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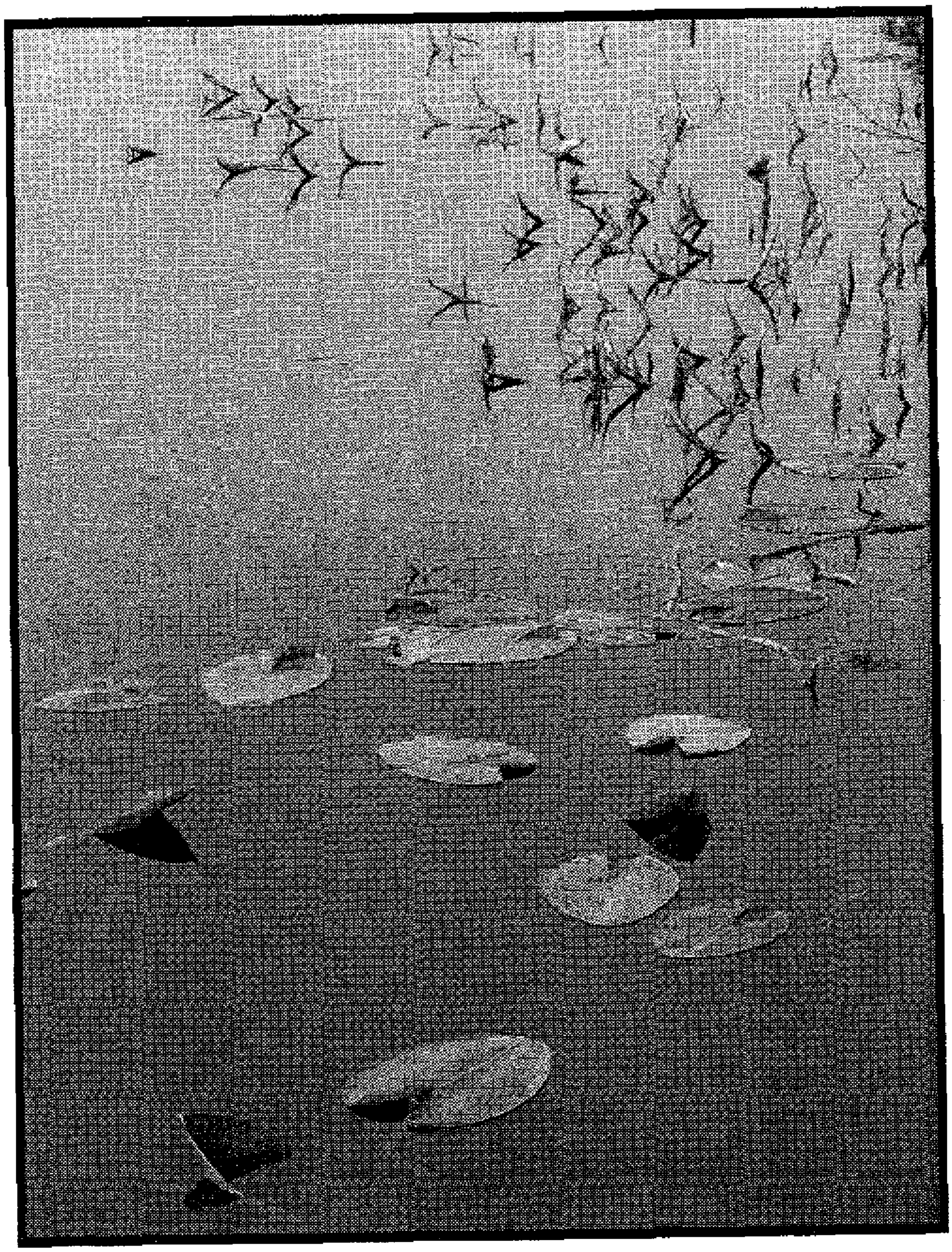


Environmental Change

The Truth and Uncertainty of Climate Change

Two ENVS Faculty Members Discuss the Role and Influence of Scientific Inquiry

*The following email exchange took place during the past winter and has been edited in places for content. The participants are **Ronald Mitchell** (Professor, Political Science) and **Gregory Bothun** (Professor, Physics), both of whom serve as core faculty members of the Environmental Studies Program and are members of the ENVS Executive Committee. The full version of the exchange is available upon request.*

Questions: Despite scientific consensus as to the existence of current and future global climate change, the public is still slow to acknowledge its presence in our lives. What role has the divide between scientific plausibility and scientific provability played in this state of affairs both nationally and abroad? How has the difference between plausibility and provability been used and why? What is the responsibility of the scientific community in communicating with the public around climate change in general and/or this issue of plausibility versus provability? Have they done or are they doing the right thing?

Mitchell: Scientific inquiry is almost always characterized by some degree of uncertainty — once uncertainty becomes (or is assumed to have become) insignificant, scientific interest in a problem declines dramatically. Science and scientists are, among other things, driven by the desire to answer questions that are not yet answered. Uncertainty enters the picture because of epistemological obstacles that get between whatever "scientific truth" may be out there in the world and our ability as humans to know what that truth is.

Research into climate change involves several fundamental types of uncertainty. The first relates to the *degree* of change in climatic conditions that has occurred over the past decades, centuries, and millennia. Consider, for example, the sources of uncertainty about how much the earth has warmed over the past, say, 5,000 years. One element of this "how much climate change has occurred" uncertainty involves what should constitute a "global average temperature." Another element involves the fact that we cannot directly measure global average temperature (indeed, what would a global average temperature thermometer measure?), but must estimate global average temperature by combining measurements of atmospheric concentrations of various elements with models and equations that tell us what the global average temperature was, given a particular mix of atmospheric concentrations of various elements. Despite these problems, most scientists doing this work believe we have significantly reduced our uncertainty on this aspect of the problem. That is, we are rather confident we know what global average temperatures have been historically, not least because various methods of estimating that global average temperature (ice cores, coral dating, tree-ring dating, etc.) have produced relatively consistent results.

The second fundamental type of uncertainty concerns the *causes* of change in climatic conditions. If we know how much average global temperature has changed, we still face significant epistemological hurdles in knowing what has caused those changes. A difficult obstacle is the fact that the climate system exhibits large natural variation in average global temperature. Records (estimates, actually) of past global average temperatures clarify that, long before humans were a significant influence on the Earth's environmental system, large variation occurred in average global temperature. These may involve natural cycles, including ocean current oscillation changes, etc. as well as exogenous events such as meteor strikes and increased solar activity. On top of uncertainty about how the climate system varied before humans arrived, there is further uncertainty in attempting to determine whether — and, if so, how much — humans have influenced the natural climate system variation.

Resolving such uncertainties involves essentially two distinct but related types of evidence and arguments. The first involve arguments in which evidence suggests a) that we can distinguish different *types* of changes that can occur in the climate system (most notably in how rapidly it changes) and b) that new types of changes in the system correlate in time with a period in which humans might conceivably have begun to influence the global climate system, that period usually considered to have begun with the industrial revolution in the mid to late 1800s. Arguments based on such correlations suggest that humans are causing some change in the system, although they do not clarify the mechanism by which humans are doing so.

The second type of evidence and argument is causal rather than correlational. The first elements of these are hypotheses about the ways in which human activity may have influenced the global environment; the most widely cited of which is through human contributions to atmospheric CO_2 concentrations. Causal arguments look for empirical evidence that supports claims that hypothesized mechanisms could and actually have caused the observed changes we see in the historical record. For example, claims that increasing levels of CO_2 generated by human use of fossil fuels and forest resources have caused increases in global average temperatures imply several observable implications about the world: that atmospheric CO_2 levels and various other indicators of CO_2 levels (and not just temperatures), as well as the human activities that generate CO_2 should have increased over the same period of time as global average temperatures. Much scientific effort has gone into looking for evidence of these "post-dictions," i.e., predictions about what we should see in the historical record. Such evidence that is found, however, rarely perfectly and uniquely shows one hypothesis as true and other hypotheses as false. Rather, evidence that lends some support to a particular hypothesis simply increases our confidence in the hypothesis (since it has not yet been refuted) but without demonstrating that something is true, because a variety of other plausible explanations may still be in play.

A third and quite important type of uncertainty involves using such evidence as we have at any point in time about past climatic change and its causes to predict future climatic changes and their impacts. Thus, imagine we had perfect information about how the climate system had changed in the past and even perfect information about what had caused those changes. We would still have a difficult time predicting the future trajectory of climate change because we simply do not know what the factors that have caused climate change in the past will be doing. Thus, knowing there is some degree of decadal variation in ocean currents does not allow us to predict, at least in any given year, what those currents will be doing in the future. More importantly, our uncertainty about the causes of climate change and how all those myriad causes of such change interact in a complex natural system makes it particularly hard to predict precisely future levels of average global temperatures. As in predicting the stock market's trajectory (where we have no uncertainty about the past historical changes that have occurred), our uncertainty about causes of changes inhibit our ability to predict its exact future trajectory.

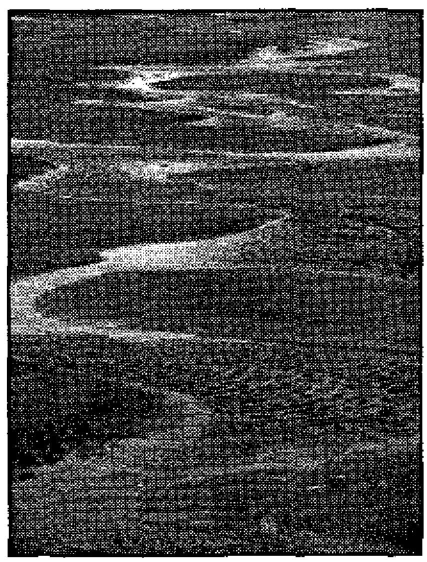
All these factors mean that when addressing complex and dynamic environmental systems, such as the climate system, there are aspects of our knowledge that are inherently uncertain. Having, I hope, provided some insight into why that is true, how should scientists communicate their findings to a public that lacks the expertise to evaluate these claims on their own?

To say there is uncertainty about the climate system and human impacts on it, is not to say that we know nothing about that system and the causes of change in it, nor is it to say we cannot make any predictions whatsoever about the future state of the climate system. Over the past three, and more, decades, scientists have accumulated considerable evidence that the climate is changing and that humans are a major contributing cause of such change. No single piece of that large collection of evidence from scientists of all disciplines, nationalities, and political leanings, would be convincing by itself, but just as dozens of pieces of circumstantial evidence that point to the same suspect make us more confident that that suspect did the crime, so too with climate change. Thus, there are solid reasons to have considerable confidence that the climate is changing and that humans are contributing to that change. Given the inherent uncertainties described above, these conclusions may be wrong but the process of scientific inquiry and professional skepticism make that increasingly unlikely.

This raises a conflict that for many scientists is quite real: the conflict between a scientific and professional commitment to communicating the truth as one sees it (which for most scientists includes being clear about how uncertain they are in their findings) and a social commitment that recognizes that non-scientists (whether politicians or the public) often use scientific uncertainties about the future benefits of changing current behavior as the rationale for refusing to incur the current costs of changing the behaviors that scientists are quite certain contribute to climate change.

Although there are shining examples of scientists who are doing a superb job of communicating science to the public, many scientists could do, I believe, a better job by being clearer about the degree, type, and areas of uncertainty about climate change. The stock market again provides a useful analog. We have considerable uncertainty about what the stock market averages will do tomorrow, less about what they will do next week, and yet less about what they will do next year. But most economists and most investors have considerable confidence not only that the stock market will be higher a decade from now than it is today and most will even predict that it will, on average, grow about seven to eight percent over the next decade. Similarly, with the climate system, our uncertainty about where it will be next week, next year, and even next decade is high. Even our uncertainty about where it will be in a century is high. However, scientists are collectively quite certain that in a century the global average temperature will be higher. They may be uncertain about the exact amount of uptake of CO_2 by the oceans or the exact sea level rise for a given change in temperature, but they are quite certain that the ocean is not taking up all the CO_2 emitted by humans and that sea level will rise significantly as average global temperature rises. Various programs exist to help train scientists to be able to engage in exactly this form of communication which tries to "square the circle" of accurately reporting the scientific truth as known in a way that also communicates the shape of our uncertainty about the world.

Bothun: Ron has suggested that a portion of the disconnect that exists between global climate change and public policy lies in the inability of the scientific community to sensibly articulate its position to the lay public or public policy makers. While I fully agree that scientists are clumsy in their interactions with the real world and are widely believed to lack sufficient emotional depth so as to be perceived as caring humans, there is likely a deeper problem at work involving the public's ability or willingness to even listen to scientific dialogue, argument and position.



A long time ago, when the world was apparently much simpler, and when we were all made in the image of our creator, the world was black and white. Natural phenomena could be explained as the will/whim of God or the Gods. Indeed, such explanations could be considered as "complete explanations." Truth was absolute —the role of uncertainty and complexity in the real world was disallowed both in terms of dialogue and thought; therefore these concepts do not exist in the real world or problem solving. While we may collectively believe that the Age of Enlightenment has actually occurred, such a belief would be a false mirror of how we really act and think, behind closed doors, as humans. That is, the lay public, which scientists are so ill-equipped to inform properly, is still caught in the dilemma of requiring complete explanations and the Truth. Therefore, the public expects that the role of scientists is to provide them with this Truth in the form of correct answers and certain solutions to extant (environmental) problems. They don't want to hear about complexity, ambiguity and uncertainty. After all, scientists are paid to produce the right answer, aren't they? In the wake of such a disconnect between the public perception of science and the actual process of science, it is quite clear that the public simply will not accept scientific plausibility as the basis for a rational public policy plan dealing with climate change. Science, of course, is incapable of providing such clarity and certainty. Little has changed for 10,000 years in this regard. The vast majority of the lay public is imprisoned by the fear of the unknown. In view of that unspoken reality, how is it even possible to expect science to impact public policy?

Indeed, the biggest shift in the scientific community with respect to the controversial issue of global warming was the rapidly growing consensus that global climate change is upon us. This followed the release of an important paper detailing northern hemisphere climate over the last 1000 years that was published on March 1, 1999, in the *Journal of Geophysical Research*. Following that, the National Academy of Sciences (in their year 2000 report) asserted that the signal of global climate change had risen out of the intrinsic noise of the system and thus scientific consensus had emerged from this vague web of complexity and uncertainty. But, scientific consensus does not constitute scientific provability, so what good is it? We are informed by truth, not by consensus. Moreover, Joe Public takes global warming literally. The next summer should be hotter than the previous one, as evidenced in his own backyard. Should that next hotter summer fail to materialize (precisely because the climate system is noisy and uncertain), Joe Public will simply mutter to himself, "Man those darn scientists never really know what they are talking about." Scientific consensus, therefore, is not an effective communication tool to the public or to public policy-makers. Only when science can chisel its findings in stone will that public or its elected leadership pay any attention.

Mitchell: I remain more hopeful than Greg that science and scientists can wield influence on the issue of climate change and the many other environmental problems facing the world. I also think that they can wield influence even before findings are absolutely certain. The recent development of processes of conducting science that include stakeholder participation at appropriate points hold promise for surmounting the real problems that Greg notes. The Intergovernmental Panel on Climate Change (IPCC) has included an increasingly diverse set of scientists in their efforts to assess our knowledge of climate change as they have progressed from the first assessment in 1990 to the fourth assessment that is currently underway. Policy-makers in Brazil, India, and Indonesia are more likely to understand — and take seriously — the findings of the IPCC if the IPCC has an inclusive process in which Brazilian, Indian, and Indonesian scientists have played a role. This reflects, in part, the political fact that "inclusiveness" increases the legitimacy of scientific processes. But it also reflects the fact that including a broad array of scientists ensures that the science which is conducted and considered in these global environmental assessments reflects both the concerns of Southern, developing countries (which often differ from those of Northern, developed countries) and the different sets of knowledge and data that these scientists have.

At the local level, we see this in the adaptive management strategies that have been an increasingly common approach to addressing environmental problems. Including scientists, forest managers, loggers, and environmental advocates in the process of determining good forest management practices in the Northwest has improved forest management (even if not solving all our forest management problems). Adaptive management and similar participatory science processes recognize that science and policy are not, should not, and cannot be conducted as completely separate, non-interacting realms. When scientists interact with stakeholders and policy-makers, two things happen. Scientists often realize that small changes in what they study and how they conduct their research can lead to large increases in how willing stakeholders and policy-makers are to accept their conclusions. But stakeholders and policy-makers also become more "literate" about science and the scientific enterprise, and become better at understanding what uncertainty is, the implications of different types of uncertainty for policy decisions, and areas of scientific knowledge certain enough to justify preventive or precautionary action. Processes in which stakeholders, policy-makers, and scientists "co-produce" knowledge — as opposed to those in which scientists conduct research and publish their results in hopes that they will influence policy — can avoid the parallel frustrations of scientists who feel their science has no impact and stakeholders and policy-makers who feel that scientists are doing research that has little practical importance. In our efforts to address global environmental problems, co-production of knowledge allows all sides to work together to ensure that scientists are answering the questions that stakeholders and policy-makers are asking, and that stakeholders and policy-makers understand the importance and policy-relevance of the answers that scientists are giving.

Bothun: I do not see this as an issue of being hopeful or being pessimistic; I merely use history as a guide. Can anyone point to any period in history and note where scientists or scientific knowledge have ever actually influenced, let alone determined, public policy? Even today, NASA/Goddard's chief scientist on climate change, James Hansen, has his reports directly edited by White House staff before they become official White House releases on climate change. No one paid attention to M. King Hubberts' 1956 prediction of "Peak Oil" in the U.S. even though it was founded on solid science and turned out to be deadly accurate. The IPCC can do everything it can to characterize and disseminate the problem, but is that going to change the driving habits of Americans? Is that going to cause India and China to slow down the emergence of their fossil fuel-based energy economy? Is that going to influence Russia in ceasing development of LNG infrastructure to export to the world at arbitrary prices by the year 2020? Science offers a big picture view of the world in which everything is connected and in which humans and nature must maintain a delicate partnership for balance and sustainability. The man on the street doesn't give a rat's ass about that scientific world view, and governments embrace economic prosperity long before they even think about proper planetary resource management.

I reiterate what was said previously: scientific consensus has emerged on global climate change and now the main scientific difference of opinion is its overall severity and rate of change. But does the fact that scientists agree now suddenly make the scientific process legitimate? What, when scientists disagreed, the process was not legit? Unfortunately, the answer to that rhetorical question is yes. Public distrust of science exists primarily because scientists actually disagree with one another. How shocking! Finally, scientists certainly can be informed by "stakeholders" of the kinds of questions they should be pursuing—it's just that the stakeholders and policy-makers generally are not receptive to the answers to those questions that science produces. There is a rather large gap between the co-production of knowledge and the application of that knowledge. The latter is wisdom which, collectively, we abundantly lack.

Photograph: "Water Flow" by Rebecca Briggs