC (2020), *supra* note 8.
[84] NATIONAL ACADEMIES OF SCIENCE, ENGINEERING, AND MEDICINE, ATTRIBUTION OF EXTREME WEATHER EVENTS IN THE CONTEXT OF CLIMATE CHANGE 51 (2016).
[85] National Academies, *Our Program Units and Divisions,* https://www.nationalacademies.org/about/organization.

advancing scientific research in these fields, and since then it has grown to a membership of nearly 12,000 scientific professionals.[86] The AMS maintains a number of publications that disseminate new research in climate science and related fields. These include the *Bulletin of the American Meteorological Society (BAMS)*, the *Journal of the Atmospheric Sciences*, the *Journal of Applied Meteorology and Climatology, Earth Interactions,* and the *Journal of Climate*, among others. These are all peer-reviewed publications with excellent standing in the scientific community. Each year, AMS also publishes a *State of the Climate* report as a supplement to BAMS as well as a special edition of BAMS on *Explaining Extreme Events from a Climate Perspective.*[87] This is an annual review of peer-reviewed research assessing how anthropogenic climate change has affected the magnitude, likelihood, and other characteristics of extreme events such as floods and heat waves.

The AGU is a professional membership organization involved in the dissemination of atmospheric, ocean, hydrologic, space, and planetary research. It was established in 1919 by the NRC and it operated as an affiliate of the National Academies until it was independently incorporated in 1972.[88] It now has more than half a million members from around the world. Like AMS, AGU maintains various peer-reviewed publications that disseminate new research in climate science and related fields. These include the *Journals of Geophysical Research*, the *Journal of Advances in Modeling Earth Systems*, *Earth and Space Science,* and *Geophysical Research Letters*. As with AMS publications, the AGU journals have excellent standing in the scientific community.

4. Peer-Reviewed Research

The assessments performed by the IPCC and other authoritative science bodies are based primarily on syntheses of peer reviewed climate research. Litigants may also rely on individual peer reviewed studies to support scientific claims (often as a supplement to IPCC reports or other synthesis documents). There are several considerations for judges when engaging with independent peer reviewed research. First, different publications have different standards for what qualifies as "peer review", and there are some journals that purport to publish "peer reviewed" research that do not actually have a legitimate peer review process – these are sometimes referred to as "predatory journals." In order to distinguish between legitimate and illegitimate publications, judges can refer to online lists of such journals;[89] they can also examine the credentials of the journal editors, the authors of the particular study at issue in the case, and the authors of other studies published in that same journal.[90]

It is also important to note that the fact that a scientific resource is *not* peer reviewed does not in and of itself doesn't mean that the resource is faulty or illegitimate. There are credible scientific

Commented [MB30]: It seems a bit odd to me to have this so far removed from the IPCC, which itself is a synthesis report of peer-reviewed research. Consider moving this up above some of the other sources.

[86] AMS, *About the American Meteorological Society,* https://www.ametsoc.org/index.cfm/ams/about-ams/.
[87] BAMS, *Explaining Extreme Events from a Climate Perspective,* https://www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/explaining-extreme-events-from-a-climate-perspective/.
[88] AGU, *Learn About AGU,* https://www.agu.org/Learn-About-AGU/About-AGU/#0.
[89] See, e.g., Beall's List of Potentially Predatory Journals and Publishers, https://beallslist.net.
[90] *See infra* §IV(C) for further insights on engaging with expert witnesses.

data and research products that do not undergo formal peer review – this includes, for example, some of the data and research products published by government agencies. Courts can consider other factors when evaluating the credibility of such resources, including the credentials of the publishing organizations and scientists, whether the findings are consistent with those from expert bodies like the IPCC, and whether the underlying methodologies have been subject to peer review.

4.5.Government Agencies

The U.S. federal government also plays a~~n~~ major role in both the production and dissemination of climate research.[91] The federal programs and agencies ~~and entities~~ that are most heavily involved in the production of climate science outputs include the U.S. Global Change Research Program (USGCRP), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), and the Environmental Protection Agency (EPA).

Commented [31]:
Maybe flip order here since you lead with USGCRP below

The USGCRP is the leading federal entity involved in the coordination and dissemination of research on climate change. The program began as a presidential initiative in 1989 and was subsequently codified by Congress in 1990 as a "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."[92] The USGCRP coordinates federal research on climate change and periodically publishes *National Climate Assessments (NCAs)* which summarize the latest science on anthropogenic climate change, including research on how climate change is affecting and may affect the U.S. now and in the future. These reports are a useful supplement to IPCC assessments insofar as they focus on the U.S. context. The *Fourth National Climate Assessment* (NCA4) was published in 2018, and the fifth assessment is anticipated in late 2023.

A number of other federal agencies, including NOAA, NASA, USGS, and EPA, are directly involved in climate research and the production of climate data products.[93] NOAA plays a particularly important role in federal climate research and dissemination – it maintains records of climate indicators (e.g., national precipitation and temperature records), and publishes monthly reports summarizing the latest climate data for the U.S. and the globe.[94] NASA also produces and maintains climate data products – these include satellite data as well as outputs from NASA

[91] Many states also have government agencies involved in the production and dissemination of climate research. But for the purposes of this chapter, we focus on scientific outputs from federal agencies, as federal judges are more likely to engage with these outputs.
[92] Global Change Research Act of 1990 (Pub. L. 101-606).
[93] This is not an exhaustive list of all federal entities involved in climate research. Other departments and agencies, including but not limited to the Department of Energy (DOE), the Department of Interior (DOI), the Department of Defense (DOD), the Department of Agriculture (USDA) and agencies and services within these departments, also conduct climate-related research relevant to their respective mandates. So many agencies are involved in climate research because climate change has such far-reaching implications for the U.S. government, citizens, and natural resources.
[94] NOAA, National Centers for Environmental Information, *Products by Category,* https://www.ncei.noaa.gov/access/monitoring/products/.

weather and climate models.[95] The USGS carries out geophysical research on climate change and its impacts as part of its *Climate Research and Development* program,[96] and it also maintains national and regional *Climate Adaptation Science Centers* which are collaborative scientific partnerships aimed at building knowledge to help resource managers and communities prepare for and respond to the effects of climate change[97] EPA primarily conducts research on the environmental and public health effects of climate change – for example, examining how climate change will affect air quality and ecosystems.[98]

The NCAs and the climate research products generated by federal agencies are generally viewed as credible and reliable sources of climate science. However, judges may need to exercise caution when engaging with government resources in some contexts – for example, when the overseeing administration has undermined, suppressed, or censored climate science in order to serve a political agenda. The level of deference granted to government analyses will also defend on the nature of the legal claims raised by parties to a case.

~~5.~~6. Other Non-Governmental Organizations

In addition to the international and U.S.-based organization described above, there are many non-governmental and academic organizations in the production and dissemination of climate research and data products. Some examples include the World Weather Attribution project, a collaboration of climate scientists that provides rapid assessments on the role of anthropogenic climate change in extreme weather events;[99] the Climate Impact Lab, a coalition of scientists, economists, and other analysts that conduct research on the impacts and costs of climate change;[100] and Climate Signals, an initiative which provides written synthesis of and data visualization products for climate attribution research.~~;~~[101] ~~the Climate Action Tracker, a scientific initiative to track government climate action and evaluate whether it is consistent with the UNFCCC goal of limiting global warming to 2°C or 1.5°C;[102] and the Carbon Tracker initiative, an independent thinktank that researches the impact of climate change on financial markets and provides research products for investors.[103]~~

Many of these entities provide high quality research products. However, these organizations do not have the same scientific standing as the major scientific organizations discussed above, and their research products often do not always undergo formal peer review. There are various ways

[95] NASA Science, Data Resources, https://climate.nasa.gov/nasa_science/data/; NASA Center for Climate Simulation, Climate Data Products, https://www.nccs.nasa.gov/services/climate-data-services.
[96] USGS, *Climate Research and Development*, https://www.usgs.gov/programs/climate-research-and-development-program.
[97] USGS, *Climate Adaptation Science Centers,* https://www.usgs.gov/programs/climate-adaptation-science-centers.
[98] EPA, *Climate Change Research*, https://www.epa.gov/climate-research.
[99] World Weather Attribution, https://www.worldweatherattribution.org/about/.
[100] Climate Impact Lab, https://impactlab.org.
[101] Climate Signals, https://www.climatesignals.org/.
[102] ~~Climate Action Tracker, https://climateactiontracker.org/~~
[103] ~~Carbon Tracker Initiative, https://carbontracker.org.~~

Commented [32]: There are some private sector entities out there these days, like Jupiter and consulting shops like ICF. They might merit a sentence.

Commented [MB33R32]: These firms work with clients. Their work does not meaningfully contribute to the public discourse, so far as I can tell. Certainly there are many other groups that produce legitimate climate science - EDF, Nature Conservancy, and many others. But I don't think you should include a list like that.

Carbon Tracker and Climate Action Initiative are not doing climate science, correct? They are conducting assessments of pledges and the like. DO they belong in this category?

Commented [JW34R32]: They're both "research" organizations but you're right that they're not involved in physical climate science. And probably not the best idea to group them with WWA (which does strike me as a fairly rigorous scientific endeavor).

And I realize that I should more explicitly call out academic organizations here (e.g., the Climate Impact Lab, which I've added to the list in lieu of those other orgs, is a joint academic/NGO initiative).

in which to evaluate the credibility of these research products. The credentials of the individuals producing the products are very important – the World Weather Attribution project, for example, consists of scientific researchers at top universities who have extensive experience in the climate and atmospheric sciences. Funding sources may also provide insights on credibility – for example, if a group is funded by fossil fuel interests or other industry actors that have a financial stake in preventing the regulation of fossil fuels, this ~~should~~could raise red flags about the credibility of any research findings. Finally, research products can also be evaluated for consistency with climate assessments from authoritative institutions like the IPCC.

Commented [35]: 'Could' or 'might' ?

~~**6. Peer-Reviewed Research**~~

Commented [MB36]: It seems a bit odd to me to have this so far removed from the IPCC, which itself is a synthesis report of peer-reviewed research. Consider moving this up above some of the other sources.

~~The assessments performed by the IPCC and other authoritative science bodies are based primarily on syntheses of peer reviewed climate research. Litigants may also rely on individual peer reviewed studies to support scientific claims (often as a supplement to IPCC reports or other synthesis documents). There are several considerations for judges when engaging with independent peer reviewed research. First, different publications have different standards for what qualifies as "peer review", and there are some journals that purport to publish "peer reviewed" research that do not actually have a legitimate peer review process – these are sometimes referred to as "predatory journals." In order to distinguish between legitimate and illegitimate publications, judges can refer to online lists of such journals;[104] they can also examine the credentials of the journal editors, the authors of the particular study at issue in the case, and the authors of other studies published in that same journal.[105]~~

III. Research on Anthropogenic Climate Change

There are several different categories of r~~R~~esearch on anthropogenic climate change ~~is a core focus of both climate science and lawsuits that implicate climate science. This research can be broadly classified into several categories~~that are potentially relevant to litigation. First, *detection and attribution* research examines the causal nexus between anthropogenic climate forcings, climatological trends (e.g., sea level rise), weather events (e.g., heat waves), and impacts (e.g., changes in agricultural productivity). Second, *source attribution* research evaluates the respective contributions of different actors, activities, sectors, and jurisdictions to anthropogenic climate change. Third, there is research aimed at *predicting future climate change* under different warming and emissions trajectories, and evaluating potential impacts on human and natural systems. Finally, there is research aimed at estimating remaining *carbon budgets* that would limit global warming to politically agreed targets such as 1.5°C or 2.0°C. For each of these research areas, we describe the underpinning methods and parameters, and we summarize key research findings, focusing on findings from the IPCC and other expert bodies. Throughout this discussion, we provide context on levels of scientific confidence and ~~seek to highlight areas of both scientific consensus and~~certainty (or uncertainty) in research findings.

Commented [37]: How about '…core focus at the intersection of climate science and lawsuits that implicate climate science.'

I feel your of 4 items immediately below is a great summary of climate-law categories, or climate-policy categories, but doesn't necessarily summarize climate science as well.

Commented [MB38R37]: Agree this sentence should be rephrased. It is generally an awkward construction. You might just cut it.

Commented [39]: 'Greater uncertainty' ?

Commented [MB40R39]: Just reiterating my earlier point that I believe educating judges about scientific uncertainty in this context is a key goal. Accordingly I agree with Radley, and think you should be careful to characterize uncertainty throughout, to counteract the idea that there can ever be true 100% certainty, and that the existence of uncertainty in and of itself is somehow problematic.

~~[104] See, e.g., Beall's List of Potentially Predatory Journals and Publishers, https://beallslist.net.~~
~~[105] *See infra* §XX for further insights on engaging with expert witnesses.~~

As a starting point to this discussion, it is important to recognize that there is global scientific consensus that anthropogenic climate change is occurring and causing pervasive impacts to human and natural environments around the world.[106] Some of the observed changes include rising sea levels, ocean warming and acidification, melting sea ice, thawing permafrost, increases in the frequency and severity of many types of extreme events, and corresponding impacts on people, communities, and ecosystems.[107] The weight of the scientific evidence demonstrates that anthropogenic climate change "is already affecting every inhabited region across the globe, with human influence contributing to many observed changes in weather and climate extremes."[108] Moreover, the warming from anthropogenic emissions that have already been released into the atmosphere will persist for centuries to millennia and will continue to cause further long-term changes in the climate system and other Earth systems.[109]

The impacts of anthropogenic climate change will become more severe as humans release more GHGs into the atmosphere. Scientists predict that the loss and damage caused by anthropogenic climate change will be severe even if we limit global warming to 1.5 or 2.0 °C (two targets established by political bodies for averting dangerous anthropogenic climate change, which are often used to formulate scenarios for climate projections) above pre-industrial levels[110] Many jurisdictions, including the U.S., have made commitments and undertaken measures to reduce GHG emissions, but global net anthropogenic emissions have continued to increase. Global warming of 1.5 and 2.0 °C will likely be exceeded within the 21st century unless deep reductions in CO_2 and other GHG emissions occur in the near future.[111]

Multiple lines of evidence support these findings, including observational data, physical understanding of the Earth's climate system and the greenhouse effect, paleoclimate reconstructions, statistical analysis, and model simulations. Moreover, as noted in Part II, the data and techniques used to evaluate anthropogenic climate change have been studied and refined for over 150 years, and there have been major advances in both attribution and predictive research in the past decades.[112]

In sum: there is scientific consensus on the reality of anthropogenic climate change and scientists can detect, attribute, and predict many of the trends and impacts caused by climate change with a high ~~or reasonable~~ level of confidence. But there are still some gaps in scientific knowledge of the climate system and uncertainty about the effects of climate change, particularly when looking at the regional or local impacts of climate change. The sections below include a discussion of scientific confidence and uncertainty in scientific findings across the various fields of climate change research.

Commented [MB41]: Why "reasonable" rather than use the IPCC terms?

[106] See IPCC AR6, ~~National Research Council~~NRC (2020), *supra* note 8X, NCA4 Vol. I.
[107] *See infra* Part III(A-C).
[108] IPCC AR6 WGI at 10. *See also* NCA Vol. I, 36 ("[e]vidence for a changing climate abounds, from the top of the atmosphere to the depths of the oceans.")
[109] *Id.* at 89, 184, 188.
[110] IPCC 1.5°C REPORT.
[111] IPCC AR6 WGI at 14.
[112] *Id.* at 184.

A. Climate Change Detection and Attribution

Climate change detection and attribution research examines the causal links between human activities, changes in the ~~global~~ climate system, and corresponding impacts on other interconnected systems.[113] Research in this field has demonstrated that human activities are the dominant cause of observed climate change.[114] This finding is based on physical understanding of the climate system, comparisons between observational data and climate models, and "fingerprinting" studies that examine the influence of anthropogenic forcing on specific climatological trends and events.[115]

Attribution and detection research can be categorized into different sub-fields, each of which corresponds with a different link in the causal chain connecting human activities to climate change-related harms:

- **Detection and attribution of global climate change** focuses on the link between anthropogenic climate forcing and corresponding changes in the global climate system, including the atmosphere, hydrosphere, cryosphere, land surface, and biosphere.
- **Extreme event attribution** examines how global climate change has affected the probability, frequency, severity, and other characteristics of extreme events such as heat waves, storms, floods, drought, and wildfires.[116]
- **Impact attribution** examines how global climate change is affecting human and natural systems. This research deals with a broad range of physical, social, health, economic, and biological impacts at global, regional, and local scales.[117]

There is also a related field of "source attribution", which examines the relative contributions of different actors and activities to global climate change, but this is a distinct area of research

Formatted: Space After: 6 pt

[113] This discussion of attribution research has been adapted and in some cases excerpted from the authors' prior publication on this topic. *See* Michael Burger, Jessica Wentz & Radley Horton, *The Law and Science of Climate Change Attribution*, 5 COLUMBIA JOURNAL OF ENVIRONMENTAL LAW 57 (2020). The discussion of scientific findings has been updated to reflect new resources, including the latest IPCC assessment (AR6).

[114] ~~National Research Council~~NRC (2020), *supra* note 8, Chapter 2. *See also* IPCC AR6 WGI; NCA4.

[115] *Id.*

[116] We discuss extreme event attribution as a separate category of attribution research because extreme events do not fit neatly into the "global climate change" or "impact" attribution categories. Weather is part of the climate system, but extreme events are often discussed as "impacts" of climate change, and there are unique challenges associated with efforts to ascertain the effect of climate change on a particular extreme event.

[117] The distinction between "changes in the global climate system" and "the impacts of climate change" is not always clear due to the broad definition of the global climate system. The IPCC defines *impacts* or *effects* to include physical impacts such as floods, droughts, and local sea level rise, as well as any other "effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure." IPCC AR6 WGI at 201. In many cases, a change in an essential climate variable (e.g., sea level rise) could be viewed as a "physical impact" of climate change. For the purposes of this chapter, we classify studies on regional changes in essential climate variables as "climate change attribution" where the primary goal of the study is to better understand how humans are affecting the global climate system, and we classify studies on floods, droughts, and local sea level rise as "impact attribution" where the primary goal of the study is to better understand how climate change is affecting a particular region or locale.

which has historically relied on different data sets and methodologies. Source attribution is discussed in Part III(B).

1. General Methods and Parameters

There are many similarities in analytical techniques used in the detection and attribution of global climate change, extreme events, and impacts. All three sub-fields rely on the foundational components highlighted in Part II, specifically: physical understanding, instrumental records, reanalysis datasets, paleoclimate reconstructions, statistical analysis, and climate models. Here, we provide additional information on how those tools are utilized across different types of detection and attribution.

a. Detection of Change

Detection and attribution is a two-step process used to identify a causal relationship between one or more drivers and a responding system. The first step – detection of change – involves demonstrating that a particular variable has changed in a statistically significant way without assigning cause.[118] To accomplish this, scientists will compare historical climate data with contemporary observations to assess the magnitude of change, and they will also evaluate whether the observed change may be due to internal variability or external forcing on the climate system. An identified change is "detected" in observations if the likelihood that it occurred due to internal variability (i.e., chance) alone is determined to be small, for example less than 10%.[119]

Scientists typically use instrumental records to identify an event or process that will be the subject of the detection and attribution study. The subject could be a gradual process, such as increases in average sea surface temperature or global mean sea level, or it could be a sudden onset event, such as a heat wave. Scientists will also use instrumental records in conjunction with other sources of climate data (e.g., re-analysis datasets and paleoclimate reconstructions) to characterize baseline climate conditions and to evaluate how those conditions have changed over time.

b. Attribution to Anthropogenic Climate Change

The second step – attribution – involves sifting through a range of possible causative factors to determine the role of one or more drivers with respect to the detected change. This is typically accomplished by using physical understanding, as well as climate models and/or statistical analysis, to compare how the variable responds when certain drivers are changed or eliminated entirely. The goal of such studies is to determine whether, how, and to what extent anthropogenic drivers have contributed to the observed change.

---

[118] David R. Easterling et al., *Detection and Attribution of Climate Extremes in the Observed Record,* 11 WEATHER AND CLIMATE EXTREMES 17 (2016); Gabriele C. Hegerl et al., *Good Practice Guidance Paper on Detection and Attribution Related to Climate Change*, *in* MEETING REPORT OF THE IPCC EXPERT MEETING ON DETECTION AND ATTRIBUTION OF ANTHROPOGENIC CLIMATE CHANGE 2 (Thomas Stocker et al. eds., 2010).
[119] IPCC AR6 WG1 at 196.

Many attribution studies use a "probabilistic" approach – i.e., researchers will seek to quantify the probability of a particular outcome (for example, three inches of rain in a day) occurring with and without anthropogenic influence on climate. However, researchers can also use a "mechanistic" approach to attribution, whereby they seek to examine how climate change has influenced one or more physical characteristics of an event or process.[120] Mechanistic studies can provide insights on, for example, the change in magnitude or severity of an extreme event that can be attributed to climate change.[121] In the rainfall example above, a mechanistic approach might look at the weather system that produced the heavy rain, and describe how one part of climate change that we understand well—say for example the warming of the atmosphere, and it's resulting increase in the amount of moisture the atmosphere can hold—contributed to the event. Mechanistic and probabilistic analyses can be combined in order to develop a more complete picture of how climate change is influencing various processes and events.[122]

Researchers use both statistical techniques and climate models when detecting and attributing change. As an example of statistical techniques, scientists use linear regression methods[123] and variants such as "optimal fingerprinting" to determine whether a change in a climate variable is statistically significant or simply part of natural variability.[124] This analysis is part of the detection of climate change and corresponding impacts, but it can also be used to support attribution statements (e.g., a finding that the spatial pattern of warming in the atmosphere was likely caused by anthropogenic emissions because it is statistically unlikely that the spatial pattern would have occurred in the absence of anthropogenic forcing on the climate). This is sometimes referred to as "observation-based" attribution.[125]

However, in practice, most studies do not rely exclusively on observation-based statistical analysis for attribution due to short observation records and complex forcing changes over the historical period.[126] Climate models are typically used for attribution because they allow scientists to separate out the effects of different forcings on the observed variable. That said, observation-based attribution findings can serve as a useful supplement to model-based findings.[127]

---

[120] *See infra* at § III(A)(3) for further discussion of the mechanistic approach and its role in extreme event attribution (also referred to as the "storyline" approach to extreme event attribution).

[121] *See, e.g.,* Michael Wehner & Christopher Samson, *Attributable human-induced changes in the magnitude of flooding in the Houston, Texas region during Hurricane Harvey*, 166 CLIMATIC CHANGE 20 (2021). *See also* Luke Harrington et al., *Integrating attribution with adaptation for unprecedented future heatwaves*, 172 CLIMATIC CHANGE 2 (2022) (discussing the differences and similarities between probabilistic and mechanistic approaches to extreme event attribution).

[122] For example, findings from both probabilistic and mechanistic studies are synthesized in IPCC assessments and other climate reports.

[123] Linear regression is a statistical method used to summarize and study relationships between two continuous (quantitative) variables.

[124] K. Hasselmann, *Optimal Fingerprints for the Detection of Time-Dependent Climate Change*, 6 JOURNAL OF CLIMATE 1957, 1957 (1993).

[125] NATIONAL ACADEMIES OF SCIENCE, ENGINEERING, AND MEDICINE, ATTRIBUTION OF EXTREME WEATHER EVENTS IN THE CONTEXT OF CLIMATE CHANGE 51 (2016).

[126] *Id.*

[127] Andrew D. King et al., *Attribution of the Record High Central England Temperature of 2014 to Anthropogenic Influences*, 10 ENVIRONMENTAL RESEARCH LETTERS, May 1, 2015, at 1; Gabriele C. Hegerl, *Use of Models and Observations in Event Attribution*, 10 ENVIRONMENTAL RESEARCH LETTERS, July 2, 2015, at 1.

Attribution studies utilizing climate models generally involve at least two sets of simulations: one that is meant to reflect the world that is, and another that is meant to reflect a "counterfactual" world without anthropogenic climate change (or without some component of anthropogenic climate change). These model simulations are ideallytypically run at least several times based on differing initial conditions multiple times [can we be more specific?] and for long duration, allowing scientists to better differentiate the climate change signal from the noise of natural variability. understand the most likely outcomes, as well as a fuller range of potential outcomes. Observational data and physical understanding provide the basis for calibrating and verifying models.

Several modeling centers have now developed standardized climate simulations designed for detection and attribution specifically, based on different parameters (e.g., researchers can evaluate the probability of an event or impact occurring both with and without certain observed changes in the climate, such as changes in sea surface temperature). Due to advances in parallel computing and model simplifications, these can be run rapidly and at high spatial resolution, yielding quick results. Indeed, when the above packages are combined with forecasts of variables with high predictability, such as sea surface temperature, projected results can be made available *in advance* of actual events. Furthermore, the tools and outputs, and models themselves, are increasingly being made publicly available. This has furthered the proliferation of attribution research in recent years.

c. Detection Without Attribution

There are potential trends and events associated with climate change that have not yet been detected through observational evidence due to short observational data records, large natural variability, or other anthropogenic influences that can "mask" the impact. For this reason, the USGCRP and other scientific bodies believe that attribution without detection can be appropriate in some circumstances – for example, where an event is so rare that trend analysis is not practical, or where a trend is masked by other human activities -- although this approach may result in lower confidence findings, as well as the possibly of false positives.[128] Ultimately, significant weight should be given to physical understanding in attribution assessments, especially in the absence of detected trends – i.e., the most robust attribution findings are those which are based on deep understanding of the mechanisms and processes by which anthropogenic forcings influence a particular variable or trend within a system.

d. Special Considerations for Extreme Event and Impact Attribution

Attribution becomes increasingly complex and challenging as the focus of research moves away from long-term, broad-scale changes in the climate system and towards more localized, discrete extreme events and climate impacts. One key challenge is conducting the analysis at the appropriate spatial and temporal scale. Whereas the detection and attribution of "global climate change" deals with changes at a large scale, typically averaged over a long period of time, extreme event and impact attribution deal with more geographically and temporally distinct forms of

[128] *See* NCA 4, Appendix C: "Detection and Attribution Methodologies Overview."

change. Natural variability, unrelated to changes in climate forcing, is larger at fine spatial and temporal scales, making it harder to identify signals associated with anthropogenic or other forcings.[129] Some climate forcers, such as aerosols, also differ both in concentration and forcing strength at subregional and subannual scales. When models are used to assess extreme events or impacts that occur at finer spatial and temporal scales than the models themselves, some type of downscaling or bias correction is needed, which can introduce additional uncertainties.

Impact attribution studies must also account for non-climate or *exogenous* variables, i.e., characteristics of human and natural systems that are not part of the climate system.[130] Consider a study examining the relationship between climate change, a heat wave, and public health impacts: the study would need to account for both climate variables at a fairly discrete geographic and temporal scale (e.g., temperature and humidity during the event) as well as non-climate variables (e.g., population risk factors for heat-related morbidity, access to air-conditioned facilities and emergency services) to ascertain the extent to which climate change caused or contributed to observed health outcomes. Confounding variables (e.g. air quality), which influence both dependent and independent variables in a study, are of special concern as they can lead to spurious associations between a driver and an event or impact.[131] The number of exogenous and confounding variables increases as attribution research moves towards an analysis of discrete impacts on humans, communities, and ecosystems.

Due to the difficulty of managing many exogenous variables, many attribution studies focus on just one "link" in the causal chain of anthropogenic climate change. This is sometimes referred to as *single- step attribution*.[132] As an example, a study may evaluate how increases in global mean surface temperature (GMST) influenced the probability of a heatwave, without specifically attributing the GMST increase to anthropogenic forcing. In such studies, the link to anthropogenic climate change can be inferred, even though the exact contribution of anthropogenic drivers is not quantified.

That said, there are a growing number of extreme event and impact attribution studies that do include attribution to anthropogenic forcing. Such studies may entail "multi-step attribution", where scientists will first seek to identify how one or more core climate variables has changed in response to human activities, and then explore the implications of that change with respect to one or more specific impacts.[133] Multi-step attribution is useful for examining causal relationships in

---

[129] *See* IPCC WGI AR6 at 117 (discussing how internal variability is stronger and uncertainties in observations, models, and external forcings are larger at the regional scale, as compared with the global scale).

[130] This may be somewhat of an oversimplification, as many variables which may appear to be "outside" of the climate system are still, to some extent, interdependent with that system.

[131] In an impact or event attribution study, the dependent variable would be the impact or event under examination (e.g., a heat wave, or an uptick in hospitalizations) and the independent variable would be the climate change-related driver of the impact or event (e.g., increases in GHG concentrations or, in some studies, increases in climate variables such as mean temperature).

[132] For further discussion of single-step and multi-step attribution approaches, *see* Dáithi Stone et al., *The Challenge to Detect and Attribute Effects of Climate Change on Human and Natural Systems,* 121 CLIMATIC CHANGE 381, 390–91 (2013).

[133] *See, e.g.,* Y. Mao et al., *Is Climate Change Implicated in the 2013-2014 California Drought? A Hydrologic Perspective*, 42 GEOPHYSICAL RESEARCH LETTERS 2805 (2015); A.P. Williams et al., *Contribution of*

complex systems, but one potential drawback of this approach is that additional, "cascading" uncertainty and potential for error is introduced with each new "step" that is added to the analysis. Extreme event and impact attribution researchers can also use an "indirect two-step" approach by referencing findings from other studies or IPCC reports to establish the "first step" in their causation analysis (e.g., the link between anthropogenic forcing and GMST), and then they can focus on the "second step" (e.g., the link between GMST and heatwaves).[134]

2. Global Climate Change Detection and Attribution

For the purposes of this Chapter, we use the term "climate change detection and attribution" to describe research on how anthropogenic forcing is affecting average conditions within the global climate system (thus distinguishing it from extreme event and impact attribution). This research specifically examines: (i) how humans are altering the chemical composition (e.g., GHG concentrations) and total radiative forcing of the climate system; and (ii) how those changes in chemical composition and radiative forcing affect other components of the climate system (e.g., atmospheric and surface temperature, water vapor, precipitation, ocean heat content, and ocean acidity).

a. Methods and Parameters

Scientists detect changes in the global climate system through instrumental records, such as the CO_2 readings from the Mauna Loa Observatory in Hawaii, remote sensing from satellites, and other platforms. Some of the key variables being monitored include atmospheric concentrations of GHGs and other radiative forcers, atmospheric and surface temperature, water vapor (humidity), precipitation, sea ice, sea levels, ocean heat content, and ocean acidity. As discussed in part II, Scientists also use climate reanalysis datasets to fill gaps in instrumental records, as well as paleoclimate reconstructions to provide a longer-term perspective on climate conditions. Paleoclimate reconstructions offer important insights, including: 1) how sensitive different aspects of the climate system are to different climate forcings at various timescales, and 2) more robust estimates of natural variability than can be gleaned from the relatively short observational record.

In order to attribute changes in the global climate system to human influence, researchers must demonstrate that a detected change is "consistent with the estimated responses to the given combination of anthropogenic and natural forcing" and "not consistent with alternative, physically plausible explanations of recent climate change that exclude important elements of the given combinations of forcings."[135] The foundation for this analysis is physical understanding of how

---

Anthropogenic Warming to California Drought During 2012-2014, 42 GEOPHYSICAL RESEARCH LETTERS 6819 (2015).

[134] *See, e.g.,* Stott et al., *Future Changes in Event Attribution Methodologies, in Explaining Extreme Events of 2016 from a Climate Perspective*, 99 Bulletin of the American Meteorological Society S1 (2018) (hereinafter "BAMS 2016") at S156 (referencing Russel E. Brainard et al., *Ecological Impacts of the 2015/16 El Niño in the Central Equatorial Pacific*, *in* BAMS 2016). *See also* David J. Frame et al., *The Economic Costs of Hurricane Harvey Attributable to Climate Change,* 160 CLIMATIC CHANGE 271 (2020).

[135] IPCC, CLIMATE CHANGE 2001: THE SCIENCE OF CLIMATE CHANGE, WORKING GROUP I CONTRIBUTION TO THE THIRD ASSESSMENT REPORT OF THE IPCC 56 (John T. Houghton et al eds., 2001) (hereinafter IPCC TAR WGI).

the climate system reacts to different radiative forcings, such as GHGs, atmospheric aerosols, solar radiation, and reflectivity (albedo), all of which influence the balance of energy in the global climate system. Scientists must also account for the global carbon cycle in order to ascertain how changes in radiative forcings will affect different components of the climate system (e.g., the relative uptake of heat and carbon dioxide by oceans). Finally, scientists must have physical understanding of natural variability within the climate system in order to ascertain whether an observed change is caused by human forcing or natural variability.

As discussed in Part II, scientists typically use climate models for attribution purposes, and the most widely used models are the CMIP model ensembles. Due to ongoing advances in physical understanding, observations, and computational power, climate models now operate at finer and finer spatial scales, include interactions across more and more components of the climate system, and generate thousands of years of model output under different forcings and initial conditions. As models have grown in sophistication, their utility for climate attribution has grown—in 2014, IPCC AR5 found that models driven by historical greenhouse gas emissions and natural forcings (e.g., volcanoes and solar variability) could already "reproduce observed continental-scale surface temperature patterns and trends over many decades, including the more rapid warming since the mid- 20th century and the cooling immediately following large volcanic eruptions."[136] Models have continued to improve since then. IPCC AR6 assessed results from climate models participating in CMIP6 and found that:

> [The CMIP6 models] include new and better representations of physical, chemical and biological processes, as well as higher resolution, compared to climate models considered in previous IPCC assessment reports. This has improved the simulation of the recent mean state of most large- scale indicators of climate change and many other aspects across the climate system. Some differences from observations remain, for example in regional precipitation patterns.[137]

However, there are still some significant differences between model results and observations, particularly with regards to the hydrological cycle and precipitation patterns. Global and even regional models are often too coarse in resolution to accurately and precisely simulate certain aspects of precipitation, particularly heavy precipitation (as there is significant variation in precipitation at a relatively small spatial and temporal scales). This is a good example of a "downscaling" challenge in climate science that researchers are actively seeking to address.[138] Such downscaling challenges are most apparent in extreme event and impact attribution, but they also appear, to a lesser extent, in climate change attribution studies. This is because many of the observed changes in the global climate system vary on a regional basis, ~~both~~ due to factors including differences in forcings and the higher natural variability at finer spatial scales.

Commented [42]:
I added this text because there are other reasons we probably don't need to get into (e.g. regional physical features like forests vs. deserts, or presence of a mountain range that blocks moisture, etc.)

[136] The IPCC issued this statement with *very high confidence*. IPCC, CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS, WORKING GROUP I CONTRIBUTION TO THE FIFTH ASSESSMENT REPORT OF THE IPCC 15 (Stocker et al. eds., 2013) [hereinafter IPCC AR5 WGI].
[137] IPCC AR6 WGI at 285.
[138] *See, e.g.,* Jie Chen & Xunchang John Zhang, *Challenges and Potential Solutions in Statistical Downscaling of Precipitation,* 165 CLIMATIC CHANGE 63 (2021).

b. Status of Research

The existing body of research leaves little room for doubt that the global climate system is changing and human activities are the primary driver of the changes. Human activities have unequivocally warmed the climate, and this has caused "[w]idespread changes in the atmosphere, ocean, cryosphere, and biosphere."[139] Thus, there is no real question as to *whether* anthropogenic climate change is occurring. Scientists have also made considerable progress towards quantifying the effect of human activities on different components of the climate system. However, there is still some uncertainty about the respective influence of different climate forcings on observed changes, including the influence of non-human forcings, as well as the magnitude of internal variability and its influence on observed changes.

i. Chemical Composition of Global Climate System

Since the onset of the Industrial Revolution more than two centuries ago, human activities have caused significant increases in atmospheric concentrations of GHGs, particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The current levels of these GHGs in the atmosphere are unprecedented on timescales spanning from thousands to millions of years.[140] IPCC AR6 found that in 2019, atmospheric CO_2 concentrations were higher than at any time in at least 2 million years (*high confidence*) and atmospheric CH_4 and N_2O concentrations were higher than at any time in at least 800,000 years (*very high confidence*).[141] Between 1750 and 2019, CO_2 concentrations increased 47% to 410 parts per million (ppm), CH4 concentrations increased 156% to 1866 parts per billion (ppm), and N_2O concentrations increased 23% to 332 ppb.[142]

Due to the global carbon cycle, not all GHGs remain in the atmosphere, and it is therefore necessary to look at multiple interconnected systems to understand the full scale of human influence on the climate system. IPCC AR6 found, with *high confidence,* that approximately 44% of anthropogenic CO_2 emissions have accumulated in the atmosphere, with the remainder absorbed

[139] IPCC AR6 WGI at 6, 148. The IPCC's finding that anthropogenic climate change is "unequivocal" reflects the major advances in climate science since earlier reports. *Id.* at 147 ("The Second Assessment Report (SAR) stated that 'the balance of evidence suggests a discernible human influence on global climate'. Five years later, the Third Assessment Report (TAR) concluded that 'there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities'. The AR4 further strengthened previous statements, concluding that 'most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations'. The AR5 assessed that a human contribution had been detected in: changes in warming of the atmosphere and ocean; changes in the global water cycle; reductions in snow and ice; global mean sea level rise; and changes in some climate extremes. The AR5 concluded that 'it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century'.").

[140] NRC (2020), *supra* note 8, at 9.

[141] IPCC AR6 WGI at 8.

[142] *Id.* ~~IPCC AR6 WGI~~ at 281. This rate of change in CO_2 and CH_4 concentrations is unprecedented in at least the past 800,000 years. *Id.* at 69. GHG concentrations have continued to rise since AR6: by the of 2022, CO_2 concentrations reached 418 ppm, CH_4 concentrations reached 1923 ppb, and N_2O concentrations reached 336.16 ppb. NOAA Global Monitoring Library, Carbon Cycle Greenhouse Gases, https://gml.noaa.gov/ccgg/.

by land and ocean CO_2 sinks.[143] Although the "airborne fraction" of CO_2 emissions has remained roughly constant over the past six decades, scientists predict that the fraction of CO_2 absorbed by land and oceans will decrease as cumulative CO_2 emissions increase.[144] Accounting for these different absorption pathways is critical in attribution research because the effect of GHGs is dependent on where those gases are stored – for example, ocean acidification is caused by ocean absorption of CO_2.

ii. Atmospheric and Surface Temperature

IPCC AR6 found "unequivocal" evidence that human influence has warmed the atmosphere, oceans, and land, and that this warming trend is unprecedented it at least the last 2000 years.[145] It is clear that human activities, primarily GHG emissions from fossil fuel combustion, are the dominant cause of the observed warming trend: the scientific evidence does not support an alternative explanation. The IPCC, USGCRP, National Academies, and other major scientific organizations have all reached the same conclusion.[146]

The IPCC found that, as of 2019, the decadal average global surface temperature had increased approximately 1.09 [0.95-1.20] °C over pre-industrial levels, with larger increases over land (1.59 [1.34-1.83] °C) than the ocean (0.88 [0.68 – 1.01]°C).[147] More recent observations show that ~~this~~ the warming trend is continuing.[148] The WMO Provisional State of the Climate Report for 2022 found that ~~global mean surface temperature (GMST) from January – September 2022 was approximately 1.15 °C higher than pre-industrial levels, and~~ the last eight years are on track to be the eight warmest on record.[149]

This rate of warming is unprecedented in at least the past 2000 years and cannot be explained by natural drivers or internal variability.[150] Rather, the warming trend is consistent with physical understanding and model simulations of the climate forcing effects of human drivers (see Figure ~~X~~1). Human activities are clearly the dominant driver of this warming trend, although there is still some uncertainty about the precise contributions of different anthropogenic forcings. IPCC AR6 found that it is *likely* that humans are responsible for approximately 1.07 [0.8-1.3] °C of the observed increase in global surface temperature, with well-mixed GHGs contributing to a warming of 1.0-2.0 °C and other human drivers (primarily aerosols) contributing to a cooling of 0.0-0.8

Commented [43]: I might cut this first portion of the sentence. It is interesting and timely, but arguably a bit vulnerable to push-back about internal variability (even though this was not an El-nino period).I might cut it for 'optics' though

Commented [JW44R43]: That's fine with me. I still want to mention that the observational record shows the warming trend is continuing – but we don't need to specify exactly how much. Added a citation to the NOAA surface temperature records.

[143] IPCC AR6 WGI at 690. Specifically, the IPCC estimates that 23% of anthropogenic CO_2 emissions have been taken up by ocean sinks, and 31% have been taken up by terrestrial ecosystems (or "land sinks"). *Id.* at 80.
[144] IPCC AR6 WGI at 744.
[145] *Id.* ~~IPCC AR6 WGI~~ at 4.
[146] See NCA4 Vol. 1; National Research Council (2020), *supra* note X, at Ch. 1.
[147] IPCC AR6 WGI at 5. The figures cited here include average estimates as well as ranges [in square brackets]. These ranges reflect the 90% uncertainty interval (meaning that there is an estimated 90% likelihood of the value being within that range). *Id.* at 41, FN 11. The IPCC AR6 uses the period of 1850-1900 as a proxy for pre-industrial temperature levels (as well as other pre-industrial climate conditions). *Id.* at 163 (see Cross-Chapter Box 11.1).
[148] NOAA Global Surface Temperature, https://psl.noaa.gov/data/gridded/data.noaaglobaltemp.html (last visited April 26, 2023).
[149] WMO, PROVISIONAL STATE OF THE GLOBAL CLIMATE IN 2022 (2022).
[150] IPCC AR6 WGI at 6.

°C.[151] Similarly, NCA4 found that there was "a likely human contribution of 93%–123% of the observed 1951–2010 change" in global temperature.[152] Thus, natural drivers and internal variability had a minimal effect on changes in global surface temperatures over this period.[153] Also noteworthy, IPCC AR6 reaffirmed, with *high confidence*, that there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause.[154]

Figure X1: Changes in Global Surface Temperature Relative to 1850-1900[155]

Human-induced climate change has also affected atmospheric temperature, contributing to warming of the troposphere (lower atmosphere) accompanied by cooling in the stratosphere (upper atmosphere).[156] Theis spatial pattern of atmospheric ~~warming and cooling~~temperature change is actually consistent with physical understanding of the climate system and model simulations of anthropogenic influence on climate change.[157] In other words, the combination of tropospheric warming and stratospheric cooling confirm predictions that changes are driven primarily by increases in GHG emissions and other human drivers rather than natural causes.[158]

Commented [45]:
I went with the more general 'the' here since meridional (not just vertical) aspects of the temperature distribution are an important part of this argument

There is also regional variation in the warming trend, as would be expected based on physical understanding of the climate system. The Arctic is warming approximately three times faster than the rest of the globe due to "Arctic amplification."[159] Annually--averaged Arctic near-surface air temperature increased by 3.1°C between 1971 and 2019.[160] (The Arctic also happens to be particularly sensitive to temperature changes, since even a small increase in temperature can cause ice and snow to melt and thus significantly alter the landscape.) Some mountain regions are also experiencing more rapid warming in part due to the effects of melting snow and ice and decreased albedo.

---

[151] *Id.* ~~IPCC AR6 WGI~~ at 5. Note that we provide average estimates in this chapter; the IPCC reports also include information about the range of possible values for surface temperature and other climate variables.
[152] NCA4 Vol. I at 14.
[153] The IPCC estimates that natural drivers like volcanoes changed global surface temperature by -0.1 to +0.1 °C, and internal variability changed it by 0.2-0.2 to +0.2 °C.
[154] IPCC AR6 WGI at ~~28~~.
[155] Source: IPCC AR6 WGI at 6 (Figure SPM.1)
[156] IPCC AR6 WGI at 70.
[157] *Id.* ~~IPCC AR6 WGI~~ at 244.
[158] For further explanation, see EUMETSAT, *Tropospheric Warming and Stratospheric Cooling in the 21st Century*, https://www.eumetsat.int/tropospheric-warming-and-stratospheric-cooling-21st-century; *Upper Atmosphere*, in ESPERE CLIMATE ENCYCLOPEDIA (Alex de Sherbinin et al. eds., 2004), *available at* https://courses.seas.harvard.edu/climate/eli/Courses/global-change-debates/Sources/Stratospheric-cooling/stratospheric-cooling-ESPHERE-encyclopedia.pdf.
[159] *See supra* § ~~XX~~ II(B)(4) (discussing feedback loops in the climate system).
[160] ARCTIC MONITORING AND ASSESSMENT PROGRAM, ARCTIC CLIMATE CHANGE UPDATE 2021: KEY TRENDS AND IMPACTS (2021).

iii. Ocean Warming, Acidification, and Sea Level Rise

As the atmosphere has warmed, so too have the oceans. IPCC AR6 found, with *high confidence*, that ocean warming has accounted for 91% of the total warming in the climate system.[161] The observational record indicates that total ocean heat content increased by 0.396 [0.329 – 0.463 *likely* range] yottajoules between 1971 and 2018.[162] It is *virtually certain* that the increase in ocean heat content has caused warming in the upper layer of the ocean (0-700 meters), and it is *very likely* that deeper layers of the ocean have warmed as well.[163] At the ocean surface, temperature has increased, on average, by 0.88 [0.68 – 1.01] °C since pre-industrial times. It is *extremely likely* that human influence is the primary driver of ocean warming.[164]

The increase in ocean heat content has also caused global sea level rise, since warmer waters occupy more volume. Global mean sea level increased by 0.20 [0.15- 0.25] meters between 1901 and 2018.[165] IPCC AR6 found, with *high confidence*, that global mean sea level has risen faster since 1900 than during any preceding century in at least the last 3000 years.[166] Moreover, the rate of sea level rise has accelerated throughout since the beginning of the 20ththe century: the average rate of sea level rise was 1.3 [0.6 – 2.1] mm per year from 1901 through 1971, increasing to 1.9 [0.8-2.9] mm per year between 1971 and 2005, and 3.7 [3.2 – 4.2] mm per year between 2006 and 2018.[167] It is *very likely* that human influence was the main driver of these increases, at least since 1971.[168]

Commented [46]:
Cut, or better yet change to 'since the beginning of the 20th century'?

Ocean deoxygenation (oxygen decline) is another consequence of ocean warming (the solubility of dissolved oxygen decreases as sea water becomes warmer). There is *high confidence* that oxygen levels have dropped in many upper ocean regions since the mid-20th century, and *medium confidence* that human-induced ocean warming contributed to this drop.[169]

The uptake of carbon by oceans is also causing ocean acidification. Researchers estimate that the surface ocean has absorbed approximately one quarter of all human CO_2 emissions.[170] This has caused the pH of the ocean surface to decrease. IPCC AR6 found that it is *virtually certain* that the pH in open ocean surface water has changed by -0.017 to -0.027 pH units since the late 1980s, and there is evidence of acidification across all regions of the oceans.[171] It is also *virtually certain* that human-caused CO_2 emissions are the main driver of ocean acidification.[172]

---

[161] This is consistent with the IPCC's prior assessment (AR5) in which it found that approximately 90% of the accumulated energy from human-induced climate change was stored within the oceans. See IPCC AR6 WGI at 283 (comparing statements from AR5 and AR6).
[162] IPCC AR6 WGI at 1214.
[163] *Id.* IPCC AR6 WGI at 349.
[164] *IPCC AR6 WGIId.* at 5.
[165] *IPCC AR6 WGI at 5.Id.*
[166] *IPCC AR6 WGI Id.* at 8.
[167] *Id.* IPCC AR6 WGI at 5.
[168] *Id.*IPCC AR6 WGI at 5.
[169] *Id.* IPCC AR6 WGI at 5, 714.
[170] *Id.* IPCC AR6 WGI at 714.
[171] *Id.* IPCC AR6 WGI at 716.
[172] *Id.* IPCC AR6 WGI at 5.

iv. Cryosphere

The observational record has shown a substantial decline in sea ice, terrestrial glaciers, and snowpack in the past century. But there is considerable geographic variation in the magnitude and rate of decline, as not all areas are warming at the same rate, and extremely cold areas might be expected to see increases in snow and ice with warming. Some of the key findings from IPCC AR6 are that: (i) there has been a substantial reduction in Arctic sea ice over the period of 1979-2019, and in 2011-2022, average annual Arctic sea ice reached its lowest level since at least 1850 (*high confidence*); (ii) there have also been substantial reductions in ice sheets: between 1992 and 2020, the Greenland Ice Sheet lost 4890 [4180 to 5640] gigatons of mass, and the Antarctic Ice Sheet lost 2670 [1800 to 3540] gigatons of mass; (iii) glaciers lost 6200 [4600 – 7800] gigatons of mass between 1993 and 2019 (*very high confidence*), glaciers lost more mass in 2010-2019 than in any other decade since the beginning of the observational record (*very high confidence*), and the rate of glacier retreat since the 1950s is unprecedented in at least the 200 years (*medium confidence*); (iv) permafrost temperatures have been increasing around the world (*high confidence*) resulting in permafrost thaw in some regions (*medium confidence*); and (v) Northern Hemisphere spring snow cover has decreased since 1978 (*very high confidence)*, and *high confidence* that this trend likely extends back to 1950 (*high confidence*).[173] Many of the observed changes in the cryosphere are a direct consequence of warming and can therefore be attributed to human influence on climate; however, there is some uncertainty about the magnitude of the change attributable to human activities as opposed to natural variability.[174]

v. Atmospheric and Ocean Circulation

Warming of the atmosphere, oceans, and cryosphere is also affecting atmospheric and ocean circulation patterns. For example, IPCC AR6 found that human influence had likely contributed to a poleward expansion of the Southern Hemisphere Hadley Cell and very likely contributed to a poleward shift of the Southern Hemisphere extratropical jet stream in summer.[175] As discussed in Part II, changes in atmospheric circulation affect (and are affected by) the distribution of heat, water vapor, and precipitation around the Earth, potentially altering regional climates and the presentation of extreme events.

There is also evidence that anthropogenic climate change is affecting ocean circulation. For example, ocean circulation patterns are partially driven by sinking cold and dense water ~~from sea ice melt~~at high latitudes; as ~~sea~~ ice melt and increased precipitation in the high latitudes make this surface water fresher and less dense~~becomes warmer~~, it may not sink as effectively, and scientists predict that this will slow down some ocean currents. There is increasing evidence that major current systems, such as the Atlantic Meridional Overturning Circulation (AMOC), may have already slowed down over the last century.[176] IPCC AR6 found that there is "insufficient data to

[173] *Id.* at 1215-1216.
[174] *Id.* §§ 3.4.2, 3.4.3.
[175] *Id.* ~~IPCC AR6 WGI~~ at 70.
[176] *Id.* at 1237 (expressing *medium confidence* in evidence that the AMOC has weakened relative to 1850-1900).

Commented [47]: Removing your clause might be even better than adding mine. Probably you should do one of the two though

Commented [JW48R47]: I like the additional info you've added here – it acknowledges a possible outcome that may seem counterintuitive in a warming climate (precisely the sort of thing that climate skeptics try to use to undermine the science).

assess the magnitude of the weakening or to properly attribute it to anthropogenic forcing."[177] However, in a recently published study, Li et al. (2023) offered new evidence that Antarctic meltwater is potentially causing a slowing of "abyssal ocean circulation" which plays a key role in the cycling of heat, carbon, oxygen, and nutrients throughout the oceans.[178] Because ocean currents play a crucial role in determining climate conditions at global, regional, and local scales, uncertainty about the effect of anthropogenic warming on ocean circulation patterns is a major source of uncertainty that cuts across climate research, and different assumptions about circulation patterns can significantly affect model projections of future changes in variables such as surface temperature, precipitation, and wind circulation.[179]

vi. Hydrological Cycle and Precipitation

Ascertaining the effect of anthropogenic forcings on the hydrologic cycle and precipitation is one of the more challenging areas of climate change attribution. Part of the challenge is detecting change – spatial gradients of precipitation can be quite large in some regions, and historical rainfall records are incomplete and contain mixed findings about the extent to which precipitation patterns have (or have not) changed since the pre-industrial era. It is also difficult to attribute precipitation changes to human influence on climate because precipitation is characterized by large natural variability across a range of timescales ranging from the intra-annual to the centennial. However, in recent years, researchers have made significant advances in the attribution of hydrological changes to anthropogenic influence and this is reflected in IPCC assessments.

The research indicates that the global hydrological cycle is intensifying as a result of anthropogenic climate change. IPCC AR6 expressed *high confidence* that climate change has contributed to an overall increase in atmospheric moisture content (i.e., water vapor) as well as precipitation intensity.[180] The increase in atmospheric moisture content is significant in multiple ways: it amplifies the global warming effect (since water vapor is a heat-trapping gas), influences precipitation patterns, and contributes to the severity of extreme events including ~~including~~ intense precipitation, storms, and wet-bulb heat extremes.

Based on physical understanding, scientists also expect that global warming will cause an overall increase in global precipitation,[181] but this "has not yet been detected and attributed to human activities given large observational uncertainties and low signal-to-noise ratio. [182]

[177] *Id.*. The IPCC's statement reflects uncertainty about the relationship between anthropogenic warming and changes in ocean circulation patterns, which is due to: (i) limitations in the observational record (e.g., the strength of AMOC has only been directly measured since 2004), (ii) significant variability in circulation patterns, and (iii) limitations in scientific understanding of the physical mechanisms behind these patterns (e.g., the feedback mechanisms involving the ocean, atmosphere, and cryosphere are not fully represented in current climate models). *Id.* at 1214.

[178] Qian Li et al., *Abyssal Ocean Overturning Slowdown and Warming Driven by Antarctic Meltwater,* 615 NATURE 841 (2023).

[179] *See* K. Bellomo et al., *Future Climate Change Shaped by Inter-model Differences in Atlantic Meridional Overturning Circulation Response*, 12 NATURE COMMUNICATIONS 3659 (2021).

[180] IPCC AR6 WGI at 1057. 1080-1081. It is also *extremely likely* that climate change has driven more evaporation over the oceans, which contributes to water vapor as well as heavier precipitation. IPCC AR6 WGI at 1080.

[181] *Id.* § 8.2.1.

[182] *Id.* at 1079.

However, there is evidence that some regions are experiencing increases or decreases in average precipitation as a result of anthropogenic climate change. For example, IPCC expressed *high confidence* that precipitation had increased at high latitudes in the Northern Hemisphere.[183] ~~More recently, the WMO State of the Climate Report found that many of the world's regions had experiencing above normal precipitation in 2022, although not all of these trends have been definitively attributed to anthropogenic climate change.[184]~~ Moreover, as noted in the discussion of extreme event attribution below, increases in the frequency and intensity of heavy precipitation events have been attributed to human influence on climate.[185]

IPCC AR6 also found that it is *very likely* that human-caused climate change has influenced global patterns in aridity, with some areas becoming more arid even though the overall hydrological cycle is intensifying.[186] This is consistent with expectations, both because some areas are expected to see decreasing precipitation, and because the warming atmosphere is able to extract more moisture via evaporation from the land surface. Anthropogenic forcing has contributed to drying in dry summer climates, including the Mediterranean, south-western Australia, south-western South America, South Africa, and western North America (*medium to high confidence*).[187]

3. Extreme Event Detection and Attribution

Extreme event attribution seeks to understand how human-induced changes in the global climate system are affecting the frequency, severity, and other characteristics of extreme weather events, including heat waves, droughts, extreme precipitation, storms, floods, and compound events (e.g., fire weather).[188] Extreme weather is part of the global climate system, and thus extreme event attribution is a subset of climate change attribution.[189] However, there are unique challenges associated with extreme event attribution precisely because it deals with climatological extremes and specific events rather than changes in long-term mean variables.

There are multiple pathways through which climate change can contribute to the intensity of extreme events. A warmer climate increases the probability and frequency of very hot days and nights, thus contributing to heat waves. A warmer climate also contributes to increased land evaporation and drier conditions, potentially increasing the severity of droughts and wildfire conditions. The intensification of the global hydrological cycle and increases in atmospheric moisture content contribute to more severe precipitation events. Increase in atmospheric moisture

Commented [49]: I might cut this

Commented [JW50R49]: I'd like to still mention this finding (although it just an observation and not an attributed trend) – but I moved to a FN so as not to distract from the attribution findings.

---

[183] *Id.* at 1057. *See also* WMO (2022), *supra* note 149 (finding that many of the world's regions experienced above normal precipitation in 2022, without specifying the extent to which this trend is attributable to anthropogenic climate forcing).

[184] ~~WMO (2022), *supra* note X.~~

[185] IPCC AR6 WGI at 8.

[186] *Id.* ~~IPCC AR6 WGI~~ at 1057. Increases in aridity can be caused by increases in evaporation as well as decreases in precipitation.

[187] *Id.*~~IPCC AR6 WGI at 1057.~~

[188] Fire weather is an example of a "compound event" because it involves compound hot, dry, and windy conditions. *See* IPCC AR6 WGI at 1519. However, a wildfire is not a purely climatological event, and thus attribution research on wildfires ~~also~~ may entails elements of "impact attribution" as described in § ~~XX~~ III(A)(4) below.

[189] ~~This section deals with climatological extremes or extreme weather. Section XX deals with the attribution of the physical aspects of extreme events that are not wholly climatological (e.g., acres burned from wildfires).~~

content and heat, coupled with increases in sea surface and ocean temperature, also contribute to more severe tropical cyclones. Generally speaking, more heat in the climate system corresponds with more energy to power storms, since atmospheric heat can be converted into kinetic energy (e.g., in the form of high winds).[190]

In early IPCC assessments, scientists recognized that climate change would affect the frequency, intensity, spatial extent, duration and timing of weather and climate extremes, but there was low confidence in the attribution of specific extreme events to human influence on climate.[191] Since then, scientific confidence in extreme event attribution has advanced significantly due to "better physical understanding of processes, an increasing proportion of scientific literature combining different lines of evidence, and improved accessibility to different types of climate models (*high confidence*)."[192] As recognized in IPCC AR6, it is "now an established fact that human-induced greenhouse gas emissions have led to an increased frequency and/or intensity of some weather and climate extremes" particularly temperature extremes.[193] The BAMS reports on *Explaining Extreme Events from a Climate Perspective* also contain many examples of specific extreme events that have been attributed to anthropogenic climate change.

a. Methods and Parameters

An "extreme" weather or climate event is defined by the IPCC as "the occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends ('tails') of the range of observed values of the variable."[194] Attribution of extremes tends to be more challenging than attribution of means for several reasons: (i) the local nature and short duration of any extremes makes then more difficult to model given the coarse resolution of climate models, (ii) the relative rarity of extreme events at a given location makes it more difficult to detect and attribute a climate change "signal" amidst the large "noise" of internal variability, (iii) the ~~cause-and-effect~~causal chains for extremes can be quite complicated (e.g., highly nonlinear).[195] There are also some modeling challenges relevant to extreme event attribution. For example, models may be to Gaussian in their extreme events (i.e., they don't produce enough of them).[196] Scientists have devised statistical approaches to avoid the problems and limitations associated with climate models, but these approaches rely on simplifying assumptions.[197] Despite these complicating factors, extreme event studies can generate ~~reasonably r~~eliable results for many

Commented [MB51]: Why "reasonably"? The audience here are judges, so "reasonableness" may carry a particular meaning when they see it, for better or for worse.

Commented [JW52R51]: Yes that's a good point. I think just "reliable" is sufficient here.

[190] E.g., extra heat content in the atmosphere can be converted to kinetic energy in storms.
[191] *See* IPCC TAR WGI, Ch. 3.
[192] IPCC AR6 WGI at 1517. *See also* National Academies (2016), *supra* note ~~111~~84 (discussing advances in extreme event attribution).
[193] IPCC AR6 WGI at 1517.
[194] IPCC AR6 WGI at 111.
[195] Sebastian Sippel et al., *Warm Winter, Wet Spring, and an Extreme Response to Ecosystem Functioning in the Iberian Peninsula*, *in* BAMS 2016, *supra* note ~~76~~134, at S80 (citing D.A. Frank et al., *Effects of Climate Extremes on the Terrestrial Carbon Cycle: Concepts, Processes, and Potential Future Impacts*, 21 GLOBAL CLIMATE CHANGE BIOLOGY 2861 (2015) and J.A. Arnone et al., *Prolonged Suppression of Ecosystem Carbon Dioxide Uptake After an Anomalously Warm Year*, 455 NATURE 383 (2008).
[196] Bo Christiansen, *The Role of the Selection Problem and Non- Guassianity in Attribution of Single Events to Climate Change*, 28 J. CLIMATE 9873 (2015).
[197] National Academies (2016), *supra* note ~~111~~84; Christiansen (2015), supra note ~~181~~196.

extreme events, though ~~but~~ confidence in attribution findings depends on the type of extreme and the location.

The results of extreme event studies are sensitive to how the research question is framed, and what methodological approaches and datasets are used. Some studies focus on individual events; others deal with a class of events over a timeframe (e.g., the 2020 North Atlantic hurricane season).[198] One critical framing question is how to define the event parameters for the purposes of the study. These parameters include the physical threshold for the extreme event (e.g., a certain temperature threshold for a heatwave) as well as the timeframe and spatial scale for the study. There are often multiple metrics that could be used for any given event—for example, a heat wave could be defined based on absolute maximum temperature, average maximum temperature over a duration of time, a combination of temperature and humidity, etc. Moreover, the geographic and temporal bounds of the event may be unclear. These framing decisions can affect the results of the study. For example, if researchers were to use the maximum temperature during a heatwave as the temperature threshold, and then focus their analysis on the location that reached the highest temperature during the event, the heat wave may appear more exceptional (or "extreme") than if the temperature and spatial scale were selected in a more generic way. This is an example of how event framing could introduce selection bias into an attribution study. Fortunately, this is not an insurmountable obstacle – for example, efforts are underway to standardize how extreme events are defined and selected for analysis, and this would have the added benefit of facilitating more systematic comparison between extreme event studies.[199]

As discussed earlier in this chapter, there are also different approaches to attribution.[200] Some studies use a probabilistic or "risk-based" approach, examining whether and to what extent climate change increased the probability (or risk) of an extreme event. Other studies use a "storyline" or "mechanistic" approach, examining how climate change affected the magnitude and/or other characteristics of an extreme event. Both approaches have benefits and drawbacks.

In probabilistic studies, researchers evaluate the likelihood of a climatological extreme occurring with and without human influence on the climate system. This is typically accomplished by using climate models to run two types of simulations: one that represents the world as it is and another that represents a hypothetical world without anthropogenic climate forcing. Researchers will then evaluate the probability of the extreme occurring in both simulations. The results are often expressed in terms of "fraction of attributable risk" (FAR), i.e., the relative risk (or risk ratio) of the extreme occurring with and without human influence on climate. In mathematical terms:

$$FAR = 1 - P0/P1$$[201]

---

[198] *See, e.g.,* Kevin A. Reed et al., *Attribution of 2020 Hurricane Season Extreme Rainfall to Human-Induced Climate Change*, 13 NATURE COMMUNICATIONS 1905 (2022).

[199] National Academies (2016), *supra* note ~~111~~84.

[200] Although many extreme event attribution studies clearly fall within one of these two categories, there are also some other approaches in the literature. As one example, Mann et al. suggested a modification to traditional frequentist statistical inference approach, that builds in prior physical understanding and updates based on experience. Michael E. Mann et al., *Assessing Climate Change Impacts on Extreme Weather Events: The Case for an Alternative (Bayesian) Approach*, 144 CLIMATIC CHANGE 131 (2017).

[201] Myles Allen, *Liability for Climate Change*, 421 NATURE 891 (2003).

P1 equals the probability of a climatic event (such as a heat wave) occurring in the presence of anthropogenic forcing of the climate system, and P0 equals the probability of the event occurring if the anthropogenic forcing were not present. If FAR equals zero, it means that anthropogenic climate change had no effect on the probability of the event occurring; if FAR equals one, it means that the event could not have happened in the absence of anthropogenic climate change; if FAR equals 0.5, it means that anthropogenic climate change doubled the probability of the event occurring. In multi-event studies, a FAR of 0.5 can be interpreted as meaning that half of the events would not have happened in a world without anthropogenic climate change.[202]

This approach was pioneered by Myles Allen in a 2003 study in which he introduced the concept of FAR as a potential basis for liability for climate damages.[203] Many other studies have since replicated Allen's approach, estimating the FAR for a range of extreme events including heat waves, droughts, and floods. This methodology derives from common approaches used in epidemiological studies and other risk-focused research. The advantages of this approach are that it is relatively well-established, understood, and accepted by the scientific community,[204] and it provides quantitative (probabilistic) findings similar to the sort of epistemological and environmental data that is often dealt with by policy-makers, planners, and courts. Drawbacks include: 1) overreliance on climate models, which as noted earlier, may not be able to simulate some types of extremes with fidelity in a baseline climate, and could have blind spots with respect to how climate change may be modifying key processes influencing the extreme event, and 2) susceptibility to Type II errors (i.e., false negatives) where the signal-to-noise ratio for an event is small due to large internal variability of the atmosphere, which is often the case for dynamically-driven events such as extreme precipitation and storms especially.[205] As such, the probabilistic approach can underestimate the extent to which anthropogenic influence has increased the likelihood of an event.[206]

The mechanistic or "storyline" approach, introduced by Trenberth et al. (2015),[207] focuses on how anthropogenic forcing may have modified the characteristics of a given event. This involves reconstructing the causal chain of events that resulted in the extreme event, typically focusing on a few central causal factors to establish attribution.[208] Mechanistic studies tend to focus on the

[202] While the term FAR is typically used in extreme event attribution, probabilistic analysis is prevalent across all forms of attribution, and the concept of "attributable risk" can in principle be applied to both mean changes in climate and a variety of climate impacts. *See, e.g.*, Thomas Knutson et al., *CMIP5 Model-Based Assessment of Anthropogenic Influence on Record Global Warmth During 2016, in* BAMS 2016, *supra* note X134, at S13.
[203] Allen (2003), *supra* note 186201.
[204] *See* National Academies (2016), *supra* note 11184, at 3.
[205] Kevin Trenberth et al., *Attribution of Extreme Climate Events*, 5 NATURE CLIMATE CHANGE 725 (2015).
[206] Some probabilistic approaches have adopted conditional risk- based analyses, both to simplify the modeling and to control for factors other than anthropogenic effects (such as natural variability, as discussed above). Conditional analyses can in some respects be thought of as a logical outgrowth of the tension between risk based and storyline conceptualizations, since they attempt to isolate the component of extreme events due to anthropogenic warming by treating other components as a control. This can lead to higher confidence in attribution statements for specific events, but it also makes the attribution findings less relevant to other events.
[207] Trenberth et al. (2015), *supra* note 190205.
[208] E.A. Lloyd & T.G. Shepherd, *Climate Change Attribution and Legal Contexts: Evidence and the Role of Storylines*, 167(3-4) CLIMATIC CHANGE 28 (2021); L. van Garderen et al., *A Methodology for Attributing the Role of*

Formatted: Font: Italic
Formatted: Font: Italic

relationship between the observed event and well-understood components of climate change, such as warming temperatures and thermodynamics. As such, they can generate higher confidence statements with regards to those specific components. The results of this analysis may be quantitative or qualitative, for example, "warming of the upper ocean and atmosphere enabled more rainfall during event Y than otherwise would have occurred" or "caused a 30% increase in rainfall over what would have occurred". Critically though, any quantitative statements, rather than being comprehensive, are linked to specific aspects of the climate system identified by the authors, such as upper ocean and atmospheric temperatures in the example above.

As with the probabilistic approach, there are advantages and drawbacks to the mechanistic approach. The chief advantages are that the mechanistic approach provides additional insights on how climate change is affecting physical characteristics of extreme events, and it allows for higher confidence attribution regarding the influence of certain aspects of climate change on certain types of events. But there are also criticisms of this approach, as articulated by Otto (2016).[209] First, mechanistic studies may not have the same broad relevance as probabilistic studies because they focus on how climate change has influenced the specific characteristics of a particular event (whereas the findings from probabilistic studies are more easily applied to a class of events – e.g., all heatwaves with temperatures above a certain threshold in a region). Second, it is an oversimplification to assume that some aspects of the climate system (and climate change) are well-understood and others are not – rather, there is a gradient of understanding across the various components of the climate system, and that understanding is constantly evolving with new research.[210] Neglecting certain aspects of or processes within the climate system can render these studies incomplete.[211]

While there is some debate about the relative merits of these two approaches, the reality is that they are complementary – they each provide different insights on the effect of anthropogenic climate change on extreme events, and one approach can be used to fill gaps where the other is unsuitable. For example, the probabilistic/risk-based approach may be more justifiable for analyzing all events above or below a certain threshold, for a class of events that are relatively well

---

Climate Change in Extreme Events: A Global Spectrally Nudged Storyline, 21(1) NATURAL HAZARDS AND EARTH SYSTEMS SCIENCES 171 (2021).

[209] Friederike E. Otto et al., *The Attribution Question*, 6 NATURE CLIMATE CHANGE 813 (2016).

[210] For example, Mann et al. (2017) notes that dynamical changes with warming are starting to come into focus: more specifically, a growing body of work based on observations and simple models supports the idea that the latitudinal pattern of mean temperature changes (including Arctic amplification) may support changes in atmospheric dynamics that supports wave resonance and 'stuck' weather, which enhances the magnitude and duration of extremes. It should be noted that global climate models generally do not reproduce this pattern of wave resonance and 'stuck' weather with warming. Michael E. Mann et al., *Influence of Anthropogenic Climate Change on Planetary Wave Resonance and Extreme Weather Events*, 7 SCIENCE REPORTS 45242 (2017).

[211] More specifically, focusing on thermodynamics – but not dynamics – within the climate system can result in an incomplete analysis, in part due to the failure to capture interactions between thermodynamics and dynamics. Otto shows how the dynamics and thermodynamics counteracted each other in 2013 German floods. *See* Otto et al. (2016), *supra* note 194209, at 815. Similarly, a study in Western Australia found dynamics/circulation changes that favor less rain, but thermodynamic (specifically sea surface temperature) changes that favor increase in rain. Thomas L. Delworth & Fanrong Zeng, *Regional Rainfall Decline in Australia Attributed to Anthropogenic Greenhouse Gases and Ozone Levels*, 7 NATURE GEOSCIENCE 583 (2014).

simulated by climate models (e.g., temperature extremes), whereas the storylines approach may be more appropriate for complex, iconic, multivariate events.[212]

Another important development in this field has been the emergence of "rapid" and "advance" (or predictive) event attribution. The World Weather Attribution (WWA) project, discussed in Part II, is at the forefront of research in this field. For example, the WWA researchers have pioneered an approach to advance attribution using seasonal forecasts in addition to observational data to simulate the influence of anthropogenic forcings on extreme events *before* they occur, thus allowing for attribution statements to be made as the event is unfolding.[213] There are concerns about the loss of scientific rigor for such rapid assessments – for example, there may be less opportunity to test the model's ability to simulate the actual event, and there may be little or no time for traditional peer review. However, the methodologies used in these assessments have been used in peer reviewed studies,[214] and rapid assessments with novel elements can be submitted for peer review after initial publication. As attribution research continues to mature, and standardization of experiments enables more multi-modal evaluations, rapid – and even advance – event attribution will almost certainly grow in prominence and robustness.

Commented [MB53]: I wonder how important WWA is for this audience. I think it is worth noting, but the important point seems to be the reliance of individual studies on peer reviewed, state of the art methodologies. Ultimately judges will be reviewing expert reports and testimony, some of which relate to rapid attribution studies but most of which will come through experts who prepare their own studies. Consider how to further underscore the point that not every climate attribution study is peer reviewed, but that that in and of itself doesn't mean that it is faulty or illegitimate.

Commented [JW54R53]: I updated the section on "Peer Reviewed Studies" in Part II with a concluding paragraph that explicitly acknowledges the point you've made here about peer review.

I don't anticipate that WWA studies will play an important role in federal litigation, but I like including WWA as an example of the broader point you've made in your comment.

b. Status of Research

IPCC AR6 noted that that the evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and their attribution to climate change, had strengthened since AR5.[215] In particular, the IPCC expressed *very high* or *high confidence* that anthropogenic climate forcing had increased the probability of heat-related and extremes, including concurrent heatwaves and droughts, as well as precipitation extremes, including precipitation associated with tropical cyclones.[216] The Fourth National Climate Assessment (NCA4) contained similar findings, focused on the U.S. context – for example, NCA4 found, with *high confidence*, that extreme heat and heavy precipitation events had increased in both intensity and frequency throughout most of the U.S., and that this was consistent with expected physical response to anthropogenic climate forcing.[217]

Generally speaking, the confidence with which scientists have been able to attribute extreme events to climate change has been highest for events that are directly related to warming trends (including ocean warming and correlated sea level rise) and increases in atmospheric water vapor.[218] Changes in extreme events that are the result of more complex interactions between variables are more difficult to attribute. But these generalizations mask substantial nuance across space and time – for example, the "noise" created by internal variability can differ substantially

[212] Elisabeth Lloyd & Naomi Oreskes, *Climate Change Attribution: When Is It Appropriate to Accept New Methods?*, 6 EARTH'S FUTURE 311 (2018).
[213] *See, e.g.,* K. Haustein et al., *Real-Time Extreme Weather Event Attribution With Forecast Seasonal SSTs*, 11 ENVIRONMENTAL RESEARCH LETTERS 064006 (2016).
[214] World Weather Attribution, *Pathways and Pitfalls in Extreme Event Attribution* (May 13, 2021), https://www.worldweatherattribution.org/pathways-and-pitfalls-in-extreme-event-attribution/.
[215] AR6 Synthesis Report, Summary for Policymakers at Para A.2.1 (cite final formatted version when available).
[216] *See infra* §§ III(A)(3)(b)(i)-(v).
[217] NCA4 Vol. I at 207–76.
[218] National Academies (2016), *supra* note X84, at 2.

depending on the location of a particular event, which means that there may be high confidence in attribution of the event in one region but low confidence for other regions. Below, we summarize research on different types of extreme events, and we highlight regional findings where available.

i. Extreme Heat

An increase in the magnitude, frequency, and duration of extreme heat events is a direct and foreseeable consequence of a warming climate,[219] and confidence in attribution findings is generally greatest for extreme heat events.[220] NCA4 found, with *very high confidence*, that the frequency and intensity of extreme heat events are increasing in most continental regions of the world, consistent with expected physical responses to a warming climate.[221] IPCC AR6 similarly found that it is "*virtually certain* that hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s," and there is "*high confidence* that human-induced climate change is the main driver of these changes."[222] Moreover, "[s]ome recent hot extremes observed over the past decade would have been *extremely unlikely* to occur without human influence on the climate system."[223] Importantly, climate change is not only contributing to extreme heat events over land – according to IPCC AR6, marine heatwaves have "approximately doubled in frequency since the 1980s (*high confidence*) and human influence has *very likely* contributed to most of them since at least 2006."[224]

The IPCC findings are consistent with a growing number of studies on extreme heat and climate change, many of which have demonstrated a very strong anthropogenic signal in such events. One of the earliest studies was authored by Stott et al. (2004) and dealt with the European heat wave of 2003. Using a probabilistic approach, the study authors found that it was very likely (confidence level >90%) that human influence had at least doubled the risk of a heatwave comparable to that which had occurred that summer.[225] The body of research linking extreme heat to anthropogenic climate change has expanded significantly since then. One meta-analysis of unprecedented extremes on a global level found that:

> [H]istorical warming has increased the severity and probability of the hottest month and hottest day of the year at >80% of the available observational area. For the most protracted hot and dry events, the strongest and most widespread contributions of anthropogenic climate forcing occur in the tropics, including increases in probability of at least a factor of 4 for the hottest month and at least a factor of 2 for the driest year.[226]

---

[219] These core characteristics of extreme heat events (magnitude, duration, frequency) are all highly sensitive to changes in mean temperatures. Radley M. Horton et al., *A Review of Recent Advances in Research on Extreme Heat Events*, 2 CURRENT CLIMATE CHANGE REPORTS 242, 242 (2016).
[220] National Academies (2016), *supra* note X84. *See also* Stephanie C. Herring et al., *Introduction to Explaining Extreme Events of 2016 From a Climate Perspective*, *in* BAMS 2016, *supra* note X134, at S2.
[221] NCA4 Vol. I at 19.
[222] IPCC AR6 WGI at 8.
[223] IPCC AR6 WGI at 8.
[224] IPCC AR6 WGI at 8.
[225] Peter Stott et al., *Human Contribution to the European Heatwave of 2003,* 432 NATURE 610, 610 (2004).
[226] Noah Diffenbaugh et al., *Quantifying the Influence of Global warming on Unprecedented Extreme Events,* 114 PNAS 488, 4881 (2017).

The BAMS reports on *Explaining Extreme Events from a Climate Perspective* also contain dozens of recent studies on the causal relationship between climate change and extreme heat.[227] In several studies, researchers have found that heat-related events would have been "virtually impossible" in the absence of anthropogenic influence on climate.[228] In a large-scale analysis of heat and rainfall extremes, Robinson et al. (2021) found that even just the 0.25°C in warming that occurred from 2011-2020 had resulted in the emergence of heat and precipitation extremes that would be virtually impossible without that level of anthropogenic warming.[229]

ii. Drought and Aridity

Although warmer temperatures are one factor that can contribute to droughts, it is more challenging to isolate the effect of anthropogenic climate change on dryness and drought conditions. Droughts are highly complex meteorological events with many different factors affecting their likelihood, severity, duration, and other characteristics. As discussed above, there is also significant natural variability in precipitation which makes it difficult to identify the anthropogenic signal through the noise of variability. There are several different types of droughts recognized in the literature, including: (i) meteorological droughts, which are defined by the degree and duration of dryness or rainfall deficit (in comparison to a normal or average amount); (ii) hydrological droughts which are defined by the impact of dryness and rainfall deficits on water supplies such as lakes, rivers, streams, reservoirs, and aquifers; (iii) agricultural droughts, which are defined by the effect of dryness and rainfall deficits on agricultural systems; and (iv) ecological droughts, which are defined by the effect of dryness and rainfall deficits on ecosystems. Attribution for hydrological droughts is particularly challenging due to the complexity of these events,[230] limited data about historical trends,[231] and the fact that human water consumption is a leading mechanism behind such droughts (potentially making it harder to detect a "climate change" signal).[232]

Researchers have made significant progress with drought attribution in recent years. In particular, many studies have found evidence of an anthropogenic signal in the heat-related aspects of drought (e.g., increased evapotranspiration) and have been able to estimate the extent to which

---

[227] BAMS, *Explaining Extreme Events from a Climate Perspective,* https://www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/explaining-extreme-events-from-a-climate-perspective/.
[228] Yukiko Imada et al., *Climate Change Increased the Likelihood of the 2016 Heat Extremes in Asia, in* BAMS 2016, *supra* note 134, at S97; John Walsh et al., *The High Latitude Marine Heat Wave of 2016 and Its Impacts on Alaska, in* BAMS 2016, *supra* note 134, at S39; S.E. Perkins-Kirkpatrick et al., *The Role of Natural Variability and Anthropogenic Climate Change in the 2017/18 Tasman Sea Marine Heatwave,* S105 *in Explaining Extreme Events of 2017 from a Climate Perspective*, 100 BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY S1(2019) [hereinafter BAMS 2017].
[229] Alexander Robinson et al., *Increasing Heat and Rainfall Extremes Now Far Outside the Historical Climate*, 4 NPJ CLIMATE AND ATMOSPHERIC SCIENCE 45 (2021).
[230] IPCC AR6 WGI at 1576.
[231] IPCC AR6 WGI at 1576.
[232] IPCC AR6 WGI at 1578. See also https://iopscience.iop.org/article/10.1088/1748-9326/8/3/034036.

armer temperatures have intensified drought conditions.[233] Based on this research, IPCC AR6 expressed *medium confidence* that human-induced climate change had contributed to ecological and agricultural droughts in some regions due to increased land evapotranspiration.[234] IPCC AR6 did not find clear evidence that anthropogenic climate was causing an increase in meteorological or hydrological droughts in most regions of the world; however, it did express *medium confidence* that precipitation deficits had increased in several regions across all continents.[235]

iii. Extreme Precipitation

IPCC AR6 and NCA4 both found clear evidence that heavy rainfall events are increasing around the world and in the U.S., respectively, and this is generally consistent with expected physical responses to a warming climate.[236] IPCC AR6 specifically found that "[t]he frequency and intensity of heavy precipitation events have increased since the 1950s over most land areas for which observational data are sufficient for trend analysis (*high confidence*), and human-induced climate change is *likely* the main driver."[237] This is another area where there have been significant advances in detection and attribution research: whereas IPCC AR5 only expressed *medium confidence* in the attribution of extreme precipitation events, IPCC AR6 found that there was "new and *robust evidence* of human influence on extreme precipitation."[238]

The IPCC's assessment relates to an overall increase in extreme precipitation at a global scale, but there are important regional and seasonal variations in rainfall. The dynamic nature of extreme precipitation events and the large internal variability in precipitation can make it more difficult to attribute specific events to climate change. IPCC AR6 specifically notes that: (i) evidence of human influence at regional scales is more limited and less robust, and (ii) the signal of anthropogenic influence is strongest for large-scale extreme precipitation events, and the chance of detecting such signals decreases.[239] At the same time, IPCC AR6 recognizes that "new evidence [of human influence on extreme precipitation at the regional scale] is emerging"[240] and there are a

[233] See, e.g., T. R. Matthews et al., *The 2014 Drought in the Horn of Africa: Attribution of Meteorological Drivers*, S83 *in Explaining Extreme Events of 2014 from a Climate Perspective*, 96 BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY S1(2015) [hereinafter BAMS 2014]. *See also* Eduardo S. P. R. Martins et al., *A Multimethod Attribution Analysis of the Prolonged Northeast Brazil Hydrometeorological Drought (2012–16)*, *in* BAMS 2016, *supra* note X134, at S65; Xing Yuan et al., *Anthropogenic Intensification of Southern African Flash Droughts as Exemplified by the 2015/16 Season*, *in* BAMS 2016, *supra* note X134, at S86; Chris Funk et al., *Anthropogenic Enhancement of Moderate-to-Strong El Niño Events Likely Contributed to Drought and Poor Harvests in Southern Africa During 2016*, *in* BAMS 2016, *supra* note X134, at S91.
[234] IPCC AR6 WGI at 8.
[235] IPCC AR6 WGI, Ch. 11.
[236] *See* NCA4 Vol. I at 19; IPCC AR6 WGI at 8.
[237] IPCC AR6 WGI at 8.
[238] IPCC AR6 WGI at 1562.
[239] IPCC AR6 WGI at 1563.
[240] IPCC AR6 WGI at 1563.

number of recent attribution studies finding that human influence was a significant driver of heavy precipitation events.[241]

As noted above, the "storyline" approach to attribution was developed in part to improve attribution for difficult to model events like extreme precipitation. Researchers used this approach to examine the effect of anthropogenic climate change on the 2013 floods in Boulder, Colorado, and found that anthropogenic drivers increased the magnitude of the rainfall for that week by approximately 30%. [242] The scientists also conducted a probabilistic analysis of potential impacts on flooding and found that this 30% increase in rainfall approximately doubled the likelihood of flood- inducing rainfall occurring during that event. In contrast, researchers using the probabilistic approach to attribution of the Boulder floods found no evidence that anthropogenic climate change had increased the probability of the event occurring.[243] This underscores the sensitivity of results to methodological choices made in extreme event attribution.

iv. Tropical and Extratropical Cyclones

Physical understanding indicates that tropical cyclones will become more severe in a warmer climate. Cyclones derive energy from sea surface temperature, and warmer sea surface temperatures thus increase the intensity of storms (in terms of wind speed, precipitation, and storm surge).[244] A warmer ocean also produces more evaporation, and a warmer atmosphere holds more moisture, thus contributing to heavier rainfall and flooding. In addition, increases in average sea levels contribute to higher storm surge levels. Based on these processes, scientists expect that climate change will increase the frequency of severe cyclones; however, climate change will not necessarily increase the overall number of cyclones.[245]

Early attribution studies on tropical cyclones generated mixed results,[246] contributing to uncertainty and low confidence in the attribution of changes in cyclone activity to anthropogenic

---

[241] See, e.g., Qiaohong Sun & Chiyuan Miao, *Extreme Rainfall (R20mm, RX5day) in Yangtze–Huai, China, in June–July 2016: The Role of ENSO and Anthropogenic Climate Change*, *in* BAMS 2016, *supra* note X134, at S102; Chunlüe Zhou et al., *Attribution of the July 2016 Extreme Precipitation Event Over China's Wuhang*, *in* BAMS 2016, *supra* note X134, at S107; Claire Burke et al., *Attribution of Extreme Rainfall in Southeast China During May 2015*, S92 *in Explaining Extreme Events of 2015 from a Climate Perspective*, 97 BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY S1(2016) [hereinafter BAMS 2015].

[242] Pardeep Pall et al., *Diagnosing Conditional Anthropogenic Contributions to Heavy Colorado Rainfall in September 2013,* 17 WEATHER AND CLIMATE EXTREMES 1 (2017).

[243] *See* Martin Hoerling et al., *Northeast Colorado Extreme Rains Interpreted in a Climate Change Context*, S17 *in Explaining Extreme Events of 2013 from a Climate Perspective*, 95 BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY S1(2014) [hereinafter BAMS 2013].

[244] *See, e.g.,* S. L. Lavender et al., *The influence of sea surface temperature on the intensity and associated storm surge of tropical cyclone Yasi: a sensitivity study*, 18 NAT. HAZARDS EARTH SYST. SCI. 795 (2018).

[245] *See* IPCC AR6 at 70 ("The proportion of tropical cyclones that are intense is expected to increase (*high confidence*), but the total global number of tropical cyclones is expected to decrease or remain unchanged (*medium confidence*).").

[246] Some early studies using the probabilistic approach found no clear evidence that anthropogenic forcings altered the probability or severity of specific cyclones. *See, e.g.,* Lei Yang et al., *Anomalous Tropical Cyclone Activity in the Western North Pacific in August 2014*, *in* BAMS 2014, *supra* note X, at S124.

climate forcing.[247] But there are many more recent studies which have identified a fairly large anthropogenic "fingerprint" on tropical cyclone characteristics and activities.[248] Based on the latest research, IPCC AR6 expressed *high confidence* that anthropogenic climate change had contributed to increases in heavy precipitation associated with tropical cyclones.[249] IPCC AR6 also found that it was *likely* that the global portion of major (Category 3-5) tropical cyclone occurrence had increased over the past four decades, and that the latitude where tropical cyclones in the western North Pacific reach their peak intensity had shifted northward during this timeframe (*medium confidence*).[250]

There is more uncertainty about the effect of a warming climate on extratropical cyclone activity.[251] IPCC AR6 expressed *high confidence* that climate change will increase the rain rates associated with extratropical storms (consistent with research on heavy precipitation events, discussed above).[252] However, few attribution studies have found a discernable anthropogenic influence on extratropical cyclones due to, e.g., large interannual-to-decadal variability in such cyclones,[253] and thus the IPCC has expressed *low confidence* in the detection and attribution of changes in extratropical cyclones.[254] In contrast to tropical cyclones, the IPCC predicts that the overall frequency of intense extratropical cyclones may decrease slightly as the climate gets warmer (*medium confidence*),[255] but extratropical cyclone intensity in the Southern Hemisphere will *likely* increase under higher warming scenarios.[256] Notably, since research was compiled for IPCC AR6, there have been some studies finding that anthropogenic forcings likely have contributed to more severe extratropical cyclones,[257] and predicting that the frequency of severe

---

[247] *See, e.g.,* S. I. SENEVIRANTE ET AL., MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION, A SPECIAL REPORT OF WORKING GROUPS I AND II OF THE IPCC (Cambridge University Press 2012) at 112 (expressing *low confidence* in the attribution of detectable changes in tropical cyclone activity to anthropogenic influences).

[248] See, e.g., Zhang et al., *Influences of Natural Variability and Anthropogenic Forcing on the Extreme 2015 Accumulated Cyclone Energy in the Western North Pacific, in* BAMS 2015, *supra* note X, at S133; Mark Risser & Michael Wehner, *Attributable Human-Induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation During Hurricane Harvey*, 44 GEOPHYSICAL RESEARCH LETTERS 12457 (2017); Geert Jan van Oldenborgh, *Attribution of Extreme Rainfall from Hurricane Harvey, August 2017,* 12 ENVIRONMENTAL RESEARCH LETTERS 1 (2017).

[249] IPCC AR6 Synthesis Report at 17 (cite final version when available); IPCC AR6 WGI at 67 (Table TS.2).

[250] IPCC AR6 WGI at 9; IPCC AR6 WGI at 67 (Table TS.2).

[251] IPCC AR6 at 70.

[252] IPCC AR6 at 86.

[253] See, e.g., Frauke Feser et al., *Hurricane Gonzalo and Its Extratropical Transition to a Strong European Storm*, *in* BAMS 2014, at S54.

[254] IPCC AR6 WGI at 70, 338.

[255] IPCC AR6 WGI at 71.

[256] See, e.g., IPCC AR6 WGI at 71, 291 (expressing *high confidence* that Southern Hemisphere storm tracks and associated precipitation have migrated poleward in recent decades, and finding that it is *likely* that wind speeds associated with extratropical cyclones will strengthen in the Southern Hemisphere under some warming scenarios).

[257] See, e.g., Mireia Ginesta et al., *A Methodology for Attributing Severe Extratropical Cyclones to Climate Change Based on Reanalysis Data: The Case Study of Storm Alex 20[redacted]*, CLIMATE DYNAMICS (2022).

extratropical cyclones may increase in the Northern Hemisphere as well as the Southern Hemisphere.[258]

v. Compound Extremes

Compound extreme events are those that occur due to the interaction of multiple climate-related extremes. Examples include fire weather conditions (a combination of hot, dry, and windy conditions), compound flooding (e.g., flooding caused by a combination of storm surge and heavy rainfall, or rapid snowmelt and heavy rainfall), and concurrent heatwaves and drought.[259] Scientific understanding of anthropogenic influence on such events largely depends on understanding of the various component events. IPCC AR6 found that human influence has *likely* increased the probability of various compound extreme everts since the 1950s.[260] There is *high confidence* that anthropogenic climate change has increased the frequency of concurrent heatwaves and droughts on a global scale, and *medium confidence* that it has increased the frequency of fire weather and compound flooding in some regions.[261] There is also *high confidence* that regions and connected sectors will experience multiple regional extreme events at the same time,[262] placing greater stress on both human and natural systems.[263]

Some individual studies have found a very strong association between climate change and increases in fire weather. For example, Liu et al. (2023) found that that global warming had increased the probability of wildfire weather that experienced in the April 2021 Cape Town wildfire by a factor of 1.9 (i.e., those weather conditions were 90% more likely as a result of warming).[264] Goss et al. (2020) conducted a multi-step analysis on California wildfires in which they showed that: (i) the frequency of "autumn fire days with extreme (95th percentile) fire weather" had more than doubled in California since the 1980s due to state-wide increases in autumn temperature (~1 °C) and decreases in autumn precipitation (~30%), and then used climate models to demonstrate that: (ii) anthropogenic climate forcings likely played a major role in explaining the observed increase in extreme fire conditions.[265] Another end-to-end study focusing on the role of extreme vapor pressure deficits (VPD) in wildfire risk found that anthropogenic

[258] *See, e.g.,* Matthew D.K. Priestly & Jennifer L. Cato, *Future Changes in the Extratropical Storm Tracks and Cyclone Intensity, Wind Speed, and Structure*, 3(1) WEATHER AND CLIMATE DYNAMICS 337 (2022); Sho Kawazoe, *Future Changes in Tropical and Extratropical Cyclones Affecting Hokkaido and Their Related Precipitation Based on Large-Ensemble Climate Simulations*, 62(3) JOURNAL OF APPLIED METEOROLOGY AND CLIMATOLOGY 341 (2023).
[259] *See* IPCC AR6 WGI at 9, FN 18.
[260] IPCC AR6 WGI at 9.
[261] IPCC AR6 WGI at 9.
[262] IPCC AR6 WGI at 135.
[263] *See infra* Section III(A)(4) ("Impact Detection and Attribution").
[264] Zhongwei Liu et al., *The April 2021 Cape Town Wildfire: Has Anthropogenic Climate Change Altered the Likelihood of Extreme Fire Weather?*, 104 BAMS E298 (2023) (finding that rising global temperatures had increased the probability of wildfire weather that experienced in the April 2021 Cape Town wildfire by a factor of 1.9, i.e., those weather conditions were 90% more likely as a result of warmer temperatures).
[265] Michael Goss et al., *Climate Change is Increasing the Likelihood of Extreme Autumn Wildfire Conditions Across California*, 15 ENVIRONMENTAL RESEARCH LETTERS 094016 (2020).

influences quintupled the risk of extreme VPD for western North America and had doubled the risk of extreme VPD in extratropical Australia.[266]

4. Impact Detection and Attribution

Many of the processes and phenomena described in the sections above could be characterized as "impacts" of climate change (e.g., sea level rise, more severe extreme events). However, for the purposes of this chapter, we use the term "impact attribution" to describe research on the effects of climate change on humans and ecosystems. This is consistent with the approach taken in recent IPCC assessments, specifically the division between Working Group I (WGI), which synthesizes research on the physical science basis for anthropogenic climate change, and Working Group II (WGII), which synthesizes research on the impacts of climate change.[267]

Impact attribution deals with the consequences and outcomes that are most relevant in legal discourse and litigation specifically, the question of who will be harmed by climate change and to what extent.[268] Impact attribution deals with consequences that are farther along the causal chain and this adds a layer of complexity to the attribution analysis. Nonetheless, there are many impacts that have been attributed to anthropogenic climate forcing with a high level of confidence and certainty.

a. Methods and Parameters

As with other areas of detection and attribution, researchers use physical understanding, observational data, statistical analysis, and climate models to detect and attribute impacts to anthropogenic climate forcing. However, as discussed earlier in this chapter, there are some unique challenges associated with impact attribution.[269] In particular, impact attribution researchers must account for a larger number of exogenous variables and processes (i.e., those not related to the climate system) which influence the impact being studied. For example, in order to attribute monetary damages or human casualties from an extreme event to anthropogenic climate change, researchers must account for other factors which contributed to those damages. Data on these exogenous variables and processes may be limited, thus contributing to uncertainty about the relative roles of climate change and other drivers in explaining an observed impact. Furthermore, in most cases, there is not a linear cause-and-effect relationship between changes in the climate system and specific impacts on humans and ecosystems. Some of the challenges associated with extreme event attribution also apply to impact attribution (potentially to an even greater extent) – for example, the spatial and temporal scale of an impact may be too fine to capture with existing climate models. All of these factors can hinder a finding of causation in impact attribution.

---

[266] Simon F.B. Tett et al., *Anthropogenic Forcings and Associated Changes in Fire Risk in Western North America and Australia During 2015/16, in* BAMS 2016, *supra* note ~~76~~134, at S60–64.
[267] *See e.g.,* IPCC AR5 Synthesis Report at 124 (clarifying that the term "impacts" in the WGII report refers to the effects of climate change on "natural and human systems" including impacts on "lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure").
[268] *See* Burger et al. (2020), *supra* note X, at 111.
[269] *See supra* Part III(A)(1)(d).

Nonetheless, researchers can draw fairly robust conclusions about the general causal connection between anthropogenic climate change and may different types of impacts, and in some cases it is possible to quantify the contribution of anthropogenic forcing. As summarized in IPCC AR6, "the knowledge base on observed and projected impacts and risks generated by climate hazards, exposure increased [since AR5]" and it is possible to express many impacts in terms of damages, harms, economic, and non-economic losses.[270] Indeed, there are a growing number of impact attribution studies that include quantitative findings – for example, estimates of the proportion of monetary damages incurred during an extreme event that is attributable to climate change,[271] and estimates of the public health impacts attributable to climate change.[272] These quantitative analyses provide valuable insights on the magnitude of climate change impacts and could potentially factor into loss and damage estimates. Qualitative analyses are also useful and can provide insights on the connection between climate change and impacts that cannot be readily quantified with a high level of confidence, including detailed qualitative explanations of the processes and mechanisms by which climate change is affecting a particular system.[273] Qualitative analyses are particularly useful for filling gaps where there are exogenous and confounding variables that would impede precise quantification of impacts associated with climate change.

b. Key Findings

In recent assessments, the IPCC has found increasingly robust evidence of substantial and wide-ranging impacts of climate change across all climate zones and continents. In particular, observed increases in the frequency and intensity of climate and weather extremes have caused "widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure" (*high confidence*).[274] Slow-onset processes, such as increases in atmospheric and ocean temperatures, ocean acidification, sea level rise, and regional decreases in average precipitation have also affected human and natural systems across the world (*high confidence*).[275] Some of the impacts which have been attributed to anthropogenic climate forcing include increases in heat-related human mortality (*medium confidence),* coral bleaching and mortality (*high confidence*), increased drought-related tree mortality (*high confidence*), increases in areas burned by wildfires (*medium to high confidence*, depending on the region), and increases in storm-related losses and damages due to sea level rise and increases in heavy precipitation (*medium confidence*).[276] These impacts are disproportionately affecting "the most vulnerable people and systems" across different regions,

[270] IPCC, CLIMATE CHANGE 2022: IMPACTS, ADAPTATION, AND VULNERABILITY, WORKING GROUP II CONTRIBUTION TO THE SIXTH ASSESSMENT REPORT OF THE IPCC (2022) [hereinafter IPCC AR6 WGII] at 8.
[271] *See, e.g.,* Benjamin H. Strauss et al., *Economic Damages from Hurricane Sandy Attributable to Sea Level Rise Caused by Anthropogenic Climate Change,* 12 NATURE COMMUNICATIONS 2720 (2021); David J. Frame et al., *The Economic Costs of Hurricane Harvey Attributable to Climate Change,* 160 CLIMATIC CHANGE 271 (2020).
[272] *See, e.g.,* Kristie L. Ebi et al., *Using Detection and Attribution to Quantify How Climate Change is Affecting Health*, 39(12) HEALTH AFFAIRS 2047 (2020).
[273] *See, e.g.,* Tom Oliver & Mike Morecroft, *Interactions Between Climate Change and Land Use Change on Biodiversity: Attribution Problems, Risks, and Opportunities*, 5(3) WIREs CLIMATE CHANGE 317 (2014).
[274] IPCC AR6 WGII at 9.
[275] IPCC AR6 WGII at 9.
[276] IPCC WGII AR6 at 9.

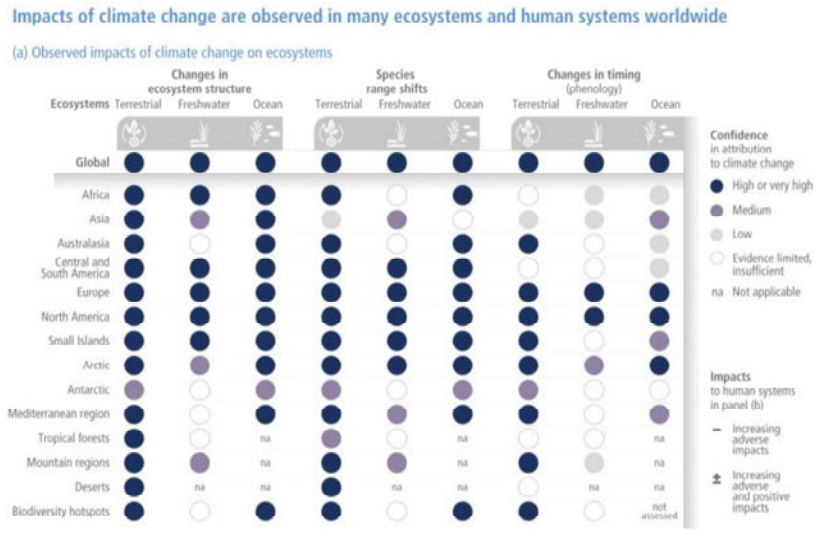
and some natural and human systems have been "pushed beyond their ability to adapt" (*high confidence*).[277]

i. Ecosystems, Species, and Ecological Indicators

There is robust evidence that climate change is adversely affecting ecosystems and species in every region of the world, and the extent and magnitude of these impacts is larger than estimated in previous assessments. IPCC AR6 found, with *high confidence*, that climate change has caused "substantial damage, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open marine ecosystems."[278] Some of the specific impacts attributable to climate change include: (i) "[w]idespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity, as well as shifts in seasonal timing" (*high confidence*); (ii) "[a]pproximately half of the species assessed globally have shifted polewards or… to higher elevations" (*very high confidence*); and (iii) "[h]undreds of local losses of species have been driven by increases in the magnitude of heat extremes" (*high confidence*), as well as mass mortality events on land and in the ocean (*very high confidence*) and loss of kelp forests (*high confidence*)."[279] Notably, changes in ecosystem structure in every region of the world have been attributed to climate change, with *high confidence* for all regions but Antarctica (see Figure X). Some ecosystems are already "reaching or surpassing hard adaptation limits", including warm-water coral reefs, some coastal wetlands, some rainforests, and some polar and mountain ecosystems (*high confidence*).[280]

Figure X. Attribution of Ecosystem Impacts in IPCC AR6

[277] IPCC WGII AR6 at 9.
[278] IPCC WGII AR6 at 9.
[279] IPCC AR6 WGII at 9. The Fifth IPCC Assessment was much more conservative in its estimate of biological impacts. *See, e.g.,* IPCC AR5 WGII at 4 (finding that only several species extinctions could be attributed to climate change with *high confidence*). The new findings in IPCC AR6 reflect advances in the field of impact attribution as well as the fact that climate change impacts on biological systems are becoming increasingly more severe.
[280] IPCC AR6 WGII at 26.



These impacts on natural systems have clear implications for human systems as well. IPCC AR6 noted that climate change-fueled ecosystem deterioration is having "adverse socioeconomic consequences" on the communities and sectors that depend on these ecosystems (*high confidence*).[281] For example, impacts on marine ecosystems have direct consequences for fisheries health and productivity. Some of the phenological changes associated with climate change, such as longer growing seasons, also have a direct impact on agricultural systems.

These findings are based on a fairly large body of research examining the effect of climate change on ecological systems, which include quantitative and qualitative analyses.[282] Much of the research deals with the effects of increasing temperatures (which are unequivocally caused by climate change) on biological systems. In one of the earliest and most comprehensive meta-analyses, Rosenzweig et al. (2008) assessed the anthropogenic signal in thousands of observed changes in biological systems and found that anthropogenic warming had contributed to approximately 95% of 829 documented physical changes, such as glacier reductions and earlier spring peak of river discharge, as well as 90% of 28,800 documented biological changes, such as earlier blooming.[283]

---

[281] IPCC WGII AR6 at 9.

[282] *See, e.g.*, Terry Root et al., *Human-Modified Temperatures Induce Species Changes: Joint Attribution*, 102 PNAS 7465 (2005); Elisabeth A. Lloyd & Theodore G. Shepherd, *Environmental Catastrophes, Climate Change, and Attribution*, 1469(1) ANNALS OF THE NEW YORK ACADEMY OF SCIENCES 105 (2020); J. Alan Pounds et al., *Widespread Amphibian Extinctions from Epidemic Disease Driven by Global Warming.* 439 NATURE 161 (2006).

[283] Cynthia Rosenzweig et al., *Attributing Physical and Biological Impacts to Anthropogenic Climate Change*, 453 NATURE 353, 354 (2008). The researchers accounted for exogenous and confounding variables such as land use change, management practices, pollution, and human demography shifts. Although key findings were presented in

Many other studies have further underscored the pervasive nature of climate change impacts on biological systems. For example, studies have demonstrated connections between anthropogenic warming and adverse impacts on fish stocks, coral reefs, and seabird communities;[284] the loss of suitable geographic ranges for species, resulting in extinctions and future extinction risk for some species;[285] and reductions in gross primary production of terrestrial ecosystems across many regions of the world.[286] Some studies have found that anthropogenic forcing may enhance ecosystem productivity in some regions; [287] however, productivity enhancements do not necessarily translate to improvements in ecosystem health or integrity,[288] and the majority of research demonstrates adverse effects on ecosystems.[289]

ii. Extreme Events and Physical Hazards

Many attribution studies straddle the line between extreme event and impact attribution, examining the effect of anthropogenic forcing on climatological extremes (e.g., heavy precipitation) and corresponding physical hazards (e.g., floods). These studies involve impact attribution insofar as the physical hazards are influenced by many variables outside of the climate system. Studies that focus solely on the climatological aspects of extreme events are discussed in Part III(A)(3) above.

Wildfires are a good example of an extreme event that is influenced significantly by climate conditions but also influenced by many non-climatological factors including land use decisions, forestry practices, fire suppression, and human ignition. Again, it can be difficult to isolate the effect of anthropogenic forcing when there are so many variables at play. However, the effect of hotter, drier conditions on wildfires can be quite profound, and as discussed above, researchers have identified a clear link between climate change and a higher frequency of "extreme fire

---

quantitative terms, each documented change was handled in a qualitative way (looking at direction of change and not amount changed). *See also* C. Parmesan & G. Yohe, *A globally coherent fingerprint of climate change impacts across natural systems*, 421 NATURE 37 (2003) (demonstrating that biological trends observed for 1,700 species were consistent with climate change predictions, and that there was a clear anthropogenic fingerprint in observed changes for 279 species).

[284] *See, e.g.*, Sophie C. Lewis & Jennie Mallela, *A Multifactor Risk Analysis of the Record 2016 Great Barrier Reef Bleaching, in* BAMS 2016, *supra* note X134, at S144; Michael Jacox et al., *Forcing of Multiyear Extreme Ocean Temperatures that Impacted California Current Living Marine Resources in 2016*, *in* BAMS 2016, *supra* note X, at S27; Russel E. Brainard et al., *Ecological Impacts of the 2015/16 El Niño in the Central Equatorial Pacific*, *in* BAMS 2016, *supra* note X134, at S21.

[285] *See, e.g.,* Chris D. Thomas et al., *Range Retractions and Extinction in the Face of Climate Warming,* 21(8) TRENDS IN ECOLOGY & EVOLUTION 415 (2006); Liang Ma et al., *Global Patterns of Climate Change Impacts on Desert Bird Communities*, 14 NATURE COMMUNICATIONS 211 (2023).

[286] See, e.g., David Gampe et al., *Increasing Impact of Warm Droughts on Northern Ecosystem Productivity Over Recent Decades,* 11 NATURE CLIMATE CHANGE 772 (2021).

[287] See, e.g., Sebastian Sippel et al., *Warm Winter, Wet Spring, and an Extreme Response to Ecosystem Functioning in the Iberian Peninsula*, *in* BAMS 2016 (found that anthropogenic climate change contributed to higher ecosystem productivity on the Iberian Peninsula through warmer winters coupled with wet springs and increases in CO_2 availability).

[288] "Ecosystem health" (or "ecosystem integrity") is a broad and nebulous concept that cannot be defined in reference to ecosystem productivity alone. *See* Marion Kruse, *Ecosystem Health Indicators,* in ENCYCLOPEDIA OF ECOLOGY (Brian Fath ed., 2nd Ed. 2019).

[289] IPCC AR6 WGII, Ch. 2-3.

weather" (which does qualify as a climatological event). Researchers have also been able to quantify the effect of anthropogenic climate change on wildfire characteristics in some regions.[290] For example, a 2016 study on wildfires in the western United States found that, while there were numerous factors that aided the recent rise in fire activity, observed warming and drying had significantly increased fuel aridity during the fire season, fostering a more favorable environment for wildfires.[291] They found that anthropogenic climate change caused over half of the documented increases in fuel aridity since the 1970s and doubled the cumulative forest fire area since 1984.[292] The same researchers published a subsequent study focused on California which found that human-induced warming had already significantly enhanced wildfire activity in the state, particularly in the forests of the Sierra Nevada and North Coast.

Floods are another example of a physical hazard influenced by both climatological and non-climatological drivers. The climate variables that are most relevant to flood impact analysis include precipitation, sea level rise, storms, and temperature (which can cause flooding through, e.g., snowmelt and permafrost thawing). IPCC AR6 expressed *high* confidence that sea level rise has contributed to increased coastal flooding in low-lying areas,[293] and *medium confidence* that climate change had contributed to an increase in compound flooding in some regions (i.e., flooding caused by a combination of storm surge and heavy rainfall, or rapid snowmelt and heavy rainfall).[294] However, in its assessment of pluvial floods (i.e., river floods), IPCC AR6 noted that the "assessment of observed rends in the magnitude of runoff, streamflow, and flooding remains challenging, due the spatial heterogeneity of the signal and to multiple drivers", and although there is *high confidence* that climate change-induced snowmelt has altered the timing of peak flows, the evidence for attribution to human forcing is mixed.[295] There are some regions where observed increases in pluvial flooding (i.e., river flooding) have been attributed to human influence with *high* and *medium confidence*.[296]

iii. Food and Water Security

Climate change has impaired food and water security in many regions of the world as a result of both slow-onset phenomena and extreme events. Some of the slow-onset phenomena with the largest impacts on food and water security include increasing temperatures, desertification, decreasing precipitation, land and forest degradation, and loss of biodiversity and ecosystem function. Extreme events such as acute droughts, floods, storms, and heatwaves can also cause acute food and water stress (e.g., when drinking water systems are contaminated during storms).

---

[290] Note that, in addition to hotter and drier conditions, wildfires can also be exacerbated by heavier winter precipitation (which causes additional fuel growth), and faster winds. As discussed in Part III(A)(3), heavier precipitation has been attributed to climate change. There is, however, uncertainty about the effect of climate change on winds which drive wildfires.

[291] John Abatzoglou & A. Park Williams, *Impact of Anthropogenic Climate Change on Wildfire Across Western US Forests,* 113 PNAS 11770, 11770 (2016).

[292] *Id.*

[293] IPCC AR6 WGI at 120.

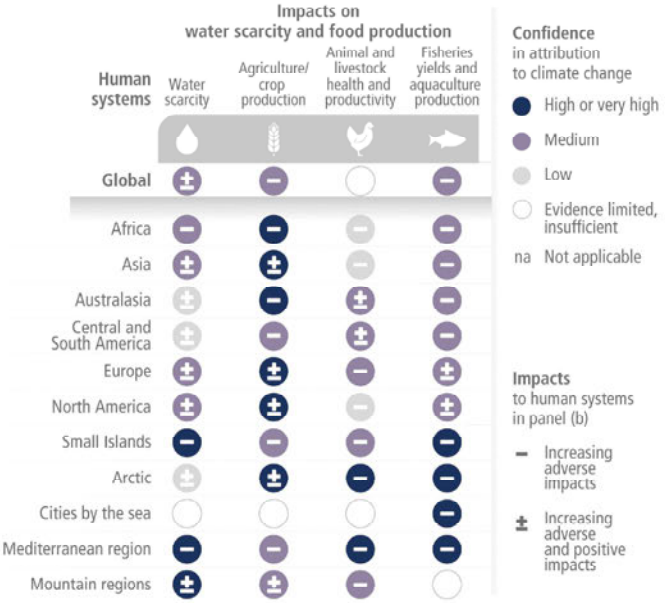
[294] IPCC AR6 WGI at 9.

[295] IPCC AR6 WGI at 1086.

[296] IPCC AR6 WGI at 140.

IPCC AR6 found that climate change has impaired agricultural productivity over the past 50 years (*medium confidence)*, with negative impacts disproportionately affecting mid- and low latitude regions (*high confidence*); that extreme events have also adversely affected food and water security (*high confidence*), exposing millions of people to acute food insecurity; and that ocean warming and acidification have adversely affected marine food productivity (*high confidence*).[297] The effect of climate change on food and water security is evident across most regions of the world, particularly with respect to fisheries yield and aquaculture production (see Figure X).

Figure X: Attribution of Water and Food Security Impacts in IPCC AR6



With regards to water security, IPCC AR6 found that changes in precipitation, snowmelt, and ice melt are altering hydrological systems, with corresponding effects on the quantity and quality of water resources.[298] Many changes in water availability and water-related hazards can be directly attributed to anthropogenic climate change (*high confidence*).[299] For example, climate-induced changes in the hydrologic cycle have affected agricultural production both positively and negatively, with negative impacts outweighing the positive ones (*high confidence*).[300] As discussed below, many other adverse impacts have been linked to climate change-induced alterations of hydrological systems.

[297] IPCC AR6 WGII at 9.
[298] IPCC AR6 WGII, Ch. 4 ("Water").
[299] IPCC AR6 WGII at 49.
[300] IPCC AR6 WGII at 50.

iv. Public Health and Well-Being

Attribution of public health outcomes from climate change can be challenging due to data requirements and the complexity of isolating causal factors that contribute to health outcomes. As noted by Ebi et al. (2017), robust detection and attribution of health impacts requires reliable long-term datasets, in-depth knowledge of the many drivers and confounding factors that affect public health outcomes, and refinement of analytic techniques to better capture the effect of anthropogenic forcing on health outcomes.[301] Two key challenges are the fact that high-quality, long-term public health data is not available for many parts of the world, and there are many confounding factors that influence public health outcomes in any given region.

Despite these limitations, the overall body of attribution research demonstrates a clear causal nexus between climate change and health outcomes.[302] IPCC AR6 expressed *very high confidence* in research showing that climate change is adversely affecting the physical and mental health of people around the world.[303] For example, attribution studies have shown that extreme heat events are resulting in human mortality and morbidity across all regions (*very high confidence*).[304] Indeed, all extreme events have direct consequences for human health and well-being, and this has been a focus of recent attribution research. Depending on the event, the effect of anthropogenic climate forcing on associated mortality or other health indicators can be quite profound. This is particularly true for heat-related impacts. For example, Åström et al. (2013) conducted a single-step attribution study on heat-related mortality in Sweden and found that mortality from heat extremes in 1980–2009 was double what would have occurred without climate change.[305] Mitchell et al. (2016) performed an end-to-end study which combined a climate model with a health impact assessment model and found that anthropogenic climate change had increased the risk of heat-related deaths

[301] Kristie L. Ebi et al., *Detecting and Attributing Health Burdens to Climate Change*, 125 ENVIRONMENTAL HEALTH PERSPECTIVES 085004-1, 085004-1(2017);

[302] As noted by Ebi et a. (2017), *supra* note X, "advances are possible in the absence of complete data and statistical certainty: there is a place for well-informed judgments, based on understanding of underlying processes and matching of patterns of health, climate, and other determinants of human well-being." To illustrate this point, the researchers discuss several contexts in which it is possible to show that a "proportion of the current burden of climate-sensitive health outcomes can be attributed to climate change": (i) heat waves, (ii) the emergence of tick vectors of Lyme disease in Canada, and (iii) the emergence of *Vibrio* in northern Europe. For heat waves, the researchers described several approaches for estimating the number of heat wave deaths attributable to anthropogenic climate change. These included two variants on multi-step attribution that would combine either the risk-based or storyline approach to extreme event attribution with an assessment of how changes in exposure to heat waves affect mortality, as well as a single-step attribution approach which would combine observations of the changes in the incidence and severity of heat waves with the exposure analysis. For *Vibrio*, the researchers found that it was possible to attribute increases in the incidence of *Vibrio* to incremental increases in sea surface temperatures, which could then be attributed to climate change. For tick vectors and Lyme disease, the researchers found that there was indirect evidence that higher temperatures were one of the forces leading to the expansion of these vectors, but that more detailed analyses of longer-term surveillance data was needed to actually quantify the relationship between climate change and tick vectors. One key takeaway from the authors of that study was that there are many different approaches to health impact attribution, including qualitative approaches.

[303] IPCC AR6 WGII at 11.

[304] IPCC AR6 WGII at 11.

[305] Daniel Oudin Åström et al., *Attributing Mortality from Extreme Temperatures to Climate Change in Stockholm, Sweden*, 3 NATURE CLIMATE CHANGE 1050, 1051. (2013). The researchers accounted for confounding variables such as urbanization and the urban heat island effect, but did not attempt to quantify human influence on observed increases in extreme heat events.

during the 2003 European heat wave by approximately 70% in central Paris and 20% in London, and that approximately 506 (± 51) deaths were attributable to climate change in Paris, and 64 (± 3) deaths were attributable in London.[306]

Where data on public health outcomes is lacking, some researchers have used changes in climate variables as proxies for health impacts.[307] For example, Mera et al., (2015) conducted a study of heat impacts in the California Central Valley using a temperature threshold of 40°C as a proxy for heat stress, and found that anthropogenic forcing had more than doubled the probability of a prolonged period (13+ days) during which temperatures exceeded that threshold.[308] This indirect approach to impact attribution is essentially a version of extreme event attribution in which authors draw reasonable inferences about public health consequences.

There are many other pathways through which climate change affects physical health. For example, climate change contributes to an increase in the prevalence of food-borne, water-borne, and vector-borne disease that cause death and illness (*very high confidence to high confidence*).[309] Climate change also exacerbates air pollution – for example, an increase in wildfire weather translates to increased wildfire smoke. Heat waves also contribute to air pollution, particularly in urban regions. The effects of climate change on air quality have been connected to increases in cardiovascular and respiratory disease.[310]

Finally, attribution research has also documented mental health challenges associated with increasing temperatures (*high confidence*), trauma from weather and climate extreme events (*very high confidence*), and loss of livelihoods and culture *(high confidence*).[311]

v. Cities, Settlements, and Infrastructure

The effects of climate change on human settlements and infrastructure are already apparent. IPCC AR6 found that sea level rise, hydrologic changes, permafrost thaw, and extreme events such as heatwaves, droughts, wildfires, and floods are already causing disruptions of key infrastructure and services such as energy supply and transmission, communications, food and water supply (see above), and transportation systems (*high confidence*).[312] In addition, cities and settlements are experiencing effects that have "extended from direct, climate-driven impacts to compound, cascading and systematic impacts (*high confidence*)." The nature and magnitude of

[306] Daniel Mitchell et al., *Attributing Human Mortality During Extreme Heat Waves to Anthropogenic Climate Change* 11 ENVIRONMENTAL RESEARCH LETTERS 1 (2016).
[307] *See, e.g.,* Daniel Mitchell, *Human Influences on Heat-Related Health Indicators During the 2015 Egyptian Heat Wave, in* BAMS 2015, *supra* note X, at S72 (examined health impacts from the 2015 Egyptian heat wave, using wet bulb globe temperature as a proxy for human discomfort caused by high heat and humidity, and found that the wet bulb temperatures observed during the heat wave were 69% more likely due to anthropogenic climate change).
[308] Roberto Mera et al., *Climate Justice and the Application of Probabilistic Event Attribution to Summer Heat Extremes in the California Central Valley*, 133 CLIMATIC CHANGE 427, 435 (2015).
[309] IPCC AR6 WGII at 11. See also IPCC AR6 WGII at 50 (finding that changes in temperature, precipitation and water-related disasters are linked to increased incidences of water- borne diseases such as cholera, especially in regions with limited access to safe water, sanitation and hygiene infrastructure (*high confidence*)).
[310] IPCC AR6 WGII at 11.
[311] IPCC AR6 WGII at 11.
[312] IPCC AR6 WGII at 53.

these impacts varies considerably depending on the region, level of exposure to climate impacts, and vulnerability of affected populations and physical infrastructure.

Coastal settlements and infrastructure are particularly vulnerable to compounding climate change impacts due to their exposure to sea level rise, more intense storms and storm surge, and the associated risk of flooding and inundation.[313] Many of these communities also depend on coastal and marine ecosystems for food security, livelihoods, and socioeconomic development – and as such, they are uniquely affected by ecosystem alterations brought about by ocean warming and acidification and other aspects of climate change.[314] IPCC AR6 found that "people, livelihoods, ecosystems, buildings and infrastructure within many coastal cities and settlements are already experiencing severe compounding impacts, including from sea level rise and climate variability (*high confidence*)."[315] Individual attribution studies indicate that some coastal areas are experiencing dramatic transformations driven primarily by sea level rise. For example, a study of flooding in Southeast Florida found that the probability of a 0.57-meter tidal flood within the Miami region had increased by more than 500% since 1994 due to a 10.9-centimeter increase in sea levels.[316]

Researchers have developed techniques for isolating the effect of anthropogenic influence on physical and economic damages associated with extreme events.[317] As noted in IPCC AR6, "[a] growing range of economic and non-economic losses has been detected and attributed to climate extremes and slow-onset events under observed increases in global temperatures in both low- and high-income countries (*medium confidence*)."[318] For example, researchers have developed estimates of the proportion of losses from major storms, such as Hurricane Harvey and Hurricane Sandy, that can be attributed to climate change.[319] This research also pertains to socioeconomic development impacts, as discussed below.

It is important to recognize that some of the increased risks associated with climate impacts are an outcome of increased exposure to those impacts. IPCC AR6 recognizes that, due to growth patterns, more people and key assets are now exposed to climate-related risks, including extreme events.[320] Cities and settlements with limited adaptive capacity (e.g., informal settlements with limited resources) have experienced the most rapid growth in urban climate vulnerability and exposure (*high confidence*).[321]

---

[313] IPCC AR6 WGII at 53 ("Coastal cities are disproportionately affected by interacting, cascading and climate-compounding climate- and ocean-driven impacts, in part because of the exposure of multiple assets, economic activities and large populations concentrated in narrow coastal zones (*high confidence*)").
[314] See *infra* § III(A)(4)(b)(vi) ("Socioeconomic Impacts").
[315] IPCC AR6 WGII at 54.
[316] William V. Sweet et al., *In Tide's Way: Southeast Florida's September 2015 Sunny-day Flood, in* BAMS 2015, *supra* note X, at S25.
[317] See, e.g., Kevin T. Sweet, *Social Inequalities in Climate Change-Attributed Impacts of Hurricane Harvey,* 13 NATURE COMMUNICATIONS 3418 (2022) (finding that climate change doubled the number of homes flooded during Hurricane Harvey, and that poorest homes were disproportionately affected).
[318] IPCC AR6 WGII at 54.
[319] Strauss et al. (2021), *supra* note X; Frame et al., (2020), *supra* note X.
[320] More people and key assets are exposed to climate-induced impacts, and loss and damage in cities, settlements and key infrastructure since AR5 (*high confidence*)." IPCC AR6 WGII at 53.
[321] IPCC AR6 WGII at 53

vi. Socioeconomic Impacts

All of the impacts described above have important implications for socioeconomic development, although attributing socioeconomic impacts to anthropogenic climate change can be tricky due to the fact that there are so many non-climate factors that also influence development trajectories. Nonetheless, attribution studies have identified clear connections between both mean and extreme changes in the global climate system and adverse economic consequences across many regions and sectors, particularly in "climate-exposed" sectors and regions that experience high exposure and vulnerability to climate change impacts (*medium to high confidence*, depending on the sector and region).[322] Economic impacts are not uniform; some areas are disproportionately affected by adverse impacts,[323] and some positive economic effects have been identified – for example, in "regions that have benefitted from lower energy demand as well as comparative advantages in agricultural markets and tourism" (*high confidence*).[324]

It is important to consider both macro- and micro-scale effects in this context. Climate change affects individual livelihoods, for example, through changes in agricultural, fishery, and ecosystem productivity, impacts on human health and food security, destruction of homes and infrastructure, loss of property and incomes (*high confidence*).[325] Again, these adverse effects are most apparent among vulnerable populations (*high confidence*).[326] For example, extreme events have had more pronounced adverse effects on human health, humanitarian, and socioeconomic outcomes in poorer regions.[327] The effects of climate change on vulnerable populations are further reducing the ability of these populations to withstand and adapt to climate impacts, while also exacerbating existing inequality (*medium confidence*).[328]

In addition, climate change is contributing to humanitarian disasters and human displacement, particularly in areas of high vulnerability to climate impacts (*high confidence*).[329] Extreme events are increasingly driving displacement across all regions of the world (*high confidence*), with

[322] *See* IPCC AR6 WGII at 11 ("Overall adverse economic impacts attributable to climate change, including slow-onset and extreme weather events, have been increasingly identified (*medium confidence*). … Economic damages from climate change have been detected in climate-exposed sectors, with regional effects to agriculture, forestry, fishery, energy, and tourism (*high confidence*), and through outdoor labour productivity (*high confidence*). Some extreme weather events, such as tropical cyclones, have reduced economic growth in the short-term (*high confidence*)"). *See also* IPCC AR6 WGII at 54 ("The effects of climate change impacts have been observed across economic sectors, although the magnitude of the damage varies by sector and by region (*high confidence*). Recent extreme weather and climate-induced events have been associated with large costs through damaged property, infrastructure and supply chain disruptions, although development patterns have driven much of these increases (*high confidence*). Adverse impacts on economic growth have been identified from extreme weather events (*high* confidence) with large effects in developing countries (*high confidence*)").
[323] See, e.g., IPCC AR6 WGII at 54 (discussing disproportionate adverse impacts on small island states).
[324] IPCC AR6 WGII at 11.
[325] IPCC AR6 WGII at 11.
[326] IPCC AR6 WGII at 54- 55 (finding, with *high confidence*, that "Economic livelihoods that are more climate sensitive have been disproportionately degraded by climate change" and that these climate-sensitive- livelihoods are "more concentrated in regions that have higher socioeconomic vulnerabilities and lower adaptive capacities").
[327] IPCC AR6 WGII at 55.
[328] IPCC AR6 WGII at 55.
[329] IPCC AR6 WGII at 11.

dipropionate effects on Small Island States (*high confidence*).[330] Impacts on food and water security, discussed above, are also adversely affecting humanitarian outcomes and socioeconomic development. There is also some evidence that climate change is contributing to violent conflict, but the statistical association is weak because non-climatic factors ate the dominant drivers of such conflicts (*medium confidence*).[331] Some of the most vulnerable groups include poor people, women, children, elderly, and indigenous populations.

B. Source Attribution

The field of "source attribution" encompasses research aimed at identifying and attributing climate change to specific sources. This research ~~is often~~may be important in litigation insofar as it addresses questions about how we should allocate *responsibility* for climate change and its impacts among different actors. A "source" could be a particular actor (e.g., a country or a company), a sector, or an activity. As noted above, source attribution has been, and remains, a distinct discipline from what is commonly labeled "detection and attribution" in the climate science community. However, these research streams have begun to converge in recent years, and there is now a growing body of research aimed at linking specific entities (e.g., countries and corporate actors) to observed changes such as sea level rise and ~~more severe~~ extreme events.[332]

1. Methods and Parameters

The IPCC does not have a working group that serves as a direct analog for "source attribution" research like ~~that~~ other issues discussed in this Chapter. IPCC Working Group III (WGIII) does synthesize some research on GHG emissions sources (e.g., estimates of regional and sectoral GHG contributions); however, the WGIII reports do not include data on the specific contributions of particular entities to global emissions, as may be required to support a legal finding of responsibility for or obligation to address climate change. Thus, source attribution data in climate litigation is often derived from sources other than IPCC reports.

Commented [MB55]: Source attribution is important in leasing and extraction cases, and has application in cases concerning prospective obligations and not only retroactive liability.

The data used in source attribution come from direct measurements of emissions, which can be performed *in situ* or remotely from satellites, as well as documentary evidence of emissions contained in corporate reports, government inventories, and other sources.[333] Where direct emissions data is lacking, scientists can use indirect methods, such as models, to estimate emissions from sources and activities. Indirect methods are particularly important for estimating emissions from land use changes and non-point sources such as agricultural operations.

---

[330] IPCC AR6 WGII at 11.
[331] IPCC AR6 WGII at 11.
[332] See, e.g., David Frame et al., *Emissions and emergence: A new index comparing relative contributions to climate change with relative climatic consequences*, 14(8) Environmental Research Letters 084009 (2019); Rachel Licker et al., *Attributing ocean acidification to major carbon producers*, 14(12) ENVIRONMENTAL RESEARCH LETTERS 124060 (2019); Friederike Otto et al., *Assigning historical responsibilities for extreme weather events*, 7(11) NATURE CLIMATE CHANGE 757 (2017); Brenda Ekwurzel et al., *The Rise in Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers*, 144 CLIMATIC CHANGE 579 (2017).
[333] Because such reports are prepared by humans, sometimes pursuant to a political or social agenda, they may contain biases or errors of a different type than those found in raw data or instrumental records.

Establishing causation in the source attribution context involves quantifying the emissions contribution of the source and ascertaining the proportional contribution of those emissions to: (i) concentrations of greenhouse gases and other forcings, and (ii) ultimately how those changes in concentrations impact, for example, sea level rise, extreme weather events, and the resultant impacts on ecosystems and/or communities. As noted above, there are some recent studies linking specific sources to global climate change and extreme events. However, most of the existing research on "source attribution" focuses on quantifying emissions from sources and determining the proportional contribution to increases in atmospheric greenhouse gases.

There are several considerations that must be considered when making this calculation. First, climate change is not a product of a single pollutant or polluting activity, and different GHGs and other forcing agents have different effects on climate in terms of magnitude, duration, location, and type of effect. Second, there are some gaps in knowledge pertaining to total emissions of certain forcing agents, including historical emissions, as well as a good deal of uncertainty about the extent and timing of historical land use changes and their impact on atmospheric concentrations of greenhouse gases.[334] Some of these land use changes, like deforestation, also impact climate in other ways.[335]

Nonetheless, scientists ~~can and~~ have endeavored to calculate the relative contributions of emissions and land use change, and, within the category of emissions, of different pollutants. In climate change attribution studies, scientists can bolster emissions data with actual measurements of atmospheric greenhouse gases (such as those taken at Mauna Loa) to determine the overall effect of human activity on climate, with the aforementioned caveats. Climate models can also be used both to evaluate the proportional contribution to atmospheric forcing agents and to ascertain the effect of that contribution on other aspects of climate change.

Finally, it is important to recognize that source attribution involves questions that cut across different social and scientific disciplines. Certainly, there is a physical science component to source attribution, as the ultimate goal is to ascertain the physical contribution of the source to anthropogenic climate change. But there are also social and normative questions that come into play when attributing emissions (or sequestration) to a particular source, particularly when trying to assign "responsibility" for emissions. Consider the many different ways that emissions can be "divvied up" across different lines—by stage of economic development, global region, country, sector, company, consumer, etc. Even within these categories, there are different ways of assigning emissions responsibility. For example, when assessing national responsibility for climate change, one can look at emissions that are generated within the country ("territorial emissions"), emissions embodied in products consumed within the country ("consumption-based emissions"), or

[334] For additional context on the state of knowledge on different GHG emission sources and their relative contribution to global climate change, see: NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE, GREENHOUSE GAS EMISSIONS INFORMATION FOR DECISION MAKING: A FRAMEWORK GOING FORWARD (2022).

[335] For example, land use decisions which change the amount of sunlight absorbed at the surface can have an important or negligible effect on climate, depending on factors such as the latitude at which the deforestation occurs, and the reflective properties of the surface underneath the previously-forested area. Another complicating factor is that climate change itself directly impacts the magnitude of sources and sinks for greenhouse gases (e.g., a warmer ocean is less able to uptake carbon dioxide, and changes in vegetation with climate change could switch some natural systems from net sources to net sinks, and vice versa).

emissions from fossil fuels produced within the country ("production-based emissions"). Similarly, when assessing corporate responsibility for climate change, there are important questions about the relative responsibility of upstream entities (e.g., fossil fuel producers) and downstream entities (e.g., manufacturers of carbon-intensive products and consumers of fossil fuels) in addition to the entities that directly generate emissions.[336]

Granted, it is entirely possible to avoid such normative questions when publishing information about source attribution. For example, a study could simply provide a breakdown of emissions across different countries using different accounting approaches (territorial, consumption-based, and production-based) without reaching any conclusions about the responsibility of different actors or source categories. But in practice, when attribution science is used in the courtroom, the question of responsibility may be of paramount importance.

International climate negotiations have historically focused on using national responsibility as the basis for allocating emission reduction burdens. This focus is evident in the United Nations Framework Convention on Climate Change (UNFCCC), which places the responsibility for reporting on and reducing emissions on national governments;[337] the "Brazilian Proposal" which emerged from UNFCCC negotiations in the mid-1990s and holds that greenhouse gas emission reduction targets should be set according to each country's historical contribution to climate change;[338] and the Paris Agreement which relies on nationally determined contributions (NDCs) as the primary basis for mitigating emissions.[339] The UNFCCC reporting framework has historically focused on *territorial emissions* (i.e., emissions generated within the country) as the metric for gauging national responsibility. However, in recent years there has been a strong push in both international and domestic for a to account for *consumption-based emissions* (i.e., emissions embodied in products consumed within the country) and *extraction-based emissions* (i.e., emissions from fossil fuels produced within the country) in additional to territorial emissions when assessing national obligations. Figure X, from Erikson & Lazarous (2013), illustrates the differences in these three accounting approaches.

Figure X: Territorial, Consumption, and Extraction-Based GHG Accounting[340]

While most national emissions inventories currently focus on territorial emissions, researchers have found that it would be relatively easy for countries to produce extraction-based and

[336] These types of considerations also factor into assessments of how to allocate the global carbon budget among different actors (see Part II(B)(3)).
[337] United Nations Framework Convention on Climate Change, May 9, 1992, S. Treaty Doc No. 102-38, 1771 U.N.T.S. 107.
[338] Emilio L. La Rovere et al., *The Brazilian Proposal on Relative Responsibility for Global Warming, in* BUILDING ON THE KYOTO PROTOCOL: OPTIONS FOR PROTECTING THE CLIMATE (Kevin A. Baumert et al. eds., 2002).
[339] Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015, T.I.A.S. No. 16-1104 [hereinafter Paris Agreement].
[340] Source: PETER ERICKSON & MICHAEL LAZARUS, STOCKLHOLM ENV'T INST., ACCOUNTING FOR GREENHOUSE GAS EMISSIONS ASSOCIATED WITH THE SUPPLY OF FOSSIL FUELS (2013).

consumption-based inventories based on readily available data.[341] In other words, pursuing these alternative accounting methodologies would not be significantly more expensive or technically challenging than the territorial approach. These alternative accounting methodologies also provide valuable insights that are not captured in the territorial approach—for example, the consumption-based approach accounts for "leakage" of GHG emissions to other countries via trade and helps countries understand the importance of developing policies aimed at reducing consumption of carbon-intensive products. Ultimately, though they may carry different legal weight, all three methodologies are useful in addressing the question of who is "responsible" for climate change.

There has also been a push to hold corporate entities responsible for contributions to climate change, particularly companies that have intentionally spread misinformation about climate science while profiting from the sale and use of fossil fuels. As detailed below, researchers have compiled detailed historical inventories of emissions attributable to some of these corporate actors. Corporate emissions inventories and disclosures also serve as a source of data for assessing corporate contributions to climate change.

2. Research Findings

a. National Contributions

Since the 1990s, countries have been preparing national GHG inventories pursuant to guidelines articulated by the United Nations Framework Convention on Climate Change (UNFCCC). These inventories encompass emissions from energy, industrial processes and product use, agriculture, land use practices, and waste. Emission estimates are based on territorial emissions. The inventories are publicly available and frequently used as a data source by researchers who analyze emission trends. They provide somewhat comprehensive coverage of recent emissions from countries, but they do not provide a complete picture of historical emissions before the 1990s and early 2000s (for some countries). There are also accounting inconsistencies in the inventories due to the issuance of different standards and reporting requirements for countries with different capacities.[342]

Governmental agencies, scientific organizations, and researchers have helped to fill these gaps through further research on national and sectoral emissions. Two key sources of data for this research are: (i) atmospheric emission measurements, and (ii) information about production and activities that contribute GHG emissions. As noted by the National Academies, "[t]he most

---

[341] Glen P. Peters, *From Production-Based to Consumption-Based National Emissions Inventories*, 65 Ecological Economics 13 (2008); Steven J. Davis & Ken Caldeira, *Consumption-Based Accounting of CO2 Emissions*, 107 PNAS 5687 (2010); Manfred Lenzen et al., *Building EORA: A Global Multi-Region Input–Output Database at High Country and Sector Resolution*, 25 Econ Sys. Res. 20 (2013); Stavros Afionis et al., *Consumption- Based Carbon Accounting: Does It Have a Future?,* 8 Wires Climate Change 1 (2017); Glen P. Peters, et al., *A Synthesis of Carbon in International Trade,* 9 BIOGEOSCIENCES 3247 (2012); Kirsten S. Wiebe & Norihiko Yamano, *Estimating CO2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015*, (OECD Sci., Tech. Indus., Working Paper 2016/05); Steven J. Davis et al., *The Supply Chain of CO_2 Emissions*, 108 PNAS 18554 (2011); Thomas Michael Power & Donovan S. Power, The Energy Foundation, The Impact of Powder River Basin Coal Exports on Global Greenhouse Gas Emissions (2013).

[342] For a more detailed discussion of limitations in UNFCCC emission inventories, see National Academies (2022), *supra* note X.

accurate and precise estimates are available for emission-producing activities that have explicit economic value (e.g., energy production) and "[n]ational CO_2 emissions from fossil fuel burning are typically well characterized by economic data on fossil fuel trade and production."[343] In comparison, there is a good deal of uncertainty about CO_2 emissions estimates from land use and land use change, as well as emissions of non-CO_2 GHGs from both industry and land use.[344] For example, recent research indicates that methane emissions from fossil fuel infrastructure are 50 percent larger than inventory estimates, and there is additional uncertainty regarding methane emissions from wetlands, reservoirs, agriculture, waste, and other sources.[345] N_2O emissions, primarily from agriculture, are another important source of anthropogenic climate forcing, and measurements of atmospheric N_2O suggest that these emissions are underestimated globally.[346]

There are different accounting approaches for estimating national emissions. For example, researchers have developed national estimates of consumption- and extraction-based emissions in addition to territorial emissions.[347] Work has also been done to quantify emissions at different scales and to evaluate emissions by different metrics (e.g., per capita emissions within a country).[348] Overall, there is a large body of emissions data that litigants and other actors can draw on – especially for U.S. CO_2 emissions, which are well-documented by both government agencies and independent researchers.

One notable finding is that the U.S. is at or near the top of emission contributions under most accounting methods. The U.S. is a clear leader in cumulative territorial emissions– the cumulative net CO_2 emissions from industrial and energy systems in the U.S. are approximately 417 billion tons (24.3% of cumulative global CO_2 from these processes).[349] The U.S. also has some of the highest per capita emissions, with a per capita CO_2 footprint of 16.2 tons, which is roughly 3 times higher than the global average.[350] There is more uncertainty about the attribution of cumulative consumption-based emissions to individual countries (due to limited data about historical emissions embodied in trade), but data since 1990 indicates that U.S. consumption-based emissions are slightly higher than territorial emissions, as ~~we are~~the U.S. is ~~a~~ net importer of carbon embodied in the products Americans ~~we~~ consume.[351]

---

[343] NATIONAL ACADEMIES (2022), *supra* note X, at 50.
[344] *Id.* As a point of reference: the uncertainty for global fossil fuel CO_2 emissions is thought to be less than less than ±8 percent, whereas the uncertainty for land use CO2 emissions is estimated at roughly ±75 percent. At the national level, these uncertainty estimates vary depending on the quality of data systems.
[345] NATIONAL ACADEMIES (2022), *supra* note X; at 50. *See also* NATIONAL ACADEMIES, IMPROVING CHARACTERIZATION OF ANTHROPOGENIC METHANE EMISSIONS IN THE UNITED STATES (2018).
[346] NATIONAL ACADEMIES (2022), *supra* note X; at 51. *See also* E. Solazzo et al., *Uncertainties in the Emissions Database for Global Atmospheric Research (EDGAR) emission inventory of greenhouse gases*, 21(7) ATMOSPHERIC CHEMISTRY AND PHYSICS 5655 (2021).
[347] *See, e.g.,* Steven J. Davis et al., *The Supply Chain of CO_2 Emissions*, 108 PNAS 18554 (2011); Glen Peters et al., *Growth in Emission Transfers Via International Trade from 1990 to 2008*, 108 PNAS 8903 (2011); DANIEL MORAN ET AL, THE CARBON LOOPHOLE IN CLIMATE POLICY: QUANTIFYING THE EMBODIED CARBON IN TRADED PRODUCTS (2018).
[348] H. Damon Matthews, *Quantifying Historical Carbon and Climate Debts Among Nations*, 6 NATURE CLIMATE CHANGE 60 (2016).
[349] Our World in Data, *United States; Country CO_2 Profile*, https://ourworldindata.org/co2/country/united-states.
[350] Our World in Data, *Per Capital CO_2*, https://ourworldindata.org/per-capita-co2.
[351] Our World in Data, *Consumption-Based CO_2*, https://ourworldindata.org/consumption-based-co2.

There is also a growing body of research aimed at linking national emissions contributions to specific aspects of climate change. Many of these studies deal with contributions to global mean surface temperature (GMST) increases, as there is robust physical understanding of the relationship between anthropogenic forcings and GMST.[352] For example, Skeie et al. (2017) used a climate model to link the territorial emissions between 1850 and 2012 from multiple countries to GMST change, taking into account historical emissions and focusing on the largest emitters, and found that China was responsible for 6–13% and the United States was responsible for 15%–26% of the observed GMST increase.[353] In a similar study, Jones et al. (2023) calculated changes in GMST attributable to national CO_2, methane (CH_4,) and nitrous oxide (N_2O) emissions from 1850-2021 and found that U.S. is responsible for .28 °C increase, approximately 17% of the warming caused by all global emissions.[354] ~~(note that differences in these findings can result from, e.g., different timeframes used for emissions estimates—Both Skeie et al. and Jones et al. use 1850 as the start year, but Jones et al. includes more recent emissions data.~~

Commented [MB56]: Incomplete/fragment.

Researchers are also examining the causal relationship between national emissions and a range of other impacts including regional/country-specific impacts, and changes in extreme events. Otto et al. (2017) was the first study to apply the nation-based emissions framework to individual extreme event attribution, focusing on an Argentina heat wave.[355] A motivation was to quantify the proportional contribution of nation states to a phenomenon—specifically a damaging extreme event—that is closer to impacts and "losses" than phenomena to which source emission approaches had previously been applied, such as changes in global mean surface temperature. The researchers used two different statistical methodologies to assess historical responsibility of the U.S. and found that historical emissions from the U.S. made the event approximately 34% (20-54% uncertainty

---

[352] See N.P. Gillett et al., *Constraining the Ratio of Global Warming to Cumulative CO_2 Emissions Using CMIP5 Simulations*, 26 JOURNAL OF CLIMATE 68444 (2013); P. Friedlingstein & S. Solomon, *Contributions of past and present human generations to committed warming caused by carbon dioxide,* 102 PNAS 10832 (2005); T. Wei et al., *Developed and Developing World Responsibilities for Historical Climate Change and CO2 Mitigation*, 109 PNAS 12911 (2012); J. Pongratz & K. Caldeira, *Attribution of Atmospheric CO_2 and Temperature Increases to Regions: Importance of Preindustrial Land Use Change,* 7 ENVIRONMENTAL RESEARCH LETTERS 034001 (2012); S.C. Lewis et al., *Assessing Contributions of Major Emitters' Paris-Era Decisions to Future Temperature Extremes,* 46 GEOPHYSICAL RESEARCH LETTERS 3936 (2019); N. Höhne et al., *Contributions of individual countries' emissions to climate change and their uncertainty*, 106 CLIMATIC CHANGE 359 (2011); B. Fu et al., *The contributions of individual countries and regions to the global radiative forcing*, 118 PNAS e2018211118 (2021).

[353] Ragnhild B. Skeie et al., *Perspective Has a Strong Effect on the Calculation of Historical Contributions to Global Warming,* 12 ENVIRONMENTAL RESEARCH LETTERS 024022 (2017). Skeie et al. noted that these findings were very sensitive to the parameters of the study, including technical decisions such as the timeframe for the analysis, as well as more normative decisions about the basis for attributing emissions (e.g., place of extraction vs. place of burning vs. place of final consumption) and about whether to look at per capita or total emissions. They also emphasized that, in non- linear systems, the proportional contribution to emissions will differ from the proportional contribution to impacts.

[354] Matthew W. Jones et al., *National Contributions to Climate Change Due to Historical Emissions of Carbon Dioxide, Methane, and Nitrous Oxide Since 1850,* 10 SCIENTIFIC DATA 155 (2023). Note that Jones et al. (2023) and Skeie et al. (2017) use different timeframes for the emissions analysis, which is one factor contributing to the different findings in these studies.

[355] Friederike Otto et al., *Assigning Historic Responsibility for Extreme Weather Events*, 7 NATURE CLIMATE CHANGE 757 (2017).

range) or 28% more likely (19-45% uncertainty range) depending on the method used.[356] **[Radley:** I didn't want to get too in the weeds re: the two methodologies, but should we say more about the uncertainty ranges here? E.g., "This research provides useful initial insights on possible measures of national responsibly, but the large uncertainty ranges illustrate the difficulty of attributing specific extreme events or climate impacts to specific emitters with a high level of precision."]

Some of this research is more prospective.[357] For example, Beusch et al., (2022) used a suite of earth system models to quantify the contributions of the five largest emitters (China, US, EU-27, India, and Russia) to projected 2030 country-level warming and extreme hot years.[358] They found that the cumulative emissions from these countries from 1991-2030 had doubled the number of countries that are expected to experience extreme hot years every one year.[359] With regards to the US specifically, they found that "If all world nations shared the same fossil CO_2 per capita emissions as projected for the US from 2016–2030, global warming in 2030 would be 0.4 °C higher than under actual current pledges, and 75% of all countries would exceed 2 °C of regional warming instead of 11%."[360]

b. Corporate Contributions

Much of the research on corporate contributions to climate change has focused on corporations involved ien fossil fuel production, energy, and other emissions intensive industries. In the foundational "Carbon Majors" study, Heede (2014) developed estimates of historical emissions for ninety producers of oil, gas, coal, and cement based on their production records.[361] The total aggregate emissions from these ninety companies totaled 914 $GtCO_2e$, equivalent to 64% of cumulative worldwide emissions of industrial CO_2 and methane from 1751– 2010. He also found that approximately half of the emissions were generated since 1986—a piece of data which could be used to contradict claims about unforeseeability (since it is difficult to argue that companies were unaware of the risks of climate change by that time). In an update to the Carbon Major study, Griffin et al. (2017) found, additionally, that 71% of industrial GHG emissions since 1988 could be traced back to the products of just 100 fossil fuel companies.[362]

Corporate emissions estimates can also be obtained through voluntary disclosures through initiatives like the Climate Disclosure Project, as well as legally mandated disclosures which are

[356] The study also examined EU responsibility, but we focus on U.S. findings for the purposes of this chapter.
[357] See, e.g., S.C. Lewis et al., *Assessing Contributions of Major Emitters' Paris-Era Decisions to Future Temperature Extremes*, 46 GEOPHYSICAL RESEARCH LETTERS 3936 (2019).
[358] L. Beusch et al., *Responsibility of Major Emitters for Country-Level Warming and Extreme Hot Years,* 3(1) COMMUNICATIONS EARTH & ENVIRONMENT 7 (2022).
[359] *Id.* The authors found that the cumulative 1991–2030 emissions were expected to result in extreme hot years every second year by 2030 in twice as many countries (92%) as without their influence (46%).
[360] *Id.* at 7.
[361] Richard Heede, *Tracing Anthropogenic Carbon Dioxide and Methane Emissions from Fossil Fuel and Cement Producers, 1854–2010*, 122 CLIMATIC CHANGE 229 (2014); RICHARD HEEDE, CARBON MAJORS: ACCOUNTING FOR CARBON AND METHANE EMISSIONS 1854-2010: METHODS AND RESULTS REPORT (2014).
[362] PAUL GRIFFIN ET AL., THE CARBON MAJORS DATABASE: CDP CARBON MAJORS REPORT 2017 (2017).

becoming increasingly common.[363] The IPCC and government agencies also compile emissions data for specific sectors (energy, transport, buildings, industry, forestry, agriculture, and waste). Sectoral data is potentially relevant whenich assessing government legal obligations related to the regulation of GHG emissions, or for comparing corporate emissions to industry norms.

Researchers have also begun conducting attribution studies aimed at linking corporate emissions to specific climate impacts (as with national emissions). Ekwurzel et al. (2017) applied emission findings from the Carbon Majors study to a simplified climate model to assess the impacts of those emission contributions on global temperature change and sea level rise.[364] They found that product emissions from the ninety carbon majors were responsible for approximately 57% of the observed rise in atmospheric CO_2, approximately 42–50% of the rise in global mean surface temperature (GMST), and 26–32% of the global sea level rise over the historical period from 1880–2010. Licker et al. (2019) attributed ocean acidification to the 88 largest industrial carbon producers, finding that their product emissions were responsible for roughly 55% of the historical decline in surface ocean pH from 1880-2015.[365]

C. PredictionsProjections of Future Climate Change

Commented [MB57]: Predictions or projections?

Climate change predictions projections provide insights on the magnitude and scope of changes and impacts that could occur under different emission trajectories and warming scenarios. There is no question that the effects of climate change will become increasingly severe and pervasive as GHGs continue to accumulate in the atmosphere. However, the relationship between emissions, changes in the global climate system, and corresponding impacts is not always linear – for example, there are potential tipping points, feedback cycles, and cascading impacts that could result in acceleration of certain trends such as sea level rise. Scientists have developed fairly sophisticated methods for predicting future changes and impacts based on anthropogenic forcing and levels of atmospheric warming. Importantly, these predictions projections are not intended to convey the world *as it will be* but rather the world *as it could be* depending on human activities going forward.

1. Methods and Parameters

Like attribution research, predictions projections of future climate change are based on physical understanding, climate datasets, statistical methods, and modelling tools. In addition, the findings from detection and attribution research, discussed above, provide the foundation for

[363] *See, e.g.*, *GHG Reporting Program,* EPA; *Mandatory GHG Emissions Reporting*, California Air Resources Board.
[364] B. Ekwurzel et al., *The Rise in Atmospheric CO_2, Surface Temperature, and Sea Level from Emissions Traced to Major Carbon Producers*, 144 CLIMATIC CHANGE 579 (2017).
[365] R. Licker et al., *Attributing Ocean Acidification to Major Carbon Producers*, 14 ENVIRONMENTAL RESEARCH LETTERS 124060 (2019).

predicting future trends, insofar as they characterize the changes that are already underway as a result of anthropogenic climate forcing. Climate change ~~predictions~~ projections are typically used in climate litigation to establish the foreseeability of future climate harms and to assess legal obligations to control GHG emissions and/or adapt to the effects of climate change.

The ~~predictions~~ projections in IPCC assessments and many other studies rely heavily on the CMIP model ensemble to simulate how changes in climate forcers, such as GHGs, may affect the global climate system. IPCC AR6 relies on CMIP Phase 6 (CMIP6), which has better representations of physical processes as well as higher resolution compared to climate models used in previous IPCC assessments.[366] The climate ~~predictions~~ projections in IPCC AR6 are based on five illustrative scenarios which reflect potential changes in GHG emissions and land uses as well as natural climate forcers. They include near-term (2021-2040), mid-term (2041-2060) and long-term (2081-2100) ~~predictions~~projections.

There is considerable confidence in the ability of global climate models to provide credible quantitative estimates of future climate change at large geographic scales.[367] Confidence in global ~~predictions~~ projections is higher for some climate variables (e.g., global mean temperature and sea level rise) than for others (e.g., precipitation). To evaluate the credibility and robustness of model ~~predictions~~projections, scientists will assess how well the model is able to simulate observed climate conditions. For example, the CMIP6 multi-model ensemble underwent a diagnostic evaluation which revealed that it captured most aspects of observed climate change well.[368] One key improvement in global climate models is that they are now better at simulating natural climate variability, which can play a significant role in shaping future climate conditions.

Global climate models deal with large-scale weather patterns; they do not have the spatial resolution to simulate the effects of anthrophonic climate change at a regional or local scale. Scientists must use regional models to simulate the interactions between changes in large-scale weather patterns and regional or local conditions. Regional climate models have much finer spatial resolution (e.g., 1-50 km grid spacing, as opposed to 100-300 km grid spacing in a global model).[369] There is generally more uncertainty and less confidence in ~~predictions~~ projections at the regional scale, due to the challenges with regional climate analysis described above. In particular, internal variability tends to play a larger role in shaping regional climate conditions, and this complicates the identification of forced climate signals at the regional level. There are methods for reducing uncertainty in regional ~~predictions~~ projections -- example, by combining and comparing results from different regional models, or by using "initial-condition" ensembles, where the same model is run repeatedly under identical forcing but with small variations in initial conditions (which helps researchers quantify uncertainty due to internal variability).[370]

---

[366] IPCC AR6 WGI at 12.
[367] *See* IPCC AR6 WGI, Ch. 4 ("Future Global Climate: Scenario-Based Projections and Near-Term Information"); *See also* David Randall & Richard Wood, *Climate Models and Their Evaluation,* in: CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (S. Solomon et al. eds., Cambridge University Press 2007).
[368] IPCC AR6 WGI at 561.
[369] Eric P. Salathé Jr. et al., *Regional Climate Model Projections for the State of Washington*, 102 CLIMATIC CHANGE 51 (2010).
[370] IPCC AR6 WGI at 562.

Even where models are unable to provide robust quantitative ~~predictions~~ projections of future climate conditions, it may be possible to qualitatively predict trends with a fairly high level of confidence. Such qualitative ~~predictions~~ projections can be used to assess climate risk and to define legal obligations related to climate change mitigation and adaptation. However, there are some variables for which it may be difficult to even reach qualitative conclusions about the direction of future trends. For example, it is unclear whether average precipitation will increase or decrease in some regions as a result of anthropogenic climate change.[371]

As noted above, climate ~~predictions~~ projections must be issued in reference to future emissions (or anthropogenic forcings) and/or warming scenarios. In its latest assessment, the IPCC used the following emission scenarios to frame its analysis: (i) a "very low" emissions scenario, where GHG emissions decline sharply, reaching net zero around 2050, followed by net negative emissions (SSP1-1.9); a "low" emissions scenario, where emissions decline quickly (but not as fast as the very low scenario), reaching net zero emissions after 2050, followed by net negative emissions (SSP1-2.6); an "intermediate" emissions scenario, where CO2 emissions remain at current levels until mid-century and then decline to net zero by 2100 (SSP 2-4.5); a "high" scenario where emissions continue to increase through the century (SSP3-7.0), and a "very high" scenario with larger emission increases, followed by a slight decline in emissions towards the end of the century (SSP5-8.5).[372] These five scenarios correspond with different temperatures increases (see Figure X), and they have been used as the basis for climate modelling in CMIP6 ensembles.

Figure X: Emission Scenarios in IPCC AR6[373]

2. Key Findings

IPCC AR6 found that "global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered", and that "global warming of 1.5°C and 2°C will be exceeded during the 21st century" unless there are deep reductions in GHG emissions in the next few decades.[374] In the near term, global warming is *more likely than* not to reach 1.5°C even under the very low GHG emission scenario (SSP1-1.9), and this level of warming will cause "unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans (*very high confidence*)."[375] Scientists predict that the loss and damage caused by anthropogenic climate change will be severe even if we limit global warming to 1.5 or 2.0° C (two

[371] Generally speaking, there is low confidence in model projections of regional precipitation. At the global scale, models project that there will be greater contrast in mean precipitation between dry and wet regions (i.e., dry areas well become drier; wet areas will become wetter) but with large regional variations. IPCC AR6 WGI at 1109. Some areas, such as the western U.S., are projected to have increased precipitation in some models and decreased precipitation in other models. *Id.* at 1110 (Figure 8.14).
[372] IPCC AR6 WGI I at 232, Cross-Chapter Box 1.4.
[373] Source: IPCC AR6 WGI at 13, Box SPM-1.
[374] IPCC AR6 WGI at 14. Even under the "very low emissions scenario", it is "very likely" that global average surface temperature will increase by 1.0°C to 1.8°C over pre-industrial levels by the end of the century. Under the "intermediate emissions scenario", it is "extremely likely" that global warming will exceed 2°C by mid-century.
[375] IPCC AR6 WGII at 13.

targets established by political bodies for averting dangerous anthropogenic climate change, which are often used to formulate scenarios for climate projections).[376] The scope and severity of risks will increase with each additional increment of warming.

Notably, for any given future warming level, many climate-related risks are higher than those assessed in AR5, and the severity of projected long-term impacts is often significantly higher than currently observed impacts like those described above (*high confidence*).[377] The effects of climate change will also interact with non-climatic risks, creasing "compound and cascading risks that are more complex and difficult to manage" (*high confidence*).[378]

Adaptation measures can play a significant role in mitigating certain risks, such as the risks associated with extreme precipitation and flooding. However, adaptation may not be as effective at mitigating other harmful impacts, such as those on biodiversity and ecosystems. Moreover, the effect of climate change on vulnerable populations and ecosystems often reduces their adaptive capacity, thus creating a compounding problem where adaptation becomes increasingly challenging and costly as climate change becomes more severe.

Some key aspects of climate change ~~predictions~~ projections are presented below. This summary is relatively brief because these are extrapolations of trends already discussed in the context of detection and attribution research. Findings are primarily presented in qualitative terms, since the actual magnitude of future impacts depends on emissions trajectories. However, some quantitative examples are provided to illustrate differences in projected impacts at different levels of warming.

a. Large-Scale Changes in the Climate System

Ongoing emissions will continue to drive major changes in the global climate system like those documented in the discussion of attribution research above. These changes include: (i) further global mean sea level rise (*virtually certain*); (ii) increased ocean acidification (*virtually certain*) and deoxygenation (*high confidence*); (iii) intensification of the global hydrological cycle, as well as an intensification of variability within that cycle, resulting in both more extreme wet weather and very dry weather (*high confidence*); and (iv) ongoing reductions in the extent and volume of all cryosphere resources such as sea ice and glaciers (*high confidence*). Natural land and ocean carbon sinks are projected to absorb a decreasing proportion of GHG emissions as emissions increase (*high confidence*).[379] Importantly, many of these changes in the climate system will be "irreversible on centennial to millennial timescales," particularly changes in the ocean, ice sheets, and global sea level.[380]

---

[376] GLOBAL WARMING OF 1.5°C. AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5°C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS 5 (Valérie Masson-Delmotte et al. eds., Cambridge University Press 2018) [hereinafter IPCC 1.5°C REPORT].
[377] IPCC AR6 Synthesis Report SPM at 15 (cite final version when available).
[378] IPCC AR6 Synthesis Report SPM at 15 (cite final version when available).
[379] IPCC AR6 Synthesis Report SPM at 12-13 (cite final version when available).
[380] IPCC AR6 Synthesis Report FP at 34 (cite final version when available).

b. Climate Extremes

Climate extremes will become more severe with each additional increment of warming. For example, compound heatwaves and droughts are projected to become more frequent across multiple locations (*high confidence*); there is a projected increase in the intensification of tropical cyclones and/or extratropical storms (*medium confidence*); 1-in-100 year extreme sea level events are projected to occur at least annually in more than half of locations by 2100 under all scenarios (*high confidence*); and there are projected increases in aridity and fire weather (*medium to high confidence*).[381] Figure X from IPCC AR6 (next page) summarizes some of the quantitative findings on the projected frequency and intensity of extreme events under different warming scenarios.

Figure X: Projected Changes in the Intensity and Frequency of Climatological Extremes[382]

c. Impacts on Humans and Natural Systems

Every region in the world will face further increases in climate hazards under all emissions scenarios (*medium to high confidence*, depending on the region and hazard). Some of the projected near-term impacts on human systems include increases in heat-related mortality and morbidity (*high confidence*); increases in food-borne, water-borne, and vector-borne disease (*high confidence*); more severe flooding in coastal and low-lying areas (*high confidence*); adverse mental

[381] IPCC AR6 Synthesis Report SPM at 13 (cite final version when available).
[382] Source: IPCC AR6 WGI at 18, Figure SPM.6.

health impacts (*very high confidence*), and adverse impacts on food and water security in many regions (*high confidence*).[383] Human and natural systems will also be affected by biodiversity loss across terrestrial, freshwater, and ocean ecosystems (*medium to very high confidence*, depending on the ecosystem).

The risks and projected adverse impacts of climate change will become increasingly severe, complex, and more difficult to manage with each additional increment of global warming (*very high confidence*).[384] At 2°C of warming, there is a significant increase in risks associated with global aggregate impacts, large-scale extreme events, and unequal distribution of risks, as compared with 1.5°C, and the magnitude of risks grows even larger at 3°C or 4°C.

The relationship between impacts and global warming is often not linear, and small temperature increases can result in dramatically more severe impacts. IPCC AR6 identifies 127 "key risks" for which the long-term assessed impacts will be up to multiple times higher than currently observed (*high confidence*).[385] For example, the risk of extinction for endemic species in biodiversity hotspots will "at least double between 1.5°C and 2°C global warming levels and to increase at least tenfold if warming rises from 1.5°C to 3°C (*medium confidence*)."[386] As another example, the projected increases in direct flood damages are 1.4-2x higher at 2°C and 2.5–3.9x higher at 3°C, as compared to 1.5°C global warming (*medium confidence*).[387] Adaptation measures can mitigate some of these impacts, but adaptation will be more costly under more severe warming scenarios.

If global warming exceeds 4°C, there will be many profound and irreversible impacts to human and natural systems. Above this threshold, the IPCC predicts that approximately 4 billion people will experience water scarcity (*medium confidence*); there will be sever hydrological changes over 10% of the global land area, resulting in both extremely high and low streamflow levels, with corresponding effects on over 2.1 billion people (*medium confidence*); approximately 50% of tropical marine species will experience local extinctions (*medium confidence*), and there will be biome shifts across 35% of global land area (*medium confidence*), with corresponding effects on ecosystems and agricultural systems.

The above findings are only a sampling of potential impacts at different temperature thresholds. Essentially all of the trends documented in the discussion of detected and attributed impacts are expected to continue and intensify as a result of continued emissions.

d. Tipping Points

---

[383] IPCC AR6 Synthesis Report SPM at 15 (cite final version when available).
[384] IPCC AR6 Synthesis Report FP at 36 ("At 2°C of global warming, overall risk levels associated with the unequal distribution of impacts (RFC3), global aggregate impacts (RFC4) and large-scale singular events (RFC5) would be transitioning to high (*medium confidence*), those associated with extreme weather events (RFC2) would be transitioning to very high (*medium confidence*), and those associated with unique and threatened systems (RFC1) would be very high (*high confidence*)").
[385] IPCC AR6 Synthesis Report FP at 36 (cite final version when available).
[386] IPCC AR6 WGII at 14.
[387] IPCC AR6 Synthesis Report FR at 36 (Cite final version when available).

Research indicates that the planet is already very close to surpassing many critical thresholds within the climate system, and some of these thresholds will likely be surpassed if global warming exceeds 1.5°C. IPCC AR6 finds that there is a "high risk" that we will surpass tipping points, resulting in abrupt and/or irreversible changes, with warming between 1.5-2.5°C, and "very high" risk with warming between 2.5-4°C.[388] But the IPCC AR6 findings also reflect significant uncertainty about precisely when and how topping points may be surpassed.[389] For example, AR6 notes that Greenland and West Antarctic ice sheets may be lost almost completely and irreversibly with warming between 2-3°C but there is only "limited evidence" for this finding. However, more recent studies on tipping points that were published after evidence was compiled for IPCC AR6 indicate that we are close to surpassing certain thresholds, and may have already surpassed some, particularly those associated with cryosphere impacts (e.g., the melting of ice sheets).[390]

D. Carbon Budgeting and GHG Mitigation

Global GHG budgets define the maximum amount of GHGs that can be released into the atmosphere while still limiting global warming to pre-defined targets, such as 1.5°C or 2.0°C. Most of the research in this area deals with the global carbon budget, since CO_2 is the dominant source of anthropogenic warming and much is known about CO_2 emissions. Researchers have developed and are continuously updating estimates of the remaining global carbon budget based on assessments of carbon cycle sources and sinks on a global level, including estimates of anthropogenic emissions and land use changes. There is also a growing body of research which aims to translate global carbon budgets into more specific emission budgets – most of this research focuses on establishing national emission budgets, but there are efforts to develop sectoral, corporate, and local carbon budgets as well.[391] Researchers have also developed estimates of the global methane (CH_4) and nitrous oxide (N_2O) budgets.[392]

1. Methods and Parameters

Estimating carbon or GHG budgets involves several steps: (i) calculating the total amount of CO_2 and/or other GHGs that can be released into the atmosphere while limiting global warming to a specific temperature target, (ii) determining how much of the budget has already been utilized by historical emissions, and (iii) calculating the remaining share of the carbon budget for subsequent years. The global carbon budget is typically expressed in terms of a range of gigatons

[388] IPCC AR6 Syntheses Report FR at 42 (cite final version when available).
[389] For example, the IPCC notes that the Greenland and West Antarctic ice sheets may be lost almost completely and irreversibly with warming between 2-3°C but there is only "limited evidence" for this finding. IPCC AR6 Synthesis Report FR at 42 (cite final when available).
[390] *See, e.g.,* McKay et al. (2022), *supra* note 36.
[391] See, e.g., One Planet Network, *Company Level Carbon Budgets,* https://www.oneplanetnetwork.org/knowledge-centre/policies/company-level-carbon-budgets
[392] *See, e.g.,* The Global Carbon Project, https://www.globalcarbonproject.org/index.htm.

of CO_2 that can be emitted at a specified probability (e.g., 67%) of remaining within a temperature target.[393]

As noted above, the IPCC has found a near-linear relationship between CO_2 and increases in global temperature, which lends confidence to carbon budget estimates. However, there are some factors which ~~introduce uncertainty into~~add complexity to the GHG budget analyses. ~~Some of this uncertainty pertains to physical understanding of the climate system — e.g.,~~ For example, as discussed above, there is some uncertainty about ~~natural variability, as well as~~ the future uptake of carbon by ocean and terrestrial systems.[394] There is also some uncertainty about the share of GHG budgets that has already been utilized (owing to uncertainty about, e.g., non-CO_2 emissions).[395] This uncertainty can be communicated by presenting historical cumulative emissions as a range.[396] It is also important to recognize that an estimate of the global budget for one GHG is dependent on assumptions about future emissions of other GHGs. Thus, to estimate the global carbon budget, researchers must make an assumption about future levels of non-CO2 emissions and their contribution to warming. Such assumptions will be always be disclosed.

The IPCC synthesizes research on GHG budgets and GHG reduction pathways.[397] Other major organizations involved in the calculation of global GHG budgets include including the Global Carbon Project, the Mercator Research Institute on Global Commons and Climate Change (MCC), and the CONSTRAIN project. Individual scholars also publish research in this field.[398]

Researchers are also developing methods and estimates for the equitable allocation of global emissions budgets among different countries and sectors.[399] Some of this research specifically deals with fossil fuel production horizons – i.e., the maximum amount of coal, oil, and gas that can be extracted and consumed without exceeding temperature targets.[400] Estimation of national carbon budgets relies on data about historical emissions on the country-level, and there are some gaps in this data (as discussed above). But ~~researchers do have a fair level of confidence~~there is

Commented [MB58]: As above, this discussion of uncertainty could be misinterpreted by judges as "there is certainty until uncertainty is introduced." But that is not really the case, and it makes uncertainty much scarier - and less quantifiable - than it is.

Commented [MB59]: Same concern as with "reasonable" - these colloquialisms could register in particular ways with judges. Since they do have actual confidence levels, perhaps name those instead.

[393] For example, IPCC AR6 found that we would need to limit global CO_2 emissions to 400 billion tons from the start of 2020 in order to have a 67% probability of remaining within 1.5°C of warming. IPCC WGI at 29.
[394] *See, e.g.,* H. Damon Matthews et al., *An Integrated Approach to Quantifying Uncertainties in the Remaining Carbon Budget*, 2 COMMUNICATIONS EARTH & ENVIRONMENT 7 (2021).
[395] See *supra* §III(B)(1) (source attribution).
[396] *E.g.,* IPCC AR6 found with *high confidence* that historical cumulative net CO_2 emissions from 1850 to 2019 were 2400 ± 240 $GtCO_2$. IPCC AR6 WGIII at 6.
[397] IPCC WGI provides the physical science basis for carbon budget estimation, and IPCC Working Group III (WGIII) synthesizes research on the mitigation of climate change. The WGIII reports include information about the sources and quantity of anthropogenic GHG emissions, remaining carbon budgets under different temperature targets, and approaches for controlling GHG emissions. IPCC, CLIMATE CHANGE 2022: MITIGATION OF CLIMATE CHANGE, WORKING GROUP III CONTRIBUTION TO THE SIXTH ASSESSMENT REPORT OF THE IPCC (2022) [hereinafter IPCC AR6 WGIII].
[398] *See, e.g.,* Matthews et al. (2021), *supra* note X; Friedlingstein et al., *Global Carbon Budget 2020*, 12(4) EARTH SYSTEM SCIENCE DATA 3269 (2020).
[399] See, e.g., K.W. Steininger et al., *Sectoral carbon budgets as an evaluation framework for the built environment*, 1(1) BUILDINGS AND CITIES 337 (2020); Kaylin Lee et al. *Fair distributions of carbon dioxide removal obligations and implications for effective national net-zero targets*, 16 ENVIRON. RES. LETT. 094001 (2021); Skeie et al. (2017), *supra* note 338; Lavanya Rajamani et al., National 'fair shares' in reducing greenhouse gas emissions within the principled framework of international environmental law, 21(8) CLIMATE POLICY 983 (2021).
[400] *See, e.g.,* S.A.C. Rekker et al., *Comparing extraction rates of fossil fuel producers against global climate goals*, 8 NATURE CLIMATE CHANGE 489 (2018).

ample data to support ~~in~~ emission estimates ~~for~~ from industrial sources in many countries, particularly wealthier countries like the U.S., and novel techniques to fill gaps in national emissions inventories are now being applied to carbon budget analyses.[401] For example, an ongoing NASA project is using satellite observations to assess emissions (sources) and removals (sinks) of CO_2 at the country level, thus aiding in efforts to allocate carbon budgets among countries.[402] As noted in the discussion of source attribution above, some studies also seek to quantify the contribution of country emissions (both historical and prospective) to specific climate impacts, and this research provides further insights on how carbon budgets could or should be divvied up among national actors.[403]

Research on the equitable allocation of carbon budgets is rooted in physical climate science, but it also implicatcs cthical and normativc qucstions[404] such as:

- Should responsibility for future emission reductions and limits on fossil fuel production be predicated on historical contributions to emissions and fossil fuels?
- Should emission budgets be defined in reference to territorial, consumption, or production-based emissions?
- Should cmission budgcts bc bascd on total or pcr capita cmissions?
- How should considerations related to economic development and gross domestic product (GDP) affect responsibilities?

These types of normative questions are beyond the scope of this chapter, but nonetheless highly relevant to the allocation of carbon and GHG budgets among national actors (or other actors).

2. Research Findings

IPCC AR6 synthesized research on the remaining carbon budget, and found that we would need to limit global CO_2 emissions to 400 billion tons from the start of 2020 in order to have a 67% probability of remaining within 1.5°C of warming, and 1150 billion tons in order to have a 67% probability of limiting warming to 2°C.[405] IPCC AR6 also included estimates of the remaining carbon budget at different temperature targets and probability levels (see Table X). Notably, historical cumulative emissions from 1850-2019 constitute approximately 85% of the

[401] National Academies (2022), *supra* note X.
[402] NASA, *National Carbon Dioxide (CO_2) budgets inferred from atmospheric observations*, https://svs.gsfc.nasa.gov/5081.
[403] *See, e.g.*, Yann Robiou de Pont & Malte Meinshausen, *Warming Assessment of the Bottom-Up Paris Agreement Emissions Pledges*, 9 NATURE COMMUNICATIONS 4810 (2018).
[404] Scholars from legal, policy, and social sciences disciplines have written on the topic of how carbon budgets should be allocated to reflect normative considerations such as justice and equity, reflecting the fact that this is one area where the law and science interact in significant ways. *See, e.g.*, Cass Sunstein & Eric Posner, *Climate Change Justice* (John M. Olin Program in Law and Economics Working Paper No. 354, 2007); Catriona McKinnon, *Climate Justice in a Carbon Budget*, 133 CLIMATIC CHANGE 375 (2015).
[405] IPCC WGI at 29. See also IPCC AR6 WGIII at 6-7.

Formatted: Highlight

total carbon budget for 1.5°C and 66% of the total carbon budget for 2°C – in other words, humans have already used a considerable share of the remaining carbon budget.[406]

Table X: Carbon Budget Estimates from IPCC AR6[407]

Table SPM.2 | Estimates of historical carbon dioxide (CO_2) emissions and remaining carbon budgets. Estimated remaining carbon budgets are calculated from the beginning of 2020 and extend until global net zero CO_2 emissions are reached. They refer to CO_2 emissions, while accounting for the global warming effect of non-CO_2 emissions. Global warming in this table refers to human-induced global surface temperature increase, which excludes the impact of natural variability on global temperatures in individual years.
{Table 3.1, 5.5.1, 5.5.2, Box 5.2, Table 5.1, Table 5.7, Table 5.8, Table TS.3}

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

[a] Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8.

[b] This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (±550 $GtCO_2$) and non-CO_2 forcing and response (±220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (±420 $GtCO_2$) are separate.

[c] Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

The IPCC analysis focuses on the remaining CO_2 budget, but efforts have been made to develop budgets for CH_4, N_2O, and other short-lived climate forcers as well.[408] As noted in the discussion of methodologies above, assumptions about historical and future emissions of non-CO_2 GHGs play an important role in shaping the budget analysis for CO_2.

[406] These figures are based on central estimates of the total carbon budget at the 67% probability level (2790 $GtCO_2$ 3540 $GtCO_2$ for 2°C). See Table X for reference data.
[407] Source: IPCC AR6 WGI at 29, Table SPM.2.
[408] Much of the current research on non-CO_2 budgets focuses on tallying up the sources and sinks of non-CO_2 emissions, rather than estimating "remaining" budgets that can be used. But this information is integral to determining the quantity of both CO_2 and non-CO_2 emissions that can be released without exceeding various temperature targets. *See, e.g.,* Global Carbon Project, *supra* note X; Marielle Saunois et al., *The Global Methane Budget 2000-2017*, 12(3) Earth System Science Data 1561 (2020); CSIRO, *Global Methane Budget*, https://www.csiro.au/en/research/environmental-impacts/emissions/global-greenhouse-gas-budgets/global-methane-budget. IPCC AR6 WGI, Ch. 5 ("Global Carbon and Other Biogeochemical Cycles and Feedbacks"); Ch. 6 ("Short-Lived Climate Forcers").

IPCC AR6 also examines emission trajectories and reduction pathways in reference to temperature targets and carbon budgets. One key finding is that the modelled pathways consistent with the continuation of *existing* policies would lead to global warming of 3.2 [2.2-3.5] °C (*medium confidence*).[409] It is possible that existing policies could result in warming at or above 4°C if climate sensitivity or carbon cycle feedbacks are larger than the best estimate (*high confidence*).[410] Based on its analysis of current policies and emission trajectories, IPCC AR6 concludes that "[d]eep, rapid and sustained GHG emissions reductions, reaching net zero CO_2 emissions and including strong emissions reductions of other GHGs, in particular CH4, are necessary to limit warming to 1.5°C (>50%) or less than 2°C (>67%) by the end of century (*high confidence*)."[411] This will need to include deep reductions in energy system CO_2 and GHG emissions (*high confidence*), which will in turn require "substantial energy system changes over the next 30 years" resulting in reduced fossil fuel consumption and increased production from low- and zero-emitting sources.[412]

Another important finding is that projected cumulative CO_2 emissions over the lifetime of existing fossil fuel infrastructure are expected to exceed the total cumulative net CO_2 emissions for limiting warming to 1.5°C, and that they are approximately equal to the total cumulative net CO_2 emissions for limiting warming to 2°C with a likelihood of 83%."[413] This means that there will inevitably be stranded fossil fuel assets if warming is limited to 2°C. In addition to some physical infrastructure, approximately 80% of coal, 50% of gas, and 30% of oil reserves cannot be burned and emitted if warming is limited to 2°C, and significantly more reserves are expected to remain unburned if warming is limited to 1.5°C (*high confidence*).[414] The economic impacts of stranded assets could amount to trillions of dollars.[415] These figures could change through additional abatement – for example, the installation of carbon capture systems at power plants and industrial facilities – but current deployment of such systems is extremely limited.

The IPCC analysis is supplemented by the United Nations Environment Programme (UNEP) "Production Gap" reports, which examine the discrepancy between planned fossil fuel production and global production levels consistent with limiting warming to 1.5 or 2°C. The 2021 report found that fossil fuel producers are planning to extract more than double the amount of oil, gas, and coal by 2030 than is consistent with limiting warming to 1.5°C.[416]

---

[409] (IPCC AR6 Synthesis Report at 33 – cite final version when available)
[410] *Id.*
[411] *Id.*
[412] IPCC AR6 WGIII at 89.
[413] IPCC AR6 SYN at 24 – cite final version when available)
[414] *Id.*
[415] IPCC AR6 WGIII at 698.
[416] https://www.unep.org/resources/report/production-gap-report-2021

IV. Judicial Engagement With Climate Science

The U.S. has seen considerable growth in the field of "climate litigation", i.e., cases that involve legal claims related to climate change mitigation, adaptation, compensation, and disclosures.[417] Many of these lawsuits implicate questions related to climate science. This section provides an overview of the types of climate cases that are being filed in U.S. courts, particularly federal courts, and describes how different areas of climate science may factor into judicial assessments of causation, foreseeability, and legal obligations and authorities. It also discusses some considerations that are relevant when evaluating the admissibility, probative value, and weight of scientific evidence and expert testimony on matters related to climate change.

There are several overarching points that should be noted at the outset of this discussion. The U.S. Supreme Court and other courts have acknowledged the~~at~~ fundamental scientific reality of anthropogenic climate change, and have cited the IPCC as an authoritative and credible source of climate science.[418] Thus, scientific disputes in climate litigation do not focus on *whether* climate change is occurring, but rather they deal with specific questions of causation, foreseeability, and responsibility – such as whether and to what extent climate change poses a risk to a particular species or natural resource under federal jurisdiction, whether the federal government has a legal obligation to control GHG emissions from a particular source category, and whether a particular emitter is liable for specific injuries that have occurred as a result of climate change.

A. Overview of Climate Litigation

Many different types of climate-related claims have been filed in state and federal courts over the past several decades. Most of the claims filed in federal courts involve questions about the federal government's obligations or authorities with respect to climate change mitigation, adaptation, and disclosures, as detailed below.

First, there are legal disputes about the scope of **federal government obligations or authorities to regulate GHG emissions** (i.e., mitigation). This category includes constitutional claims alleging that the government has violated fundamental rights due to inadequate control of GHG emissions (these are sometimes called "atmospheric trust" cases, as the public trust doctrine is typically invoked alongside substantive due process). It also includes administrative lawsuits seeking regulatory action for GHG emissions pursuant to the Clean Air Act (CAA) or other federal

[417] "Mitigation" refers to actions to reduce greenhouse gas emissions and other anthropogenic drivers of climate change. "Adaptation" refers to actions to prepare for and respond to the effects of climate change on human and natural systems. "Compensation" refers to payments or other resources given to people who have experienced loss and damage as a result of anthropogenic climate change. "Disclosures" refer to the analysis and disclosure of information related to climate change (particularly climate change-related risks) in government and corporate documents such as environmental impact statements and financial reports.

[418] *See, e.g.,* Massachusetts v. E.P.A., 549 U.S. 497 (2007); Coalition for Responsible Regulation v. EPA, 684 F.3d 102 (D.C. Cir. 2012); Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1189 (9th Cir. 2008); Dine Citizens Against Ruining Our Env't v. Haaland, 59 F.4th 1016 (10th Cir. 2023). *See also* Maria L. Banda, *Climate Science and the Courts: A Review of U.S. and International Judicial Pronouncements,* ENVIRONMENTAL LAW INSTITUTE (2020).

CJP0005526

statutes, as well as lawsuits where federal agencies are defending GHG regulations against industry and/or state challenges.

Second, many lawsuits filed against the federal government involve questions about **procedural obligations to account for and disclose climate change-related considerations in administrative decision-making.** These typically take the form of Administrative Procedure Act (APA) and National Environmental Policy Act (NEPA) claims alleging that federal agencies have not adequately accounted for climate change-related considerations in administrative documentation prior to undertaking final agency action. Cases in this category may focus on agency obligations to account for GHG emissions from administrative actions, such as the emissions attributable to fossil fuel leases and natural gas pipelines. They may also focus on agency obligations to account for the effects of climate change on the action and its affected environment – for example, a lawsuit may argue that an agency is obliged to account for observed and predicted hydrological changes in its assessment of a water management project.

Third, there are some cases that deal with the federal government's **substantive obligations or authorities to prepare for and respond to the effects of climate change on resources or matters under its jurisdiction** (i.e., adaptation). For example, there have been hundreds of Endangered Species Act (ESA) cases that involve climate science-related claims. These include cases where plaintiffs are trying to compel the federal government to issue protections for climate change-imperiled species (e.g., a listing decision for the polar bear), as well as cases where the government is defending ESA protections for climate change-imperiled species against legal challenges. There are other contexts where federal agencies have substantive obligations to prepare for and respond to climate change impacts – for example, when publishing land management plans, when establishing quotas for the sustainable use of resources, and when making decisions about federal infrastructure that may be affected by climate change. To date, most lawsuits implicating federal adaptation obligations have focused on procedural obligations rather than substantive obligations,[419] but federal courts may see an increasing number of these adaptation-related claims as the effects of climate change become more manifest.

There has also been a recent uptick in predominantly state law **cases against corporate actors**, particularly fossil fuel companies. ~~Many~~ Approximately two dozen cases have been filed in state

Commented [MB60]: Jessica - SCOTUS denied cert in these cases today, meaning they will all proceed in state court. Up to you to decide how to proceed with that information, but it now seems highly unlikely that federal judges will be addressing issues of causation in these cases.

Commented [JW61R60]: I want to mention these types of cases because: (i) there is the one RICO claim in federal court, and (ii) the committee noted that state law judges may also read this manual. It could even be a resource for judges in other jurisdictions.

But I've tried to de-emphasize this type of litigation in the Chapter. I'll see if further edits are needed below.

[419] For adaptation-oriented claims involving public lands management, sustainable use quotas, and resource conservation. the focus on procedural (NEPA) claims is likely due to the difficulty of pursing substantive claims following *Norton v. Southern Utah Wilderness Alliance*, 542 U.S. 55, 69 (2004) and *Lujan v. National Wildlife Federation,* 497 U.S. 871 (1990), both of which substantially narrowed opportunities for judicial review of public lands and resource management decisions. *See* Michael C. Blumm & Sherry L. Bosse, *Norton v. SUWA and the Unraveling of Federal Public Land Planning*, 18 DUKE ENVIRONMENTAL LAW & POLICY FORUM 105 (2007). As for adaptation-oriented claims involving other types of agency action: there simply have not been many such cases filed to date. But there is a reasonable probability that more adaptation-oriented lawsuits will be filed as the effects of climate change become more severe and pervasive. For more on this topic, see Jacob Elkin, *Climate Science in Adaptation Litigation in the U.S.* (Sabin Center for Climate Change Law 2022). For an example of a lawsuit involving a substantive adaptation-oriented claim against a federal agency, see Sound Action v. U.S. Army Corps of Engineers, No. C18-0733JLR, 2019 WL 446614 (W.D. Wash Feb. 5, 2019) (plaintiffs challenged the U.S. Army Corps of Engineers' jurisdiction determination for shoreline armoring projects because the Corps did not use high tide data that reflected ongoing sea level rise; a district court denied the Corps' motion to dismiss, and the Corps subsequently settled with plaintiffs).

court by municipal and state governments seeking either compensation for climate damages or changes in corporate conduct. These lawsuits allege that the companies have violated tort and consumer protection laws by intentionally deceiving the public about climate change so that they could continue profiting from the sale and use of fossil fuels. ~~Almost all Most of the current cases seeking to impose liability on corporate actors for climate contributions are based on state law theories, but~~Federal judges are unlikely to encounter similar lawsuits, but t~~at the time of this writing, t~~here is at least one corporate lawsuit based on federal law claims ~~that is still~~ active at the time of this writing.[420] Corporate actors may also be sued for the "failure to adapt" to climate change (e.g., the failure to prepare a coastal facility that stores hazardous substances for the effects of sea level rise and more severe storms),[421] or the "failure to disclose" known climate risks (e.g., in federal securities filings).[422] At this time, adaptation and disclosure-oriented claims against corporate actors are still relatively rare in the U.S., but as with the federal government adaptation claims, these types of lawsuits may become more common as the effects of climate change become more severe.

Formatted: Underline color: Auto

B. Legal Applications of Climate Science

As noted in the introduction, there are several ways in which climate science may factor into the resolution of such lawsuits. First, climate science ~~is often~~may be used to support claims of **causation** – specifically, claims that emissions from a particular defendant or activity contributes, has contributed or will contribute to climate change-related harms. Such causation questions ~~typically~~ may arise in cases where plaintiffs are seeking to establish legal obligations on the part of defendants to either control GHG emissions, provide compensation for climate change-related damages, or analyze and disclose the GHG emissions associated with their activities (as may be required in the context of a NEPA review).[423] Second, climate science ~~is often~~may be used to establish that climate-related risks or harms were **foreseeable.** Claims related to foreseeability may arise in cases involving climate disclosures, substantive obligations to control GHG emissions or provide compensation for climate change damages, and in cases involving obligations to respond or adapt to the effects of climate change. Finally, climate science ~~is often~~may be used to support claims about the scope of a defendant's **legal obligations** with regards to GHG mitigation, adaptation, or compensation for climate damages.

---

[420] Municipalities of Puerto Rico v. Exxon Mobil Corp., No. 3:22-cv-01550 (D.P.R. 2022).

[421] *See, e.g.*, ExxonMobil Complaint for Declaratory and Injunctive Relief and Civil Penalties at para 170; Conservation Law Found. v. Exxon Mobil Corp., No. 1:16-cv-11950 (D. Mass. Sep. 9, 2016); Complaint and Jury Demand, Conservation Law Foundation, Inc. v. Shell Oil Products US, No. 1:17-cv-00396 (D.R.I. Aug. 28, 2017). *See also* Jennifer Klein, *Potential Liability of Governments for Failure to Prepare for Climate Change*, Sabin Center for Climate Change Law (2015); Jacqueline Peel & Hari M. Osofsky, *Sue to Adapt?,* 99 MINNESOTA LAW REVIEW 2177, 2193–95 (2015).

[422] *See* Mark Latham, *Environmental Liabilities and the Federal Securities Laws: A Proposal for Improved Disclosure of Climate Change-Related Risks*, 39 ENVTL. L. 647, 680 (2009).

[423] Note that cases seeking monetary compensation for contributions to climate change are still quite rare, and the vast majority of U.S. cases involve state law claims. In contrast, climate disclosure cases are quite common in U.S. federal courts – these typically take the form of NEPA lawsuits against federal agencies.

1. Causation

~~Many~~ Some climate cases involve the question of whether a defendant has breached its legal obligations by causing or contributing to climate change-related harms. This issue arises in lawsuits seeking government regulation of GHG emissions, lawsuits challenging the failure to analyze and disclose GHG emissions in NEPA reviews and other planning contexts, ~~as well as~~and lawsuits seeking to impose liability in corporations for their contributions to climate change. For example, plaintiffs may argue that a government defendant has breached its statutory or constitutional duties as a result of regulatory inaction or affirmative policies (e.g., fossil fuel subsidies) causing GHG emissions that endanger public health and welfare. Causation may also be an issue in cases where the government is defending GHG regulations against legal challenges, insofar as it may be necessary to demonstrate that those emissions cause some form of environmental or public harm in order to justify the regulatory action. Finally, the issue of causation tends to be a major element of the standing analysis across these different types of lawsuits.

As discussed in Parts II and III, it is an established fact that human GHG emissions are causing global climate change. Thus, causation disputes in climate litigation typically deal with ~~the~~ one or both ends of the causation chain linking emissions to impacts (i.e., questions of source attribution and impact attribution). The "source attribution" questions pertain to the defendant's contribution to climate change – e.g., what are the emissions attributable to the defendant's conduct, and do those emissions surpass a threshold of materiality or substantiality as may be necessary to establish legal causation? The "impact attribution" questions pertain to the nature of the alleged harm – e.g., has the plaintiff experienced a specific and concrete injury that is attributable to climate change? These two sets of questions combine into the overarching question of whether the defendant is responsible for the climate change-related harms that are at issue in the case.

The contours of this analysis will differ depending on the nature of the claim and the status of the litigants. One important consideration is whether the case requires a showing of particularized injury as opposed to generalized harm. A showing of particularized injury is required for standing. Specifically, for Article III standing, plaintiffs must demonstrate that: (i) they have experienced an injury-in-fact that is concrete and particularized, and actual or imminent, not conjectural or hypothetical; (ii) the injury-in-fact is fairly traceable to the defendants' allegedly unlawful actions; and (iii) the injury could be redressed by a favorable court decision.[424] Plaintiffs who are suing on the basis of climate change-related injuries may be able to establish these elements by presenting evidence that they are experiencing a unique injury as a result of climate change, and that the defendant has made a substantial enough contribution to global climate change such that the injury can be fairly traced to the defendant's conduct.[425]

Commented [MB62]: In truth not many cases really fall into this category, right? I wonder if the category can be expanded to be more inclusive and include, eg, NEPA or other statutory claims over energy production and infrastructure, where the obligation is to assess, not necessarily to regulate or stop. Which is to say, I think you could lead more directly into the standing discussion in federal statutory cases, rather than leading with more of a focus on the corporate accountability cases, which are really no longer relevant to federal judges.

Commented [JW63R62]: Yes, I think "some" is probably the better description. I do think it makes sense to include the NEPA claims that involve project GHG emissions, although most of those cases have not involved detailed causation disputes, and plaintiffs have been able to establish standing on relaxed procedural grounds or by alleging harm from other deficiencies in the NEPA analysis. But causation could be a bigger issue in future NEPA claims (e.g., if plaintiffs dispute significance).

[424] Lujan v. Defs. of Wildlife, 504 U.S. 555 (1992).

[425] The second and third elements of standing (causation and redressability) are closely related, sometimes referred to as "two sides of the same coin." *See* Ctr. For Biological Diversity v. EPA, 90 F. Supp. 3d 1177, 1190 (W.D.

The Supreme Court's decision in *Massachusetts v. EPA* is illustrative.[426] The state of Massachusetts and other petitioners had filed a lawsuit challenging EPA's denial of a petition to regulate GHG emissions from motor vehicles under the Clean Air Act. One of EPA's stated rationales for declining the petition was that "a causal link between greenhouse gases and the increase in global surface air temperatures was not unequivocally established."[427] EPA also argued that the petitioners lacked standing because they could not demonstrate ap particularized injury that could be fairly traced to its decision not regulate GHG emissions from motor vehicles. However, the Supreme Court disagreed, finding that:

> The harms associated with climate change are serious and well recognized. The Government's own objective assessment of the relevant science and a strong consensus among qualified experts indicate that global warming threatens, inter alia, a precipitate rise in sea levels, severe and irreversible changes to natural ecosystems, a significant reduction in winter snowpack with direct and important economic consequences, and increases in the spread of disease and the ferocity of weather events. That these changes are widely shared does not minimize Massachusetts' interest in the outcome of this litigation.[428]

The Court also went on to find that Massachusetts had suffered a particularized and cognizable injury based on documentary evidence and expert testimony describing climate-related impacts such as the loss of state-owned property to rising sea levels, the added costs to deal with emergency response measures caused by more frequent intense storm surge flooding events, damage to state-owned historic, archaeological, and natural resources; and damage to state-owned facilities and infrastructure along the coast.[429] The Court held that this injury could be fairly traced to EPA's decision not to regulate based on IPCC reports, which demonstrated a clear causal nexus between GHG emissions and climate change impacts as a general matter, and emissions data showing that the unregulated source category (U.S. motor vehicles) generated approximately 1.7 billion metric tons of CO_2 in 1999 (more than 6% of worldwide emissions). The Court noted that this was a "meaningful contribution" to global emissions by any metric.[430] With regards to redressability, the Court acknowledged that Clean Air Act regulation would not fully mitigate the problem, but the prospect of partial redress was all that was required for Article III standing.[431]

Wash. 2015); Gonzales v. Gorsuch, 688 F.2d 1263, 1267 (9th Cir. 1982); Duke Power Co. v. Carolina Envtl. Study Grp., 438 U.S. 59, 74 (1978). Thus. If plaintiffs establish that their injury can be "fairly traced" to the defendant's conduct, then there is a reasonable prospect that a court order which compels a change in that conduct will at least partially mitigate the injury. However, if the court does not have the authority to issue a remedy, then it may find that plaintiffs lack standing based on this third element. *See infra* § XX ("Legal Obligations and Authorities").

[426] Massachusetts v. E.P.A., 549 U.S. 497 (2007).
[427] *Id.* at 497.
[428] *Id.* at 499.
[429] The Court noted that Massachusetts had a "special position and interest" in the case, in part because "it actually owns a great deal of the territory alleged to be affected" by climate change, and in part because of its status as a sovereign state. *Id.* at 520-523. The Court referred to data in the petitioners' affidavits showing that "global sea levels rose between 10 and 20 centimeters over the 20th century as a result of global warming and have already begun to swallow Massachusetts' coastal land" and that "[r]emediation costs alone . . . could reach hundreds of millions of dollars." *Id.* at 521-23.
[430] *Id.* at 525.
[431] *Id.* at 525-26.

Formatted: Normal (Web)

Turning to the merits of the lawsuit, the Court held that GHG emissions qualified as "air pollutants" within the meaning of the Clean Air Act, and that EPA had an obligation to regulate those emissions unless it "determine[d] that greenhouse gases do not contribute to climate change" or otherwise provided "some reasonable explanation as to why it cannot or will nto exercise its discretion to determine whether they do."[432] Although the Court remanded to EPA to make its own determination on these issues, the Court's own decision contained ample information indicating that those GHG emissions did endanger public health and welfare (e.g., the Court's assertion that the "harms associated with climate change are serious and well recognized" and the Court's finding that GHG emissions from motor vehicles qualified as a meaningful contribution to global climate change). As discussed below, EPA did issue an affirmative endangerment finding for GHG emissions from this source category shortly after the Court issued this judgment.

Since *Massachusetts v. EPA* was decided, other courts have grappled with the question of what constitutes a "meaningful" GHG contribution for standing purposes. There is no clear standard for defining this threshold. Some decisions have cast doubt on whether the GHG impacts of smaller regulatory decisions are sufficiently large to establish standing.[433] Other courts have held that questions about GHG contributions and causation are factual inquiries so closely linked to the merits of plaintiffs' claims that they should be addressed at trial rather than during the threshold standing stage of litigation.[434] Indeed, this question of whether emissions are a legally cognizable cause of harm is directly relevant to the merits of cases involving legal disputes about government or corporate responsibility for GHG emissions and climate change-related harms.[435] The threshold of legal relevance will presumably depend on the legal standard applied in the case.[436] Attribution research and predictive research can provide technical insights to help answer this question, including insights on the scope and magnitude of impacts that could be attributed to those emissions. However, the question of legal relevance or significance is ultimately a legal determination.

---

[432] *Id.* at 501 ("EPA can avoid promulgating regulations only if it determines that greenhouse gases do not contribute to climate change or if it provides some reasonable explanation as to why it cannot or will not exercise its discretion to determine whether they do.")

[433] See, e.g., Wash. Envtl. Council v. Bellon, 732 F.3d 1131, 1135 (9th Cir. 2013) (emissions from Washington power plants amounting to 6% of state's total GHG emissions not a "meaningful contribution" to climate change), reh'g en banc denied, 741 F.3d 1075 (9th Cir. 2014); Amigos Bravos v. U.S. Bureau of Land Mgmt., 816 F. Supp. 2d 1118, 1136 (D.N.M. 2011) (254,730 metric tons of GHGs per year that might result from the approval of 92 oil and gas leases were not a "meaningful contribution" to global climate change).

[434] See, e.g., Comer v. Murphy Oil USA, 585 F.3d 855, 864 (5th Cir. 2009); Juliana v. United States, 339 F. Supp. 3d 1062, 1096 (D. Or. 2018).

[435] For a more detailed discussion of these causation questions in both government and corporate litigation, see Burger et al., (2020), *supra note* X, at 153-215.

[436] For example, in tort and consumer protection filed against fossil fuel companies, it is often necessary for plaintiffs to demonstrate that the defendants have made a "substantial contribution" to their injury (and the meaning of this term differs depending on the jurisdiction). For ~~CAA~~ Clean Air Act litigation, EPA has a legal obligation to regulate GHG emissions from source categories if those emissions will "cause or contribute" to the endangerment of public health and welfare. These vague textual standards have been fleshed out, to some extent, through litigation – but as with standing, there are no firm quantitative thresholds for such standards, and these are ultimately subjective, case-specific determinations.

Courts also continue to confront questions about whether plaintiffs' injuries can be fairly traced to global climate change. The evidence required to demonstrate such causation depends on the type of injury and the scope of the plaintiff's affected interests. Attribution data tend to be more robust for impacts at a broader spatial and temporal scale, and for certain types of impacts (e.g., heat-related impacts). A plaintiff like the state of Massachusetts will experience many climate impacts at a relatively broad spatial scale, and there is a high probability that at least some of those injuries can be attributed to climate change with reasonable confidence. This is also true for many cities and communities – the breadth of local interests affected by climate change can be quite large, and some communities are directly exposed to trends and events that have been attributed to climate change with high confidence.[437] It is potentially more difficult to downscale impact attribution claims to the level of individual injury, but this really depends on the specific injury at issue.[438]

These types of impact attribution questions tend to be less prominent in cases where litigants do not need to demonstrate particularized harm as a result of climate change. For example, in order to defend a Clean Air Act endangerment finding for GHG emissions from a source category, EPA need only show that the emissions from the source category "cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health or welfare."[439] The findings from scientific bodies like the IPCC and USGCRP provide ample support for this sort of generalized endangerment finding.[440]

For example, when EPA issued an endangerment finding for GHG emissions from motor vehicles, it specifically relied on IPCC, USGCRP, and NRC reports to establish a causal link between those emissions and public endangerment.[441] In *Coalition for Responsible Regulation v. EPA*, the D.C. Circuit Court of Appeals held that EPA's reliance on these external studies was entirely proper, and that the endangerment finding was supported by a "substantial" body of

---

[437] For example, many communities are already experiencing frequent floods and inundation as a result of sea level rise. William Sweet et al., *Sea Level Rise and Nuisance Flood Frequency Changes around the United States*, NOAA Technical Report NOS CO-OPS 073 (2014); Kristina A. Dahl et al., *Effective Inundation of Continental United States Communities with 21st Century Sea Level Rise,* 5 Elementa: Science of the Anthropocene 37 (2017). Many communities have also been adversely affected by extreme events that were likely exacerbated by climate change, such as Hurricane Harvey. *See* Wehner & Sampson (2021), *supra* note X.

[438] The case of *Juliana v. US* provides an example of how attribution research can factor into standing disputes as well as the merits of cases involving government obligations and individual rights. For a detailed discussion of that case, see Burger et al. (2020), *supra* note X, at 164-166. *See also* Jessica Wentz, *Climate Science and Litigation,* Ch. 10 in Edward Elgar Research Handbook on Climate Change Litigation (forthcoming 2023) (cite final version when available).

[439] CAA § 202(a)(1); 42 U.S.C. 7521(a)(1).

[440] Another example would be NEPA lawsuits where plaintiffs are seeking to compel federal agencies to account for GHG impacts from federal actions. Plaintiffs do not need to prove that GHG emissions from a federal action will cause them specific harm in order to establish that the federal government has an obligation to analyze and disclose those emissions under NEPA. Granted, plaintiffs must still have standing to sue – but causation requirements are relaxed for procedural claims under NEPA, and plaintiffs can also establish standing on the basis of injuries flowing from other deficiencies in the NEPA documentation. *See* Jessica Wentz, *Environmental Impact Assessment* in GLOBAL CLIMATE CHANGE AND U.S. LAW, 3rd Ed. (Michael B. Gerrard, Jody Freeman, Michael Burger, eds., 2022).

[441] Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66,495, 66,510-11 (Dec. 15, 2009).

evidence amassed through decades of scientific research on climate change.[442] The court specifically confronted arguments that there was "too much uncertainty" about the science underpinning climate change, and that EPA had improperly "delegated" its judgment to the IPCC, USGCRP, and NRC by relying on those assessments of climate science.[443] The Court disagreed on both counts. In upholding EPA's reliance on the external studies, it noted that these "peer reviewed assessments synthesized thousands of individual studies on various aspects of greenhouse gases and climate change" and that EPA was "not required to re-prove the existence of the atom every time it approaches a scientific question."[444] The court also specifically rejected petitioners' argument that EPA could not rely on IPCC assessments because some of the studies referenced therein were not peer reviewed – it noted that the IPCC assessment relied on approximately 18,000 studies that *were* peer reviewed, and petitioners had not "uncovered a 'pattern' of flawed science" in the assessments which undermined the endangerment finding.[445] On the more general issue of whether there was too much uncertainty about climate change impacts to justify the endangerment finding, the Court found that EPA had supported its determination through three key lines of evidence: (i) "basic physical understanding" of the greenhouse effect, (ii) observational evidence of past climate change, and (iii) models predicting how the climate will respond to GHG concentrations in the future.[446]

Arguably the greatest attribution challenge in climate litigation is that of quantifying harm in cases seeking monetary damages based on defendants' contributions to climate change. In these cases, plaintiffs may use adaptation costs as a proxy for climate-related damages, but there are questions about how to calculate those costs and attribute them to specific defendants. Attribution researchers have begun to unpack some of the challenges associated with quantifying damages attribute to specific emissions or emitters, and some of the source attribution research discussed in Part III does address this challenge. However, it remains to be determined how courts will handle such damages claims. It is also important to recognize that claims for monetary compensation are still relatively rare in U.S. climate litigation, and at the time of this writing, there is only one active federal case that is seeking monetary compensation (specifically, a racketing lawsuit filed by Puerto Rican municipalities against Exxon Mobil and other fossil fuel companies).[447]

2. Foreseeability

There are many different types of climate cases that implicate questions about the foreseeability of climate change impacts. For example, in cases involving climate change disclosures and adaptation obligations, the core factual dispute typically centers on whether or not impacts are foreseeable as this as this bears on whether the defendant has an obligation to analyze and disclose those impacts (e.g., in NEPA documentation) or take substantive measures to prepare for and respond to those impacts. Foreseeability is also an issue in some cases involving

[442] Coalition for Responsible Regulation v. EPA, 684 F.3d 102, 120 (D.C. Cir. 2012).
[443] *Id.* at 119-121.
[444] *Id.* at 120.
[445] *Id.* at 125.
[446] *Id.* at 120-21.
[447] Municipalities of Puerto Rico v. Exxon Mobil Corp., No. 3:22-cv-01550 (D.P.R. 2022).

substantive obligations related to GHG mitigation and climate compensation~~ – for example, it is a core element in lawsuits alleging that corporate actors contributed to climate change by intentionally misleading the public about climate science and the potential harms of products such as fossil fuels~~. Finally, questions about foreseeability are to some extent embedded in the causation analysis described above (particularly where plaintiffs are seeking to establish standing based on an "imminent" injury).

Commented [MB64]: Again, just seeking to minimize the emphasis on these cases.

Both attribution research and predictive research can be used to demonstrate the foreseeability of climate change impacts. Attribution research provides insights on the trends and impacts that are already occurring a result of anthropogenic climate change, which in turn supports determinations that such trends and impacts are not hypothetical or speculative. Predictive research provides insights on the future trajectory of those trends and impacts under different emissions and warming scenarios. Courts can refer to scientific assessments of confidence and likelihood when evaluating whether specific trends and impacts are foreseeable as opposed to speculative or hypothetical. There may also be contexts where litigants need to demonstrate that GHG emissions are reasonably foreseeable, in which case source attribution data is most relevant.

Some of the most detailed scientific disputes involving the foreseeability of climate impacts have arisen in the context of Endangered Species Act (ESA) litigation.[448] Many of the ESA cases address how federal agencies should deal with scientific uncertainty when evaluating the foreseeability and likelihood of specific trends and impacts that may pose a threat to a species (e.g., warmer ocean temperatures, the loss of Arctic sea ice, declines in food sources). Although courts are generally deferential to agency conclusions about scientific uncertainty, an agency cannot simply ignore climate change-related threats on the basis of uncertainty or imprecision – the agency must formulate a rationale finding about the probability of threats, taking into account the "best scientific evidence", including available climate research.[449]

There are also cases where parties may dispute the foreseeability of GHG emissions. Such disputes may arise, for example, in the context of NEPA litigation where plaintiffs are seeking disclosure of emissions from federal actions, and in the context of lawsuits involving corporate climate disclosures. In this context, courts can refer to source attribution data to determine whether a defendant has failed to disclose reasonably foreseeable emissions.

3. Legal Obligations and Authorities

Climate science can also inform judicial determinations about the scope of a defendant's legal obligations and/or authorities with regards to climate change mitigation, adaptation, disclosures, or compensation. For example, outside of the U.S., courts have relied on a combination of attribution research, predictive research, and carbon budgeting analyses to establish GHG

[448] *See* Jessica Wentz, *Climate Change Attribution Science and the Endangered Species Act,* 39 Yale Journal on Regulation 1043 (2022); Daniel Kim et al., *Judicial Review of Scientific Uncertainty in Climate Change Lawsuits: Deferential and Nondeferential Evaluation of Agency Factual and Policy Determinations*, 46 Harvard Environmental Law Review 367 (2022).

[449] *See, e.g.,* Greater Yellowstone Coalition, Inc. v. Servheen, 665 F.3d 1015 (9th Cir. 2011); Defenders of Wildlife v. Jewell, 176 F.Supp. 3d 975 (D. Mont. 2016). *See also* Wentz (2022), *supra* note X; Kim et al., *supra* note X.

reduction obligations for national governments and, in one recent case, a corporate entity.[450] However, all of these decisions have been issued in countries that have incorporated human rights into their domestic legal systems, and federal courts in the U.S. have generally refrained from adjudicating comparable rights-based claims.[451]

To the extent that federal courts have weighed in on government obligations and authorities to control GHG emissions, it has been in the context of statutory claims, primarily those brought under the Clean Air Act. Indeed, most federal climate cases involve statutory and administrative law claims where the judiciary is tasked with reviewing whether an agency has acted in a manner that is arbitrary or capricious, an abuse of discretion, or contrary to the law. In this context, climate science provides insights on: (i) the scope of scientific evidence that must be considered by the agency before it decides on a course of action, and (ii) whether the agency has made a rational decision based on that evidence.

As described in the discussion of "causation" above, attribution research can play a role in cases involving statutory obligations to regulate GHG emissions, particularly where courts are tasked with evaluating whether the emissions from a source category will cause or contribute to public or environmental harm. Courts may also encounter legal disputes that involve performance- and technology-based pollution control requirements, such as the Clean Air Act's mandate that EPA adopt regulations for existing air pollution sources that reflect the "best system of emission reduction" for a pollutant. In that context, research on GHG mitigation pathways and technologies is particularly relevant for establishing obligations, as it can provide insights on matters such as the feasibility, cost, and efficacy of different emission reduction approaches.

Courts will also continue to encounter legal disputes about the scope of agency obligations to account for climate change science in other administrative contexts. Many of these lawsuits involve NEPA claims, which cover a wide array of different types of federal actions. Courts have consistently held that agencies have an obligation to account for the contribution of federal actions to global climate change (typically be quantifying and disclosing GHG emissions).[452] Agencies also have an obligation to analyze the effects of climate change on the proposed action and its affected environment, insofar as these effects are foreseeable and relevant to assessing the

[450] *See, e.g.,* Neubauer, et al. v. Germany, Bundesverfassungsgericht [BVerfG] [Federal Constitutional Court], Mar. 24, 2021, Case No. BvR 2656/18/1, BvR 78/20/1, BvR 96/20/1, BvR 288/20; *Urgenda Foundation v. The State of The Netherlands* [2019] ECLI:NL:HR:2019:2006; Milieudefensie v. Royal Dutch Shell [2021] ECLI:NL:RBDHA:2021:5337.

[451] A number of rights-based claims have been filed against federal and state governments in the U.S., but to date, none of these claims have made it to a full trial. The federal constitutional claims have generally been dismissed based on separation of powers concerns – i.e., courts believe that a judicial remedy for such claims (ordering GHG reductions) is beyond the scope of their authority. Courts may characterize the case as raising a non-justiciable "political question" or they may find that plaintiffs lack standing due to the absence of a judicial remedy, but the separation of powers doctrine is at the heart of these determinations. *See, e.g.,* Juliana v. U.S., 947 F.3d 1159 (9th Cir. 2020); Animal Legal Def. Fund v. United States, 404 F. Supp. 3d 1294, 1300 (D. Or. 2019).

[452] Jessica Wentz, *Environmental Impact Assessment,* Ch. 6 in GLOBAL CLIMATE CHANGE AND U.S. LAW (Michael B. Gerrard et al. eds., ABA 2023). *See also* Michael Burger and Jessica Wentz, *Evaluating the Effects of Fossil Fuel Supply Projects on Greenhouse Gas Emissions and Climate Change Under NEPA*, 44 WM. & MARY ENVTL. L. & POL'Y REV. 423 (2020).

environmental impacts of the action.[453] Future NEPA lawsuits may raise questions about whether agencies have issued rational findings regarding the significance of emissions from fossil fuel infrastructure, and research on source attribution, impact attribution, and carbon budgeting is potentially relevant to such claims.[454] Notably, in the NEPA context, the agency's core legal obligation is to account for foreseeable environmental effects – and thus the analysis of foreseeability and legal obligations is one and the same.

The analysis of foreseeability will also play a major role in shaping an agency's legal obligations to assess, prepare for, and respond to the effects of climate change on resources and matters under its jurisdiction. To date, most of the decisions pertaining to the federal government's use of climate science have occurred in the context of ESA litigation. Courts have consistently held that climate science qualifies as the "best available science" that must be considered when agencies are making decisions about listing determinations, critical habitat designations, and other decisions involving the management and protection of endangered and threatened species.[455] Courts have vacated and remanded many ESA actions where federal agencies have ignored relevant climate science or issued decisions that were not supported by the science.[456] Federal agencies have also relied on climate science in its defense of ESA protections for climate change-imperiled species – for example, using the science to justify listing decisions by showing that climate change-related threats to the species are reasonably foreseeable.[457] There will likely be additional legal disputes about the federal government's obligations and authorities to account for the effects of climate change in the context of natural resource management, conservation, and endangered species protection as the impacts of climate change on natural resources and ecosystems become more severe.

As discussed above, there has also been an uptick in litigation against corporate actors, and federal courts may encounter cases that raise questions about corporate obligations with respect to climate change mitigation, adaptation, disclosures, and compensation for damages. There are a number of ways in which climate science could potentially support judicial assessments of legal obligations in these contexts. For example, research on carbon budgets and GHG mitigation pathways may be relevant when determining the scope of corporate obligations with regards to

---

[453] *Id. See also* AquAlliance v. U.S. Bureau of Reclamation, 287 F.Supp.3d 969, 1023-24 (E.D. Cal. 2018) (finding that the Bureau of Reclamation had violated NEPA by failing to meaningfully assess the effects of ongoing climate change on a water management project and its environmental outcomes).

[454] For example, a court could find that it is arbitrary and capricious for a federal agency to reach a conclusion on the significance of emissions from fossil fuel infrastructure without considering recent IPCC findings on the remaining carbon budget and the proportion of fossil fuels that can be utilized without exceeding temperature targets.

[455] *See* Wentz (2022), *supra* note X. *See also* Alejandro E. Camacho, *Endangered Species Act*, Ch. 8 in GLOBAL CLIMATE CHANGE AND U.S. LAW (Michael B. Gerrard et al. eds., ABA 2023) (discussing the federal government's treatment of climate change-related considerations across different types of ESA actions).

[456] *See, e.g.,* Greater Yellowstone Coalition, Inc. v. Servheen, 665 F.3d 1015 (9th Cir. 2011); Defenders of Wildlife v. Jewell, 176 F.Supp. 3d 975 (D. Mont. 2016); Nat. Res. Def. Council v. Kempthorne, 506 F. Supp. 2d 322 (E.D. Cal. 2007); Pac. Coast Fed'n Fishermen's Ass'ns v. Gutierrez, 606 F. Supp. 2d 1122, 1184 (E.D. Cal. 2008); South Yuba River Citizens League v. NMFS, 723 F. Supp. 2d 1247, 1274 (E.D. Cal. 2010); Ctr. for Biological Diversity v. Salazar, 804 F. Supp. 2d 987, 1008 (D. Ariz. 2011).

[457] *See, e.g., In re Polar Bear Endangered Species Act Listing & 4(d) Rule Litig.*, 794 F. Supp. 2d, *aff'd sub nom. In re* Polar Bear Endangered Species Act Listing & Section 4(d) Rule Litig., 709 F.3d 1 (D.C. Cir. 2013); *Alaska Oil & Gas Ass'n*, 840 F.3d 671 (9th Cir. 2016).

GHG reductions. Source attribution data, impact attribution data, and climate ~~predictions~~ projections would relevant when assessing disclosure obligations with regards to GHG emissions and climate change impacts. Impact attribution data and climate ~~predictions~~ projections would also be relevant to assessing the scope of corporate obligations to prepare for and adapt to the effects of climate change. Finally, if courts determine that corporations are in fact liable for climate change-related injuries, they can potentially rely on source attribution data, impact attribution data, and information about adaptation costs in order to quantify damages owed to plaintiffs.

C. Engaging with Scientific Evidence and Expert Testimony

There are several key takeaways from the scientific discussion in Parts II and III that are relevant to judicial engagement with expert testimony and scientific evidence on the issue of climate change. First, climate science is not a uniquely uncertain or novel field; climate researchers rely on robust scientific methods and principles to characterize the climate system and ascertain ~~cause-and-effect~~causal relationships within that system. There is no reason to view climate science with greater skepticism than other scientific disciplines. Second, the science is clear that climate change is not a purely "future problem", although this framing is sometimes used in legal and political contexts.[458] It is already affecting human and natural systems across the planet, and many trends and impacts have been attributed to anthropogenic climate change with a high level of confidence. Third, all climatological events are taking place in the context of anthropogenic climate change, and the absence of definitive attribution findings does not mean that a particular trend, event, or impact has not been influenced by anthropogenic forcing. There will inevitably be more robust findings related to detection and attribution as the science continues to evolve and the impacts of climate change become more apparent. Indeed, with each new IPCC assessment, there is greater scientific confidence in both the attribution of observed trends and ~~predictions~~ projections of future trends. Finally, "uncertainty" with regards to climate science goes in both directions: the consequences of anthropogenic climate change could be more or less severe than predicted. Thus, it should not be assumed that uncertainty justifies inaction on climate change – the role of uncertainty when assessing legal obligations will depend on the type of claim.[459]

It is also important to keep in mind that different standards of evidence often apply in scientific studies and court cases.[460] For example, when courts assess causation in civil litigation, they often look at whether a particular outcome was "more likely than not" caused by the defendant's conduct (i.e., a greater than 50% probability). In contrast, climate studies typically present findings at 90%, 95%, or 99% confidence levels, consistent with general scientific practice. These confidence levels reflect the probability that the true value of a parameter falls within a specified range (the "confidence interval") in the study.[461] The IPCC reports take a broader approach, presenting

Commented [MB65]: As noted elsewhere I think this needs to be said way up above.

Commented [JW66R65]: I say essentially the same thing at the end of the introduction.

I also made some updates to Part II(E) "communicating uncertainty" to reinforce this point.

[458] *See* Friederike Otto et al., *Causality and the Fate of Climate Litigation: The Role of the Social Superstructure Narrative,* 13(5) GLOBAL POLICY 736 (2022).
[459] For example, in cases where the precautionary principle applies, the fact that there is uncertainty about the risks of climate change would potentially weigh in favor of a finding of a legal duty to mitigate those risks.
[460] *See* Elisabeth A. Lloyd et al., *Climate Scientists Set the Bar of Proof Too High,* 165 CLIMATIC CHANGE 55 (2021) (discussing the mismatch between scientific and legal standards of proof).
[461] *See supra* Part II(E) ("Communicating Uncertainty").

scientific findings at a range of different levels of certainty, and using a variety of language to communicate different types of uncertainty.[462] Legal decisionmakers may find the IPCC language particularly useful insofar as it includes language describing:

- Scientific confidence in findings (e.g., very high, high, medium, low, very low)
- Probability that findings are valid (e.g., virtually certain 99-100%; very likely 90-100%; likely 66-100%; more likely than not, >50%; about as likely as not 33-66%; unlikely 0-33%; very unlikely 0-10%; and exceptionally unlikely, 0-1%)
- Availability of evidence for findings (e.g., robust, medium, limited)
- Level of agreement in findings (e.g., high, medium, low)

The confidence statements in IPCC assessments are based on both the level of agreement and availability of evidence for the finding.[463] As illustrated in Part III, the IPCC has found that many impacts and trends can be attributed to anthropogenic climate change with high confidence and at a high probability.

Another important takeaway from this Chapter is there are many credible and authoritative organizations involved in the assessment, synthesis, and dissemination of climate research, including but not limited to the IPCC. Judges can and should defer to the expert judgment of these organizations, thus avoiding a "battle of the experts" with respect to scientific claims that clearly fall within the purview of these expert climate assessments. Nonetheless, expert witnesses still play an important role in communicating and interpreting scientific evidence in climate litigation. Part of this role may involve simply summarizing findings from the IPCC and other authoritative bodies and explaining the relevance of those findings to a particular case. Expert witnesses are also often needed to support factual claims that are beyond the scope of broad-scale climate assessments like IPCC reports – e.g., claims about the effects of climate change on a particular locale or individual. When that is the case, expert witnesses may provide testimony based on individual studies or impact assessments (including government assessments). They can also answer questions to help clarify the methods and findings from specific studies – for example, explaining why a particular timeframe or historical baseline was used in a study, or explaining the level of uncertainty inherent in a particular finding.

There are contexts where expert witnesses may use reasonable inferences to fill gaps in the scientific record. For example, an expert could draw a reasonable inference that climate change is increasing the severity of extreme heat events in a community or locale based on observational records even if there is not a targeted attribution study for those events. Such an inference would potentially be reasonable because there is such a strong causal relationship between anthropogenic climate change and more severe heat waves. As argued by Lloyd & Shepherd (2021), "proceeding from the general to the specific is a process of deduction and is an entirely legitimate form of

[462] *See supra* Part II(E). *See also* IPCC AR6 WG1 at 4.
[463] A. Kause et al., *Confidence Levels and Likelihood Terms in IPCC Reports: A Survey of Experts from Different Scientific Disciplines,* 173 CLIMATIC CHANGE 2 (2022).

scientific reasoning" and "well aligned with the concept of legal evidence."[464] Granted, the reasonableness of any such inferences will ultimately depend on factors such as the nature of the impact and the region where it located. Our point is simply that such inferences *may* be valid and potentially helpful in the absence of attribution research that deals with the precise claims being made in a case.

Disputes may arise regarding the admissibility of expert testimony in climate cases.[465] ~~As discussed in Chapter X, when such disputes arise, judges must find that the expert witness is qualified to provide testimony on the subject matter, that the witness's scientific and technical knowledge will help the trier of fact understand the subject matter, that the expert's opinion is based on sufficient facts or data, that it is the product of reliable principles and methods, and that the witness has reliability applied those principles and methods to the facts of the case.[466] The *Daubert* standard outlines criteria for assessing reliability:[467]~~

- ~~Whether the scientific theory or technique can be (and has been) tested;~~
- ~~Whether it has been subjected to peer review and publication;~~
- ~~The known potential error rate;~~
- ~~The existence and maintenance of standards controlling its operation; and~~
- ~~Whether it has a degree of "general acceptable" within a "relevant scientific community."[468]~~

~~The *Daubert* inquiry is a "flexible" one, focused solely on the principles and methodologies underlying scientific research.[469] All factors are relevant but not necessarily dispositive — for example, a judge may find that expert testimony is still admissible even if it is not based on peer-reviewed research, so long as there are other indicators of reliability.[470]~~

Formatted: Normal, Justified, Indent: First line: 0.25", Space After: 6 pt, Line spacing: Multiple 1.08 li, No bullets or numbering

Formatted: Normal

---

[464] Elisabeth A. Lloyd & Theodore G. Shepherd, *Climate Change Attribution and Legal Contexts: Evidence and the Role of Storylines,* 167 CLIMATIC CHANGE 28 (2021).

[465] As discussed in Chapter X, when such disputes arise, judges must find that the expert witness is qualified to provide testimony on the subject matter, that the witness's scientific and technical knowledge will help the trier of fact understand the subject matter, that the expert's opinion is based on sufficient facts or data, that it is the product of reliable principles and methods, and that the witness has reliability applied those principles and methods to the facts of the case. The *Daubert* standard outlines criteria for assessing reliability: (i) whether the scientific theory or technique can be (and has been) tested; (ii) whether it has been subjected to peer review and publication; (iii) the known potential error rate; (iv) the existence and maintenance of standards controlling its operation; and (v) whether it has a degree of "general acceptable" within a "relevant scientific community". Liesa L. Richter & Daniel J. Capra, *The Admissibility of Expert Testimony* [cross-reference final chapter]. See also Federal Rules of Evidence, Rule 702; Rule 104(a). *See also* Federal Rules of Evidence, Rule 702; Rule 104(a).

[466] ~~Liesa L. Richter & Daniel J. Capra, *The Admissibility of Expert Testimony* [cross-reference final chapter in manual]. See also Federal Rules of Evidence, Rule 702; Rule 104(a).~~

[467] ~~Most federal courts apply the *Daubert* standard, but some decisions still apply the older *Frye* standard, which only requires "general acceptance" within the relevant scientific community. Michael Morgenstern, Daubert v. Frye: *A State-by-State Comparison*, THE EXPERT INST. (Apr. 3, 2017),~~

[468] ~~Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579, 592-95 (1993).~~

[469] ~~Daubert at 580.~~

[470] ~~Daubert at 594.~~

Formatted: Normal (Web)

Formatted: Font: 10 pt

Most of the principles and methodologies used in climate research should satisfy the *Daubert* test, particularly where they have been accepted by the IPCC and other authoritative institutions. The techniques used in the study of climate have been tested and refined for decades, new research is typically published through peer-reviewed channels, studies are typically accompanied by information about error rates,[471] there are standards and controls to ensure the reliability of research findings, and most studies use methodologies that have been accepted by the IPCC, National Academies, and other scientific organizations. When judges are confronted with novel research techniques or studies that have not yet been synthesized in IPCC reports, they can solicit insights from expert witnesses on the underlying scientific principles and methods.[472]

There is also the question of whether the witness is qualified – this will depend on the scope of the testimony. Generally speaking, experts making claims about the physical science basis for climate change should have expertise in one or more Earth science fields such as climatology, atmospheric sciences, meteorology, hydrology, geophysical sciences, or cryosphere sciences. Experts making claims about the effects of climate change may have other types of expertise, which will depend on the type of impact(s) that they are testifying to (e.g., in economics, biology, public health, or social sciences). It may be reasonable for an expert witness with generalized knowledge on climate to testify on matters outside of their direct expertise if they are referring to findings from external scientific assessments such as the IPCC report.

[Mike and Radley: The sample chapters provided by the committee did not include conclusions, so I omitted one here as well. But I think we have the option of including one – e.g., if you think it would be useful to reiterate some points here.]

Commented [MB67]: Consider shortening this discussion. The editors noted that the chapter need not go deep into *Daubert*, and you could possibly just get directly to the final point about novelty and appropriateness.

Commented [MB68]: I think your takeaways cover it.

V. Acknowledgments

The authors would like to acknowledge the contributions of Michael Burger for his legal expertise and feedback on this chapter.

VI. Glossary

[471] As discussed above, studies often include information about Type I (false positive) and Type II (false negative) errors, as well as the p-value (the probability of obtaining results at least as extreme as the observed result, assuming that the null hypothesis is correct). A 5% p-value cut-off is commonly used to ensure the validity of results. In addition, climate studies and IPCC reports use confidence levels to communicate the likelihood that a finding is valid, and most individual studies use a high confidence level (e.g., ≥ 90%) corresponding with a low margin of error. These confidence statements may not be directly relevant to the *Daubert* inquiry insofar as they deal with the validity of findings rather than methodologies. See Daubert at 580 (the focus of the *Daubert* inquiry "must be solely on principles and methodology, not on the conclusions that they generate"). However, they are relevant when assessing the credibility and probative value of expert testimony.

[472] For example, a scientific expert can provide insights on whether a "novel" research technique actually represents a significant departure from general practices within the climate science community. In many cases, purportedly "novel" techniques are based on minor changes to (or advances in) well-established research methods.

The following terms and definitions were adapted from various sources including the Intergovernmental Panel on Climate Change (IPCC),[473] the World Meteorological Organization (WMO), the U.S. Global Change Research Program (USGCRP), and the U.S. Environmental Protection Agency (EPA).

Adaptation: The process of adjustment to actual or anticipated climate change and its effects.

Anthropogenic climate change: A change in climate which can be attributed directly or indirectly to human activity.

Anthropogenic emissions: Emissions of greenhouse gases (GHGs), precursors to GHGs, and aerosols caused by human activities. These activities include the burning of fossil fuels, deforestation, land use, and land-use changes, livestock production, fertilization, waste management, and industrial processes.

Atmosphere: The gaseous envelope surrounding the Earth, which is comprised of five layers (troposphere, stratosphere, mesosphere, thermosphere, and exosphere). The atmosphere is comprised of various gases, including water vapor and GHGs. The atmosphere is one component of the global climate system.

Attribution: The process of evaluating the relative contributions of multiple causal factors to a change or event.

Biogeochemical cycle: The biological, geological, and chemical cycling of elements such as carbon between different global systems (including living and non-living systems). The carbon cycle is an example of a biogeochemical cycle.

Biosphere: The part of the Earth system comprising all ecosystems and living organisms, including within the atmosphere, on land (terrestrial biosphere), or in oceans (marine biosphere).

Carbon budget: The amount of cumulative net global anthropogenic emissions that would result in limiting global warming to a given level within a given probability, taking into account the effect of other anthropogenic climate forcers. The carbon budget may be calculated in reference to carbon dioxide (CO_2) emissions exclusively, or in reference to combined emissions of CO2, methane (CH_4), and nitrous oxide (N_2O), and other gases.

Carbon dioxide (CO_2): A heat-trapping gas. It occurs naturally but is also a by-product of burning fossil fuels and biomass, land-use change, and industrial processes. It is the principal anthropogenic GHG that affects the Earth's radiative balance. It is the reference gas against which the potency of other GHGs is measured and therefore has a global warming potential (GWP) of 1.

Climate: The climate can be defined, alternatively, as the the state of the climate system, or the average weather conditions over a period of time ranging from months to thousands or millions of years. The World Meteorological Organization (WMO) uses a standard period of 30 years to characterize climate conditions. (See also: Climate System.)

Climate change: A change in the state of the climate (or global climate system) which can be identified by changes in the mean and/or variability of properties and that persists for an extended period, typically decades or longer. The climate system changes in time under the influence of its

[473] See: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_AnnexVII.pdf

own internal dynamics and because of external forcings such as volcanic eruptions, solar variations, orbital forcing, and anthropogenic forcings.

Climate forcer: Any substance that affects the flow of energy coming into or out of the global climate system, thus affecting the amount of heat retained within the system. Anthropogenic climate forcings include GHGs, aerosols, and changes in land use that make land reflect more or less solar energy. There are also natural climate forcings, such as solar radiation and the particulate matter from volcanic eruptions. (See also: Radiative forcing.)

Climate forcing: The net effect of various climate forcers on the flow of energy coming into or out of the global climate system.

Climate model: A qualitative or quantitative representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes. Climate models are used as research tools to study and simulate the effect of anthropogenic forcings on the climate system.

Climate projection: A simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases, aerosols, and changes in land use, generally derived using climate models.

Climate system: The global system which determines climate conditions, consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere and the interactions between them.

Confidence interval: A range of values calculated from the results of a study within which the true value is likely to fall. The range of this interval depends on the *confidence level* - e.g., if the confidence level is 95%, then there is a 95% probability that the true value of a parameter will fall within the range of values provided in the confidence interval. The size of a confidence interval provides insight on the level of precision and range of uncertainty in study results.

Confidence level: The probability that a particular value falls within a specified confidence interval.

Cryosphere: The frozen components of the Earth system, including sea ice, lake ice, river ice, snow cover, glaciers, and frozen ground. The cryosphere is part of the global climate system.

Detection: The process of demonstrating that the climate system (or a system affected by the climate system) has changed in some defined statistical sense. As per IPCC definitions, an identified change is detected in observations if its likelihood of occurrence due to internal variability alone is determined to be small, for example <10%.

Fraction of Attributable Risk: In climate change research, the fraction of attributable risk (FAR) is the ratio of a particular outcome occurring with and without human influence on climate. Mathematically speaking, FAR = 1 - P0/P1 (where P1 equals the probability of the outcome occurring in the presence of anthropogenic forcing of the climate system, and P0 equals the probability of the event occurring if the anthropogenic forcing were not present).

Global warming potential (GWP): A measurement of the radiative forcing from a unit of a given substance, accumulated over a chose time horizon, relative to that of CO_2.

Greenhouse gas (GHG): A gas that absorbs incoming solar radiation (i.e., heat) in the atmosphere, preventing it from escaping into space.

CJP0005542

Hydrosphere: The components of the Earth system comprised of liquid surface and subterranean water, such as oceans, seas, rivers, freshwater lakes, underground water, and wetlands. The hydrosphere is part of the global climate system.

Methane (CH_4): A greenhouse gas; methane is the main constituent of natural gas, and key anthropogenic sources of methane include oil and gas systems, landfills, agricultural and livestock activities, coal mining, fossil fuel combustion, wastewater treatment, industrial processes, and land use changes. Methane is more than 25 times as potent as CO_2, but it has a shorter atmospheric lifetime and is eventually converted into CO_2 in the atmosphere. Methane is the second largest contributor to anthropogenic climate forcing, after CO_2.

Natural variability: Naturally occurring variations in the mean state and other statistical measures of the climate.

Nitrous Oxide (N_2O): A greenhouse gas produced by agriculture, fuel combustion, industrial processes, and waste management systems, as well as natural systems. Nitrous oxide is approximately 300 times more potent than CO_2 but it is shorter lived in the atmosphere. Nitrous oxide also contributes to ozone depletion. It is the third largest contributor to anthropogenic climate forcing, after CO_2 and methane.

Radiative forcing: The change in energy flux within the Earth's atmosphere caused by natural or anthropogenic climate forcers (e.g., increasing atmospheric concentrations of CO_2). Positive radiative forcing occurs when the Earth receives more incoming energy from sunlight than it radiates into space, and this net gain of energy causes warming.

Relative risk: See "Fraction of Attributable Risk".

Tipping point: A critical threshold beyond which a system reorganizes, often abruptly and/or irreversibly.

VII. References

Select References on Climate Science

American Meteorological Society, *Explaining Extreme Events from a Climate Perspective,* https://www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/explaining-extreme-events-from-a-climate-perspective/.

Climate Science, in STANFORD ENCYCLOPEDIA OF PHILOSOPHY (first published May 11, 2018), *available at* https://plato.stanford.edu/entries/climate-science/.

IPCC, CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE SIXTH ASSESSMENT REPORT OF THE IPCC (2021).

IPCC, CLIMATE CHANGE 2022: IMPACTS, ADAPTATION, AND VULNERABILITY, WORKING GROUP II CONTRIBUTION TO THE SIXTH ASSESSMENT REPORT OF THE IPCC (2022).

IPCC, CLIMATE CHANGE 2022: MITIGATION OF CLIMATE CHANGE, WORKING GROUP III CONTRIBUTION TO THE SIXTH ASSESSMENT REPORT OF THE IPCC (2022).

IPCC, GLOBAL WARMING OF 1.5°C. AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5°C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS (2018).

NATIONAL ACADEMIES OF SCIENCE, ENGINEERING, AND MEDICINE, ATTRIBUTION OF EXTREME WEATHER EVENTS IN THE CONTEXT OF CLIMATE CHANGE (2016).

NATIONAL RESEARCH COUNCIL, CLIMATE CHANGE: EVIDENCE AND CAUSES: UPDATE 2020 (2020).

U.S. GLOBAL CHANGE RESEARCH PROGRAM, FOURTH NATIONAL CLIMATE ASSESSMENT, VOL 1: CLIMATE SCIENCE SPECIAL REPORT (2017)

U.S. GLOBAL CHANGE RESEARCH PROGRAM, SECOND STATE OF THE CARBON CYCLE REPORT (2018).

WMO, PROVISIONAL STATE OF THE GLOBAL CLIMATE 2022 (Nov. 2022).

Select References on Climate Science and the Law

Myles Allen, *Liability for Climate Change*, 421 NATURE 891 (2003).

Maria L. Banda, *Climate Science and the Courts: A Review of U.S. and International Judicial Pronouncements,* ENVIRONMENTAL LAW INSTITUTE (2020).

Michael Burger et al., *The Law and Science of Climate Change Attribution*, 5 COLUMBIA JOURNAL OF ENVIRONMENTAL LAW 57 (2020).

Daniel Kim et al., *Judicial Review of Scientific Uncertainty in Climate Change Lawsuits: Deferential and Nondeferential Evaluation of Agency Factual and Policy Determinations*, 46 Harvard Environmental Law Review 367 (2022).

E.A. Lloyd & T.G. Shepherd, Climate Change Attribution and Legal Contexts: Evidence and the Role of Storylines, 167(3-4) CLIMATIC CHANGE 28 (2021).

Exhibit 27

Email from Jessica Wentz, non-resident fellow, Sabin Center, to Radley Horton, Professor, Columbia University, and Michael Burger, Executive Director, Sabin Center (Apr. 29, 2023)

Message

From: Jessica Wentz [redacted]
on behalf of Jessica Wentz [redacted]
Sent: 4/29/2023 7:44:32 PM
To: Radley Horton [redacted]
CC: Michael Burger [redacted]
Subject: Re:
Attachments: Wentz and Horton - Climate Science Chapter - Reference Manual on Scientific Evidence.docx; Reference Guide on Climate Science - Draft 4-19-23 merged comments + edits.docx

Thanks Radley. As always, your comments and edits are very helpful.

Here is the revised chapter. All comments/changes are tracked on the "merged" version (Radley, I think captured all of your additional edits to the first 40 pages). I've also attached a clean version that is fully formatted and ready for submission.

Mike, your comments and edits were also very helpful. I've made a number of changes to the legal section, addressing both yours and Radley's comments. I think we've made it clear that federal judges will primarily confront claims involving the federal government's obligations or authorities. But I did retain some discussion of the corporate liability lawsuits as there is the one federal RICO claim and it is possible that state judges or judges in other jurisdictions might also want to use this manual as a resource.

I'm planning to submit tomorrow around noon. If there are any pressing issues, please let me know before then. I think it's OK if we need to make some minor edits during the next round of revisions.

Best,

Jessica

On Sat, Apr 29, 2023 at 8:44 AM Radley Horton [redacted] wrote:

> Hi Jessica,
>
> This is another phenomenal effort. I am privileged to have had the opportunity to provide comments and proposed light edits on it.
>
> The attached includes my comments and suggested edits through the end of the document.
>
> I also read over the earlier parts of this document that included your next iteration based on my edits through the first ~40+ pages or so. I am very happy with everything (I think I made a couple tiny edits again to the first ~40+ pages, but they were so negligible that if it proves complicated to look over the first 40+ pages for my tiny 'second-iteration' changes, you need not bother.
>
> Brilliant work.
>
> PS I am available today and tomorrow over email and phone if you would like to discuss/iterate anything together.
>
> Radley [redacted]

[redacted]

--

Radley Horton, Ph.D. (*he/him/his*)
Lamont Research Professor
Lamont-Doherty Earth Observatory, Columbia University Earth Institute
61 Route 9W, P.O. Box 1000, Palisades, NY 10964

Adjunct Research Scientist, Center for Climate Systems Research, NASA GISS
Adjunct Professor, Ecology, Evolution, and Environmental Biology, Columbia University

Office: [redacted]
Cell: [redacted]
Fax:
Twitter: [redacted]

*Because I do not receive some emails sent to my giss.nasa email address, I request that you please use my columbia email address [redacted] instead. Thank you.