Isaac Marks Memorial Lecture
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CONVERGENCE AND DISPARITY IN CLIMATE CHANGE

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This lecture is about convergence and disparity with respect to climate change—disparity between what scientists believe and what the American people believe. As to convergence: a few years ago I visited a famous patch of water in which two great rivers join, where the inflowing Rio Negro meets the Solemoes, becoming the great Amazon downstream of the junction. To the amazement of tourists, the line between the black water and the relatively clear main stream is distinguishable for miles below the junction. But this wedding of the waters isn't exactly harmonious: along the line there are strong eddies, hinting at a violent subsurface hydrology.

Something like the meeting of these two rivers happens also at the convergence where science intersects with public policy—and politics. Some scientists may insist that policies about science, technology, and related regulation by the state ought to be *based on the science*. The public, however, has a right to be engaged in this process and will defend that right. Sometimes individuals will question whether the scientific case for a decision is reliable; at other times they may claim that an alternative decision based on other values (perhaps cultural or economic) should trump science in the decision because it yields greater benefits. The resulting eddies, pitting various stakeholders against one another—some darker than others—are characteristic of this convergence too.

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We have at hand such a classic struggle as the science of climate change—represented by the vast majority of its professional practitioners—meets a skeptical public. This dispute is so well known that I will touch on only one contemporary example. In the *New York Times*, the month of March 2010 went out like a lion, with a story on the 30th headlined: "Scientists and Weathercasters at Odds over Climate Change." Weathercasters read forecasts on television, usually forecasting only local or regional weather within the span of a week or less. It seems that many of them express skepticism about global warming on their broadcast or blogs. Some have referred to it a "scam." An especially interesting note in the *Times* story described a recent study by researchers at Yale and George Mason. According to the study, 56% of Americans surveyed trust these weatherpersons on the topic more than they do the media or public figures like Al Gore. In a succession of other national polls, the proportion of Americans who agree that global temperature is increasing and that human activities are responsible for much of the change has dropped to nearly 50%. Among practicing scientists who work in the climate sciences (atmospheric physics, chemistry, oceanography, and climate history, etc.) the comparable figure is in the neighborhood of 98%.

Weather, of course, is not climate, nor vice-versa. Yet there is a serious disparity problem here, and it is one to which we return at the end of this lecture.

But meanwhile, we need to consider what it is that science says about climate change—and the right place to begin is *not* a few years back when someone had just invented the phrase "global warming." Instead we must go back to Sweden in 1894, when the distinguished chemist Svente Arrhenius, who had studied past ice ages, was worried that we might have another. He knew that atmospheric carbon dioxide was largely responsible for the warming "greenhouse effect," and he calculated that if there was only half the amount in the atmosphere, it would reduce the temperature of Europe by four to five degrees Celsius—enough to produce another ice age. Arrhenius also considered how atmospheric CO_2 changes naturally. He and a colleague studied the natural cycles of CO_2—volcanic emissions, uptake by oceans and terrestrial vegetation, and so forth. They soon realized that human activities were adding more CO_2 to the atmosphere by combusting coal and other fossil fuels, and by burning forests. Arrenius supposed that if these activities were to occur over thousands of years, they might actually dominate the natural cycle—so he calculated what would happen to the global temperature if the CO_2 concentration doubled—reaching 560 parts per million over volume (ppv/m) from the pre-industrial level of 280 ppm/v. The answer was remarkable: it would raise global temperatures by five to six degrees Celsius.

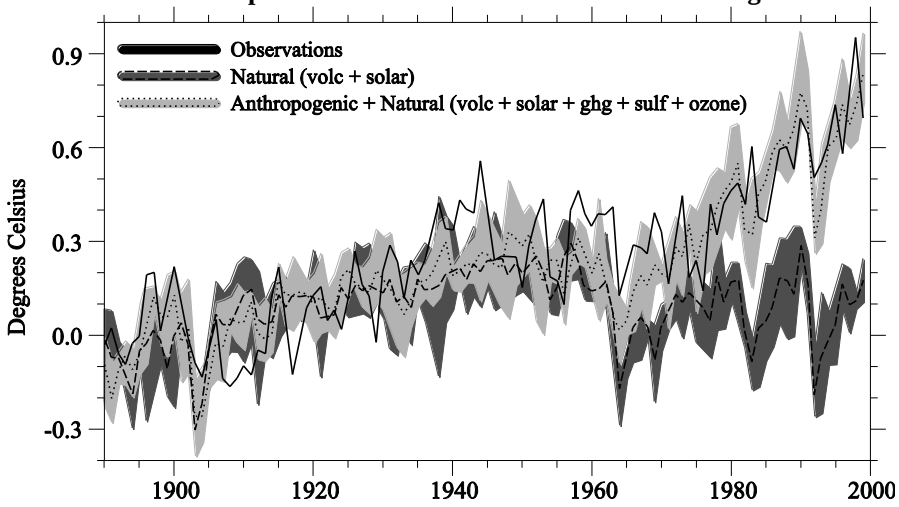
Why was this remarkable? Well, in its time, it was improbable that something like this would ever happen. The rates of fossil fuel combustion were slow then, and the ocean would absorb the added CO_2. Arrhenius, however, could not have imagined the growth rates associated with the Industrial Revolution, which in the past hundred years took us from 280 to 385 ppm/v, with yet more increases locked in. The really remarkable part of this story is that his nineteenth century estimates closely approximate the predictions now made by the best contemporary computer-generated climate models. Global warming is not some

modern narrative; it is an old Scandinavian tale—one that our skeptical contemporaries should hear.

Our scientific understanding of climate change mechanisms today is partly based on data gained from empirical observations of atmospheric gas concentrations, or temperature, or stored carbon, and partly based on modeling of likely future states. Models are tested by applying them to past conditions, and seeing whether the predictions they make are verified. What the scientific community believes—and the public, as you have seen, sometimes doubts—is what is known as the IPCC Consensus. This consensus reflects the perspective of a 250-plus collection of international scientists called the Intergovernmental Panel on Climate Change, a creature of the UN and the World Meteorological Organization. In essence, the consensus says: warming of the climate system is unequivocal, and it is very likely due to the human-caused increase in greenhouse gas concentrations. Furthermore, even if these concentrations were stabilized, warming and the rise of the sea level would continue for centuries because of the long time-scales associated with carbon cycles. Predicted temperature rise during this century could lie between one and three degrees Celsius.

Three graphs plot some of the most important of these relationships, and they describe the reality of our recent climate in clear terms. Figure 1 sets forth three correlations: the dashed line traces the result of what natural forces (volcanism, solar variation, etc.) have done to the temperature history in the last century, and the dotted line shows the influence of those forces *plus the effects of human activities.* These lines depend on model reconstructions, with the shading surrounding each showing the variance. The solid line illustrates actual real world measurements. This line agrees almost precisely with the one that includes human activities, and not at all with the one showing only natural forces.

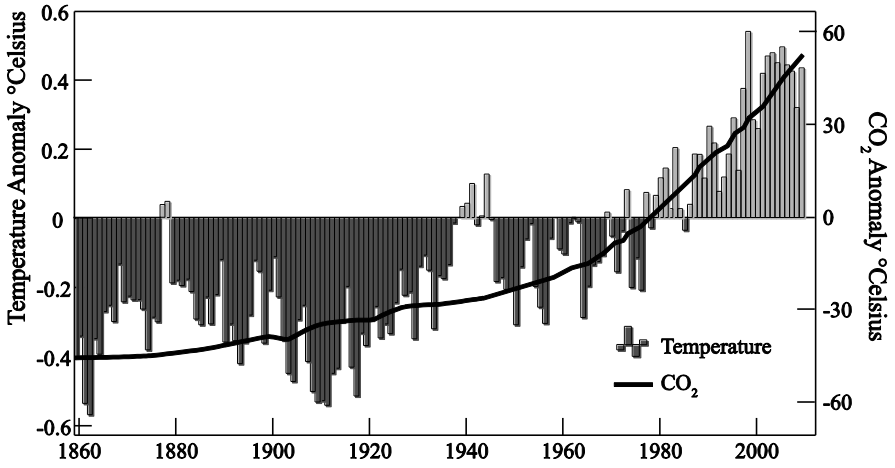
Figure 1
Global Temperature Anomalies From 1890–1919 Average[1]



[1] Gerald A. Meehl et al., *Combinations of Natural and Anthropogenic Forcing in Twentieth-Century Climate*, 17 J. CLIMATE 3721, 3723 (2004).

Figure 2 shows the temperature changes (lighter shading signifying warmer and darker shading indicating colder) relative to a baseline, reflecting the 1961–1990 period, against the average content of carbon dioxide in the atmosphere measured at Mauna Loa. Aside from the hot period marking World War II, the significant elevation in average temperature did not begin until CO_2 concentration started its abrupt increase. That jump is what Michael Mann at Penn State has described as the "hockey stick" signal—the one that correlates the rapid temperature rise with that of human-caused fossil fuel combustion and the burning of forests in many countries.

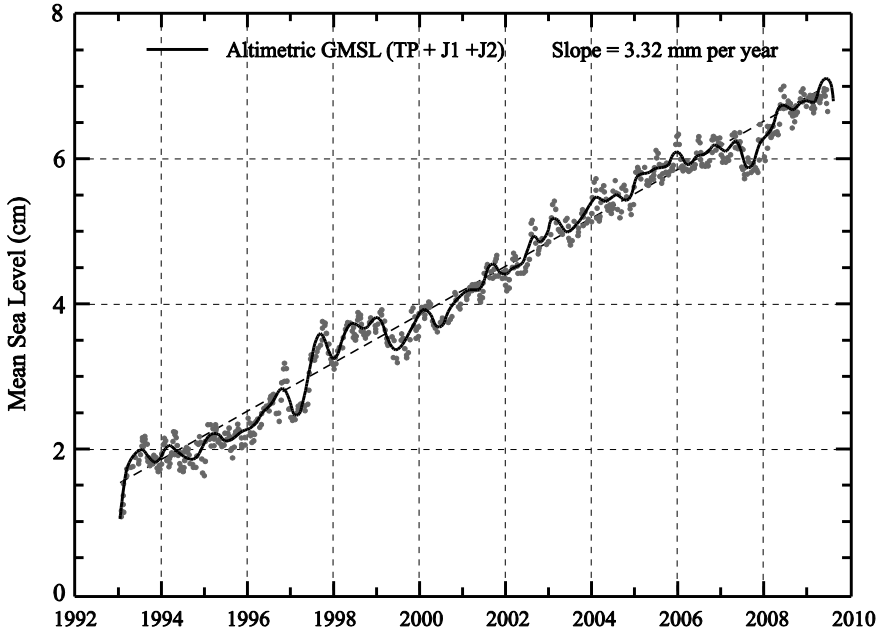
Figure 2
Global Temperatures and Carbon Dioxide 1860–2009[2]



[2] Kevin E. Trenberth, *Global warming: Coming ready or not!*, NAT'L CENTER FOR ATMOSPHERIC RESEARCH, 9 http://www.ucar.edu/educ_outreach/ulw/trenberth10.pptx (last visited Sept. 1, 2010).

Finally, Figure 3 shows the measured rate of sea level rise from 1993 to the present. This level has increased during that time by only 55 mm, part of which is due to the thermal expansion of water and the rest of which is due to outflow from melting glaciers. A question increasingly raised by climate scientists is whether global temperature and sea level will continue this steady increase, or whether they might take us across the threshold of some dynamic, sudden change and into a new climate regime. Some believe that the IPCC Consensus has understated that possibility: recent United Nations Environment Programme (UNEP) estimates show a 60% increase in the estimated melting rates of the ice caps in Greenland and Antarctica. Furthermore, the emission rates of CO_2 and other greenhouse gases are continuing to rise—now increasing annually by more than 2%. As a result, the retreats of mid-continent glaciers in the Himalayas and elsewhere are threatening water supplies needed for power and irrigation by some of the world's poorest people.

Figure 3
Sea Level is Rising: From Ocean Expansion and Melting Glaciers[3]



This is why the Sierra Club is committed to a Climate Recovery Campaign that will push both mitigation of greenhouse gas emissions as well as adaptation to the effects of present and future climate change. The Sierra Club emphasizes new renewable energy solutions like solar and wind, establishing prices on CO_2 emissions, developing building designs for energy efficiency, fixing the transportation sector with sensible biofuels and power conversions, and supporting programs for resilient habitats and sustainable human communities.

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[3] *Id.* at 19.

Members and donors of the Sierra Club—1.3 million, in fact—think they can help implement these solutions, and there is much that they and others in the environmental movement can do to promote the needed convergence between science and policy. But there is trouble ahead at the science–policy convergence, which is plagued by these eddies of disagreement between what most scientists believe and what the American public will agree on.

In reflecting on this disjuncture, it seems that it has several possible sources. One is that the science underlying climate change is complex and difficult for many of us in the scientific community to explain clearly and convincingly. Those who try may come across as smart but also arrogant or elitist. This attracts few supporters from a society in which edginess and political hostility is now everywhere close to the surface.

Second, the connection between the scientific community and the public has traditionally been mediated by transmission through the news media, and that linkage has been stunningly transformed by the financial crisis affecting publishing. Science journalists are fleeing newspapers for the blogosphere, and it appears that in the new world of news every citizen can be a reporter. As one thoughtful critic put it, we have moved from the journalism of verification to the journalism of announcement.[4]

Third, there is limited understanding about what factors govern human behavior with respect to the environment and what is happening to it. My colleague Paul Ehrlich and I once published a short piece in *Science* suggesting what we called a Millennium Assessment of Human Behavior (MAHB). MAHB would provide answers to questions like: aren't individual human decisions and actions at the root of most environmental problems? What motivates them? How do people form their own behavioral responses to new resource opportunities? In particular, with respect to this disjunction, MAHB would have answered: what makes individuals accept or reject "expert" judgments? If we cannot engage the social sciences and the humanities in this exploration, we may never understand the problem.

Finally, I want to turn to another much more troublesome source of the public response to the science. It is the existence of an active, well-financed denial industry that urgently—and often effectively—promotes the position that global warming is a hoax. Recently, it has attempted to capitalize on some emails taken illegally from a British climate center, and it has pounced on a mistake about glacial recession made by one of the IPCC working groups. None of this affects the scientific case for the IPCC Consensus, but the denial groups are able to bill it as a scandal. If one conducts a Google search for the word "climate," one gets ten entries: "Climate Gate" near the top, and—later on the list—"Climate Gate scandal," "Climate Gate emails," and "climate change hoax." This tells us at least that the denial movement understands search engine optimization.

We learn from Climate Gate that Senator James Imhofe (R-Oklahoma), ranking member of the Environment and Public Works Committee, has had the

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[4] ALEX S. JONES, LOSING THE NEWS: THE FUTURE OF THE NEWS THAT FEEDS DEMOCRACY 3 (2009).

minority staff of the Committee investigate a list of seventeen climate scientists whom he has identified as being "key players" in the Climate Gate controversy. Most of these scientists are members of the National Academy of Sciences. Senator Imhofe announced that the scientists' report may lead to exploring possible criminal penalties. An action of that kind would be as implausible as it is improper, but it suggests the extent of the backlash.

Where did all this start? For the early phases, we turn to the historian of science, University of California San Diego Professor Naomi Oreskes. She has explored the connections between different cases in which a strong scientific consensus has been challenged by powerful interests that mount a counterattack. In each instance, the counterattackers have employed a strategy called "teach the controversy," claiming that there is disagreement within the claimed scientific consensus. This technique was used previously to promote doubts that cigarette smoking causes lung cancer. The interesting part of the story is that, at some point early on, the cigarettes-and-cancer crowd had multiple personal interactions with the early members of the climate denial movement, presumably helping the latter work out their strategy. Oreskes provides details in her recent book with Conway entitled *Merchants of Doubt*. Those interested in a humorous piece about denying science for regulatory ends should consult Chris Buckley's book *Thank You for Smoking*.

One of the denial industry's most useful methods in "teaching the controversy" is to harass scientists using discovery procedures in hope of revealing issues that might weaken their case or embarrass them. One of these attempts has involved University of Arizona, where Professor Malcolm Hughes—a climate scientist distinguished enough to be listed among Senator Imhofe's proto-criminals—is pondering a demand from something called the Landmark Legal Foundation. That organization focuses much of its time on anti-immigration work, but from Professor Hughes it wants all email communications with other climate scientists and confidential peer-review documents from his correspondence with journals that have published his papers.

As a journal editor, I took the confidentiality of such material seriously, but at *Science* we also held that the primary data supporting new research findings must be shared with anyone who wanted to repeat the experiment and/or validate the result. Please understand that this request does *not* involve any such data; rather, it is a hunt for material that might prove damaging to the author's reputation, and it infringes on his private, confidential exchanges with colleagues.

Having learned of this case, I decided to write a letter to President Robert Shelton, arguing, with some legal help, that the University has a solid position for declining to make the requested documents available. This, I am happy to report, was a wasted effort, because I soon discovered that President Shelton had already decided to decline the request without persuasion.

President Shelton's highly principled position has protected the University of Arizona and its faculty from serious damage to scholarship, and confirms the University's enviable reputation in the higher education community.

The denial industry's attempt to gain access to the private communications of individual researchers exemplifies its efforts to exacerbate the disjunction between the public and scientific communities. The goal of this effort is to maintain the disparity between what the vast majority of scientists working on climate change believe—that global temperatures are increasing, and human activities are responsible—and what the general public perceives—that there is uncertainty as to either of these well-supported facts. How can the disparity be repaired? Scientists need to make strong and careful assessments of their findings—and then contest, forcefully and candidly, illegitimate claims that there are real doubts about those findings. Finally, communications among scientists and the processes of journal peer review need to be protected from those who claim access to them not to evaluate the validity of the results, but instead to construct false charges of possible misconduct. Such unfortunate efforts experienced by scientists in this institution, and support of the scientists by University of Arizona administration, constitute a case study on the importance of protecting scientific research from political attack.