

# ADAPTATION AND THE COURTROOM: JUDGING CLIMATE SCIENCE

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*Climate science is increasingly showing up in courtroom disputes over the duty to adapt to climate change. While judges play a critical role in evaluating scientific evidence, they are not apt to be familiar with the basic methods of climate science nor with the role played by peer review, publication, and training of climate scientists. This Article is an attempt to educate the bench and the bar on the basics of the discipline of climate science, which we contend is a distinct scientific discipline. We propose a series of principles to guide a judge's evaluation of the reliability and weight to be accorded a given climate scientists' claim or opinion. The principles are designed to aid a judge in evaluating whether the expert's testimony complies with the Daubert test for the admissibility of scientific evidence but are broadly applicable to a judge's evaluation of agency science-based decisions.*

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## INTRODUCTION

Science is becoming increasingly important in litigation and agency proceedings related to climate change. With the growing emphasis upon adaptation, the potential for disputes in which climate science will be relevant will only multiply. Judges play a critical role in evaluating scientific evidence, from decisions regarding whether the evidence is admissible in a trial to the weight that it should be accorded in determining particular facts. Judges, however, are not apt to be familiar with the basic methods of climate science and, in particular, how to evaluate the reliability and relevance of climate studies and expert testimony. This Article is an effort to fill this gap. In doing so, we hope to help judges exercise their responsibility to ensure that litigation outcomes are informed by climate science and, at the same time, that climate science receives due consideration in the courtroom.

Although judges have access to a wide variety of tools designed to enhance their knowledge and familiarity with scientific principles and their application,<sup>1</sup> independent treatment of climate science is warranted. Court cases in which climate science is introduced, while increasing in number, are still relatively novel. Most judges are unlikely to have been exposed to climate science in the context of litigation. Climate science is also distinguishable from the types of scientific evidence a judge encounters most commonly in her courtroom. Unlike forensics, for example, knowledge of climate is not gained primarily through laboratory experiments, though some aspects of climate science, such as dating the age of ice cores, require

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1. The Reference Manual on Scientific Evidence, a handbook developed in large part for judges and now in its third edition, contains separate chapters on different areas of science, including, for instance, chapters on DNA identification evidence, exposure science, epidemiology, neuroscience, and engineering. COMM. ON SCI., TECH., & LAW, NAT'L RESEARCH COUNCIL OF THE NAT'L ACADS., REFERENCE MANUAL ON SCIENTIFIC EVIDENCE xvii (3d ed. 2011).

proficiency in laboratory techniques. Climate science is also a rapidly developing field of scientific inquiry. Although this does not render climate science unique, it prevents judges from relying wholly upon the published peer-reviewed literature. Such literature may not reflect new discoveries and understandings, including those related to climate change in specific locations. Finally, because of the politicization of climate science and the extensive coverage lent to climate science in the popular press, it is all the more important that judges approach cases involving climate science with some understanding of its discipline, its methods, and what constitutes climate science expertise.

Climate science may be introduced in numerous types of judicial proceedings, each of which is governed by distinct standards for admissibility and weight. This Article deals with two basic types: judicial review of the actions of a federal administrative agency and the civil trial. By statute, agency action is broadly subject to judicial review by interested parties. In this context, judges are frequently called to decide the reasonableness of the agency's reliance upon science in support of its action. In the trial setting, judges are required to screen scientific testimony, excluding testimony deemed unreliable and irrelevant from the body of evidence referred to by the jury or judge in deciding the case. Where a case is tried before a judge, as opposed to a jury, the judge must decide not only whether the testimony is admissible, but the weight to which it should be accorded in view of any conflicting evidence.

Obviously, the applicable standard of judicial review will strongly influence the manner in which climate science is evaluated by the judge or agency decisionmaker. While the opportunities for judges to evaluate climate science have been thus far largely limited to judicial review of agency actions, in the future, judges are likely to oversee the introduction of climate science in the trial setting. The latter context will result in subjecting the testimony of a climate scientist to greater scrutiny than the former, given that the court does not have the benefit of the agency's evaluation of the science and the testimony may be heard by a jury.

This Article will first discuss the methods of climate science and then turn to issues related to judicial review of agency decisions relying upon climate science as well as the admissibility of climate science testimony. To help illustrate the issues that judges may confront in evaluating climate science testimony and evidence, this Article will draw upon three rapidly evolving areas of climate science: projections of sea level rise, drought, and catastrophic climatic events such as hurricanes and tropical storms. Here our purpose is to help judges apply existing standards to the current body of climate science and the testimony of climate scientists within the contexts of legal disputes that are likely to arise.

## I. BACKGROUND

### *A. The Litigation Context for Disputes over Climate Science*

Two of the main contexts in which judges will be required to evaluate climate science are challenges to agency action (or failure to act) in addressing climate change and actions for injunctive relief or damages attributable to climate change.

Thus far, climate change litigation has been dominated by the former, and specifically by claims that the causes or effects of climate change have not adequately been incorporated into monitoring, impact assessment, or disclosure procedures and claims that government rules or permit conditions fail to adequately mitigate greenhouse gas emissions.<sup>2</sup> Some examples of the former are cases in which environmental organizations challenge an agency permit for failure to discuss the impacts of the permitted activity upon climate change as the plaintiff alleges is required under the National Environmental Policy Act.<sup>3</sup> The Supreme Court case *Massachusetts v. EPA* is an example of the latter: a suit in which states and environmental organizations successfully challenged the Environmental Protection Agency's (EPA) failure to regulate greenhouse gases under an existing statutory obligation.<sup>4</sup> In the future, we are likely to see even more cases of this latter type,<sup>5</sup> cases that will require judges to review the manner in which an agency decisionmaker has interpreted and applied the relevant climate science. *Coalition for Responsible Regulation v. EPA* provides an example of how climate science will be implicated in such cases. There, states and industry organizations challenged the EPA's determination, pursuant to the Clean Air Act, that emissions of greenhouse gases endanger public health and

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2. David Markell & J.B. Ruhl, *An Empirical Assessment of Climate Change in the Courts: A New Jurisprudence or Business as Usual?*, 64 FLA. L. REV. 15, 32 (2012) (asserting that these claims respectively make up 42 and 43 percent of the climate cases filed thus far).

3. See e.g., *City of Los Angeles v. Nat'l Highway Traffic Safety Admin.*, 912 F.2d 478, 481 (D.C. Cir. 1990).

4. See *Massachusetts v. EPA*, 549 U.S. 497, 534–35 (2007). The legal questions in the case concern whether the plaintiffs had established a sufficiently immediate harm to themselves that could be redressed by EPA regulation, *id.* at 525–26, and whether greenhouse gases were subject to regulation as “air pollutants” under the Clean Air Act. *Id.* at 505. Because the climate change impacts alleged by the plaintiffs were not contested, the Court did not need to wade very far into climate science in ruling for the plaintiffs. *Id.* at 526.

5. Jolene Lin, *Climate Change and the Courts*, 32 LEG. STUD. 35, 56 (2012) (predicting that, with the introduction of more climate law and policies in various jurisdictions, the use of litigation to press for regulation will decline and cases in which judges are asked to review the climate change-related decisions of regulators will increase).

welfare.<sup>6</sup> Among their claims, the plaintiffs contended that the EPA's decision was based upon flawed science.<sup>7</sup> The EPA has announced its intent to promulgate a series of greenhouse gas control measures pursuant to the Clean Air Act and other authorities, each of which will most certainly rely upon the agency's view of climate science, and each of which is likely to be challenged in court on that very basis. Regulatory decisions by other agencies are likely to be the source of court review of climate science as well. For example, the Department of Interior is currently facing a backlog of petitions requesting the listing of species as threatened or endangered under the Endangered Species Act due to habitat losses attributable to climate change.<sup>8</sup> The Department's decision of whether to list species in response to these petitions could trigger legal challenges.

While claims triggering a civil trial in which climate science is likely to be introduced as evidence have not figured prominently in the climate actions filed so far, it is possible this too could change in the future.<sup>9</sup> The growing emphasis upon climate change adaptation—measures to reduce the severity and cost of climate change impacts—is likely to herald a new phase in climate change litigation characterized by very different types of lawsuits.<sup>10</sup> The most likely defendants in adaptation-related litigation are local government authorities with responsibility for permitting development of vulnerable areas, such as the coastal zone, and also for constructing protective infrastructure, such as sea walls and windbreaks.<sup>11</sup> Plaintiffs may target

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6. *Coal. for Responsible Regulation, Inc. v. EPA*, 684 F.3d 102, 119 (D.C. Cir. 2012) (upholding the EPA's scientific judgment that emissions of greenhouse gases can “reasonably be anticipated to endanger public health or welfare”), *reh. en banc denied*, *Coal. for Responsible Regulation, Inc. v. EPA*, No. 09-1322, 2012 WL 6621785 (D.C. Cir. Dec. 20, 2012).

7. See Joint Opening Brief of Non-State Petitioners and Supporting Intervenors at 89–92, *Coal. for Responsible Regulation v. EPA*, No. 09-1322 (D.C. Cir. May 20, 2011).

8. See Todd Woody, *Wildlife at Risk Face Long Line at U.S. Agency*, N.Y. TIMES, Apr. 20, 2011, available at <http://www.nytimes.com/2011/04/21/science/earth/21species.html?pagewanted=all> (discussing scope of backlog).

9. Thus far only a handful of cases have sought damages attributable to climate change and, with the exception of one still-pending case, each has been dismissed prior to trial. See *Am. Elec. Power Co. v. Connecticut*, 131 S. Ct. 2527, 2529, 2540 (2011); *Comer v. Murphy Oil USA*, 585 F.3d 855, 859–60 (5th Cir. 2009), *vacated*, 607 F.3d. 1049 (5th Cir. 2010) (vacated for failure to muster a quorum to rehear the case en banc); *Native Village of Kivalina v. ExxonMobil Corp.*, 663 F. Supp. 2d 863, 869, 883 (N.D. Cal. 2009); *California v. General Motors Corp.*, No. C06-05755 MJJ, 2007 WL 2726871, at \*2, \*16–17 (N.D. Cal. Sept. 17, 2007) (dismissing the case).

10. *Markell & Ruhl*, *supra* note 2, at 35 (“one can reasonably foresee actions being filed to require legislative or agency action on climate change adaptation measures”).

11. GRIFFITH UNIV., CLIMATE RESPONSE: ISSUES, COSTS AND LIABILITIES IN ADAPTING TO CLIMATE CHANGE IN AUSTRALIA 13 (Ralf Buckley ed. 2007), available at [https://www3.secure.griffith.edu.au/03/ertiki/tiki-download\\_file.php?fileId=701](https://www3.secure.griffith.edu.au/03/ertiki/tiki-download_file.php?fileId=701) (“[W]e are more likely to see disgruntled property owners seek compensation from other sources. Their

a variety of aspects of the development authorities' responsibilities. Examples might include their adoption of impact benchmarks, such as the expected sea level rise by 2100;<sup>12</sup> their choice of protective standards in various planning schemes, such as minimum elevations for new developments; their case-specific rulings on individual development applications, perhaps approving development applications in vulnerable areas; and the authorities' role in advocating or limiting the construction of protective infrastructure, such as levees, sea walls and storm water systems.<sup>13</sup>

Rejection of development applications based upon climate change risk may expose government decisionmakers to claims for compensation or for damages. In the United States, compensation may be demanded based upon the contention that a permit denial so diminishes the value of the property as to effect "regulatory taking" of property.<sup>14</sup> Local government authorities could also be sued for damages resulting from weather events consistent with climate change. Plaintiffs experiencing personal injuries or property losses may argue the government breached the applicable standard of care when failing to prevent erosion or landslides, shore up roads and bridges, undertake disease prevention programs, or preserve natural resources.<sup>15</sup> Success of these claims may turn on the scope of immunity provided to local governments for tort actions.

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most likely target will be development authorities, including state governments and local councils, for approving development in vulnerable areas.").

12. Many states have adopted sea level rise benchmarks. Nevertheless, the recent controversy over the benchmark recommended by a panel of scientists in North Carolina demonstrates the pivotal role of climate science in future policy debates and hence the importance of climate science to future litigation over climate policy actions. *See, e.g.*, Bruce Henderson, *Coastal N. C. Counties Fighting Sea-Level Rise Prediction*, NEWSOBSERVER.COM, May 28, 2012, available at <http://www.newsobserver.com/2012/05/28/2096124/coastal-nc-counties-fighting-sea.html> (last accessed Sept. 27, 2013) (describing the seemingly successful attack by coastal economic development group upon the projection, by a state-appointed science panel, of one-meter sea level rise by 2100).

13. GRIFFITH UNIV., *supra* note 11, at 14.

14. *See Lucas v. S. C. Coastal Council*, 505 U.S. 1003 (1992) (governmental prohibition that substantially diminishes all use and value of land gives rise to a claim for compensation under the Fifth Amendment so long as the prohibition does not constitute a nuisance).

15. *See* Philippa England, *Heating Up: Climate Change Law and the Evolving Responsibilities of Local Government*, 13 LOCAL GOV'T L. J. 209, 217 (2008) (stating that "[i]t's not hard to envisage the type of actions or events, triggered at least in part, by the impacts of climate change that could give rise to law suits (premised on claims of negligence or nuisance) against local governments"). Such litigation may result from a lack of other sources of compensation for the injured property-owner. Property owners may lack insurance for the weather event causing damage and such coverage may be unavailable or prohibitively expensive. In Australia, 23 percent of households lack insurance and insurance policies generally do not cover storm surge, coastal erosion and sea level rise. THE PARLIAMENT OF THE

In lawsuits seeking to compel, enjoin, or obtain damages resulting from adaptation measures, a key component of the evidence presented will consist of studies of predicted climate change impacts and the testimony of climate scientists. Such evidence can be expected to be introduced by either the plaintiff or the defendant, or both. Parties can be expected to fight hard to have climate change evidence more favorable to their position admitted into evidence and given weight, and to fight vigorously to have the climate change evidence of their opponent excluded or to at least be accorded as little weight as possible.

### *B. Applicable Standards of Judicial Review*

#### 1. Federal Rules of Evidence

In the trial context, parties may seek to introduce expert testimony with respect to climate change. This may provoke challenges by the opposing party to either the admissibility of the testimony or the weight to be accorded to it. For example, in the context of their challenge to Vermont's adoption of California's greenhouse gas emission standards for new vehicles, automobile dealerships challenged the reliability and relevance of the expert testimony of Vermont's climate scientist witnesses.<sup>16</sup> Although not successful, the case is illustrative of the types of challenges that could be made to expert climate science testimony.<sup>17</sup>

Issues related to the admissibility of climate science will depend, in large part, upon the test employed by the courts to exclude scientific testimony deemed unreliable. Since the 1920s, federal courts have distinguished scientific testimony from other types of testimony, applying a strict standard of scrutiny to the admissibility of the former.<sup>18</sup> This distinction was

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COMMONWEALTH OF AUSTRALIA, *MANAGING OUR COASTAL ZONE IN A CHANGING CLIMATE* 115, 115-20 (2009).

16. *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie*, 508 F.Supp.2d 295, 310 (D. Vt. 2007).

17. The potential applicability of *Daubert*, discussed *infra*, to climate science has not been lost on the scholarly community. A few articles discuss the issue specifically. *See, e.g.*, Christopher R. Reeves, *Climate Change on Trial: Making the Case for Causation*, 32 AM. J. TRIAL ADVOC. 495 (2009). Most on point is: Ryan Hackney, *Flipping Daubert: Putting Climate Change Defendants in the Hot Seat*, 40 ENVTL. L. 255 (2010).

18. This differential treatment is based upon the argument that "(1) Science is generally more difficult to understand than other areas of expertise; (2) science is not only relatively impenetrable, but it is more impressive than non-scientific evidence, posing a special danger that jurors will give too much weight to evidence that carries with it the trappings of scientific truth; and (3) until a period of rigorous testing passes, few scientists will be available to testify to the limitations or risks of errors in a scientific analysis. As a result, the usual safeguards of the trial process—cross-examination and opposing testimo-

embodied in the Federal Rules of Evidence adopted in 1975, which provide for the admission of “scientific, technical, or other specialized knowledge” only where it will assist the trier of fact.<sup>19</sup> From 1923 to 1993, federal courts required that, to be admissible, the method upon which a scientific expert testified have “gained general acceptance” within the relevant scientific community.<sup>20</sup> Such a standard is clearly deferential to the scientific community. In 1993, however, in the case of *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, the Supreme Court replaced the scientific community with the trial judge, charging the judge with the obligation to ensure that the basis of an expert’s testimony is “(1) scientific knowledge that (2) will assist the trier of fact to understand or determine a fact in issue.”<sup>21</sup> While disinclined to announce a definitive checklist of factors governing the judge’s determination of when expertise constitutes “scientific knowledge,” the Court suggested that the court consider “whether [the theory or technique] can be (and has been) tested,” whether it has been “subjected to peer review and publication,” has a “known or potential error rate,” and, last of all, meets the *Frye* test of ascertaining the degree of its “general acceptance” within a “relevant scientific community.”<sup>22</sup> The Supreme Court elaborated upon *Daubert* in two subsequent cases, *General Electric Co. v. Joiner*, which upheld the “abuse of discretion” standard to a trial judge’s determinations excluding testimony under *Daubert*,<sup>23</sup> and *Kumho Tire Co. v. Carmichael*, in which the Court extended the *Daubert* test to technical, in addition to scientific, testimony.<sup>24</sup>

While federal courts are bound by the Federal Rules of Evidence to follow *Daubert* and most—a total of 33—state courts do as well, numerous states follow the *Frye* test or their own admissibility test.<sup>25</sup> Among the

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ny—may be unavailable or ineffective.” D.H. Kaye, *The Dynamics of Daubert: Methodology, Conclusions, and Fit in Statistical and Econometric Studies*, 87 VA. L. REV. 1933, 1967 (2001).

19. See FED. R. EVID. 702. Expert testimony that is based upon scientific or technical knowledge is subjected to a heightened scrutiny. To be admissible, the testimony of ordinary experts need only be helpful to the jury about matters beyond the knowledge or experience of most jurors. CHARLES T. MCCORMICK, HANDBOOK OF THE LAW OF EVIDENCE § 13, at 28 (1954). Expert testimony itself departs from the usual rules of evidence in that an expert is allowed to testify to his or her opinions while nonexperts may only testify to their personal experience or observation. *Id.* at 30.

20. *Frye v. United States*, 293 F. 1013, 1014 (D.C. Cir. 1923).

21. *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 592 (1993).

22. *Id.* at 592–95.

23. *General Electric Co. v. Joiner*, 522 U.S. 136, 141–43 (1997).

24. *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999).

25. TERRY BUDD, ERIC R.I. COTTLE & CLIFTON T. HUTCHINSON, EXPERT WITNESS ANSWER BOOK 2012 65 (2012).

states following *Frye* rather than *Daubert* are California, Florida, and New York.<sup>26</sup>

In general, the application of the admissibility standards for scientific evidence occurs if and when a party challenges the reliability of the other side's expert. To resolve such challenges, the judge may hold a "Daubert hearing," a mini-trial within a trial, in which the two sides of the case present witnesses and evidence in support of their contention that the expert's testimony does or does not meet the standard of reliability required under *Daubert*. The upshot of a successful *Daubert* challenge is that the judge will bar the expert from testifying at trial. The losing party can appeal this determination, but a trial court's evidentiary rulings must be upheld unless they constitute an abuse of discretion.<sup>27</sup>

The true extent to which trial attorneys make use of *Daubert* in an attempt to exclude the testimony of the opposing side's expert witnesses is unclear. A recent study by an accounting firm claims *Daubert* challenges have risen 250 percent between 2000 and 2010,<sup>28</sup> while the number of civil cases filed in federal trial courts rose comparatively slightly.<sup>29</sup>

Regardless, *Daubert* itself is extremely controversial and nothing in this Article should be read to endorse its use. Critiques range from the more prosaic: that the test imposes a difficult and onerous burden upon generalist judges,<sup>30</sup> to the more troubling: that "*Daubert* and its progeny have exerted a stultifying effect on tort and product liability suits filed in federal courts," shutting down such suits by excluding the plaintiff's expert evidence and hence, in many cases, the whole of the plaintiff's evidence.<sup>31</sup> Nevertheless, its broad adoption, both by federal courts and by the majority of state courts, means that judges must be prepared for a *Daubert* challenge to a party's expert climate scientist and able to apply the *Daubert* factors to the scientist's testimony.

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26. *Id.* at 71.

27. *General Electric Co.*, 522 U.S. at 141–43 (affirming that the "abuse of discretion" standard that generally applies to an appeals court review of a trial court's evidentiary rulings also applies to its rulings with respect to scientific expert testimony excluded under *Daubert* and that this was the case regardless of whether the trial court's ruling dictated the result in the case).

28. PRICE WATERHOUSE COOPER, DAUBERT CHALLENGES TO FINANCIAL EXPERTS: AN 11-YEAR STUDY OF TRENDS AND OUTCOMES 6 (2011), available at [http://www.pwc.com/en\\_US/us/forensic-services/publications/assets/daubert-study-2010.pdf](http://www.pwc.com/en_US/us/forensic-services/publications/assets/daubert-study-2010.pdf).

29. See Maggie Tamburro, *Daubert Challenges Up 250%*, BULLSEYE (Jan. 31, 2012), <http://www.ims-expertservices.com/blog/2012/daubert-challenges-up-350/>.

30. See *Confronting the New Challenges of Scientific Evidence*, 108 HARV. L. REV. 1481, 1488–90, 1492–98 (1995) (the "theoretically appealing" criteria of testability and falsifiability may be too complicated for courts to apply).

31. Gary Edmond, *Supersizing Daubert Science for Litigation and Its Implications for Legal Practice and Scientific Research*, 52 VILL. L. REV. 857, 863 (2007).

## 2. Judicial Review of Agency Action

A judge's review of climate science relied upon by an administrative agency arises in the context of a judge's review of the basis for and adequacy of the agency's decision. Such review is governed by the applicable standards of judicial review of administrative decisions. Integral to such standards are various subprinciples governing whether, when, and to what degree a court is to accord the agency's decision some measure of deference. These deference principles are in turn reflective of various normative views of the value of administrative agency decisionmaking more generally. At the federal level, standards of judicial review of agency action are governed by the Administrative Procedure Act (APA) and are distinct from the standards and rules applicable under the Federal Rules of Evidence that govern a judge's decisions to admit or give weight to expert testimony in the trial context.<sup>32</sup>

Under the APA, judicial review of informal rulemakings, such as those the EPA uses to promulgate climate regulations, are governed by the "arbitrary and capricious" standard of review.<sup>33</sup> Despite its name, courts actually apply a "hard look review" standard to an agency's policy determinations formed on the basis of technical or scientific judgments. To survive this standard, agencies must thoroughly explain every step in their reasoning process, from how it construed the applicable statutory text to how it dealt with the evidence for, against, or missing from its analysis.<sup>34</sup> The emphasis of the court's review is on the rationality of the agency's decisionmaking process; while rigorous in its review of the agency reasoning process, the court is supposed to defer to the agency's ultimate policy judgments.<sup>35</sup>

With respect to agency decisions based upon technical matters within its field of expertise, a long line of cases states that reviewing courts should be at their most deferential.<sup>36</sup> For example, the Court has stated that reviewing courts must provide an agency with "some leeway where its

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32. For discussion of the standards applicable in the trial context, see *supra* text accompanying notes 16–30.

33. See, e.g., *Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 30 (1983).

34. See, e.g., *id.* at 42–43; *Citizens to Preserve Overton Park, Inc. v. Volpe*, 401 U.S. 402, 414 (1971).

35. *Overton Park*, 401 U.S. at 416 (stating the standard of review "is a narrow one," and the Court is not "to substitute its judgment for that of the agency.").

36. See *Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst.*, 448 U.S. 607, 656 (1980) (plurality opinion); *Balt. Gas & Elec. Co. v. Natural Res. Def. Council, Inc.*, 462 U.S. 87, 103 (1983); *Sigma-Tau Pharm., Inc. v. Schwetz*, 288 F.3d 141, 146 (4th Cir. 2002); *Texas Oil & Gas Ass'n v. EPA*, 161 F.3d 923, 933 (5th Cir. 1998); *BP Exploration & Oil, Inc. v. EPA*, 66 F.3d 784, 792 (6th Cir. 1995); *Lead Indus. v. EPA*, 647 F.2d 1130, 1145 (D.C. Cir. 1980).

findings must be made on the frontiers of scientific knowledge.”<sup>37</sup> Thus, agencies are free to adopt their own interpretations of the science—applying conservative assumptions, for example—“so long as [the agency’s findings] are supported by a body of reputable scientific thought.”<sup>38</sup> The rationale for such deference is comparative institutional competence: agencies are thought to be in a better position than generalist judges to make policy decisions in light of scientific uncertainty.<sup>39</sup> This technical expertise deference principle is separate from, but related to, the more general deference principle according to which courts are to defer to an agency interpretation of the statute it administers where the statute is silent or ambiguous as to the question at issue.<sup>40</sup>

The degree to which courts actually apply deference to agency technical judgments is subject to some dispute. Based upon a review of the case law, one scholar has recently claimed that courts actually apply the same probing hard look review to agency scientific considerations as they do to the agency’s reasoning process in any technical area.<sup>41</sup> Such skepticism is in keeping with other sources trending toward a more exacting scrutiny of an agency’s reliance upon scientific information. Among such sources is the 2001 Data Quality Act (DQA), which requires the White House Office of Management and Budget (OMB) to promulgate guidelines “maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by [an] agenc[y].”<sup>42</sup> The DQA also requires each federal agency to promulgate guidelines fulfilling this same objective, and requires each agency to establish mechanisms for affected persons to seek and obtain the “correction” of information maintained or disseminated by an agency in violation of the agency’s guidelines.<sup>43</sup> According to the guidelines it issued pursuant to the DQA, the EPA follows five general assessment factors when evaluating the quality and relevance of scientific information: soundness, applicability and utility, clarity and completeness,

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37. *Indus. Union Dep’t*, 448 U.S. at 656; see also *Balt. Gas & Elec.*, 462 U.S. at 103 (“[A] reviewing court must remember that the Commission is making predictions, within its area of special expertise, at the frontiers of science. When examining this kind of scientific determination, as opposed to simple findings of fact, a reviewing court must generally be at its most deferential.”).

38. *Indus. Union*, 448 U.S. at 656.

39. Emily Hammond Mezell, *Super Deference, the Science Obsession, and Judicial Review as Translation of Agency Science*, 109 MICH. L. REV. 733, 734 (2011).

40. *Chevron, USA, Inc. v. NRDC*, 467 U.S. 837, 842–45 (1984) (outlining the general principle of deference courts must apply when faced with an agency’s interpretation of a statute it administers).

41. Mezell, *supra* note 39, at 734.

42. Act of Dec. 21, 2000, Pub. L. No. 106-554, § 515, 114 Stat. 2763, A-154 (2001).

43. *Id.*

uncertainty and variability, and evaluation and review.<sup>44</sup> Pursuant to the DQA, the EPA's own Inspector General recently issued a ninety-nine-page report evaluating the EPA's compliance with the various OMB- and EPA-issued guidelines promulgated under the Act.<sup>45</sup>

Thus, while an agency's scientific assessments are not technically subject to a *Daubert*-like scrutiny, the DQA clearly pushes agencies to justify the scientific basis of their decisions in a manner very reminiscent of the *Daubert* factors. Certainly many commentators would go further and subject agency decisions to *Daubert*.<sup>46</sup>

## II. CHARACTERISTICS OF THE FIELD OF CLIMATE SCIENCE RELEVANT TO LITIGATION

### *A. Climate Science as a Distinct Scientific "Discipline"*

As a distinct field of science, climate science is of comparatively recent origin. Until approximately the 1980s, climate science was a blanket term referring to aspects of meteorology, oceanography, glaciology, some aspects of geography, and earth sciences.<sup>47</sup> Since then, climate science has matured into a distinct scientific "discipline" in that it "has a distinct subject matter, a research agenda, a curriculum, an associated theoretical framework and a common approach to study using appropriate techniques for understanding and discovering new knowledge."<sup>48</sup> The research goals of climate science are generally defined by prominent university departments as understanding and

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44. SCI. POLICY COUNCIL, U.S. ENVTL. PROT. AGENCY, A SUMMARY OF GENERAL ASSESSMENT FACTORS FOR EVALUATING THE QUALITY OF SCIENTIFIC AND TECHNICAL INFORMATION 4 (2003).

45. OFFICE OF INSPECTOR GEN., U.S. ENVTL. PROT. AGENCY, PROCEDURAL REVIEW OF EPA'S GREENHOUSE GASES ENDANGERMENT FINDING DATA QUALITY PROCESSES (2011) (finding that the EPA had failed to follow OMB guidelines should its endangerment finding be considered a highly influential scientific assessment).

46. Some commentators argue that courts should apply, in reviewing agency science-based decisions, the rigorous scientific review standards applicable in the trial context. See, e.g., Paul S. Miller & Bert W. Rein, "Gatekeeping" Agency Reliance on Science and Technical Materials After *Daubert*: Ensuring Relevance and Reliability in the Administrative Process, 17 *TOURO L. REV.* 297, 324–27 (2000); D. Hiep Truong, *Daubert and Judicial Review: How Does an Administrative Agency Distinguish Valid Science from Junk Science?*, 33 *AKRON L. REV.* 365, 389–90 (2000); Wendy E. Wagner, *Importing Daubert to Administrative Agencies Through the Information Quality Act*, 12 *J.L. & POL'Y* 589, 597 (2004) (commenting that certain IQA petitions "bear a striking resemblance to *Daubert* motions").

47. Dennis Bray & Hans van Storch, *Climate Science: An Empirical Example of Postnormal Science*, 80 *BULL. AM. METEOROLOGICAL SOC'Y* 439, 439 (1999).

48. WILLY OSTRENG, *CROSSING SCIENTIFIC BOUNDARIES BY WAY OF DISCIPLINES, COMPLEXITY* 11 (Willy Ostreng ed., 2008).

predicting human-caused and natural environmental changes at the local to global scales and on time scales from centuries to millions of years.<sup>49</sup> The research questions of the field are described by one institution as including interannual climate variability; physics and dynamics of El Niño; studies of present and future changes in the chemical composition of the atmosphere in relation to global warming and ozone depletion; effects of cloud and cloud feedbacks in the climate system; paleoclimate reconstructions from ice cores, banded corals, tree-rings, and deep-sea sediment; the origin of ice ages; air-sea interactions; climate theory; and terrestrial and marine ecosystem response to global change.<sup>50</sup> Climate science deals with both natural and anthropogenic aspects of the Earth's climate.

Climate science has the organizational features of a scientific discipline, such as peer-reviewed academic journals, departments found at top research universities,<sup>51</sup> and advanced degrees.<sup>52</sup> Educational institutions and non-profit organizations bestow awards for research in climate science.<sup>53</sup> In

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49. See, e.g., *Climate Science*, COLUM. UNIV. DEP'T EARTH & ENVTL. SCI., <http://eesc.columbia.edu/disciplines/climate-science> (last visited Oct. 26, 2013); *Climate Sciences*, SCRIPPS INST. OCEANOGRAPHY, UNIV. CAL. SAN DIEGO, <https://scripps.ucsd.edu/doctoral/program-areas/climate-sciences-cs> (last visited Oct. 26, 2013); ENVTL. EARTH SYSTEM SCI., STAN. U. SCH. EARTH SCI. (Oct. 26, 2013), <http://pangea.stanford.edu/departments/eess/>.

50. *Climate Sciences*, SCRIPPS INST. OCEANOGRAPHY, UNIV. CAL. SAN DIEGO, <https://scripps.ucsd.edu/doctoral/program-areas/climate-sciences-cs> (last visited Oct. 26, 2013).

51. Researchers specializing in climate science are found most frequently in academic departments devoted to geosciences, earth sciences, atmospheric sciences, or ecology and evolutionary biology. See, e.g., *About POAC*, MASS. INST. TECH. PROGRAM IN ATMOSPHERES, OCEANS & CLIMATE, <http://eaps-www.mit.edu/paoc/about> (last visited Aug. 31, 2013); *Atmospheric Chemistry and Climate*, HARV. U. DEP'T EARTH & PLANETARY SCI., <https://eps.harvard.edu/pages/atmospheric-chemistry-and-climate> (last visited Aug. 31, 2013); *Climate Sciences*, SCRIPPS INST. OCEANOGRAPHY, UNIV. CAL. SAN DIEGO, <https://scripps.ucsd.edu/doctoral/program-areas/climate-sciences-cs> (last visited Oct. 26, 2013) (listing "Climate Science" as a distinct discipline within its Department).

52. See academic programs cited *supra* notes 49–51.

53. Examples include The Bayer Climate Award, presented in honor of groundbreaking contributions to fundamental research in climate science, see *The Bayer Climate Award*, BAYER FOUNDATIONS <http://www.bayer-foundations.com/en/bayer-climate-award.aspx> (last visited Oct. 1, 2013), the Oeschger medal from the European Geosciences Union, the American Geophysical Union's Climate Communication Prize and the Roger Revelle Medal.

A growing number of awards are now given for excellence in climate science communication. In 2011, the Stephen H. Schneider Award for Outstanding Climate Science Communication was created. The first award was given to Dr. Richard Alley, Professor of Geosciences, Penn State University. Google has initiated a program for Climate Communication Fellows. See *Google Lays Out Climate Communication Initiative*, BLUE AND GREEN TOMORROW, <http://blueandgreentomorrow.com/microblog/google-lays-out-climate-communication-initiative/> (last visited Oct. 1, 2013). On the flip-side, the Pacific Institute has instituted the "Climate B. S. of the Year Award" ("B. S." standing for "bad science"). In

perhaps the most telling indication of the field's acceptance and legitimacy by the main-stream science community, climate scientists are the frequent recipients of science's most distinguished awards.<sup>54</sup>

### 1. The Methods of Climate Science

Scientists studying climate change seek to understand past, present, and future changes in climate systems, as well as the workings of the mechanisms that drive these changes. An important aspect of climate change science is to understand how the buildup of atmospheric concentrations of greenhouse gases, attributable primarily to anthropogenic sources, will affect future climate. To do so, scientists must be able to isolate climate impacts attributable to such higher elevations from those attributable to natural variability in the climate system.

Because there is only one Earth, it is not possible to use control group experiments to distinguish impacts attributable to higher concentrations of greenhouse gases from changes attributable to natural variability. Climate scientists are thus forced to resort to alternatives that use multiple methods to identify what changes are likely to result from human-induced climate change, and what changes are not. This includes first determining the range of natural variability in various climate elements.<sup>55</sup> Scientists must then project levels of greenhouse gas concentrations in the atmosphere in the future as well as the likelihood of the occurrence of climate changes outside the boundaries of natural variability that will correspond to these higher concentrations together with the various interactions and feedbacks triggered or accentuated by the elevated greenhouse gas concentrations.<sup>56</sup>

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2011, the award was given to "the entire field of candidates currently stumping in New Hampshire for the Republican Party presidential nomination." Dean Kuipers, *And the 2011 Awards for Bad Climate Science Goes To . . .* L.A. TIMES, Jan. 5, 2011, available at <http://articles.latimes.com/2012/jan/05/local/la-me-gs-2011-bad-climate-science-awards-20120105>.

54. For instance, James Hansen, one of the most outspoken climate scientists on policy matters, among other distinctions, was elected to the National Academy of Sciences and is the recipient of the 7th Annual Heinz Award in the Environment, the American Geophysical Union's Roger Revelle Medal, and the Carl-Gustaf Rossby Research Medal from the American Meteorological Society. See *NASA's Jim Hansen to Retire*, THE EARTH INSTITUTE COLUMBIA UNIVERSITY, <http://www.earth.columbia.edu/articles/view/3077> (last visited Oct. 27, 2013).

55. See, e.g., Vladimir M. Kattsov et al., *Future Climate Change: Modeling and Scenarios for the Arctic*, in ARCTIC CLIMATE IMPACT ASSESSMENT 99, 100 (2005) (describing modeling as it pertains to Arctic climates).

56. For a discussion of models used by scientists in projecting climate change, see D.A. Randall et al., *Climate Models and Their Evaluation*, in CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 589 (S. Solomon et al. eds., 2007), available at <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf>; Kattsov et al., *supra* note 55, at 101.

One of the bedrock tools employed by climate scientists is the climate model. The climate model is often referred to as a general circulation model, or an Earth system model.<sup>57</sup> It is variable in spatial resolution, spatial area represented, and physical, biological, and chemical attributes.<sup>58</sup> Climate models can be used to project climate conditions based upon various data inputs or “forcings,” such as solar radiation, volcanic material in the atmosphere, and the atmospheric concentration of greenhouse gases.<sup>59</sup> Climate models are based upon knowledge of how the climate system works, and are evaluated against observed satellite, instrumental, paleoclimate, and other data.<sup>60</sup> Climate models consist of interacting components, each of which simulates a different part of the climate system. There are four primary components of global climate models: “atmosphere, land surface, ocean, and sea ice.”<sup>61</sup> Increasingly, land ice components are being added.<sup>62</sup>

Climate science includes the methods used to evaluate the performance of the models and understand the uncertainty associated with climate model projections and predictions. Climate scientists use observations of actual climate conditions to verify the results of climate models. The quality of a climate model is evaluated based upon its ability to reproduce known characteristics of the climate at a prior time in history.<sup>63</sup> Thus, for instance, a scientist is more likely to trust a model’s projections of future climate conditions—atmospheric temperature, for instance—if the same model accurately simulates ancient temperatures or the end of the last ice age 11,500 years ago, such as documented by an analysis of sediment and ice cores from around the globe. According to the Intergovernmental Panel on Climate Change (IPCC), there is considerable confidence that Atmosphere-Ocean General Circulation Models (AOGCMs or GCMs) provide credible quantitative estimates of future climate change, particularly at continental and larger scales.<sup>64</sup> However, “[c]onfidence in these estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation).”<sup>65</sup>

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57. See, e.g., D.A. Randall et al., *supra* note 56, at 591.

58. See *id.* at 601.

59. See generally *id.* (describing various forcings used in climate models).

60. See generally *id.* (describing evaluation of climate models).

61. *Climate Models*, U.S. CLIMATE CHANGE SCI. PROGRAM, [http://science.energy.gov/-/media/\\_pdf/news/in-focus/2008/Factsheet\\_climate\\_models\\_final\\_v2.pdf](http://science.energy.gov/-/media/_pdf/news/in-focus/2008/Factsheet_climate_models_final_v2.pdf) (last visited Aug. 31, 2013).

62. See, e.g., Randall et al., *supra* note 56, at 601.

63. *Id.*

64. *Id.* at 591.

65. *Id.*

As a result of the need to estimate the uncertainty in model projections of future climate conditions, many climate scientists are paleoclimatologists, or scientists expert in the reconstruction of the Earth's climate during earlier time periods. Ice cores are windows into the composition of the air during ancient times and can also be used to construct temperature records dating back hundreds of thousands of years.<sup>66</sup> Dendroclimatology, or the study of past climate using trees, can also provide clues to earlier climates, since properties such as tree growth and chemistry responds to various climatic variables.<sup>67</sup> Sediments, cave formations, corals, and many other paleoclimate "proxies" can also shed light on the paleoclimate.<sup>68</sup>

In projecting the effects of higher elevations of greenhouse gas concentrations, scientists must take into account the feedbacks set in motion by one climatic factor or by the interactions between climatic factors. "Positive feedback" in the climate system includes impacts resulting from climate change that in turn contribute to greater climate change, speeding it up or making it worse in some cases.<sup>69</sup> An example of a positive feedback to climate change includes the melting of the polar ice sheets.<sup>70</sup> Such melting decreases the albedo of the glaciers, or the capacity of the light-colored ice sheet to reflect the sun's energy back into space where it can't warm the Earth's atmosphere. As a result, the melting of the polar ice sheets is both an effect of global temperature increases as well as a cause of further warming. Another example of a positive climate change feedback is the ecosystem changes projected for currently rain-forested areas, such as northern Brazil. Drier, hotter conditions resulting from climate change may result in the die-back of Amazonian rainforest tree species, and the concomitant loss of large amounts of carbon from this globally significant carbon pool.<sup>71</sup> Thus, climate-change driven changes in species are projected to

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66. Eystein Jansen et al., *Paleoclimate in CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS* 433, 439 (S. Solomon et al. eds., 2007), available at <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter6.pdf>.

67. See *id.* at 439.

68. See *id.* For instance, climate scientists test current models by evaluating how well they simulate the warm conditions in the time period between five and nine thousand years ago, which is considered the time period in recent climate history with the warmest summers in the Northern Hemisphere. Stephen H. Schneider, *Can Modeling of the Ancient Past Verify Prediction of Future Climates? An Editorial*, 8 *CLIMATE CHANGE* 117, 117-19 (1986).

69. See Randall et al., *supra* note 56, at 633.

70. See Mark C. Serreze & Roger G. Barry, *Processes and Impacts of Arctic Amplification: A Research Synthesis*, 77 *GLOBAL & PLANETARY CHANGE* 85 (2011).

71. See Brian Cook, Ning Zeng & Jin-Ho Yoon, *Will Amazonia Dry Out? Magnitude and Causes of Change from IPCC Climate Model Projections*, 16 *EARTH INTERACTIONS*, no. 3, 2012 at 2; Yadvinder Malhi et al., *Exploring the Likelihood and Mechanism of a Climate-Change Induced Dieback of the Amazon Rainforest*, 106 *PROC. NAT'L ACAD. SCI.* 20610 (2009).

further accelerate climate impacts by enhancing the buildup in greenhouse gas concentrations.

Finally, an important method of climate science consists of the “downscaling” of global climate models to project the nature and degree of climate change impacts for distinct geographic areas or for discrete aspects of the climate system. Downscaling is key to the policymaking and legal aspects of climate change adaptation, as decisionmakers need to know not the global average increase in surface temperatures, but exactly how much hotter it will be in, for example, Dallas, Texas, or how much sea level rise can be expected in Queensland, Australia. Global climate models are considered reasonably reliable in representing the average climate of the planet as a whole. However, the resolution of such models is considered “coarse;”<sup>72</sup> impacts are projected for boxes in a grid measuring two to four degrees latitude and longitude and ten to twenty layers deep into the atmosphere.<sup>73</sup> Global climate models are thus considered “low-resolution” and less capable of projecting the details of climate variability on a regional or local scale.<sup>74</sup> Global climate models are considered especially poor at simulating the details of the hydrological responses to climate change at the scale of a watershed, for instance.<sup>75</sup>

Climate scientists engage in different methods for projecting climate on a finer scale. The first, or dynamic downscaling, consists of nesting a regional climate model within a global climate model.<sup>76</sup> A second method downscales projections from GCMs through statistical relationships that capture the empirical links between large-scale and local climate elements and the application of these links to output from global or regional models.<sup>77</sup> Sometimes stochastic weather generators are used to estimate the influence of climate on weather at a particular location.<sup>78</sup>

Climate scientists are generally more confident today of their ability to make regional projections of climate impacts than they were in the recent past. For example, the U.S. Global Change Research Program has published projections of climate change impacts for different regions of the United States.<sup>79</sup> Nevertheless, the enterprise can still be characterized by

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72. See, e.g., Randall et al., *supra* note 56, at 629.

73. Yonas P. Dibike & Paulin Coulibaly, *Hydrologic Impact of Climate Change in the Saguenay Watershed: Comparison of Downscaling Methods and Hydrologic Models*, 307 J. HYDROLOGY 145, 146 (2005).

74. See, e.g., Randall et al., *supra* note 56, at 592.

75. See, e.g., Dibike & Coulibaly, *supra* note 73.

76. See Kattsov et al., *supra* note 55, at 130.

77. See *id.* at 136.

78. See, e.g., Dibike & Coulibaly, *supra* note 73, at 147.

79. U.S. GLOBAL CHANGE RESEARCH PROGRAM, GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES, (Thomas R. Karl et al. eds., 2009).

significant uncertainty. In a recent news article appearing in *Science Magazine*, climate scientists' views on the accuracy of downscaled projections of climate change were decidedly mixed.<sup>80</sup> Some scientists expressed confidence in the quality of the projections of downscaled climate models, at least on a regional scale.<sup>81</sup> Others, however, expressed concern that the results of such models are interpreted as being more certain than they are in reality.<sup>82</sup>

## 2. Peer-Reviewed Publications

Peer-reviewed publications in the field of climate science encompass high-profile government reports containing the consensus views of a group of scientists and individual journal articles by scientists and their laboratories. The pre-eminent climate change science consensus government reports are those published at regular intervals by the Intergovernmental Panel on Climate Change (IPCC), an international intergovernmental body established in 1988 by the United Nations Environment Programme and the World Meteorological Organization whose role is to provide "policy-relevant but not policy-prescriptive information on key aspects of climate change."<sup>83</sup> The IPCC has published four major reports assessing the current status of the scientific understanding of climate change and its impacts and is in the midst of preparing a fifth report. These reports are widely considered the "gold standard" for objective climate science.<sup>84</sup>

The reason for the eminence of the IPCC reports is the meticulous procedures followed by a broad range of climate scientists in order to generate the reports. For the Fourth Assessment Report, published in 2007, 450 climate scientists from 130 countries served as lead authors and were assisted by another 800 scientists, who served as contributing authors.<sup>85</sup> Another

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80. Richard A. Kerr, *Vital Details of Global Warming Are Eluding Forecasters*, 334 *SCIENCE* 173, 173–74 (2011).

81. *Id.*

82. *Id.* at 174.

83. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, STATEMENT ON IPCC PRINCIPLES AND PROCEDURES (2010), available at <http://www.ipcc.ch/pdf/press/ipcc-statement-principles-procedures-02-2010.pdf>; see also INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, PRINCIPLES GOVERNING IPCC WORK, amended June 9, 2012, available at <http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles.pdf> ("The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation.").

84. See e.g., *Wanted: An IPCC for Biodiversity*, 465 *NATURE* 525, 525 (2010).

85. *Structure*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, [http://www.ipcc.ch/organization/organization\\_structure.shtml#Um60KpTF3Jc](http://www.ipcc.ch/organization/organization_structure.shtml#Um60KpTF3Jc) (last visited Oct. 28, 2013).

2500 scientists provided reviewer comments.<sup>86</sup> The work of each of these scientists on the IPCC reports is voluntary; the IPCC does not employ any of the reports' scientific experts.<sup>87</sup> The preparation of the reports involves a thorough scientific assessment of the literature to distill from it key messages to which the authors then assign a level of confidence. Prior to publication, every word of the IPCC Summary for Policymakers reports is approved not only by the participating scientists, but by the more than 120 participating governments.<sup>88</sup>

For the most part, IPCC reports rely upon the published, peer-reviewed studies appearing in scientific journals. However, the IPCC does allow citation to the so-called "grey literature": non-peer-reviewed reports including technical reports, conference proceedings, statistics, and observational datasets.<sup>89</sup> Some consider reliance on grey literature for items such as statistical information as necessary for the IPCC to publish policy-relevant science.<sup>90</sup> Use of grey literature as authority in an IPCC report is governed by strict IPCC guidelines,<sup>91</sup> though a highly publicized use of grey litera-

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86. *Id.*

87. *Id.*

88. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, UNDERSTANDING CLIMATE CHANGE: 22 YEARS OF IPCC ASSESSMENT (2010), available at [http://www.ipcc.ch/pdf/press/ipcc\\_leaflets\\_2010/ipcc-brochure\\_understanding.pdf](http://www.ipcc.ch/pdf/press/ipcc_leaflets_2010/ipcc-brochure_understanding.pdf). See generally, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, PROCEDURES FOR THE PREPARATION, REVIEW, ACCEPTANCE, ADOPTION, APPROVAL AND PUBLICATION OF IPCC REPORTS, amended Sept. 4, 2008, available at <http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a.pdf> (describing the procedures for IPCC report preparation and review). This is not to say, however, that the IPCC reports are without flaws. Well-publicized errors in the Fourth Assessment Report may have undermined the credibility of the IPCC with the general public, despite the scientific community's general agreement that the errors were minor and did not influence any of the Report's overall conclusions concerning climate change. One volume of the IPCC report erroneously states that 80% of the Himalayan glacier area will disappear by 2035. This projection is actually contradicted in two other places in the Fourth Assessment report, which includes accurate assessments of glacier decline. In a second error, the Report states that 55% of the Netherlands is below sea level while in reality, only 26% of the country is below sea level. There are a few other reputed errors in the several volume report. *IPCC Errors: Fact and Spin*, REALCLIMATE (Feb. 14, 2010), <http://www.realclimate.org/index.php/archives/2010/02/ipcc-errors-facts-and-spin/>.

89. InterAcademy Council, Climate Change Assessments: Review of the Processes and Procedures of the IPCC 63 (2010), available at [http://www.ipcc.ch/pdf/IAC\\_report/IAC%20Report.pdf](http://www.ipcc.ch/pdf/IAC_report/IAC%20Report.pdf).

90. See *id.*

91. See INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, NOTES ON THE INFORMAL TASK GROUP ON PROCEDURES 6, approved Oct. 14, 2010, available at [http://www.ipcc.ch/meetings/session32/inf04\\_p32\\_review\\_ipcc\\_proc\\_proced\\_notes\\_informal\\_task\\_group.pdf](http://www.ipcc.ch/meetings/session32/inf04_p32_review_ipcc_proc_proced_notes_informal_task_group.pdf); see also, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, PROCEDURES FOR THE PREPARATION, REVIEW, ACCEPTANCE, ADOPTION, APPROVAL AND PUBLICATION OF IPCC REPORTS, *supra* note 88.

ture in the Fourth Assessment Report demonstrates that the guidelines are not always followed.<sup>92</sup> Following criticism of the citation, in the Fourth Assessment Report, of a non-peer-reviewed magazine article for what turned out to be an erroneous claim regarding the fairly imminent disappearance of Himalayan glaciers, the IPCC revisited its guidelines for the citation of grey literature.<sup>93</sup>

Other highly regarded peer-reviewed governmental consensus reports include those published by the United States Global Change Research Program and the National Research Council of the National Academies of Science. Congress has tasked the USGCRP to publish assessments of the impacts of climate change in the United States every four years. The latest such USGCRP assessment was published in 2009.<sup>94</sup> Similarly, the USGCRP publishes peer-reviewed synthesis reports.<sup>95</sup>

Aside from highly regarded consensus reports, climate science findings are to be found in the peer-reviewed scientific journal literature. This relevant journal literature consists of nonspecialized general scientific journals that publish research spanning all scientific disciplines as well as specialty journals that publish only or primarily climate science research. *Nature*, *Science*, *Proceedings of the National Academies of Science* and *Proceedings of the Royal Academy* are considered the most prestigious general science journals. These journals also receive top “impact factor,” or “IF,” scores.<sup>96</sup> A journal’s IF score reflects the average number of citations to recent articles published

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92. The IPCC Fourth Assessment report reported that all glaciers in the Himalayas could disappear by 2035. The source of this claim was a quote from a climate scientist reported in a 1999 story published in *New Scientist*, a nontechnical, non-peer-reviewed journal about science. Fred Pearce, *Debate Heats Up Over IPCC Melting Glaciers Claim*, NEWSIDENTIST (Jan. 11, 2010, 5:21 PM), <http://www.newscientist.com/article/dn18363-debate-heats-up-over-ipcc-melting-glaciers-claim.html>.

93. Press Release, Intergovernmental Panel on Climate Change, Further IPCC Strengthening Agreed at Plenary Session in Abu Dhabi, (May 13, 2011), *available at* [http://www.ipcc.ch/news\\_and\\_events/docs/ipcc33/PRESS\\_RELEASE\\_Outcomes\\_abu\\_dhabi\\_13\\_may.pdf](http://www.ipcc.ch/news_and_events/docs/ipcc33/PRESS_RELEASE_Outcomes_abu_dhabi_13_may.pdf) (“[M]agazines and newspapers are in principle not valid sources and that [sic] blogs, social networking sites and broadcast media are not acceptable sources of information for IPCC reports.”).

94. U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 79. A draft form of the 2013 assessment, while unpublished, is currently available to the public at: <http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-fulldraft.pdf>.

95. U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 79.

96. See *Impact Factors for Journals Published By Nature Publishing Group*, NATURE, [http://www.nature.com/npg/company\\_info/impact\\_factors.html](http://www.nature.com/npg/company_info/impact_factors.html) (last accessed Oct. 30, 2013); *Science Magazine*, SCIENCE, <http://www.sciencemag.org/site/marketing/info/> (last accessed Oct. 30, 2013); *About PNAS*, PROCEEDINGS OF THE NAT’L ACAD. OF THE SCIENCES, <http://www.pnas.org/site/aboutpnas/> (last accessed Oct. 30, 2013); *2012 Impact Factors Now Available*, ROYAL SOCIETY PUBLISHING, [http://royalsocietypublishing.org/site/authors/impact\\_factors.xhtml](http://royalsocietypublishing.org/site/authors/impact_factors.xhtml) (last accessed Oct. 30, 2013).

in the journal.<sup>97</sup> IF scores are calculated on an annual basis for journals indexed in Thomson Reuters *Journal Citation Reports* and can be accessed through the ISI Web of Knowledge.<sup>98</sup> The ISI Web of Knowledge also includes a journal's "Eigenfactor" score, which is an alternative method of ranking the importance of a journal.<sup>99</sup> Some of the top general science journals publish a climate specialty journal. For example, *Nature* publishes a separate journal devoted entirely to climate science and policy: *Nature Climate Change*. Importantly, in addition to the top scientific journals, there exist numerous specialty academic science journals that publish climate science research. Many of these journals are categorized by ranking outlets as earth science journals,<sup>100</sup> though some fall under the biological sciences.<sup>101</sup>

### 3. Climate Science Training and Qualifications

Climate science education typically includes both disciplinary and interdisciplinary training, often with undergraduate coursework and degrees in basic supporting natural or social science (e.g., math, physics, chemistry, earth sciences, atmospheric sciences, or oceanography), and graduate degrees in programs that augment and broaden this basic science with a focus more on climate. Climate experts usually have PhD degrees that require the

97. The Thomson Reuters Impact Factor, THOMSON REUTERS, <http://wokinfo.com/essays/impact-factor/> (last visited Oct. 30, 2013).

98. *Journal Citations Reports*, THOMSON REUTERS, <http://thomsonreuters.com/journal-citation-reports/> (last visited Oct. 26, 2013).

99. EIGENFACTOR.ORG: RANKING AND MAPPING SCIENTIFIC KNOWLEDGE, <http://www.eigenfactor.org/> (last visited Oct. 26, 2013).

100. Under the Eigenfactor scoring system, the following constitute the top 10 journals out of the 223 journals classified under "Geosciences":

1. REV. GEOPHYSICS
2. ANN. REV. EARTH & PLANETARY SCI.
3. CLIMATE DYNAMICS
4. J. GEOPHYSICAL RES.
5. BULL. AM. METEOROLOGICAL SOC'Y
6. AM. J. SCI.
7. EARTH-SCI. REV.
8. PALEOCEANOGRAPHY
9. GLOBAL BIOGEOCHEMICAL CYCLES
10. J. CLIMATE

See *Mapping Science*, EIGENFACTOR.ORG, <http://www.eigenfactor.org/map/index.php> (select "Geosciences" from the drop-down list) (last accessed Oct. 3, 2013).

101. For instance, the Eigenfactor scoring system lists the journal *Global Change Biology*, which is devoted to the publication of climate science, under the category "Ecology and Evolution." See EIGENFACTOR.ORG, <http://www.eigenfactor.org/rankings.php?bsearch=global+change+biology&searchby=journal&orderby=eigenfactor> (last accessed Oct. 3, 2013).

development, completion, and publication of original climate research. The field of climate science is now broad enough that few can become experts in all areas of the science, and this is one reason why scientific assessments such as that carried out by the IPCC involve scientists from a diverse set of disciplinary backgrounds and research expertises. In some cases, undergraduate climate science degrees that are awarded include, for example, climate dynamics (how various components of the climate system—the atmosphere, ocean, land, and cryosphere—interact), atmospheric physics and dynamics, paleoclimatology, atmospheric chemistry, quantitative aspects of global environmental problems, and ocean geochemistry.<sup>102</sup> The curriculum for advanced degrees varies widely, depending upon the area of climate science specialization.<sup>103</sup>

Climate expertise is by definition somewhat shallow and narrow for early-career climate scientists, and becomes deeper and broader with time in the field. This trajectory requires an active research program, and thus growing expertise is usually evidenced by a growing number of peer-reviewed publications that have impact, e.g., by being well cited by the scientific papers of peers and by inclusion in consensus assessment or synthesis documents. A broadening of climate expertise also often occurs with time, and is usually reflected in peer-reviewed publications that appear in a widening range of climate and other journals. In essence, to be considered an expert requires a substantial number of peer-reviewed climate science publications, many of which are well cited by peers in the literature.<sup>104</sup>

High levels of climate expertise are also usually associated with significant scientific prominence. Indicators of such prominence include awards and other recognition by climate-related professional organizations, leadership in national and international climate activities, participation as a lead author in a relevant aspect of the IPCC, membership in U.S. National Academy of Sciences (NAS) Boards and Committees, and membership in

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102. See *A Prototype Undergraduate Climate Change Curriculum*, ATMOSPHERIC SCI. CTR., UNIV. OF CAL. AT BERKELEY, <http://www.atmos.berkeley.edu/curriculum.html> (last visited Oct. 3, 2013).

103. For instance, graduate students in climate science at Scripps Institution of Oceanography choose between specializations in climate-ocean-atmosphere, geosciences of the Earth, oceans and planets, and ocean biosciences. See *Doctoral Program Areas*, SCRIPPS INST. OF OCEANOGRAPHY, UNIV. OF CAL. SAN DIEGO, <https://scripps.ucsd.edu/doctoral/program-areas> (last visited Oct. 3, 2013).

104. See Ove Hoegh-Guldberg, *Who's Your Expert? The Difference Between Peer Review and Rhetoric*, THE CONVERSATION (June 16, 2011, 11:33 PM), <http://theconversation.edu.au/whos-your-expert-the-difference-between-peer-review-and-rhetoric-1550> (revealing that none of the four persons who publicly criticized the scientific validity of an Australian government report on climate change had published, in the peer-reviewed scientific literature, articles that supported their critique of the government report).

the NAS itself. Climate experts are likely to demonstrate their expertise in multiple such ways.

### III. POTENTIAL ISSUES WHEN EVALUATING CLIMATE SCIENCE

With respect to climate science, application of the traditional tests for evaluating the reliability of expert scientific testimony is an uneasy fit at best. The following discusses aspects of climate science as well as circumstances that could arise that would complicate the judge's task of evaluating the reliability and relevance of climate science.

#### *A. Climate Impact Projections Cannot be Tested Through Randomized Control Tests that Produce a Known "Rate of Error"*

In *Daubert*, the Court implicitly expressed a preference for the randomized control test as the means for determining the falsifiability of a given hypothesis when it listed the "known or potential rate of error" as a factor to be considered by judges when evaluating the reliability of a given scientific method.<sup>105</sup> Nevertheless, because such tests are not possible with respect to the projections of climate science, climate scientists must resort to other means for falsifying hypotheses.

According to classical understanding, scientific knowledge is that which is derived from statements susceptible to an empirical test capable of proving the statement false. This understanding of scientific knowledge is attributable to Karl Popper, who settled on falsifiability as a way of distinguishing views based upon science from those based upon opinion, belief, or conjecture.<sup>106</sup> Because scientific knowledge thus consists of hypotheses that are capable of being refuted and which have yet to be refuted, it is a large subset of human knowledge—all knowledge that can, at least in theory, be tested for being false, even if it has yet to be, and perhaps will never be, subjected to such tests.<sup>107</sup> The Supreme Court, in *Daubert*, cites Popper,

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105. See *Daubert v. Merrell Dow Pharms.*, 509 U.S. 579, 594 (1993) (citing the specific consideration of the error rate of spectrographic voice identification by courts and professional organizations governing spectrographic analysis); *ENCYCLOPEDIA OF EPIDEMIOLOGY* 360 (Sarah Boslaugh ed., 2008) (suggesting that *Daubert's* "error rate" suggests a quantifiable measurement of error, such as *p*-value or Type I or Type II errors, each of which provides information on random error).

106. KARL R. POPPER, *REALISM AND THE AIM OF SCIENCE* xix (W.W. Bartley III ed., 1983).

107. See KARL R. POPPER, *CONJECTURES AND REFUTATIONS: THE GROWTH OF SCIENTIFIC KNOWLEDGE* 44, 47–48 (Routledge 2002) (1962).

together with another logical empiricist, Carl Hempel, for the proposition that testing is critical to a statement's status as scientific knowledge.<sup>108</sup>

Scientific knowledge gained through randomized, controlled experiments is often considered the best evidence of the lack of falsification of a particular statement.<sup>109</sup> Such experiments are frequently used to identify causal agents for a particular phenomenon.<sup>110</sup> The benefit of using laboratory trials to determine the efficacy of a particular methodology to predict a phenomenon or event is that, through the repetition of the trial, scientists can determine the accuracy of the method. Such accuracy can be expressed by either its rate of Type I (false-positive) or Type II (false-negative) error. Scientists most commonly report the Type I error rate, or the probability that a given method has falsely rejected the null hypothesis. A Type I error rate of 0.05 or less is considered sufficiently low that the experiment can be considered to have validly rejected the null hypothesis.<sup>111</sup>

Ideally, it is precisely such "whole-Earth, system-scale experiments, incorporating the full complexity of interacting processes and feedbacks" that are needed to falsify hypotheses concerning the expected changes resulting from human-induced elevations in greenhouse gas concentrations.<sup>112</sup> Because there is only one Earth, it is not possible to have both a "control group" and an "experimental group" to test the hypotheses of climate science. Nevertheless, just because climate science projections cannot be tested through randomized control tests does not mean that they do not constitute scientific knowledge. Popper himself noted that "falsifiability . . . has *nothing* to do with the question of whether or not certain possible experimental

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108. *Daubert*, 509 U.S. at 593 (citing CARL G. HEMPEL, *PHILOSOPHY OF NATURAL SCIENCE* 49 (1966) and KARL R. POPPER, *CONJECTURES AND REFUTATIONS: THE GROWTH OF SCIENTIFIC KNOWLEDGE* 37 (5th ed. 1989)).

109. Eliza F. Chakravarty & James F. Fries, *Science As Experiment; Science As Observation*, 2 *NATURE CLINICAL PRACTICE RHEUMATOLOGY* 286, 286–87 (2006) ("Randomized, blinded, controlled experiments are often considered the highest level of evidence in the methodologic hierarchy.")

110. Thus scientists wishing to test whether sleep-deprivation impairs driving performance might assemble two groups of individuals, one of which receive plenty of sleep and the other which do not and, under controlled conditions, observe their driving. The observation of a statistically-significant incidence of poorer driving performance within the sleep-deprived group is strong evidence of the rejection of the null hypothesis—that sleep-deprivation has no effect upon driving performance. Pierre Philip et al., *Fatigue, Sleep Restriction and Driving Performance*, 37 *ACCIDENT ANALYSIS & PREVENTION* 473, 473 (2005).

111. See, e.g., *id.* at 476 (noting significance and rejection of null hypothesis where  $p < 0.05$ ).

112. H. Le Treut et al., *Historical Overview of Climate Change*, in *CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS* 93, 98 (S. Solomon et al. eds., 2007), available at <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter1.pdf>.

results would be accepted as falsifications.”<sup>113</sup> Instead, climate science employs a sort of “weight of the evidence” approach, falsifying hypotheses through multiple pathways, including the verification of model projections through observed phenomenon.

*B. Climate Science is Characterized by Many Uncertainties but also by a Continuing Rapid Pace of New Discoveries*

While much is known about climate change, much continues to be not well understood. For example, scientists have hypotheses, but often do not know the exact probability or mechanics of “abrupt climate change” (e.g., in ocean circulation, ice sheet collapse, or a catastrophic release of ocean-sediment methane).<sup>114</sup> Also, for example, scientists do not know about some critical aspects of cloud formation and thus the details of how changing clouds may influence climate change impacts.<sup>115</sup> Finally, climate impacts at the regional and local levels are subject, among other things, to the uncertainties of downscaling techniques. Nevertheless, our knowledge of the climate is developing at a breakneck pace.<sup>116</sup>

The pace of new discoveries in climate science has implications for a judge’s determination of what methods or conclusions are “generally accepted” within the field. The actual state of knowledge within the field may have advanced beyond that found in the scientific consensus documents published by organizations such as the IPCC and hence a judge’s reliance upon such documents would fail to reference the most valid up-to-date scientific findings. For example, knowledge of how sea level will most likely rise in the future is changing fast. In its 2007 Report, the IPCC projected a sea level rise of 18 to 59 centimeters by 2100, plus an unspecified amount that could come from the melting of the Antarctic and Greenland ice sheets.<sup>117</sup> The entirety of the quantified range derived from what could be simulated with models (e.g., thermal expansion of a warming ocean), and excluded what could not (the dynamical response of ice sheets). Since that

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113. KARL R. POPPER, REALISM AND THE AIM OF SCIENCE xx (W.W. Bartley III ed., 1983).

114. SUBCOMM. ON GLOBAL CHANGE RESEARCH, U.S. CLIMATE CHANGE SCI. PROGRAM, ABRUPT CLIMATE CHANGE (2008).

115. Randall et al., *supra* note 56, at 602.

116. Each year, the World Resources Institute publishes summaries of the major new discoveries in climate change that have occurred over the past several years. *See e.g.*, AARON STRONG, KELLY LEVIN & DENNIS TIRPAK, WORLD RESOURCES INST., CLIMATE SCIENCE 2009-2010: MAJOR NEW DISCOVERIES (2011).

117. LENNY BERNSTEIN ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT, at 45 (2007) *available at* [http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4\\_syr.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf) (last visited Oct. 27, 2013).

time, however, new peer-reviewed papers have helped create a consensus that a sea level rise of one meter or more by century's end could occur if ice sheet mass loss is included.<sup>118</sup> This more recent estimate is based upon glaciological constraints, as well as correlations between historical sea level rise and observed temperature, and methodologies that incorporate the potential contributions of ice sheets to sea level rise. Despite their departure from the IPCC estimates, “[t]hese new results have found wide recognition in the scientific community”<sup>119</sup> and thus constitute the most accurate estimates of sea level rise available today.

*C. Climate Science of Potentially Greatest Relevance to Litigation—  
Projected Impacts at the Regional and Local Scales—Is Often Less Certain  
Than Projected Impacts at the Global Scale*

It is likely that much of the litigation over climate change will grapple with climate change impacts at the regional and local scales. In Australia, for example, planning authorities have appealed the grant of development permits in coastal areas based upon the risk that such areas will be flooded due to sea level rise attributable to climate change.<sup>120</sup> The projection of local climate impacts can be associated with greater scientific uncertainty, but not always. Over the next couple decades, local sea level may be dominated by regional oceanographic conditions and influences of storms, and thus be less certain than global sea level projections. In contrast, the uncertainties associated with mapping likely local sea level rise impacts for fifty to 100 years out into the future will likely be dominated by, and thus be on the same order as, the uncertainties associated with global sea level rise

118. Aslak Grinsted, J.C. Moore & S. Jevrejeva, *Reconstructing Sea Level from Paleo and Projected Temperatures 200 to 2100 AD*, 24 CLIMATE DYNAMICS 461 (2009); Radley Horton et al., *Sea Level Rise Projections for Current Generation CGCMs Based on the Semi-Empirical Method*, 35 GEOPHYSICAL RES. LETTERS L02715 (2008); S. Jevrejeva, J.C. Moore & A. Grinsted, *How Will Sea Level Respond to Changes in Natural and Anthropogenic Forcings By 2100?*, 37 GEOPHYSICAL RES. LETTERS L07703 (2010); W.T. Pfeffer, J.T. Harper & S. O’Neel, *Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise*, 321 SCIENCE 1340 (2008); Stefan Rahmstorf, *A Semi-Empirical Approach to Projecting Future Sea-Level Rise*, 315 SCIENCE 368 (2007); Stefan Rahmstorf, Mahé Perrette & Martin Vermeer, *Testing the Robustness of Semi-Empirical Sea Level Projections*, 39 CLIMATE DYNAMICS 861 (2012); M. Vermeer & Stefan Rahmstorf, *Global Sea Level Linked to Global Temperature*, 106 PROC. NAT’L ACAD. SCI. 21527 (2009).

119. Stefan Rahmstorf, *A New View on Sea Level Rise*, 4 NATURE REP. CLIMATE CHANGE 44 (2010), available at <http://www.nature.com/climate/2010/1004/full/climate.2010.29.html>.

120. See e.g., *Gippsland Coastal Bd. v S. Gippsland Shire Council* [2008] VCAT 1545 (The Civil and Administrative Tribunal of the Australian state of Victoria overturned the grant, by a local city council, of permits for housing on the coast due to the risk of sea level rise and flood inundation attributable to climate change).

projections. Temperature change will also likely be strongly correlated over large regions and less so at the subregional level. We know our climate models are more reliable at the global or continental scale than down at the regional or local scale. Uncertainty at the regional scale can be even more substantial for hydroclimatic variables such as rain and snowfall, as well as for climate extremes like drought, floods, and hurricanes.<sup>121</sup> Although climate change can be downscaled from global climate models to be of use at local scales, the methodology for downscaling global climate models is still under development. The conclusions generated by such downscaling are subject to many qualifications. Additionally, given the localized nature of the impacts considered, it is very possible that the publication record on place-specific impacts will be thin or perhaps even nonexistent.<sup>122</sup> Thus, judges could be left to sorting out the reliability and relevance of a climate scientists' testimony concerning projected climate impacts based only upon the particular scientists' qualifications and the methods upon which they rely in deriving their conclusions.

#### IV. GUIDELINES FOR EVALUATING CLIMATE SCIENCE

We propose a series of principles to guide a judge's evaluation of the reliability and weight to be accorded a given climate science claim or opinion. The principles are designed to aid a judge in evaluating whether the expert's testimony complies with the *Daubert* test and thus are not necessary when a court reviews an agency's science-based decision. Nevertheless, because of the trend toward requiring compliance with *Daubert* factors through the strictures of the Data Quality Act, these principles are likely relevant to a judge's review of agency decisions as well.

*Principle 1. The weight accorded the published opinion of a climate scientist should reflect the degree to which the publication in which it appears represents a consensus view of well-credentialed climate scientists, is one in which climate scientists regularly publish as well as the selectivity of the publication.*

In many cases, the scientific issues at stake will have been the subject of published studies containing the consensus views of well-credentialed climate scientists. The periodic IPCC reports are examples of such publications. They represent the consensus view of the authors and review editors invited by their governments to participate in writing the report.

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121. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION (2012).

122. See generally, *supra* notes 71–80 and accompanying text.

There are numerous other broadly-based consensus reports on climate science, including those produced by the U.S. Global Change Research Program and the Arctic Climate Impact Assessment. These reports generally constitute the “gold standard” in climate change science, as they represent a synthesis of the peer-reviewed literature on climate science, as performed by the world’s best-credentialed climate scientists.<sup>123</sup>

As discussed above, however, preparation of these synthesis reports are a major undertaking and are completed in periodic intervals. At the time of a judge’s evaluation, the state of research science may have moved beyond that expressed in a synthesis report. As a result, a judge should take the conclusions set forth in a synthesis report as a sort of baseline view of the relevant climate science, but should be open to replacing that view with that espoused in the more recent peer-reviewed literature.

In reviewing the recent literature, the judge’s job is more difficult. Reliable work should be based on peer-reviewed publications, with the number of supporting publications serving as an indication of general acceptance by the relevant scientific community of experts. Methods and scientific results can be judged more robust if they have stood the test of time (i.e., years) and are cited in subsequent publications by peers in a favorable and uncontroversial manner. Reliable climate science methodologies should include estimates of uncertainty based on clear algorithms.

*Principle 2. The weight accorded conclusions based on a particular methodology or model(s) should depend upon the degree to which the method or model(s), or hierarchy of models, accurately represent observed climate conditions of the present and the past. Where possible, an expert should provide evidence from the peer-reviewed literature regarding the accuracy of the method or model(s), or, if the application is novel, a systematic assessment of method or model accuracy should be provided.*

Climate scientists use various methods to assess why a part of the climate system has varied or changed in the past, and how it may vary and change in the future. Although the use of models is not the only valid approach, it is often the most sophisticated and justified.<sup>124</sup> Here, we focus on climate models as an example, but the same principles of evaluation extend to other methods as well. Climate models can be relatively simple or complex, but in all cases, it is possible to examine how well they simulate the present (e.g., the seasonal cycle and climatology of relevant parts of the globe), recent past (e.g., variations observed in the thermometer record, usually during the last 100 or more years in most of the United States) and

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123. See discussion *supra* Part II.A.2.

124. See discussion *supra* Part II.A.1.

deeper past (e.g., some or all of the last 500 to 150,000 years as recorded in the paleoclimatic record).<sup>125</sup> Most important is an examination of how models being used in testimony simulate the observed record of variables critical to the particular litigation. As discussed above, how well the model simulates past climate conditions is the best method of testing the accuracy of a model's predictions of the future.

As with other scientific methods, models being used for assessments of future climate change are usually described and documented in the peer-reviewed literature, complete with evaluations of the model's performance. One good measure of model reliability is that it is widely used and cited in the peer-reviewed literature. Ideally, the model in question has been used widely for problems similar to those arising in the litigation and this self-same use of the model has been extensively evaluated, and the accuracy of the model's conclusions endorsed, in the peer-reviewed literature.

Nevertheless, this will not always be the case. Litigants may engage an expert to testify as to conclusions from models that have not been extensively evaluated in the peer-reviewed literature. Alternatively, an expert may testify as to results of a novel application of a model that has otherwise received approval in the peer-reviewed literature. This may particularly be the case with respect to litigation concerning adaptation measures that relies upon the downscaling of global or regional climate models.

A judge will want to ensure that the party introducing such testimony presents some basis for the accuracy of the model's predictions by providing evidence of the accuracy of the model with respect to simulating known climate conditions of the present and past. A judge may also wish to ask whether alternative downscaling approaches are available and how well does the model being relied upon compare to the alternatives. Finally, as with other acceptable methods, climate model assessments should include estimates of uncertainty based on clear, reproducible algorithms.

*Principle 3. Experts testifying on issues related to climate should be trained in climate science in particular, and not just in any field of science.*

With respect to testimony as a witness in a trial, the Federal Rules of Evidence permit a witness to testify as to "scientific, technical, or other specialized knowledge" so long as that witness is qualified as an expert.<sup>126</sup>

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125. See discussion *supra* Part II.A.1.

126. Rule 702 of the Federal Rules of Evidence reads: "A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

Qualification as an expert is an inquiry distinct from the admissibility of the opinions of the expert. It is also less exacting. Following the letter of Rule 702, courts hold that the degree of knowledge or training necessary is only that which enables the expert to “help” the trier of fact; in other words, the expert must only have more knowledge, practical experience or training than the judge so as to be able to tell the judge something he or she does not know. The expert need not be an acknowledged leader in his or her field. Under the Rules, the reliability and relevance of the substance of an expert’s testimony is distinct from his or her qualifications as a scientific expert.<sup>127</sup>

Like any scientist, a climate science expert should have an advanced degree in science from a reputable educational institution. They should also be able to demonstrate peer-reviewed research publications. Yet because, as demonstrated above, climate science is its own unique field of science with its own methods, any expert testifying as to climate science should be able to point to publication in journals devoted to and/or training experience in scientific fields most closely-related to the climate science issues in dispute: atmospheric sciences, earth science, ocean sciences, paleoclimatology, ecology, biogeochemistry, and related fields. A strong measure of expertise is not just a few publications in one or two journals, but many publications in multiple peer-reviewed journals. If the work in these peer-reviewed publications is also widely cited, and agreed with, by other scientists, it is likely that they are truly considered experts by their peers in the areas of climate science in which they publish.

Moreover, because the field of climate science has itself become quite broad, status as an expert in one area of climate science does not necessarily render a scientist an expert in all areas of climate science. Again, a good metric of expertise is whether the scientist has published in the areas of climate science that are relevant to the case at hand and that their work is widely cited by others within the field. In a 2010 paper appearing in *Proceedings of the National Academy of Sciences*, the authors compared the professional influence of scientists claiming an association between climate change and anthropogenic emissions of greenhouse gases to those who

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- (a) the expert’s scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
  - (b) the testimony is based on sufficient facts or data;
  - (c) the testimony is the product of reliable principles and methods; and
  - (d) the expert has reliably applied the principles and methods to the facts of the case.”

FED. R. EVID. 702.

127. *Id.*

denied such an association.<sup>128</sup> The authors found that the scientists claiming an association had published far more peer-reviewed articles in more prestigious journals than those who denied such an association. This research has been criticized for equating scientific merit with “the number, productivity, or prominence of those holding a certain view—truth by majority rule or oligarchical fiat.”<sup>129</sup> Nevertheless, it would seem that unless one provides evidence of a barrier to expressing alternative views, such that one is less able to publish one’s views in the peer-reviewed literature, the number and prestige of the journal would constitute a valid metric for the most-considered knowledge on a particular topic.<sup>130</sup>

### CONCLUSION

Climate science is increasingly making an appearance in U.S. courtrooms. While in most instances, judges are asked to review an agency’s evaluation of the climate science, this may soon change with an increased emphasis upon climate adaptation measures. Such measures may generate trials in which climate change science is introduced in an adversarial context as important evidence. In this context, judges will be asked to take a more active role in evaluating the reliability and relevance of climate science. The judge’s role is all the more challenging given that climate science differs from the types of science, usually based upon laboratory experiments that are most often the basis for expert testimony in the courtroom. To judges in their evaluation of climate science, we have tried to provide some relevant information on the methods of climate science and the manner in which climate science has matured into a distinct discipline. Finally, we have provided three principles to guide a judge’s evaluation of the reliability and relevance of expert climate science.

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128. William R.L. Anderegg, James W. Prall, Jacob Harold & Stephen H. Schneider, *Expert Credibility in Climate Change*, 107 PROC. NAT’L ACAD. SCI. 12107 (2010).

129. Lawrence Boderstein, *Regarding Anderegg et al. and Climate Change Credibility*, 107 PROC. NAT’L ACAD. SCI. E188 (2010), available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3012507/>.

130. See Hoegh-Guldberg, *supra* note 104.

