ICTA INTERNATIONAL CENTER FOR TECHNOLOGY ASSESSMENT

Communicating Uncertainty in the Science of Climate Change:

An Overview of Efforts to Reduce Miscommunication Between the Research Community and Policymakers & the Public

Summary: Special interest groups and policymakers opposed to legislative action to reduce human emissions of CO_2 and other greenhouse gases often cite "uncertainty" in climate change science to justify their position. While there is much uncertainty in climate science (and there always will be), many researchers in the field insist that this uncertainty does not justify the lack of a policy response. In fact, scientists know a great deal about climate change, and there is a strong scientific consensus that the Earth is warming significantly, primarily due to human activities.

The United States is the world's leading emitter of greenhouse gases that contribute to global warming, yet the response by U.S. policymakers to the problem has been weak. The longer we ignore global warming, the greater the likely consequences of climate change become. Therefore, it is crucial to break the existing policy roadblock on this issue. To do this, scientists and policymakers must work to improve communication between each other and between themselves and the public.

As a first step, a hearing in the U.S. Senate's Committee on Commerce, Science & Transportation on "Communicating Uncertainty in Climate Change Science" would let leading climate scientists explain what they mean when they talk about "uncertainty" in climate change science. The hearing would allow scientists to work with policymakers to devise a means of communicating uncertainty so as not to preclude a policy response. A number of climate researchers have published work on communicating uncertainty. Potential witnesses for a hearing on "Communicating Uncertainty in Climate Change Science" would include:

- Dr. Chris Forest of the Massachusetts Institute of Technology
- Dr. James Hansen of the NASA Goddard Institute for Space
- Dr. Martin R. Manning of the IPCC Working Group I Support Unit
- Dr. Richard Moss of the U.S. Global Change Research Program
- Dr. Stephen Schneider of Stanford University
- Dr. Peter H. Stone of the Massachusetts Institute of Technology
- Dr. Mort Webster of the University of North Carolina
- Dr. Tom Wigley of the U.S. National Center for Atmospheric Research Studies

Introduction

Many policymakers, along with the current administration, have opted to take a "wait-to-learn" approach to climate change, hoping that scientific discoveries will clarify the problem and offer better policy options than are currently available. In the words of Mort Webster from the University of North Carolina, "[D]iscussions of climate policy are typically framed as a choice of acting now or waiting until we know more about the problem."[1] The wait-and-see politicians and advocates for industries that produce the bulk of greenhouse gas emissions often cite the high level of "uncertainty" in climate change science, uncertainty that climate researchers freely admit is substantial. However, a growing number of climate scientists fear that waiting to resolve more of the uncertainties in climate science would be a mistake. Webster writes that "the ability to learn more and reduce uncertainty in the future is *not* necessarily a valid argument for delaying abatement" of greenhouse gas emissions.[2] Barrie Pittock and his colleagues at Australia's Climate Impact Group note that many of the uncertainties about future climate change concern the rate at which people will emit greenhouse gases in the coming decades. Therefore, they argue, a policy response that would shrink emissions would actually decrease some of the uncertainty in climate change projections and simultaneously reduce climate change's potential future damage to society and the environment.[3]

Unfortunately, some special interests opposed to addressing the problem of climate change have picked up on the wait-to-learn concept and have begun trumpeting the uncertainties in climate models and projections. By doing so, they have often misrepresented the actual state of climate science. Climatologist J.D. Mahlman from the National Center for Atmospheric Research warns, "When either uncertainty or natural variability is systematically used to push a prestated position, be wary. Science may just have been misused, to the net loss of a more rational effort to establish what is really going on in the science of this daunting problem."[4]

In fact, the uncertainties do not diminish the voluminous knowledge scientists have acquired regarding global warming and its potential impacts on future climate. "It would be wrong to imagine that the science of climate change is somehow more fraught with uncertainty than many other areas where society has pressing concerns," writes Martin R. Manning of the Intergovernmental Panel on Climate Change (IPCC) Working Group I Support Unit.[5]

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[1] Mort Webster, "The Curious Role of 'Learning' in Climate Policy," *Energy Journal* 23 (2002): 97-119.

[2] Ibid, 117. Emphasis in the original.

[3] A. Barrie Pittock, et al., "Probabilities Will Help Us Plan for Climate Change," *Nature* 413 (20 Sept. 2001): 249.

[4] J.D. Mahlman, "Science and Nonscience Concerning Human-Caused Climate Warming," *Annual Review of Energy & Environment* 23 (1998): 100.

[5] Martin R. Manning, "The Difficulty of Communicating Uncertainty," *Climatic Change* 61 (2003): 9.

What Is Uncertainty?

Uncertainty in Science and in Policymaking

The term “uncertainty” means different things to different people and in different contexts. Typically, scientists view uncertainty as an intrinsic component of scientific inquiry. This is not a bad thing. Out of any meaningful scientific discovery inevitably arise new questions and new avenues for exploration. In science, nearly all conclusions contain an element of uncertainty, because declaring something a “certainty” requires a degree of knowledge seldom attainable in the real world. For the vast majority of scientific inquiries, including those regarding global climate change, there are simply too many variables and too many fine details for us to ever completely eliminate uncertainty.

However, just because a scientist notes uncertainties in his work or that of his colleagues, it does not mean the work is flawed or that we cannot draw strong conclusions from it. For example, when scientists say that there are many uncertainties surrounding the science of global climate change, we should not interpret this to mean that scientists doubt that the Earth is warming, that warming is having an effect on climate, or that human greenhouse gas emissionsare largely responsible for that warming. The overwhelming scientific consensus is that these assertions are true. (See the Appendix.)

Policymakers, and the public in general, view uncertainty in a wholly different light. Uncertainty represents a lack of knowledge: an incomplete picture. Whereas for scientists uncertainty points the way towards further action, for policymakers it tends to breed indecision. Policymakers desire to make decisions based on a complete set of facts after all uncertainty has been eliminated. As discussed above, however, this is an idealistic situation that in most cases the scientific community is unable to provide. According to ecologists G.A. Bradshaw and Jeffrey G. Borchers, “The idea that greater certainty can be obtained and allow for more ‘certain’ conditions for decision making with better and faster science is based on the erroneous supposition that uncertainty is finite. ... Whether or not they continue to be science-based, environmental policy formulation and decision making will be accomplished under conditions of uncertainty.”[6]

The truth is, we can never eliminate uncertainty. In fact, new scientific discoveries often create new uncertainties, so that as our knowledge about climate change improves the number of uncertainties in the science may actually increase. For example, the determination that an increase in the global mean surface temperature is likely to also increase cloud formation in the future climate represents a significant advance of our understanding of global warming. However, scientists are not certain how cloud formation might feedback into the overall climate system and affect the future warming of the planet. So, while our overall understanding of climate change has increased, so has the number of uncertainties in the science.

Of course this does not mean that there is an insurmountable disconnect between science and policy. Just because a scientist admits that we don’t know everything, it does not mean we don’t know enough to act. In fact, the scientific understanding of climate change and the role of human emissions in bringing it about has increased by an

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[6] G.A. Bradshaw and Jeffrey G. Borchers, “Using Scientific Uncertainty to Shape Environmental Policy,” in *IUFRO Task Force on Forest Science-Policy Interface*, International Union of Forest Research Organizations Occasional Paper No. 13, May 1999, <http://aliens.csir.co.za/iufro/publications/op13/op13-paper-bradshaw.pdf>

extraordinary degree over the past two decades. The lack of complete knowledge does not preclude a policy response.

Policymakers act in the face of uncertainty all the time. There is a much greater collection of evidence that human activities are warming the planet and altering global climate in a dangerous way than that an asteroid or other massive near-Earth-object will collide with the Earth over the next 100 years. Yet, the Senate Committee on Commerce, Science and Transportation recently held a hearing on near-Earth-objects that garnered prominent national and international headlines.[7] Furthermore, Congress routinely makes budgetary decisions based on economic projections that include huge levels of uncertainty.

Uncertainties in Climate Science

Uncertainty in climate change arises from two sources: 1.) Uncertainties regarding how the climate system works and how researchers should represent specific processes in computerized climate models, and, 2.) Variables related to the future actions of human beings, which are subject to unpredictable policy decisions and human activities.

The main uncertainties in the climate system itself concern system feedbacks—that is, how the warming of the Earth will alter the conditions that drive future climate change. An example of this is the effect of clouds on global warming. An increase in the development of low-atmosphere clouds would reflect more solar radiation away from the Earth and potentially reduce global warming. However, an increase in the formation of high-atmosphere clouds would tend to capture a greater portion of the infrared radiation emitted by the surface of the Earth, potentially exacerbating the overall warming of the planet. Scientists confidently project that in a warming Earth, cloud formation will increase. They do not know, however, whether these clouds are more likely to form at high or low levels in the atmosphere. This creates an uncertainty in the computer climate models that scientists must evaluate and, to the best of their abilities, compensate for.

It should be noted that for every uncertainty, there are many climate model inputs that scientists understand very well. While these climate models are inevitably imperfect, they can accurately simulate the climate over the past century, and they are the best tools we have for projecting the future course of climate change. Also, they are improving rapidly. To dismiss them because of uncertainties in how the climate works would be foolish. A better approach is for scientists to acknowledge the uncertainties, analyze them, and use their expert judgments to make the best possible estimates for unknowns, such as the effect of future cloud formation on climate change.[8]

The second type of uncertainty in climate change assessments involves variables difficult todefine because they depend on the decisions and actions of unpredictable human beings. For instance, climate modelers have no way ofpre cisely determining future policy actions, economic growth, and technological innovations, all of which may affect greenhouse gas emissions. While scientists can make assumptions to reduce uncertainties, it is impossible for them to eliminate these uncertainties altogether. Scientists have responded to the problem by developing numerous scenarios to cover a

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[7] Maggie Fox, "Search to Find Dangerous Asteroids Nearly Complete," Reuters, 7 April 2004.

[8] J.D. Mahlman, "Science and Nonscience Concerning Human-Caused Climate Warming," *Annual Review of Energy & Environment* 23 (1998): 83-105.

huge range of potential future emissions. They then plug the entire data set into the computer models and get a range of potential results.

While this effectively deals with the uncertainty, it creates new problems. The implication is that any figure within the range of future global warming, say 1.4° to 5.8°C by the year 2100, is equally likely. This allows those interested in ignoring climate change to point to the low end of the scale and say that things will not be so bad. Conversely, those who advocate strong action may point to the high end of the scale. In fact, the real answer is likely to lie somewhere in the middle. Perhaps, the best way to clarify the situation is for scientists to present the entire range, but use expert judgments and analyses to determine which figures in the range are more likely than others to represent the actual outcome.[9]

Despite the uncertainties in climate change science, it is reasonable for policymakers to act based on the best information available. Waiting to act until researchers resolve the uncertainties in climate science—that is, adopting the wait-to-learn approach—is unrealistic. First, as explained above, some of the uncertainties in climate science will never be resolved—they are simply unknowable. Second, as pointed out by Mort Webster on the University of North Carolina, Chris Forest of the Massachusetts Institute of Technology, and their colleagues, inertia in the Earth's climate and ocean systems and the fact that atmospheric concentrations of greenhouse gases are cumulative mean that once the effects of global warming occur, any actions taken to address these problems will take decades or even centuries to have any effect. They write that "effective mitigation action must be started decades before the climate changes of concern are actually observed."[10] In other words, if we wait to learn, we may find that we have waited too long.

Communicating Uncertainty

Over the past few years, climate scientists have begun addressing the difficulties of communicating uncertainty in climate change to nonscientists and of providing scientific informationabout uncertainty that may be useful in the formulation of policy responses to the problem of climate change. This process involves two primary steps: (1.) quantifying the uncertainties, and (2.) communicating the quantified uncertainties in such a way that policymakers might still find the underlying information useful.[11]

Quantifying Uncertainties

Quantifying uncertainties in climate change science is, understandably, a tricky business. It boils down to determining how much we don't know about each particular variable in the climate models. There is an entire branch of statistics, known as Bayesian statistics, that allows scientists to develop reasonable probability statements based on

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[9] J.D. Mahlman, "Science and Nonscience Concerning Human-Caused Climate Warming," *Annual Review of Energy & Environment* 23 (1998): 83-105.

[10] Mort Webster, et al., "Uncertainty Analysis of Climate Change and Policy Response," *Climatic Change* 61 (2003): 295-320.

[11] Mort Webster, "Communicating Climate Change Uncertainty to Policy-Makers and the Public," *Climatic Change* 61 (Nov. 2003): 1-8.

expert assessments of the models and data going into them.[12] That is, scientists can use Bayesian analysis to formulate a statement, for example, that they are X% sure that the global temperature rise over the coming century will fall between Y° C and Z° C.

The advantage of a probabilistic statement, is that rather than presenting a complete range of potential temperature changes over the next century and implying that any figure in the range is equally likely, it gives policymakers a smaller range of the most likely outcomes. Webster and Forest, et al., write that if scientists simply present a non-probabilistic range of climate change results, then for the data to be meaningful in a policy context *someone* is going to make a judgment about which part of the range is most likely. They argue that the scientific community has a responsibility to offer judgments on likelihood because, after all, they have studied the processes and phenomena that lead to uncertainty and are in the best position to quantify likelihoods, as difficult as that can be. This does not preclude policymakers and the public from weighing this information and arriving at other judgments in their decisions but it gives them the judgment of experts from which to start.[13]

One way scientists can generate probabilistic statements useful in a policy context is for them to compute "probability density functions" (pdfs) for the main sources of uncertainty in the climate change models. A pdf, basically, defines the probability that an uncertain variable falls within a certain range. By assigning pdfs to the main uncertainties in a climate model, researchers can induce a computer climate model to create an output pdf—that is, for example, a probability statement for the Earth's mean surface temperature rise over a given time period. According to Tom Wigley of the U.S. National Center for Atmospheric Research and Sarah Raper of the Climatic Research Unit, University of East Anglia, UK, the benefit of using pdfs to refine non-probabilistic ranges, such as those presented in the IPCC Third Assessment Report (TAR), is that the "results ... place the warming range given in the TAR into a more realistic context by expressing the range in probabilistic form, accounting for emissions, climate sensitivity, carbon cycle, aerosol forcing, and ocean-mixing uncertainties."[14] When scientists limit the range of each uncertainty going into the overall model, the output is not a broad range of outcomes that are implicitly equally plausible, but rather a smaller range of outcomes that are likely.

Researchers have already begun the task of computing pdfs based on the accumulated opinions of experts. James S. Risbey of Carnegie Mellon University and his colleagues provide an example of a protocol to translate expert judgments on uncertainties regarding a specific climate change issue into quantifiable, probabilistic expressions useful to policymakers. The authors note that early "efforts to describe and communicate uncertainty in climate change knowledge have tended to resist quantification and the temptation to be too specific." However, this approach misled policymakers concerning the nature of the uncertainties in climate change science and provided them little information useful for devising policies.

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[12] Jim Giles, "When Doubt Is a Sure Thing," *Nature* 418 (August 2002): 477.

[13] Mort Webster, et al., "Uncertainty Analysis of Climate Change and Policy Response," *Climatic Change* 61 (2003): 295-320; John Reilly, "Re:[Fwd: RE: Climate Change and Uncertainty]," personal email (1 July 2004).

[14] T.M.L. Wigley and S.C.B. Raper, "Interpretation of High Projections for Global-Mean Warming," *Science* 293 (13 April 2001): 451-454.

The Risbey, et al., protocol is merely one example of the ways that scientists can devise probability statements to account for the uncertainty in their work. While a detailed explanation of the protocol lies beyond the scope of this paper, the authors emphasize that any method that devises probabilities based on expert judgments to quantify uncertainties in climate change science should:

- explain as many of the expert judgments as is possible or reasonable
- allow the judgments to be expressed quantitatively
- include probabilities to show which expressions of the uncertainties are most likely
- include the entire reasonable range of expert opinion[15]

Climate researchers have begun using this sort of uncertainty analysis to assign probabilities to global warming ranges, and to provide more precise assessments than, say, the IPCC TAR. These more precise assessments may be of greater use to policymakers than earlier simple ranges that provide no assessment of the uncertainties. Below are brief explanations of several recent efforts.

A. Webster and Forest

Uncertainty analyses by Mort Webster of the University of North Carolina, Chris Forest of MIT, et al. used expert opinions to assess the likely levels of future emissions of greenhouse gases, and emissions of other short-lived pollutants that affect climate. Additionally, they used analyses of climate changes over the 20th century to assess climate sensitivity to increases in greenhouse gas emissions, heat uptake by the oceans, and the effect of aerosols on climate. Employing their uncertainty analyses, Webster, Forest, et al. find that if greenhouse gas emissions continue unabated, there is a 50% chance that the Earth's mean surface temperature will rise by more than 2.4° C by 2100 and a 97.5% chance that the rise will be less than 4.9° C. Under a scenario in which policies achieve "aggressive emissions reductions," the authors provide a 50% chance that the temperature increase by 2100 will exceed 1.6° C and a 97.5% chance that the increase will not exceed 3.2° C.[16]

B. Wigley and Raper

Tom Wigley of the U.S. National Center for Atmospheric Research and Sarah Raper of the Climatic Research Unit, University of East Anglia, UK, have attempted to clarify the TAR's projected range of warming over the coming century of 1.4° C to 5.8° C. They computed pdfs for the main uncertainties in the TAR range and found that in the absence of policies to mitigate climate change, there is a 90% probability that the Earth's mean surface temperature will rise by 1.7° C to 4.9° C by 2100.[17]

C. Stott and Kettleborough

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[15] James S. Risbey, et al., "A Protocol to Articulate and Quantify Uncertainties in Climate Change Detection and Attribution," *Climate Research* 16 (10 Nov. 2000): 61-78.

[16] Mort Webster, et al., "Uncertainty Analysis of Climate Change and Policy Response," *Climatic Change* 61 (2003): 295-320.

[17] T.M.L. Wigley and S.C.B. Raper, "Interpretation of High Projections for Global-Mean Warming," *Science* 293 (13 April 2001): 451-454.

British climatologists Peter Stott and J.A. Kettleborough also employed uncertainty analyses to constrain the range of the projected global mean temperature rise. Computing pdfs to assess the uncertainties in their climate model, the researchers projected with 95% confidence that the temperature rise by 2100 under a scenario characterized by high carbon emissions (the IPCC A1FI scenario) would be between 3.0° C and 6.9° C. Under a scenario with strong measures to mitigate greenhouse gas releases (the IPCC's B1 scenario), the researchers projected with 95% confidence that the temperature rise by 2100 would be between 1.2° C and 3.3° C.[18]

Communicating the Quantified Uncertainties

In an editorial comment in the journal *Climatic Change* Martin R. Manning of the IPCC Working Group I Support Unit says that the media has often exaggerated controversies among climate scientists, especially in reports on the policy implications of climate change. In fact, he writes: "It would be wrong to imagine that the science of climate change is somehow more fraught with uncertainty than many other scientific areas where society has pressing concerns." When communicating with the public and policymakers, climate scientists should strive to avoid "straying into one of the twin traps of ignoring the necessary caveats or producing statements so hedged in qualifications as to misrepresent what we really do understand."[19]

Prior to the drafting of the IPCC's TAR, Stephen H. Schneider of Stanford University and Richard H. Moss of Battelle Pacific Northwest National Laboratory submitted a paper recommending ways for the lead authors of the TAR to effectively communicate the inherent uncertainties in climate change science without misleading the public or policymakers. Schneider and Moss note, "The term 'uncertainty' can range in implication from a lack of absolute sureness to such vagueness as to preclude anything more than informed guesses or speculation."[20]

They add that researchers need to learn to differentiate between "science" and "science for policy." The latter, they write, "involves being responsive to policymakers' needs for expert judgment at a particular time, given the information currently available, even if those judgments involve a considerable degree of subjectivity."[21]

Scientists have long realized that it is impossible to describe many aspects of climate science quantitatively, that is, using exact numerical figures. The majority of the effects of global warming have yet to occur, so climate change projections are necessarily based on data (such as future greenhouse gas emissions) that may change. Therefore, researchers are better able to "obtain semi-quantitative assessments of uncertainties." Schneider and Moss suggested prior to the completion of the TAR that climate scientists could eliminate some confusion by using precisely defined language to indicate the probability that an event will occur. They proposed assigning rigid percentage probabilities to specific terms used in the report to connote degrees of uncertainty. Thus

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[18] Peter A. Stott and J.A. Kettleborough, "Origins and Estimates of Uncertainty in Predictions of Twenty-First Century Temperature Rise," *Nature* 416 (18 April 2002): 723-726.

[19] Martin R. Manning, "The Difficulty of Communicating Uncertainty," *Climatic Change* 61 (November 2003): 9-16.

[20] Richard H. Moss and Stephen H. Schneider, "Uncertainties in the IPCC TAR: Recommendations to Lead Authors for More Consistent Assessment and Reporting," in *Guidance Papers on the Cross-Cutting Issues of the Third Assessment Report of the IPCC*, ed. R. Pachauri et al., (2000), 35.

[21] Ibid, 36.

the phrase “very high confidence” would pertain to a statement with a 95 to 100% confidence level. Other terms proposed by Schneider and Moss appear in Table 1.[22]

Table 1. IPCC Working Group II Definitions

Term	**Confidence Level**
Very High Confidence	95 to 100%
High Confidence	67 to 95%
Medium Confidence	33 to 67%
Low Confidence	5 to 33%
Very Low Confidence	0 to 5%

The lead authors of Working Group II of the IPCC TAR, which included Schneider, used these terms and definitions in their report. The lead authors of Working Group I used a similar system but altered the terms and definitions slightly, adding two additional categories (see Table 2).

Table 2. IPCC Working Group I Definitions

Term	**Confidence Level**
Virtually Certain	Greater than 99%
Very Likely	90-99%
Likely	66-90%
Medium Likelihood	33-66%
Unlikely	10-33%
Very Unlikely	1-10%
Exceptionally Unlikely	Less than 1%

However, using precisely defined probabilistic terms does not eliminate the possibility that policymakers and the public will misinterpret statements on climate change science. Climatologists Anthony G. Patt and Daniel P. Schrag argue that the IPCC report’s use of specific language following Schneider and Moss’s proposal (e.g. employing the terms “virtually certain,” “very likely,” etc.) has the potential to mislead non scientific readers, including policymakers. This is because the IPCC in its attempt to communicate probability (the likelihood an event will happen, independent of the consequences) employs terms commonly used to communicate risk (the likelihood an event will cause a significant effect). Psychological studies show that people tend to exaggerate the likelihood of events with serious consequences. For example, a weather forecaster may describe a 10% chance of a major hurricane striking a city as “unlikely,” while the same forecaster may describe a 10% chance of minor snow flurries as “very unlikely.” Even though the two events have the same probability of occurring, the more serious of the two is seemingly deemed more likely.

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[22] Ibid, 44.

At the same time, however, researchers have found listeners tend to compensate for this type of exaggeration. In the example cited above, research subjects who were told there was an "unlikely, perhaps very unlikely" chance of a hurricane striking their city placed a lower probability on the event than subjects told there was an "unlikely, perhaps very unlikely" chance of snow flurries. This study and others like it show that even when people hear the same language used to describe the probability of two events, they tend to judge the more extreme as less likely to occur—they compensate for the exaggeration of the person providing the information.

This psychological phenomenon can have implications for scientists communicating the probability of climate change events to policymakers. Because the IPCC authors, and other climate scientists, assign a set definition for each of the probabilistic terms they use (see Tables 1 and 2), these terms do not reflect the normal exaggeration for events with high consequences. That is, they do not exaggerate high-risk events. However, policymakers, reporters, and other nonscientists who read the report are likely to compensate for such exaggeration, even though it has not occurred. The result, say Patt and Schrag, is that "people will have a tendency to overestimate the likelihood of low-magnitude events, and under-estimate the likelihood of high-magnitude events." Overall, this is likely to lead to policymakers "under-responding to the aggregate risks associated with climate change."

Patt and Schrag suggest that policymakers and scientists can overcome the problem as long as they are aware it exists. Policymakers, when reading the IPCC reports and other scientific publications regarding climate change, must pay greater attention to detail. They should "both notice and adopt the IPCC's precise, potentially counterintuitive, meaning of probabilistic language." Even more importantly, scientists must encourage their lay audiences to pay close attention to detail. They must clearly match any descriptive terms they use to the exact probability ranges those terms indicate.[23]

Martin R. Manning partially discounts the arguments of Patt and Schrag. He notes that the intended audience for the IPCC reports consists of policymakers and their advisors, who are "familiar with very precise and legalistic use of language." He also argues that many of the consequences of events described in the IPCC reports are not so disparate (at least not on the order of "snow flurries" versus "a hurricane" as used in the Patt and Schrag example) as to result in interpretational bias.

However, he notes that because the IPCC TAR does not incorporate a risk-assessment element, it may unintentionally persuade policymakers to ignore low probability events that, if they did occur, would bring extremely serious consequences. For example, the TAR says that the collapse of the Western Antarctic ice sheet during the 21st century is "very unlikely," which under the IPCC's definition of the term means there is a 1 to 10% chance that it will happen. The use of the term "very unlikely" may lead policymakers to ignore this threat. However, because the collapse of the Western Antarctic ice sheet would cause a potentially cataclysmic rise in sea levels, the risk (defined as probability times consequences) is actually very significant.[24]

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[23] Anthony G. Patt and Daniel P. Schrag, "Using Specific Language to Describe Risk and Probability," *Climatic Change* 6 (2003): 17-30.

[24] Martin R. Manning, "The Difficulty of Communicating Uncertainty," *Climatic Change* 61 (November 2003): 9-16.

Conclusion

The science of climate change is affected by two types of uncertainty: 1.) unknown aspects of how the climate system works, and 2.) unknowable variables concerning how future human actions (including policy responses) will impact climate change. It is impossible for scientists to eliminate these uncertainties. However, policymakers and the general public should not misconstrue this to mean that researchers do not know much about the climate and cannot provide useful projections of the Earth's future global temperature rise. Also, it is a mistake for policymakers to attempt to use scientific uncertainties to justify a "wait-to-learn" approach to dealing with climate change.

Confusion often arises when scientists attempt to communicate the significance of uncertainties in climate science to lay audiences. A number of researchers have published papers on methods for improving the communication of uncertainty in climate change. Many of these advocate the use of precisely defined probabilistic terms to indicate just how certain scientists are that a particular effect of climate change will occur.

Researchers can devise these probabilistic statements by using expert opinions to evaluate uncertainties in the climate science. Many climate scientists feel that this approach is desirable when communicating with policymakers and other non-scientists, because it allows experts, rather than non-experts, to make any subjective judgments that go into climate projections. In order for data to have any significance for policymakers, these judgments (such as determining which temperature within the IPCC's projected temperature increase over the coming century is most likely) will certainly be made. It becomes a question of who is going to make the judgments—the scientists who have a greater understanding of the uncertainties that contribute to the range of potential temperature rises, or special interests, policymakers, and members of the public who probably have a lesser understanding of the uncertainties.

Climate scientists have made great strides in developing improved methods for communicating their findings and the role of uncertainty to policymakers and the public. However, this only addresses one side of the equation. The next step must entail ensuring that policymakers and the public get the message. Towards this end, the International Center for Technology Assessment proposes a series of congressional hearings designed to improve communication between climate scientists and policymakers. An initial hearing on "Communicating Uncertainty in Climate Change Science" would take place in the U.S. Senate's Committee on Commerce, Science & Transportation. This hearing and others in the series would allow scientists who have considered the problems associated with communicating climate science to policymakers to explain these problems and propose solutions. The hearings would also provide an opportunity for policymakers to explain what sorts of information are need to get past the uncertainty hurdle and advance the formulation of an effective policy response to climate change.

It is also important that the scientists who have done significant work on communicating the uncertainties in climate change share their ideas with other scientists in the field. A whitepaper clearly articulating the leading ideas on communicating climate findings (and the role of uncertainties) to policymakers and the public would assist in this regard.

Beyond congressional hearings, a public education and media campaign would improve policymakers' and the general public's understanding of climate science and the role of uncertainty. An effective campaign would consist of national media outlet editorial board meetings, a press conference centered on the congressional hearings featuring researchers who have done work on the role of uncertainty in climate science, and advertisements in national newspapers and magazines explaining the strength of existing climate change science and the need for an immediate policy response by Congress and the administration.

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CTA Global Warming Project Coordinator
September 2004

Appendix: The Use of Probabilistic Language in the IPCC TAR

Using terms and definitions in Table 2, the authors of these two sections of the IPCC report were able to state a number of findings and unambiguously convey their levels of certainty. Among "virtually certain" (greater than 99% chance of being correct) findings are:

- The levels of greenhouses gases in the atmosphere are increasing because of human activities, and are now more than 30% higher than pre-industrial levels.
- The accumulation of greenhouse gases in the atmosphere absorb and re-radiate infrared radiation, increasing the surface temperature of the planet.
- Greenhouse gases that accumulate in the atmosphere will affect the planet's climate for many centuries.
- Over the past 100 years, the average surface temperature of the Earth has risen by 0.4° to 0.8°C.

Among the "very likely" (90-99% chance of being accurate) findings are:

- A doubling of atmospheric CO_2 above pre-industrial levels (we are already 30% above pre-industrial levels) will raise the mean surface temperature of the Earth by between 1.5° and 4.5°C.
- By the year 2100, the mean surface temperature of the Earth will rise by between 1.4° and 5.8°C.
- Sea levels will rise by between 25 and 75 cm due to thermal expansion of sea water by 2100. (The sea level rise could be much greater due to the melting of landlocked ice, but this does not fall in the "very likely"—90-99% accurate—category.)
- Warming of the Earth will increase mean global precipitation by 1.5-2.5% per 1°C of surface temperature rise.

Among the "likely" (66-90% chance of being accurate) findings are:

- Northern mid-latitude continents will become more prone to desertification due to decreases in soil moisture.
- Tropical storms will become more intense in warmer ocean waters.
- There will be more extreme warm-weather events and fewer extreme cold-weather events.