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Forecasting the End of Climate Change Litigation: Why Expert Testimony Based on Climate Models Should Not Be Admissible.

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Alvaro Hasani

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“Rather than seeing models as describing literal truth, we ought to see 
them as convenient fictions which try to provide something useful.”¹

-- David Frame, climate modeler, Oxford University.

I. Introduction

Expert witnesses play a pivotal role in the American judicial system. They are capable of having a significant influence on the jury primarily because of the way in which a jury perceives a witness labeled an expert. ² Indeed, a jury more readily accepts as true the opinion of expert witnesses merely because of their designation as such.³ It is not surprising then, given the potential of such expert to affect the outcome of litigation, that many have scrutinized and criticized their use in the courtroom.⁴ Specifically, this paper focuses on “scientific models” as utilized in environmental-tort litigation. Expert witnesses rely on these models to analyze exposure to pollutants, carcinogens, contaminations and more importantly for the purpose of this paper, even global

¹ David Frame, climate modeler, Oxford University (available at http://rsta.royalsocietypublishing.org/content/365/1857/1971.full (last visited April, 2012)).
² E.I. de Pont de Nemours and Co., Inc. v. Robinson, 923 S.W.2d. 549, 553 (TX. 1995).
³ Id.
warming. Their analysis is a primary factor when determining liability in suits for damages.

While scientific models are nothing new, modern computing technology has equipped scientists with tremendous processing power enabling them to create increasingly complex models capable of simulating previously unmanageable problems. This new technology, coupled with recent federal environmental statutes has given rise to unprecedented climate change litigation. Additionally, modern public sensibility about environmental protection will undoubtedly lead to more environmental-tort actions. It is inevitable therefore, that scientific models will be scrutinized for their purported reliability and relevance in the courtroom. Accordingly, it is imperative that we explore and evaluate the science behind the scientific models that expert witnesses in the aforementioned litigations will rely on to proffer their expert testimony. This paper will show that based on a careful assessment of the science behind these models, testimony stemming from climate models should not be admissible pursuant to the governing standard for the admissibility of expert testimony.

Part II of this paper will provide an account of recent environmental-tort litigation in an attempt to illustrate the nature of climate change suits, that is the common claims and disposition of these types of cases. This part will also explain the reason behind the proliferation of these types of cases under state common law nuisance claims irrespective

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of the fact that previous litigation in this area has been easily disposed of under federal law. Part III defines and explains the scientific models that may have been used in those cases and models that could be used in future similar cases. It first describes the makeup and function of a scientific climate model and then provides evidence of the inherent limitations of these models. Part IV explores the current legal standard for the admissibility of expert testimony as delineated in federal case law and statute. This part gives a detailed description of each major case that has significantly contributed to the standard as well as the current federal rule of evidence that applies to expert testimony. Part V considers climate models in conjunction with the standard for admissibility and determines whether testimony, which relies on scientific models to prove the existence of climate change, can meet that legal standard. Based on this assessment, the paper ultimately establishes that such testimony cannot meet the legal standard for admissibility primarily because of the uncertainty associated with scientific models. Part VI deals with yet another problem that climate models could face. This portion describes how causation, while not necessarily an initial judicial determination for purposes of admissibility, may also prove problematic for climate models. Finally, part VII acknowledges the shortcomings of Daubert and advocates for a new standard while maintaining that as it currently stands, Daubert will prove challenging for climate change litigation that depends on climate models.
II. The Nature of Climate Change Litigation

Incredibly, the notion that our global climate is susceptible to change has been recognized as early as 1827. (See Appendix A). While the actual cause of that existence is often vigorously disputed, the resulting damage is virtually uncontested. One apparent adverse consequence of climate change is rising sea levels. The Intergovernmental Panel On Climate Change (IPCC) has noted that “[o]bservations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea level rise.”

Because rising sea levels are capable of inundating wetlands and eroding beaches and coastal lines, it is often the subject of environmental litigation. Some other examples of adverse impacts resulting from climate change include “shrinkage of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of mid-to high-latitude growing seasons, poleward and altitudinal shifts of plants and animal...

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8 See also, App. A for a detailed outline of climate change law and policy.
9 “global warming” and “climate change” will be used interchangeably throughout the paper.
10 For a general discussion on the effects of rising sea level see generally SUSANNE C. MOSER, CLIMATE CHANGE AND SEA-LEVEL RISE IN MAINE AND HAWAII: THE CHANGING TIDES OF AN ISSUE DOMAIN, in Ronald B. Michell, et al., Global Environmental Assessment (2006).
13 See e.g. Massachusetts v. EPA, 549, U.S. 497 (2007) (Plaintiff’s alleged that Defendant’s activities resulted in climate warming and caused coastal erosion).
ranges, declines of some plant and animal populations, and earlier flowering of trees, emerging of insects, and egg-laying in birds.”

The major dispute in this subject area centers on the question of who is responsible for the climate change and whether anything could be done to curtail its impact. Certainly, while the dangers of climate change are readily apparent, litigation could not ensue if these changes were purely natural as opposed to man made. However, the idea that climate change is man made has gained widespread acceptance in the scientific community. For instance, in 2007 the IPCC concluded that climate changes as observed in the last half century cannot be explained without “accounting for human emissions of greenhouse gases.” And even though other factors have previously influenced climate change, such as deviations in the earth’s orbit and the ice age, the IPCC concluded that anthropogenic gases are responsible for the recent changes.

Other prominent scientific bodies have substantiated IPCC’s findings. In 2005 for example, the National Academies of Science in the U.S. along with other G8 nations “issued an unprecedented joint statement blaming greenhouse gasses for the earth’s recent warming trend.” It is because of this consensus among the scientific community

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15 Vandenbergh & Steinemann, supra note 11, at 1680.
17 Vandenbergh & Steinemann, supra note 11, at 1680 (citing Intergovernmental Panel on Climate Change, Climate Change 2007: The Physical Science Basis 10-12 (2007)).
and the fact that damage resulting from climate change is a legally recognized injury, that climate change litigation has emerged and will continue to proliferate.

A. Climate Change Litigation

In order to fully appreciate the proliferation of climate change litigation, a brief survey of these cases is in order.

1. Massachusetts v. EPA

Unquestionably, one of the most high-profiled litigation relating to climate change is Massachusetts v. EPA. In that case, environmentalists, frustrated with government’s haphazard attempt to regulate emissions of carbon dioxide, petitioned the EPA to regulate “greenhouse gas emissions from new motor vehicles under §202 of the Clean Air Act.” However, the EPA decided that although it had the authority to regulate CO\textsubscript{2} emissions, the Clean Air Act did not authorize it to issue mandatory regulations to address climate change and that even if the Act required it to regulate the emission of greenhouse gases, it would be unwise for it to do so. EPA’s decision was then appealed to the D.C. Circuit, which held that the EPA had properly exercised its discretion in refusing to regulate greenhouse gasses. The U.S. Supreme Court reversed. The Court held that as a preliminary manner, Plaintiffs had standing to bring the claim because the state of Massachusetts was experiencing erosion of its coastal land due to

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19 See Massachusetts v. EPA, 549 U.S. 497 (2007); In re Quantification of Envir. Costs, 578 N.W. 2d 794, 796-97 (Minn. Ct. App. 1998) (affirming agency's calculation of harm from Carbon Dioxide gasses); See also Daniel A. Farber, Basic Compensation for Victims of Climate Change, 155 U. PA. L. REV. 1605, 1613 (2007) (recognizing that damage resulting from climate change is a cognizable injury).
21 Id. at 510.
22 Id. at 511.
23 Id. at 514.
24 Id.
rising sea levels resulting from global warming. Then the Court held that because Congress had already given EPA the authority to regulate greenhouse gasses, the EPA acted arbitrarily and capriciously in refusing to do so.

Shortly after the debut of Massachusetts v. EPA, aggrieved parties harmed by the effects of global warming took notice and began initiating actions against the emitters of greenhouse gases. And while Plaintiffs in Massachusetts v. EPA sought only policy changes, these subsequent cases focused more on recovery of damages.

2. California v. General Motors Corporation

In California v. General Motors Corporation, the state of California filed suit against General Motors alleging public nuisance under both federal and state common law. Specifically, California alleged that General Motors had, as a result of their automobile production, emitted massive quantities of carbon dioxide into the atmosphere. The Complaint explained that this elevated level of carbon dioxide traps atmospheric heat thereby causing global warming. As a result of this global warming, California alleged that they have suffered economic damage. For instance, it was alleged that the shrinkage of the Sierra Nevada snow pack will likely cause flooding and compromise California’s water system. As a result, California has to financially invest in studies and infrastructure in order to prevent flooding and assure the safety of the State’s

25 Id. at 534.
26 Id.
27 This case was initiated in 1999 as an administrative law case whereby environmentalists filed a rulemaking petition with the EPA. See Massachusetts v. EPA, Id. at 510. See also Brooks E. Harlow & Roy W. Spencer, Ph.D., An Inconvenient Burden of Proof? Co2 nuisance Plaintiffs Will Face Challenges in Meeting the Daubert Standard, 32 ENERGY L.J. 459, 464 (2011).
28 Id.
31 Id at ¶ 2.
32 Id.
drinking water.\textsuperscript{33} The Complaint also alleged that, as a consequence of global warming, rising sea levels will result in the erosion of California’s beaches and that prolonged heat waves will cause wild fires, leading to the destruction of their forest and possibly death and injury to its citizens. All of these adverse impacts, the Complaint alleged, will cost the State millions of dollars.\textsuperscript{34} Ultimately though, the federal district court avoided the thorny issue of global warming and dismissed the case on the grounds of political question doctrine.\textsuperscript{35}

\textbf{3. \textit{Comer v. Murphy Oil USA}}

In \textit{Comer v. Murphy Oil USA},\textsuperscript{36} Plaintiffs were residents and landowners along the Mississippi Gulf Coast. They brought a class action suit against the Murphy Oil USA company alleging that their operation of energy, fossil fuels and chemical industries “caused the emission of greenhouse gasses that contributed to global warming, \textit{viz.}, the increase in global surface air and water temperatures, that in turn caused a rise in sea levels and added to the ferocity of Hurricane Katrina, which combined to destroy the plaintiffs’ private property, as well as public property useful to them.”\textsuperscript{37} Plaintiffs asserted claims for compensatory and punitive damages, among others.\textsuperscript{38} The District Court granted defendants’ motion to dismiss the claims on the grounds of standing and political question doctrine.\textsuperscript{39} While the Fifth Circuit originally reversed the District

\textsuperscript{33} Id. For a detailed description of this case see also, Farber, \textit{supra} note 12, at 1091.
\textsuperscript{34} Id at ¶ 56.
\textsuperscript{36} 585 F.3d 855 (5th Cir. 2009).
\textsuperscript{37} At 859.
\textsuperscript{38} Id.
\textsuperscript{39} Id. at 860.
Court’s decision with respect to justicability, the Circuit subsequently hearing the case *en banc* dismissed the appeal for lack of a quorum.\(^{40}\)

4. **Native Village of Kivalina v. ExxonMobil Corporation**

In *Native Village of Kivalina*,\(^{41}\) an Eskimo village and the City of Kivalina brought suit against numerous energy and utility companies under federal and state common law of nuisance. These Plaintiffs alleged that Defendant’s emission of greenhouse gasses had caused global warming and as a consequence, “the Arctic sea ice that protects the Kivalina coast from winter storms ha[d] diminished, and that the resulting erosion and destruction will require the relocation of Kivalina's residents.”\(^{42}\) Accordingly, Plaintiffs sought damages for the cost they would have to incur in order to relocate the village.\(^{43}\) The estimated cost for this relocation was valued at approximately $400 Million.\(^{44}\) Again, the District Court granted Defendant’s motion to dismiss under standing and political question doctrine.\(^{45}\) The case is currently in the process of appeal.

5. **Connecticut v. American Electric Power Company**

In *Connecticut v. American Electric Power Company*,\(^{46}\) eight States along with New York City and three land trusts brought an action under federal and state common law against six electric power corporations that owned and operated fossil-fuel-fired power plants in approximately 20 states.\(^{47}\) Plaintiffs sought abatement of Defendants’ emission of greenhouse gasses and thereby the decline of contribution to global

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\(^{40}\) Comer v. Murphy Oil USA, 607 F.3d 1049 (5th Cir. 2010).
\(^{42}\) Id. at 869.
\(^{43}\) Id.
\(^{44}\) Id.
\(^{45}\) Id. at 883.
\(^{47}\) Id.
warming.\textsuperscript{48} The Complaint alleged that “global warming, to which Defendants contribute as the five largest emitters of carbon dioxide in the United States ... by emitting 650 million tons per year of carbon dioxide, is causing and will continue to cause serious harms affecting human health and natural resources.”\textsuperscript{49} Plaintiff Complaint explained that “carbon dioxide acts as a greenhouse gas that traps heat in the earth's atmosphere, and that as a result of this trapped heat, the earth's temperature has risen over the years and will continue to rise in the future... [and global warming] will accelerate over the coming decades unless action is taken to reduce emissions of carbon dioxide.”\textsuperscript{50}

True to form, the Federal District Court granted Defendant’s motion to dismiss based on political question doctrine.\textsuperscript{51} The Second Circuit however, reversed the District Court’s decision and held that Plaintiff’s had sufficiently established standing.\textsuperscript{52} The U.S. Supreme Court struck the final blow. The Court dismissed the case on grounds that the Clean Air Act preempted “any federal common law right to seek abatement of carbon dioxide emission from fossil-fuel-fired power plants.\textsuperscript{53}

**B. Proliferation of Litigation Resulting From State Law Nuisance Claims**

Although *Connecticut v. American Electric Power Company*, was an action requesting abatement rather than recovery damages, its holding is especially significant for purposes of this paper. The holding, while it precluded federal common law claims of nuisance based on preemption, did not expressly state that the Clean Air Act preempts

\textsuperscript{48} Id.
\textsuperscript{49} Id.
\textsuperscript{50} Id.
\textsuperscript{51} Id. at 271.
\textsuperscript{52} *Connecticut v. American Elec. Power Co.*, 582 F.3d 309, 389 (2d Cir. 2009).
state law nuisance.\textsuperscript{54} In fact, the Court plainly noted that “[n]one of the parties have briefed preemption or otherwise addressed the availability of a claim under state nuisance law. We therefore leave the matter open for consideration on remand.”\textsuperscript{55} As a result, climate change litigation based on state common law nuisance is expected to increase. Indeed, scholars have unequivocally maintained that the Second Circuit will permit state common law nuisance claims and have noted that the Supreme Court’s pass on state law nuisance claims will result in many more cases being brought under state common law.\textsuperscript{56} These scholars have argued that the Clean Air Act will in all likelihood not preempt state common law of nuisance. They explain:

Defendants will likely argue that the state law claims are preempted by the CAA. However, the threshold for preemption is higher than for the doctrine of displacement, which was the basis of the Court's decision in AEP. So long as damages suits do not interfere with the Congressional purpose of the CAA, claims may be permitted. And the CAA contains a savings clause for private actions: Nothing in this section shall restrict any right which any person (or class of persons) may have under any statute or common law to seek enforcement of any emission standard or limitation or to seek any other relief (including relief against the Administrator or a State agency).\textsuperscript{57}

Additionally, there appears to be precedent for permitting state common law nuisance claims for damages, irrespective of federal regulation dealing the discharged pollutants.\textsuperscript{58}

Indeed, in \textit{International Paper Co. v. Ouellette},\textsuperscript{59} the U.S. Supreme Court “permitted plaintiffs to maintain a damages action for water pollution under state common law

\textsuperscript{54} Id. at 2540.
\textsuperscript{55} Id.
\textsuperscript{56} Harlow & Spencer, \textit{supra} note 27.
\textsuperscript{57} Id at 464.
\textsuperscript{58} Id.
nuisance theory, notwithstanding that the Clean Water Act prescribed regulations governing discharge of pollution into waterways.60

Evidently, the holding in Connecticut v. American Electric Power Company, has not and will not thwart climate change litigation due to preemption. While virtually all of these cases have been disposed of on justiciability grounds, state common law will provide for their resurrection. In fact, as recent as 2011, climate change litigation based on state common law have been initiated in several federal district courts and eleven state courts.61 It is therefore inevitable that courts will have to confront scientific testimony in climate change litigations.

III. Climate Change Models

When considering the aforementioned cases, one thing is apparent. Climate change litigation depends on the threshold issue of global warming. In any of the above-mentioned cases, Plaintiffs could have succeeded only by proving the existence of global warming or climate change and by establishing that Defendants were the cause of that existence. Given the hefty reliance on the threshold issue of climate change and causation, experts are going to be indispensable in demonstrating that our climate is actually changing due to anthropogenic conduct. Their assertion of this will derive from climate models.

60 Harlow & Spencer, supra note 27, at 464 (citing Int'l Paper Co. v. Ouellette, 479 U.S. 481, 497-500 (1987)).
61 See Id. (citing Complaint for Declaratory & Injunctive Relief at 1, Loorz v. EPA, No. 11-2203 (N.D. Cal. May 4, 2011) and Answer of Defendants to Plaintiffs' Amended Complaint for Declaratory & Injunctive Relief, Svitak v. State, No. 11-2-16008-4 (Wash. Super. Ct. King Co. June 24, 2011)).
A. Methodology Of Climate Models

The dangers of climate change by way of anthropogenic gas emissions are based solely on the study of climate models. In its very essence, these models simulate how the atmosphere will react to increased anthropogenic gasses. But for the purpose of this paper, it is critical to fully comprehend the science behind these models and how they actually work.\textsuperscript{62}

Generally, a scientific model is “a representation of the behavior of an object or process, often in mathematical or statistical terms.”\textsuperscript{63} Climate models represent a virtual system that evolves in the same way as the real world. In order to achieve this simulation, these types of models attempt to incorporate all the known elements that affect climate (see Appendix B),\textsuperscript{64} which can be represented in mathematical equations based on natural scientific laws, empirical data and observations.\textsuperscript{65} These equations are then incorporated into computer language along with other information, such as topography and vegetation, to form the basis of a climate model.\textsuperscript{66}

Earlier models were somewhat deficient because of their incapacity to account for many of the factors that influenced climate.\textsuperscript{67} For example, these antiquated models, due to the lack of technology, approximated certain processes, which in turn resulted in gaps

\textsuperscript{62} It is important to note that the task of explaining and describing the functionality of a scientific model is a daunting endeavor. Indeed, it is a subject deserving of its own paper, if not book. Accordingly, for the purpose of this paper, only a generalized description of these models will be given that will suffice to serve the thesis of the paper.
\textsuperscript{64} For the different natural elements that may be incorporated in a climate model see App. B.
\textsuperscript{66} Id.
\textsuperscript{67} Id.
and uncertainties.\textsuperscript{68} However, climate models have developed tremendously as a result of supercomputers.\textsuperscript{69} Apparently, current models are superior because they can now incorporate many factors that were once too complex to integrate. For instance, the advancement in technology has enabled models to be “more finely grained--with smaller cells providing more detail on processes--and enable the incorporation of ocean currents and other factors too complex for the early models.”\textsuperscript{70} Today’s models are even capable of taking into account “aerosols such as sulfur-dioxide plumes caused by industrial sources; river and estuary water mixing, which affects ocean salinity; sea ice; and terrestrial processes.”\textsuperscript{71} Additionally, recent models can “incorporate the terrestrial biosphere, including vegetation and soil carbon cycles.”\textsuperscript{72} Even the data itself, as used in climate modeling, has improved as a result of “more sophisticated measurements for surface sea temperature (SST), satellite data, and more careful and comprehensive data sets of ground-based measures.”\textsuperscript{73}

One scientist has explained how a particular model named after the Goddard Institute for Space Studies (GISS) actually functions:

Like all climate models, GISS . . . divides the world into a series of boxes. Thirty-three hundred and twelve boxes cover the earth's surface, and this pattern is repeated twenty times moving up through the atmosphere . . . . [I]n the world of the model, features such as lakes and forests and, indeed, whole mountain ranges are reduced to a limited set of properties, which are then expressed as numerical approximations. Time in this grid-world

\textsuperscript{68} Id.
\textsuperscript{69} Id.
\textsuperscript{70} Id.
\textsuperscript{71} Id. (citing David A. Randall et al., Climate Models and Their Evaluation, in Intergovernmental Panel on Climate Change, Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 589, 592 (S. Solomon et al. eds., 2007)).
\textsuperscript{72} Id.
\textsuperscript{73} Id. (citing Hervé Le Treut et al., Historical Overview of Climate Change Science, in Intergovernmental Panel on Climate Change).
moves ahead for the most part in discrete, half-hour intervals, meaning that a new set of calculations is performed for each box for every thirty minutes that is supposed to have elapsed in actuality. Depending on what part of the globe a box represents, these calculations may involve dozens of different algorithms, so that a model run [may involve] more than a quadrillion separate operations. A single run of the GISS model, done on a supercomputer, usually takes about a month. The model calculates changes in each block based on fundamental laws and on “parameterizations.” These parameterizations approximate complex physical processes with simpler equations that capture the physical results but without all the details of the process.\textsuperscript{74}

Kolbert’s description of the GISS climate model bespeaks characteristics that are common among all climate models. (See Appendix C).\textsuperscript{75}

\section*{B. Limitations Of Climate Models}

Undoubtedly, climate models have come a long way and improved tremendously. Nevertheless, some maintain that even today’s most sophisticated models are still susceptible to certain deficiencies. For example, because natural systems are so complex it is almost impossible to accurately describe these systems mathematically.\textsuperscript{76} Therefore, every model involves simplifications and thus their result “will never correspond exactly with reality.”\textsuperscript{77} This uncertainty is further complicated by the human element. Decisions such as which element of a system to integrate into a model, which type of model is best suited for the purpose, and uncertainties as to whether one has gathered precise data about the system and importantly whether data has been accurately input, all contribute to the inaccuracy of the model.\textsuperscript{78}

\textsuperscript{75} For an example of what a typical climate model looks like see App. C.
\textsuperscript{76} Swinehart, supra note 5, at 1288.
\textsuperscript{77} Id.
\textsuperscript{78} Id.
One other major deficiency of current models has to do with their inability to accurately account for the complex dynamics of clouds. This is significant because clouds are responsible for reflecting up to two-thirds of the planet’s light.\(^79\) This is especially alarming when considering that global temperature can deviate 2.0 to 5.0 degree Celsius, depending on what estimations were used for cloud behavior.\(^80\) The concern was echoed by the IPCC when it noted that “[i]t is somewhat unsettling that the results of a complex climate model can be so drastically altered by substituting one reasonable cloud [parameterization] for another . . .”\(^81\)

With the inherent deficiencies of models in mind, modelers attempt to minimize these uncertainties by way of calibration, which in and of itself is alarming. The process of calibration adjusts a model to a point where it can precisely predict a natural event that has already occurred.\(^82\) This might involve “placing coefficients in front of one or more source terms or adding a constant to an individual equation so that it will produce the desired result.”\(^83\) Therefore, the mere fact that a model is capable of proving historical data once it has been properly calibrated does not necessarily mean that the model will accurately predict future events.\(^84\) For instance, “if a beach-erosion model was calibrated using historical rates of erosion at one beach, the model will accurately regurgitate those historical rates but will likely err in approximating any future rate at that same beach . . .[and] if the same model is then applied to a new natural system—i.e., a different

\(^79\) Id. (citing Hervé Le Treut et al., Historical Overview of Climate Change Science, in Intergovernmental Panel on Climate Change).
\(^80\) Id.
\(^81\) Id.
\(^82\) Id. (citing Orrin H. Pilkey & Linda Pilkey-Jarvis, Useless Arithmetic: Why Environmental Scientists Can’t Predict the Future 43 (2007)).
\(^83\) Id.
\(^84\) Id.
beach than the one at which it was calibrated--the model's accuracy will drop precipitously.”  

The lack of transparency coupled with the solitude nature of the development of these models is also troublesome. Their cryptic character has to do with their inherent complexities. Indeed, “it is virtually impossible for any one individual to comprehend fully every line of computer code, the vast array of assumptions made, or the interplay of the numerous underlying physical processes [of computer models].” Additionally, because the climate factors integrated into a model are solely based on the modeler’s discretion with regard to its role and significance, an objective evaluator of these models could not determine for sure the purpose and accuracy of each of these factors, especially if its documentation is unavailable or unintelligible. This makes it extremely difficult to achieve independent replication of model prediction, a fundamental principle in reliable science.

With the character and functionality of these models in mind, we now turn to the standard of admissibility for expert witnesses and will then assess whether testimony based on climate models can meet the demonstrated standard.

**IV. Admissibility of Expert Witnesses**

Arguably, courts have struggled for the better part of the 20\(^\text{th}\) century to define the standard with which the admissibility of expert witnesses should be determined.

Nevertheless, through a process of trial and error, federal courts have finally developed a

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86 Id.
87 Id.
legal standard out of case law and subsequent statutory codification. It is important to note that while the developed legal standard is wholly federal, it is nonetheless highly significant even for those cases arising out of state common law since state courts apply some form of the federal standard for determining the admissibility of expert witnesses. For instance, roughly 25 states apply the federal Daubert standard while 10 states apply the Frye test.\footnote{David E. Bernstein & Jeffrey D. Jackson, The Daubert Trilogy in the States, 44 JURIMETRICS J. 351, 355 n. 25 (2004); See also Harlow Spencer, supra note 27.} The remaining states apply a variation of the two standards.\footnote{Id.}

Additionally, challenges to the admissibility of expert testimony could prove to be critical. One study has shown that Defendants are successful in excluding Plaintiffs’ expert testimony an astonishing two-thirds of the time\footnote{Michael Risinger, Navigating Expert Reliability: Are Criminal Standards of Certainty Being Left on the Dock?, 64 ALB. L. REV. 99, 108-10, 145-47 (2000).} and that summary judgment motions based on Daubert challenges were decided against the plaintiff in over ninety percent of the time.\footnote{Lloyd Dixon & Brian Gill, Changes in the Standards for Admitting Expert Evidence in Federal Civil Cases Since the Daubert Decision, 8 PSYCHOL. PUB. POL’Y & L. 251 (2002).} Considering therefore, that climate change litigation is wholly reliant on the ability of experts to establish a causal relationship between global warming and Defendants’ conduct, their testimony will be indispensable. It is therefore useful to provide a brief background on the legal standard of admissibility of expert witnesses.

\textbf{A. Frye v. United States}

The judiciary first established the common law standard concerning the admissibility of expert witnesses in \textit{Frye v. United States}.\footnote{293 F. 1013 (D.C. Cir. 1923).} In \textit{Frye}, the Defendant was accused of murder. As part of his defense, Defendant sought to introduce at trial the results of a systolic blood pressure deception test in an attempt to establish his
truthfulness about the events in question and thereby his innocence. The Defense maintained that this test, which was a precursor to the polygraph test, would indicate whether or not the Defendant was being truthful as “conscious deception or falsehood, concealment of facts, or guilt of crime, accompanied by fear of detection when the person is under examination, raises the systolic blood pressure.”

The Court proceeded to answer the question by looking at the scientific community and examining whether such methodology of expertise had gained general acceptance within the community. After careful consideration, the Court held the evidence of a systolic blood pressure test inadmissible because it had not gained general acceptance in the scientific community and was therefore deemed to be unreliable. Evidently, under this standard courts were not required to analyze the scientific method but rather only consider whether such method was generally accepted in the relevant scientific community. This standard became known as the “general acceptance” test.

However, the test was often criticized for being too rigid and unyielding and dangerously capable of excluding reliable evidence. So in 1975, Congress enacted the Federal Rules of Evidence, which some commentators noted called into question the continuance of the Frye “general acceptance” test. As a result, the U.S. Supreme Court decided to consider the issue once more.

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93 Id. at 1013.
94 Id.
95 Id. at 1014.
B. Daubert v. Merrell Dow Pharmaceutical inc.

In Daubert v. Merrell Dow Pharmaceutical inc., the Court rejected the “general acceptance” test as articulated in Frye and set forth a new standard for determining the admissibility of expert witnesses in federal court. The Plaintiffs in the case, parents of two disabled children, alleged that the children’s serious birth defects resulted from the mother’s prenatal ingestion of a prescribed drug that was marketed at the time by Merrell Dow Pharmaceuticals. Defendant in the case offered expert testimony indicating that no study has ever linked the drug to fetal deformities. Plaintiffs’ experts concluded that the drug at issue could have caused the children’s birth defects. They had based their conclusions on extensive experimental studies of the chemical structure of the drug, test tube experiments as well as live animal studies, which all linked the drug to deformities. The trial court, relying on the Frye standard, granted Defendant’s summary judgment motion and found that the Plaintiff’s experts did not meet Frye’s “general acceptance” standard. The Court of Appeals affirmed. The U.S. Supreme Court, in recognizing that the enacted Federal Rules of Evidence made no mention of the Frye standard, concluded that the standard “absent from, and incompatible with, the Federal Rules of Evidence, should not be applied in federal trials.”

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100 While the Frye general acceptance test is no longer used in federal courts, it is important to note that it may be alive and well in some state courts. See. E.g., Flanagan v. State, 625 So. 2d 827, 828 (Fla. 1993) (noting that the standard still lives on in the state of Florida. “[A]n expert's opinion which is based on a scientific principle, theory or methodology is admissible only when the underlying scientific principle, theory or methodology is generally accepted in the field in which it belongs.”).
101 Daubert, at 582.
102 Id.
103 Id. at 583.
104 Id.
106 Daubert, 509 U.S. at 588-89.
the Federal Rules of Evidence. The newly established standard bestowed upon Judges a sort of gatekeeping function to “ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable.”

The Daubert Court also provided some guiding factors to determine the admissibility of expert witnesses. These factors were certainly not meant to be exhaustive nor were they meant to be determinative on the issue. The factors included: (i) whether the theory or technique can and has been tested; (ii) whether the theory or technique has been subjected to peer review and publication; (iii) the theory or technique’s “known or potential rate or error”; (iv) whether there are standards that control the theory or technique's operation; and (v) the degree to which the theory or technique has been accepted in the relevant scientific community (“general acceptance test”).

While the Court in *Daubert* attempted to clarify the standard for the admissibility of expert witnesses, it unfortunately yielded more questions than answers. One of the questions left unanswered by *Daubert* was whether the guidelines and standards as established by the Court, applied to all expert witnesses or only scientific witnesses. The Court in *Kumho Tire Co. v. Carmichael* undertook the task of clarifying the issue raised by *Daubert*.

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107 Id.
108 Id. at 589.
109 Id. at 593-594.
110 Id. at 593-594.
C. Kumho Tire Co. v. Carmichael

In *Kumho*, Plaintiffs brought an action against a tire manufacturer after one of the rear tires of Plaintiffs’ minivan exploded while driving, resulting in an accident.\(^\text{112}\) Plaintiffs relied on an expert in tire failure analysis who concluded that the blow out resulted from a defect in the design of the tire.\(^\text{113}\) Using the *Daubert* guidelines, the Court excluded the testimony of purported expert as an expert witnesses because it concluded that the expert did not meet the required factors as established by the Supreme Court and therefore indicated that the expert’s methodology was not reliable.\(^\text{114}\) However, the Eleventh Circuit reversed. It held that *Daubert* restricted its holding only to testimony that was scientific in nature.\(^\text{115}\) The Court explained that because the expert’s testimony in the case at bar fell outside the scope of science and was based on experience, it was outside the bounds of the *Daubert* holding and thus the trial court erred when it relied on the factors set forth in *Daubert*.\(^\text{116}\) The U.S. Supreme Court disagreed. It noted that rule 702 did not distinguish between scientific, specialized or other knowledge.\(^\text{117}\) Consequently, the Court concluded that *Daubert’s* gatekeeping responsibility applies to all matters described in Federal Rule of Evidence 702.\(^\text{118}\)

D. Federal Rule of Evidence 702

Congress has now amended Rule 702 to promulgate the standards as established in *Daubert* and *Kuhmo*. Under the new Federal Rule of Evidence 702, expert testimony is admissible if it complies with the following criteria:

\(^{112}\) Id. at 142.  
\(^{113}\) Id. at 143.  
\(^{114}\) Id. at 145.  
\(^{115}\) Id. at 146.  
\(^{116}\) Id.  
\(^{117}\) Id. at 147.  
\(^{118}\) Id.
If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.\textsuperscript{119}

Federal courts now use this rule to screen and determine the admissibility of expert witnesses.

\textbf{V. Applying The Standard of Admissibility to Climate Models}

The quote at the beginning of this paper is demonstrative of the inherent problems of climate models and thereby the trouble in relying upon them in climate change litigation. Certainly, climate models could prove useful. Indeed, their results, no matter how uncertain, could effectuate positive social policy by inducing cautionary proactive measures. Nevertheless, social policy notwithstanding, their uncertainty should not be disregarded in cases where civil liability is solely determined on the evidence derived from climate models. Naturally, before we can hold anyone civilly liable we must first ensure that the imposition of liability is not grounded in “convenient fiction” but rather credible evidence. The aforementioned legal standard for admissibility of expert testimony attempts to serve this purpose. Pursuant to this established standard, expert testimony based on climate models should not be admissible.

\textsuperscript{119} \textsc{Fed. R. Evid.} 702.
A. Whether the Theory or Technique Can and Has Been Tested

As previously discussed, the Daubert Court provided some guiding factors to determine the admissibility of expert witnesses. The first of these factors was whether the theory or technique can and has been tested. This first factor would go against the admissibility of expert testimony based on climate models because the theory of global warming has not and indeed cannot be tested. Scientists cannot perform an experiment on the actual atmosphere and any experiment that would attempt to simulate the atmosphere would lack the complexity associated with it. Likewise, model results cannot be observed directly in nature, as they are merely simplifications of complex systems rather than the actual systems themselves. Additionally, because climate models attempt to forecast climate in trends of decades or centuries, their accuracy cannot be tested immediately. As some scholars have explained, because of this long waiting period, “[i]n an effort to attempt to validate the models, scientists have therefore engaged in ‘hindcasting.’ In other words, they have applied their models to data about past CO\textsubscript{2} concentrations and temperatures. But hindcasting lacks the rigors of forecasting since the answer (the observed temperature record) is already known in advance.”

The first Daubert factor is also problematic with regard to causation. For instance, while it is generally accepted the CO\textsubscript{2} has caused the recent climate change, evidence suggests that climate change has emerged prior to the advent of CO\textsubscript{2}

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120 It is important to note that in climate change litigation, the issue of contention will not be whether the expert qualifies as an expert. Certainly, climatologists will have sufficient scientific, technical or other specialized knowledge to assist the trier of fact. The issue will center around whether a climatologist can rely on climate models to proffer his or her expert testimony.
121 Harlow & Spencer, \textit{supra} note 27.
122 Swinehart, \textit{supra} note 5.
123 Harlow & Spencer, \textit{supra} note 27 (citations omitted).
emissions.\footnote{124} Therefore, the direction of causation itself is disputable and should not be admissible. Furthermore, while \textit{Daubert} demands that scientific knowledge “connotes more than subjective belief or unsupported speculation”\footnote{125} climate models simply assume that in response to increased CO$_2$ emissions cloud changes will increase rather than reduce temperatures.\footnote{126} This assumption however has never been tested and amounts to mere speculation rather than scientific knowledge.\footnote{127}

\textbf{B. Whether the Theory or Technique Has Been Subject to Peer Review and publication}

Peer review is a process of self-regulation that adds credibility to scientific work. This process attempt to expose “incorrect or inadequate [information and] improve the accuracy and clarity of published reports.”\footnote{128} While the theory of global warming has been published in peer-review articles, it has yet to gain unanimous consensus among the scientific community. Indeed, there currently exists a considerable amount of published articles that directly contradict the existence of global warming.\footnote{129} In fact, over 31,000 scientists have signed a petition opposing any recent findings of global warming and insisting that there currently exists no substantial reliable

\begin{footnotes}
\footnote{124} Id.
\footnote{125} Id. (citing Daubert at 590).
\footnote{126} Id.
\footnote{127} Id.
\end{footnotes}
evidence that would affirm the existence of global warming. Accordingly, while the theory has been subject to peer review, the scientific community’s findings are seemingly inconclusive.

C. Whether the Theory or Technique Has a Known Rate of Error

The knowledge of error rate is critically important for determining the reliability of the methodology employed by experts. Without this knowledge, one cannot ascertain the reliability of one’s method to construct and interpret a climate model. Unfortunately, when it comes global warming, error rate is non-existent. Again, the reason for this is that climate models predict climate many decades in advance or even centuries. Therefore, their results could not be verified presently, if at all. However, even if we could determine the error rate for climate models, it is likely that the rate would arguably be high enough to constitute unreliable evidence. This high rate would most likely be influenced by factors that contribute to a model’s uncertainty such as “(i) model imperfection, (ii) omission of important processes, (iii) lack of knowledge of initial conditions, (iv) sensitivity to initial conditions, (v) unresolved heterogeneity, (vi) occurrence of external forcing, and (vii) inapplicability of the factor of safety concept.” Other factors leading to a high rate of error in predictive climate models include “structural errors in methodology stemming from aggregation (i.e., lumping two

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131 See Roy W. Spencer, Should Climate Models Be Accepted as Evidence in a Court of Law?, Climate Realists, June 9, 2009, available at http://www.climaterealists.com/index.php?id=3555 (last visited April, 2012) (noting that error rate is not only presently unknown but it is also unknowable).
or more real-world processes into one modeling process or integrating empirical data
over a physical volume) or simplification (i.e., averaging data inputs by using the median
value in a data set)." Ultimately though, it is the predictive nature and the uncertainty
of climate models, that serve as an obstacle to ascertainable error rate as contemplated by
Daubert.

D. Whether Standards Exist that Control the Theory or Technique's Operation

Unquestionably, modelers employ certain universal standards in constructing and
interpreting climate models. These standards are based on natural scientific laws,
empirical data and observations. Nevertheless, the lack of transparency associated with
the construction of climate models render these universal standards meaningless.
Certainly, if one cannot ascertain the methods employed to construct climate models then
the model cannot be replicated or tested by someone other than the original developer.
Its function therefore becomes limited. Moreover, the subjectivity involved in the
development of models, that is decisions as to which element of a system to integrate into
a model or which type of model is best suited for the purpose, further disguise the
standards used. With the methods of development virtually concealed, it would be
difficult to determine if all modelers followed the same standard.

133 See Swinehart, supra note 5.
E. Whether the Theory or Technique has Been Accepted in the Relevant Scientific Community

As previously mentioned, there currently exists a considerable amount of published articles that directly contradict the existence of global warming. Over 31,000 scientists have voiced their concerns about what they believe to be a lack of evidence pointing to the existence of global warming. Therefore, it is questionable whether the science behind climate models and the existence of what they purport to predict has actually gained general acceptance among the scientific community. Additionally, while Daubert did not fully abrogate the “general acceptance” test as articulated in Frye, it placed particular emphasis on testing and verifiability by way of the scientific method. Even if one presumes that the theory of global warming has gained general acceptance among the scientific community, the theory has yet to be tested or verified by way of the scientific method. This very fact directly contradicts the recommendation set forth in Daubert. Indeed, “where validation is utterly lacking, general acceptance even if found to exist for [global warming] theories should not suffice for admissibility.”

F. Whether the Testimony Assists the Trier of Fact

The Federal Rules of Evidence, while attempting to codify the standards of

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138 Harlow & Spencer, supra note 27.
admissibility of expert witnesses as laid out by the U.S. Supreme Court, placed particular importance on whether the testimony would assist the trier of fact. This specific criterion, while not an enumerated factor under *Daubert*, goes to the relevancy issue as explained in *Daubert*. With that said, it is evident that testimony based on climate models cannot assist the trier of fact. For instance, it has been noted that even the most objective of experts will succumb to the pressures of our adversarial system and ultimately skew their purported findings in a defensive attempt to not look foolish during cross-examination. Their willingness to advocate for their own side often leads to the dilution of their objectivity. Stated differently, our adversarial system, based on zealous advocacy and the expert’s allegiance to one side results in a testimony that is overly one sided and subjective. Given the expert’s bias and the ease with which climate models may be manipulated, that is by way of subjectively deciding which elements to include, which model to use and how to interpret its results, experts may effortlessly influence the results of climate models to serve their ultimate interests. This overly one-sided testimony then, when proffered by each party cannot assist the trier of fact to determine the evidence and may in fact confuse them.

Moreover, the cumbersome rules of evidence in our judicial system also affect the testimony given by experts and thereby hinder rather than assist the trier of fact. For example, in our courtrooms experts are generally not permitted to editorialize and explain their nuanced analysis. As expert witnesses, they are only supposed to answer what is asked of them, which in turn forces them to make categorical and unequivocal

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141 This is particularly true during cross-examination.
assertions, contradictory to the very method they employ in their field. Modelers are not immune from this phenomenon. When proffering expert testimony, they will be obligated to make categorical and unequivocal assertions about very complex climate models that require detailed explanation and description in order to fully appreciate and comprehend their results. Accordingly, testimony based on climate models does not assist the trier of fact and may actually result in confusion and proffered of unreliable subjective rather than objective testimony.

VI. Problem of Causation

Another critical obstacle for expert testimony based on climate models has to do with the onerous task of proving causation. Admittedly, causation is not necessarily a Daubert factor nor is it required as part of a judge’s consideration when determining the admissibility of expert testimony. The trier of fact rather is ultimately responsible for determining causation. Nevertheless, this point bears noting since it has a significant impact on climate change litigation that utilize climate models.

As already discussed, Plaintiffs in climate change litigation need not only prove the actual existence of global warming but also a causal link between it and the Defendant’s conduct. This will be virtually impossible. As judge Jenkins noted in California v. General Motors Corporation, “the court is ill-equipped to decide how much auto emissions contribute to global climate change, what is and what is not a reasonable amount of greenhouse gas emissions, and who should bear the costs of global climate
change.” Additionally, inherent uncertainty in climate models does not help matters. For instance, even *Daubert* demands expert testimony to be “sufficiently tied to the facts of the case” and there is “nothing in either *Daubert* or the Federal Rules of Evidence requir[ing] a district court to admit opinion evidence that is connected to existing data only by the *ipse dixit* (unproven statement) of the expert.” Yet, “there is currently no scientific evidence to link a local source of carbon emissions to local damage.” Therefore, the difficulty in first proving the existence of global warming and then establishing that a specific source of emission caused a specific result, will culminate in the inevitable extinction of climate change litigation.

**VII. Daubert’s Deficiencies**

As already established, a model’s inherent uncertainty poses significant challenges to its admissibility. Yet, some have argued that uncertainty alone should not constitute grounds for the exclusion of these models and that the real cause of the problem lies with the *Daubert* standard itself. As one scholar has explained, the Court in *Daubert* “took it for granted that there is a distinct, well-demarcated ‘scientific method,’ comprising criteria that can be clearly identified and objectively applied to determine the validity of scientific evidence.” Apparently, the Court assumed that

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146 Swinehart, *supra* note 5.

experimental science is the controlling method for scientific inquiry as evidenced by their proposed criteria of testability and error rate.\textsuperscript{148} That assumption however, greatly oversimplifies the intricacy of methods and procedures that characterize current scientific practice.\textsuperscript{149} While the experimental method undoubtedly “occupies a preeminent position within science,” it is certainly not the only technique utilized for scientific inquiry.\textsuperscript{150} Indeed, “[t]o be ‘scientific,’ a theory does not necessarily have to be subjected to experimental testing.”\textsuperscript{151} Consider for instance the widely accepted scientific theory of natural selection. It “rests on a massive amount of empirical observation but does not easily lend itself to experimental verification.”\textsuperscript{152} The same is true of the “big bang theory.”\textsuperscript{153} In fact psychology, psychiatry, anthropology and sociology—all valid theories in human sciences—are incapable being tested through controlled experiments.\textsuperscript{154}

Another problematic aspect of Daubert relates to judicial activism, which could in turn have an adverse impact on legitimate but newly developed sciences. As Jasanoff explains, Daubert “presupposed that judges would approach the issue of scientific validity with no preconceived notions about science.”\textsuperscript{155} In reality however, “[f]ar from acting as gatekeepers who merely let “good science” in through the courtroom door, post-Daubert judges have emerged as active participants in making science, consistent with their lay understandings of how science should be made.”\textsuperscript{156} Stated differently, judges

\begin{itemize}
\item \textsuperscript{148} Id.
\item \textsuperscript{149} Id.
\item \textsuperscript{150} Id.
\item \textsuperscript{151} Id.
\item \textsuperscript{152} Id.
\item \textsuperscript{153} Id.
\item \textsuperscript{154} Id. Consider also interdisciplinary fields such as history and art.
\item \textsuperscript{155} Id.
\item \textsuperscript{156} Id.
\end{itemize}
differentiate between “good science” and “junk science” by incorporating first their own understanding of what science is or should look like. While certainly understandable, this method of determination when coupled with mechanical adherence to the *Daubert* factors, is capable of excluding “good science” that is merely nascent\(^\text{157}\) and unsuitable for experimental verification. Certainly, climate models could be susceptible to this phenomenon.

Admittedly, the standard for admissibility of expert witnesses as established in *Daubert* is far from perfect.\(^\text{158}\) It is now evident “after more than a decade's experience with *Daubert* that the lower courts have applied it quite vigorously to screen out not only ‘junk science’ but also a good deal of ‘sound science’ as well.”\(^\text{159}\) Unquestionably, the legal standard as it currently functions must be adjusted to ensure the inclusion of reliably expert testimony while at the same time filter out expert testimony that proves to be unreliable. However, if history is indicative of things to come, establishing a new standard for the admissibility of experts will be an onerous endeavor. Importantly, it is critical to bear in mind that *Daubert* is the current standard for determining the admissibility of expert witnesses. As imperfect as it may be, this paper has established that so long as it controls, *Daubert* will thwart litigation that dependant on climate models.

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\(^{157}\) Or perhaps incomprehensible.


\(^{159}\) Id.
VIII. Conclusion

The resulting damage and potential danger of global warming is undeniable. Nor do I contest the fact that anthropogenic conduct has wholly or partially contribute to our global climate change. Furthermore, climate models have certainly proven to be a useful tool from a policy perspective to curtail the emission of greenhouse gasses, even if only out of an abundance of caution. Nevertheless, models should not be admissible in court to prove liability. Their demonstrated uncertainty, while acceptable from a policy perspective, should not be utilized to determine wrongdoing and thereby justify significant monetary compensation. Indeed, while only a preponderance of evidence is required in civil litigation, the burden of determining liability should not be met by proffering dubious evidence. All of the evidence must be reliable and capable of assisting the trier of fact. Climate models, at their current stage, fail to meet this standard. Accordingly, any future litigation premised on the theory of global warming, which would then rely on expert testimony based on climate models, should not get passed a Daubert hearing. As imperfect of a standard as it may be, it is undeniably presently controlling.
# Appendix A

## Climate Change Law and Policy Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1827</td>
<td>Jean-Baptiste Fourier suggests the existence of an atmospheric “greenhouse” effect keeping the Earth warmer than it would otherwise be.</td>
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<tr>
<td>1890s</td>
<td>Swedish scientist Svante Arrhenius and American P.C. Chamberlain independently argue that increasing concentrations of atmospheric carbon dioxide from the burning of fossil fuels could lead to global warming.</td>
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<tr>
<td>1957</td>
<td>U.S. oceanographer Roger Revelle warns that people are conducting a “large-scale geophysical experiment” on the planet by releasing GHGs. Colleague David Keeling establishes the first continuous monitoring of atmospheric carbon dioxide levels and finds regular annual increases.</td>
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<tr>
<td>1979</td>
<td>The First World Climate Conference calls on governments “to foresee and prevent potential man-made changes in climate.”</td>
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<tr>
<td>1985</td>
<td>The first major international conference on the greenhouse effect at Villach, Austria, warns that GHGs will “in the first half of the next century, cause a rise of global mean temperature which is greater than any in man's history” and that sea levels could rise by up to a meter.</td>
</tr>
<tr>
<td>1987</td>
<td>The warmest year on record. The 1980s are the warmest decade recorded to date, with seven of the eight warmest years recorded up to 1990.</td>
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<tr>
<td>1988</td>
<td>Dr. James Hansen of NASA tells a congressional hearing that “global warming is at hand.” A meeting of climate scientists in Toronto subsequently calls for 20% cuts in global carbon dioxide emissions by the year 2005. The U.N. sets up the IPCC to analyze and report on scientific findings.</td>
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<tr>
<td>1990</td>
<td>The IPCC’s first report finds that the planet has warmed by 0.5°C in the past century. The IPCC warns that only strong measures to halt rising greenhouse gas emissions will prevent serious global warming.</td>
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<td>1992</td>
<td>The U.N. Framework Convention on Climate Change, signed by 154 nations in Rio, seeks to prevent “dangerous” warming from greenhouse gases and sets an initial nonbinding target of reducing emissions from industrialized countries to 1990 levels by the year 2000.</td>
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<tr>
<td>1995</td>
<td>The IPCC’s second report concludes that current warming “is unlikely to be entirely natural in origin” and that “the balance of evidence suggests a discernible human influence on global climate.” The report predicts global warming by the year 2100 will be between 1°C and 3.5°C.</td>
</tr>
<tr>
<td>1999</td>
<td>Scientists, reconstructing the global climate for the last 1000 years, using weather records, tree rings, coral, and ice-core readings, declare that the decade of the 1990s is the hottest in at least the last millennium.</td>
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<tr>
<td>2002</td>
<td>The United States’s Climate Action Report 2002 warns of the substantial disruption of snow-fed water supplies, the loss of coastal and mountain ecosystems, and more frequent heat waves. The trilateral North American Commission for Environmental Cooperation calls for “immediate action” to tackle greenhouse gases. 2002 is the second hottest year ever recorded.</td>
</tr>
<tr>
<td>2005</td>
<td>The Kyoto Protocol enters into force, requiring most industrialized countries to make cuts in their GHG emissions. Hurricane Katrina devastates New Orleans and two separate studies link global warming to the increased intensity and frequency of hurricanes.</td>
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</tbody>
</table>

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Appendix B

Different Natural Elements Incorporated Into A Climate Model\textsuperscript{161}

Appendix C

An Example of A Climate Model\textsuperscript{162}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{climate_model_diagram.png}
\caption{Physical Processes in a Model}
\end{figure}

\textsuperscript{162} National Oceanic and Atmospheric Administration, \textit{Climate Model}, Available at http://celebrating200years.noaa.gov/breakthroughs/climate_model/modeling_schematic.html (last visited April, 2012).