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The Scientific Consensus on Climate Change: How Do We Know We're Not Wrong?

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In December 2004, *Discover* magazine ran an article on the top science stories of the year. One of these was climate change, and the story was the emergence of a scientific consensus over the reality of global warming. *National Geographic* similarly declared 2004 the year that global warming "got respect" (Roach 2004).

Many scientists felt that respect was overdue: as early as 1995, the Intergovernmental Panel on Climate Change (IPCC) had concluded that there was strong scientific evidence that human activities were affecting global climate. By 2007, the IPCC's Fourth Assessment Report noted it is "extremely unlikely that the global climate changes of the past fifty years can be explained without invoking human activities" (Alley et al. 2007). Prominent scientists and major scientific organizations have all ratified the IPCC conclusion. Today, all but a tiny handful of climate scientists are convinced that earth's climate is heating up and that human activities are a significant cause.

Yet many Americans continue to wonder. A recent poll reported in *Time* magazine (Americans see a climate problem. 2006) found that only just over half (56 percent) of Americans think that average global temperatures have risen despite the fact that virtually all climate scientists think that they have.[1]

• already sets up a proleptic position

• presents the context for topic / establishes key problem

• points out emergence of a consensus & that it's an issue of serious importance

• states there is evidence

• cites this evidence

• this intro. sets up descrepancy between 2 views: scientific vs. popular

• describes the argument scientists have (notice here it is not angled as necessarily the author's argument)

• provides rebuttal and statistical data (logos)

hints turning point in argument

More startlingly, a majority of Americans believe that scientists are still divided about the issue. In some quarters, these doubts have been invoked to justify the American refusal to join the rest of the world in addressing the problem.

This book deals with the question of climate change and its future impacts, and by definition predictions are uncertain. People may wonder why we should spend time, effort, and money addressing a problem that may not affect us for years or decades to come. Several chapters in this book address that question—explaining how some harmful effects are already occurring, how we can assess the likely extent of future harms, and why it is reasonable to act now to prevent a worst-case scenario from coming true.

This chapter addresses a different question: might the scientific consensus be wrong? If the history of science teaches anything, it's humility. There are numerous historical examples where expert opinion turned out to be wrong. At the start of the twentieth century, Max Planck was advised not to go into physics because all the important questions had been answered, medical doctors prescribed arsenic for stomach ailments, and geophysicists were confident that continents could not drift. Moreover, in any scientific community there are always some individuals who depart from generally accepted views, and occasionally they turn out to be right. At present, there is a scientific consensus on global warming, but how do we know it's not wrong?

The Scientific Consensus on Climate Change

Let's start with a simple question: What is the scientific consensus on climate change, and how do we know it exists? Scientists do not vote on contested issues, and most scientific

- continues to establish key problem ("denial syndrome" or public poorly informed?)
- establishes content for chapter
- contrasts chapter from others
- highlights expert opinion
- sets up the central question
- creates exigency
- points out the 2 views, particularly the public's view
- metadiscourse
- outlining what will be discussed in this chapter/book
- hints what the argument is mainly about/the position taken
- introduces central question
- presents example/evidence/analogy
- poses rhetorical question & states main claim
- phrases directive which is both author & audience oriented in participation
- poses rhetorical question

questions are far too complex to be answered by a simple yes or no, so how does anyone know what scientists think about global warming?

Scientists glean their colleagues' conclusions by reading their results in published scientific literature, listening to presentations at scientific conferences, and discussing data and ideas in the hallways of conference centers, university departments, research institutes, and government agencies. For outsiders, this information is difficult to access: scientific papers and conferences are by experts for experts and are difficult for outsiders to understand.

Climate science is a little different. Because of the political importance of the topic, scientists have been unusually motivated to explain their research results in accessible ways, and explicit statements of the state of scientific knowledge are easy to find.

An obvious place to start is the Intergovernmental Panel on Climate Change (IPCC), already discussed in previous chapters. Created in 1988 by the World Meteorological Organization and the United Nations Environment Program, the IPCC evaluates the state of climate science as a basis for informed policy action, primarily on the basis of peer-reviewed and published scientific literature (IPCC 2005). The IPCC has issued four assessments. Already in 2001, the IPCC had stated unequivocally that the consensus of scientific opinion is that earth's climate is being affected by human activities. This view is expressed throughout the report, but the clearest statement is: "Human activities . . . are modifying the concentration of atmospheric constituents . . . that absorb or scatter radiant energy. . . . [M]ost of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations" (McCarthy et al. 2001, 21). The 2007

• points out divide between sci. comm. & general public

• transitions from general to specific

... to even more specific, presenting evidence

• poses a rhetorical/transitional question

• shows how complex the science world is & how outsiders are affected

• explains how making info. accessible bridges that divide

• explains what one organization does & why they are relevant

• appeals to authority to establish author's own credibility

• cites evidence thru use of quotation

IPCC reports says "very likely" (Alley et al. 2007). The IPCC is an unusual scientific organization: it was created not to foster new research but to compile and assess existing knowledge on a politically charged issue. Perhaps its conclusions have been skewed by these political concerns, but the IPCC is by no means alone it its conclusions, and its results have been repeatedly ratified by other scientific organizations.

In the past several years, all of the major scientific bodies in the United States whose membership's expertise bears directly on the matter have issued reports or statements that confirm the IPCC conclusion. One is the National Academy of Sciences report, *Climate Change Science: An Analysis of Some Key Questions* (2001), which originated from a White House request. Here is how it opens: "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise" (National Academy of Sciences 2001, 1). The report explicitly addresses whether the IPCC assessment is a fair summary of professional scientific thinking and answers yes: "The IPCC's conclusion that most of the observed warming of the last 50 years is likely to have been due to the increase in greenhouse gas concentrations accurately reflects the current thinking of the scientific community on this issue" (National Academy of Sciences 2001, 3).

Other U.S. scientific groups agree. In February 2003, the American Meteorological Society adopted the following statement on climate change: "There is now clear evidence that the mean annual temperature at the Earth's surface, averaged over the entire globe, has been increasing in the past 200 years. There is also clear evidence that the abundance of greenhouse gases has increased over the same period. . . . Because human activities are contributing to climate change, we have a col-

- shares objective of organization
- admits that conclusions are affected by fear of damage to the earth
- insists this group is not the only one w/ concl.
- presents evidence thru authoritative quotation
- specifically selects another quote w/ high qualification in wording
- highest qualification embedded in authoritative quotation (from another scientific group)
- moves from general to specific (scientific bodies)
- further evidence that global warming exists

lective responsibility to develop and undertake carefully considered response actions" (American Meteorological Society 2003). So too says the American Geophysical Union: "Scientific evidence strongly indicates that natural influences cannot explain the rapid increase in global near-surface temperatures observed during the second half of the 20th century" (American Geophysical Union Council 2003). Likewise the American Association for the Advancement of Science: "The world is warming up. Average temperatures are half a degree centigrade higher than a century ago. The nine warmest years this century have all occurred since 1980, and the 1990s were probably the warmest decade of the second millennium. Pollution from 'greenhouse gases' such as carbon dioxide (CO_2) and methane is at least partly to blame" (Harrison and Pearce 2000). Climate scientists agree that global warming is real and substantially attributable to human activities.

These kinds of reports and statements are drafted through a careful process involving many opportunities for comment, criticism, and revision, so it is unlikely that they would diverge greatly from the opinions of the societies' memberships. Nevertheless, it could be the case that they downplay dissenting opinions.[2]

One way to test that hypothesis is by analyzing the contents of published scientific papers, which contain the views that are considered sufficiently supported by evidence that they merit publication in expert journals. After all, any one can *say* anything, but not anyone can get research results published in a refereed journal.[3] Papers published in scientific journals must pass the scrutiny of critical, expert colleagues. They must be supported by sufficient evidence to convince others who know the subject well. So one must turn to the scientific literature to be certain of what scientists really think.

Before the twentieth century, this would have been a trivial task. The number of scientists directly involved in any given debate was usually small. A handful, a dozen, perhaps a hundred, at most, participated—in part because the total number of scientists in the world was very small (Price 1986). Moreover, because professional science was a limited activity, many scientists used language that was accessible to scientists in other disciplines as well as to serious amateurs. It was relatively easy for an educated person in the nineteenth or early twentieth century to read a scientific book or paper and understand what the scientist was trying to say. One did not have to be a scientist to read *The Principles of Geology* or *The Origin of Species*.

Our contemporary world is different. Today, hundreds of thousands of scientists publish over a million scientific papers each year.[4] The American Geophysical Union has 41,000 members in 130 countries, and the American Meteorological Society has 11,000. The IPCC reports involved the participation of many hundreds of scientists from scores of countries (Houghton, Jenkins, and Ephraums 1990; Alley et al. 2007). No individual could possibly read all the scientific papers on a subject without making a full-time career of it.

Fortunately, the growth of science has been accompanied by the growth of tools to manage scientific information. One of the most important of these is the database of the Institute for Scientific Information (ISI). In its Web of Science, the ISI indexes all papers published in refereed scientific journals every year—over 8,500 journals. Using a key word or phrase, one can sample the scientific literature on any subject and get an unbiased view of the state of knowledge.

Figure 4.1 shows the results of an analysis of 928 abstracts, published in refereed journals during the period 1993 to 2003,

- discusses science before 21st century
- points out in past, more simple
- calls attention to background of sci. comm.
- provides example
- discusses how science has evolved in today's world
- acknowledges how complex science is now (contrasts)
- provides cited data
- author's tone: sarcastic / cynical
- describes today's technology
- Provides more data
- rationalizes that there is too much info. to consume

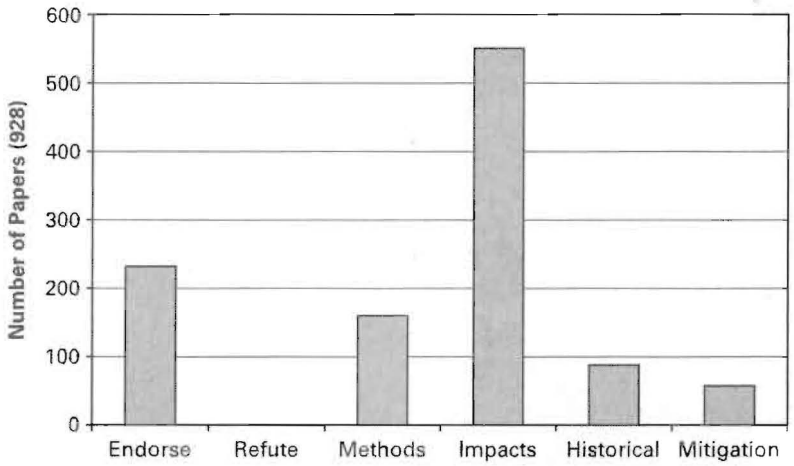

Figure 4.1
A Web of Science analysis of 928 abstracts using the keywords "global climate change." No papers in the sample provided scientific data to refute the consensus position on global climate change.

produced by a Web of Science search using the keyword phrase "global climate change."[5] After a first reading to determine appropriate categories of analysis, the papers were divided as follows: (1) those explicitly endorsing the consensus position, (2) those explicitly refuting the consensus position, (3) those discussing methods and techniques for measuring, monitoring, or predicting climate change, (4) those discussing potential or documenting actual impacts of climate change, (5) those dealing with paleoclimate change, and (6) those proposing mitigation strategies. How many fell into category 2—that is, how many of these papers present evidence that refutes the statement: "Global climate change is occurring, and human activities are at least part of the reason why"? The answer is remarkable: none.

A few comments are in order. First, often it is challenging to determine exactly what the authors of a paper do think about global climate change. This is a consequence of experts writing for experts: many elements are implicit. If a conclusion is widely accepted, then it is not necessary to reiterate it within the context of expert discussion. Scientists generally focus their discussions on questions that are still disputed or unanswered rather than on matters about which everyone agrees.

This is clearly the case with the largest portion of the papers examined (approximately half of the total)—those dealing with impacts of climate change. The authors evidently accept the premise that climate change is real and want to track, evaluate, and understand its impacts. Nevertheless, such impacts could, at least in some cases, be the results of natural variability rather than human activities. Strikingly, none of the papers used that possibility to argue against the consensus position.

Roughly 15 percent of the papers dealt with methods, and slightly less than 10 percent dealt with paleoclimate change. The most notable trend in the data is the recent increase in such papers; concerns about global climate change have given a boost to research in paleoclimatology and to the development of methods for measuring and evaluating global temperature and climate. Such papers are essentially neutral: developing better methods and understanding historic climate change are important tools for evaluating current effects, but they do not commit their authors to any particular opinion about those effects. Perhaps some of these authors are in fact skeptical of the current consensus, and this could be a motivation to work on a better understanding of the natural climate variability of the past. But again, none of the papers used that motivation to argue openly against the consensus, and it would be illogical if they did because a skeptical motivation does not

constitute scientific evidence. Finally, approximately 20 percent of the papers explicitly endorsed the consensus position, and an additional 5 percent proposed mitigation strategies. In short, the basic reality of anthropogenic global climate change is no longer a subject of scientific debate.[6]

Some readers will be surprised by this result and wonder about the reliability of a study that failed to find any arguments against the consensus position when such arguments clearly exist. After all, anyone who watches the evening news or trolls the Internet knows that there is enormous debate about climate change, right? Well, no.

First, let's make clear what the scientific consensus is. It is over the reality of human-induced climate change. Scientists predicted a long time ago that increasing greenhouse gas emissions could change the climate, and now there is overwhelming evidence that it *is* changing the climate and that these changes are in addition to natural variability. Therefore, when contrarians try to shift the focus of attention to natural climate variability, they are misrepresenting the situation. No one denies the fact of natural variability, but natural variability alone does not explain what we are now experiencing. Scientists have also documented that some of the changes that are now occurring are clearly deleterious to both human communities and ecosystems (Arctic Council 2004). Because of global warming, humans are losing their homes and hunting grounds, and plants and animals are losing their habitats (e.g., Kolbert 2006; Flannery 2006).

Second, to say that global warming is real and happening now is not the same as agreeing about what will happen in the future. Much of the continuing debate in the scientific community involves the likely rate of future change. A good analogy is evolution. In the early twentieth century, paleontologist

- presents data
- concludes climate change is happening
- addresses the opposition (rebuts)
- poses (sarcastic) rhetorical/transitional question
- emphasizes
- discusses the P.O.V. of those who deny there is an issue
- cites evidence
- describes cause & effect
- gives analogy

- rationalizes audience reaction to this info. (skepticism)
- challenges those who question the validity of her study

George Gaylord Simpson introduced the concept of "tempo and mode" to describe questions about the manner of evolution—how fast and in what manner evolution proceeded. Biologists by the mid-twentieth century agreed about the reality of evolution, but there were extensive debates about its tempo and mode. So it is now with climate change. Virtually all professional climate scientists agree on the reality of human-induced climate change, but debate continues on tempo and mode.

Third, there is the question of what kind of dissent still exists. The analysis of the published literature presented here was done by sampling, using a keyword phrase that was intended to be fair, accurate, and neutral: "global climate change" (as opposed to, for example, "global warming," which might be viewed as biased). The *total* number of papers published over the last ten years having anything at all to do with climate change is probably over ten thousand, and no doubt some of the authors of the other over nine thousand papers have expressed skeptical or dissenting views. But the fact that the sample turned up no dissenting papers at all demonstrates that any remaining professional dissent is now exceedingly minor.

This suggests something discussed elsewhere in this book—that the mass media have paid a great deal of attention to a handful of dissenters in a manner that is greatly disproportionate with their representation in the scientific community. The number of climate scientists who actively do research in the field but disagree with the consensus position is evidently very small.

This is not to say that there are not a significant number of contrarians but to point out that most of them are not climate scientists and therefore have little (or no) basis to claim to be

- anticipates/addresses questions in readers' minds
- establishes the grounds on which her research is fair
- discusses the stance of "contrarians" "dissenters"
- introduces a scientific concept
- describes past debates
- claims that now there is no debate, but an agreement
- shows us she is fair & open in her research
- explains her research process & findings
- points out the disproportion
- speculates on # of climate scientists
- discredits her opponents

experts on the subjects on which they boldly pronounce. Some contrarians, like the physicist Frederick Seitz, were once active scientific researchers but have long since retired (and Seitz never actually did research in climate science; he was a solid-state physicist). Others, like the novelist Michael Crichton, are not scientists at all. What Seitz and Crichton have in common, along with most other contrarians, is that they do no new scientific research. They are not producing new evidence or new arguments. They are simply attacking the work of others and mostly doing so in the court of public opinion and in the mass media rather than in the halls of science.

This latter point is crucial and merits underscoring: the vast majority of materials denying the reality of global warming do not pass the most basic test for what it takes to be counted as scientific—namely, being published in a peer-reviewed journal. Contrarian views have been published in books and pamphlets issued by politically motivated think-tanks and widely spread across the Internet, but so have views promoting the reality of UFOs or the claim that Lee Harvey Oswald was an agent of the Soviet Union.

Moreover, some contrarian arguments are frankly disingenuous, giving the impression of refuting the scientific consensus when their own data do no such thing. One example will illustrate the point. In 2001, Willie Soon, a physicist at the Harvard-Smithsonian Center for Astrophysics, along with several colleagues, published a paper entitled "Modeling Climatic Effects of Anthropogenic Carbon Dioxide Emissions: Unknowns and Uncertainties" (Soon et al. 2001). This paper has been widely cited by contrarians as an important example of a legitimate dissenting scientific view published in a peer-review journal.[7] But the issue actually under discussion in the paper is how well models can predict the future—in other

words, tempo and mode. The paper does not refute the consensus position, and the authors acknowledge this: "The purpose of [our] review of the deficiencies of climate model physics and the use of GCMs is to illuminate areas for improvement. Our review does not disprove a significant anthropogenic influence on global climate" (Soon et al. 2001, 259; see also Soon et al. 2002).

The authors needed to make this disclaimer because many contrarians do try to create the impression that arguments about tempo and mode undermine the whole picture of global climate change. But they don't. Indeed, one could reject all climate models and still accept the consensus position because models are only one part of the argument—one line of evidence among many.

Is there disagreement over the details of climate change? Yes. Are all the aspects of climate past and present well understood? No, but who has ever claimed that they were? Does climate science tell us what policy to pursue? Definitely not, but it does identify the problem, explain why it matters, and give society insights that can help to frame an efficacious policy response (e.g., Smith 2002).

So why does the public have the impression of disagreement among scientists? If the scientific community has forged a consensus, then why do so many Americans have the impression that there is serious scientific uncertainty about climate change?[8] There are several reasons. First, it is important to distinguish between scientific and political uncertainties. There are reasonable differences of opinion about how best to respond to climate change and even about how serious global warming is relative to other environmental and social issues. Some people have confused—or deliberately conflated—these two issues.

- she criticizes/ attacks the example provided
- presents more evidence
- points out those in denial
- poses transitional questions
- cites her rationale
- poses rhetorical question
- metadiscourse
- differentiates between the 2 issues

- asks us to think about the effect
- leads us in
- addresses public opinion

Scientists are in agreement about the reality of global climate change, but this does not tell us what to do about it.

Second, climate science involves prediction of future effects, which by definition is uncertain. It is important to distinguish among what is known to be happening now, what is likely to happen based on current scientific understanding, and what might happen in a worst-case scenario. This is not always easy to do, and scientists have not always been effective in making these distinctions. Uncertainties about the future are easily conflated with uncertainties about the current state of scientific knowledge.

Third, scientists have evidently not managed well enough to explain their arguments and evidence beyond their own expert communities. The scientific societies have tried to communicate to the public through their statements and reports on climate change, but what average citizen knows that the American Meteorological Society even exists or visits its home page to look for its climate-change statement?

There is also a deeper problem. Scientists are finely honed specialists trained to create new knowledge, but they have little training in how to communicate to broad audiences and even less in how to defend scientific work against determined and well-financed contrarians. Moreover, until recently, most scientists have not been particularly anxious to take the time to communicate their message broadly. Most scientists consider their "real" work to be the production of knowledge, not its dissemination, and often view these two activities as mutually exclusive. Some even sneer at colleagues who communicate to broader audiences, dismissing them as "popularizers."

If scientists do jump into the fray on a politically contested issue, they may be accused of "politicizing" the science and

- points out that climate change is real
- distinguishes between certain & uncertain
- notes weaknesses/past mistakes

- discusses possible scenarios

- refers to the divide in comm.
- poses rhetorical question

- addresses sci. comm. vs. public (divide)

- calls to attention the 1 reason why there is a divide
- describes diff. scientists' attitudes about their work & who they reach

compromising their objectivity.[9] This places scientists in a double bind: the demands of objectivity suggest that they should keep aloof from contested issues, but if they don't get involved, no one will know what an objective view of the matter looks like. Scientists' reluctance to present their results to broad audiences has left scientific knowledge open to misrepresentation, and recent events show that there are plenty of people ready and willing to misrepresent it.

It's no secret that politically motivated think-tanks such as the American Enterprise Institute and the George Marshall Institute have been active for some time in trying to communicate a message that is at odds with the consensus scientific view (e.g., Gelbspan 1997, 2004). These organizations have successfully garnered a great deal of media attention for the tiny number of scientists who disagree with the mainstream view and for nonscientists, like novelist Michael Crichton, who pronounce loudly on scientific issues (Boykoff and Boykoff 2004).

This message of scientific uncertainty has been reinforced by the public relations campaigns of certain corporations with a large stake in the issue.[10] The most well known example is ExxonMobil, which in 2004 ran a highly visible advertising campaign on the op-ed page of the *New York Times*. Its carefully worded advertisements—written and formatted to look like newspaper columns and called op-ed pieces by ExxonMobil—suggested that climate science was far too uncertain to warrant action on it.[11] One advertisement concluded that the uncertainties and complexities of climate and weather means that "there is an ongoing need to support scientific research to inform decisions and guide policies" (Environmental Defense 2005). Not many would argue with this commonsense conclusion. But our scientists have concluded that existing research warrants that decisions and policies be made today.[12]

In any scientific debate, past or present, one can always find intellectual outliers who diverge from the consensus view. Even after plate tectonics was resoundingly accepted by earth scientists in the late 1960s, a handful of persistent resisters clung to the older views, and some idiosyncratics held to alternative theoretical positions, such as earth expansion. Some of these men were otherwise respected scientists, including Sir Harold Jeffreys, one of Britain's leading geophysicists, and Gordon J. F. MacDonald, a one-time science adviser to Presidents Lyndon Johnson and Richard Nixon; they both continued to reject plate tectonics until their dying day, which for MacDonald was in 2002. Does that mean that scientists should reject plate tectonics, that disaster-preparedness campaigns should not use plate-tectonics theory to estimate regional earthquake risk, or that schoolteachers should give equal time in science classrooms to the theory of earth expansion? Of course not. That would be silly and a waste of time.

No scientific conclusion can ever be proven, and new evidence may lead scientists to change their views, but it is no more a "belief" to say that earth is heating up than to say that continents move, that germs cause disease, that DNA carries hereditary information, and that HIV causes AIDS. You can always find someone, somewhere, to disagree, but these conclusions represent our best current understandings and therefore our best basis for reasoned action (Oreskes 2004).

How Do We Know We're Not Wrong?

Might the consensus on climate change be wrong? Yes, it could be, and if scientific research continues, it is almost certain that some aspects of the current understanding will be modified, perhaps in significant ways. This possibility can't be denied.