Advance Written Testimony

Kerry A. Emanuel

Massachusetts Institute of Technology

Cambridge, Massachusetts

Hearing on

Climate Change: Examining the Processes Used to Create Science and Policy

House Committee on Science, Space, and Technology

U.S. House of Representatives

Thursday, March 31st 2011

Room 2321, Rayburn House Office Building

I am Kerry Emanuel, the Breene M. Kerr Professor of Atmospheric Science at the Massachusetts Institute of Technology, where I have been on the faculty for almost 30 years. I have taught atmospheric science and climate physics for nearly 33 years and am a member of the National Academy of Sciences. I am here today to affirm my profession's conclusion that human beings are influencing climate and that this entails certain risks. If we have any regard for the welfare of our descendents, it is incumbent on us to take seriously the risks that climate change poses to their future and to confront them openly and honestly.

By the closing decades of the 19th Century, science had firmly established that the main constituents of our atmosphere, molecular nitrogen and oxygen – which together comprise about 97% of the mass of the atmosphere – are almost completely transparent to solar and terrestrial radiation. Without the handful of trace gases that do interact with radiation, notably water vapor, carbon dioxide, and methane, our planet would be a snowball. Of these so-called greenhouse gases, water vapor is the most important, but cycles through the atmosphere on a time scale of roughly two weeks. Its concentration is highly variable and is controlled mostly by temperature; warming the atmosphere increases its concentration. The other important greenhouse gases include carbon dioxide, methane, and nitrous oxide. These gases have atmospheric lifetimes of decades to thousands of years and have concentrations that are approximately constant over the globe. It is a remarkable fact that these long-lived gases, though they constitute a tiny fraction of our atmosphere, make life as we know it possible. I reiterate that these basic facts of physics and chemistry were established more than a century ago and are not remotely controversial among scientists.

Already in 1897 the Swedish chemist Svante Arrhenius predicted that industrial activity would increase carbon dioxide concentrations and calculated (by hand) that doubling the concentration would cause global surface temperatures to rise by 5-6 degrees centigrade. Modern science projects somewhat lower temperature increases, but Arrhenius's estimate is remarkably close to modern estimates considering the information and techniques at his disposal. Today, students at MIT and elsewhere can do hand calculations or use simple models of radiative and convective heat transfer to explore climate physics, and they find climate sensitivities in the same range as those reported in the first National Academy of Sciences report on anthropogenic climate change in 1979. Global climate models were first developed in the 1960s and have advanced rapidly over the past few decades; they are used as tools to help us understand and predict climate, but it is not the case that they are the single or even most important tool for these purposes. Even before the advent of global models, there was enough science to warrant concern, and already in 1965 President Lyndon Johnson warned Congress that we were changing the composition of our atmosphere at our peril.

Understanding of climate physics was such that, by 1950 or so, we could state with confidence that doubling carbon dioxide concentration would increase global surface temperatures by just over 1 degree centigrade if there were no feedbacks in the system. The most important feedback – increasing water vapor with temperature – serves to amplify the warming. Other feedbacks involving clouds, aerosols, ocean currents, and many other attributes of the complex system remain somewhat uncertain, and when codified in the form of climate models are the principal sources of the still considerable uncertainty in climate projections.

Highly accurate measurements of carbon dioxide began in 1958 and show beyond doubt that concentrations have been increasing from their pre-industrial value of around 280 parts per million to over 390 parts per million today. Analysis of gas bubbles trapped in ice cores show that current levels have not been experienced on our planet for at least a million years.

It is hardly surprising the doubling the concentration of the most important long-lived greenhouse gas will lead to noticeable climate change. Paleoclimate studies inform us that climate change over the history of our planet has been caused primarily by changing sunlight, owing to changes in the sun itself and to the earth's orbit around it, to aerosol particles injected into the atmosphere by volcanoes, and by changing concentrations of greenhouse gases. For example, increased levels of greenhouses gases remain the only plausible mechanism for explaining very warm climates such as that of the Eocene around 50 million years ago, when tropical plants and animals lived near the North Pole.

Over the past few decades, when solar output, as measured by satellites, has been decreasing slightly, there is little doubt that increasing global temperature is attributable to ever more rapidly increasing concentrations of greenhouse gases. We are undertaking an enormous experiment, and so far the response of the planet has been pretty much along the lines predicted more than a century ago.

And yet our understanding of the climate system is far from perfect. We do not fully understand such issues as the feedback effects of clouds and the cooling effect that manmade aerosols have on climate. These uncertainties are reflected in climate projections, which at present range from benign to catastrophic.

It is in such a scientific environment that our generation confronts the various risks associated with climate change. These risks have been well catalogued and endlessly discussed, but let me here focus on just one: the changing distribution of the supply of water. One of the more robust consequences of a warming climate is the progressive concentration of rainfall into less frequent but more intense events. Dry areas of the world, such as the Middle East, are expected to become drier, while flash floods should become more frequent. We are already seeing evidence of these changes in rainfall data. Reductions in rainfall in semi-arid regions lead to decreasing agricultural production, which in turn leads to food shortages. The potential for political destabilization of these regions is large and is matter of great concern to our Department of Defense, as outlined in their 2007 report ***National Security and the Threat of Climate Change***[1]. To quote directly from that report: *Unlike most conventional security threats that involve a single entity acting in specific ways and points in time, climate change has the potential to result in multiple chronic conditions, occurring globally within the same time frame. Economic and environmental conditions in already fragile areas will further erode as food production declines, diseases increase, clean water becomes increasingly scarce, and large populations move in search of resources. Weakened and failing governments, with an already thin margin for survival, foster the conditions for internal conflicts, extremism, and movement toward increased authoritarianism and radical ideologies. The U.S. may be drawn more frequently into these situations, either alone or with allies, to help provide*

[1] Available from the CNA Corporation, 4825 Mark Center Drive, Alexandria, Virginia, 22311, or http://securityandclimate.cna.org/report/

stability before conditions worsen and are exploited by extremists. The U.S. may also be called upon to undertake stability and reconstruction efforts once a conflict has begun, to avert further disaster and reconstitute a stable environment. And, *The U.S. and Europe may experience mounting pressure to accept large numbers of immigrant and refugee populations as drought increases and food production declines in Latin America and Africa*.

Among the recommendations of this report is one that states that *The U.S. should commit to a stronger national and international role to help stabilize climate change at levels that will avoid significant disruption to global security and stability*.

In assessing risk, scientists have historically been notably conservative. It is part of the culture of science to avoid going out on limbs, preferring to underestimate risk to provoking the charge of alarmism from our colleagues. A good example is the recent tragic earthquake and tsunami in Japan. Examination of seismic risk maps prepared before that earthquake show that the seismologists had estimated that the magnitude of the largest earthquake that one could reasonably expect to encounter in the region was about 8.2, substantially weaker than what actually occurred. For this reason, the Fukushima-Daiichi nuclear power plant was not designed to withstand the magnitude of earthquake and tsunami that disabled it. In our own country, the levees that protect New Orleans were designed for storm surge events somewhat less severe than we now believe are likely there. And, in the climate arena, summertime arctic sea ice has been declining somewhat more rapidly than had been projected.

Far from being alarmist, scientists have historically erred on the side of underestimating risk.

In recognition of the potential importance of manmade climate change, scientists organized one of the largest efforts ever made to communicate science to the public and to policy makers. I speak of the Intergovernmental Panel on Climate Change, developed under the auspices of the World Meteorological Organization in 1988. It is strictly a communications enterprise (it neither performs nor supports research) and involves large numbers of climate scientists. In my view, the four assessment reports it has issued so far continue the conservative tradition in science. For example, in its second report, issued in 1995, fully seven years after climate scientist James Hansen told Congress he was 99% certain that increasing greenhouse gas concentrations were causing the earth to warm up, the IPCC said rather more cautiously that "*The balance of evidence suggests a discernible human influence on global climate*." But by the time it issued its most recent report, in 2007, the large amount of evidence that had accumulated in the interim forced it to conclude that *warming of the climate system is unequivocal,* and that *most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations*. The report, which includes the input of more than 1,200 authors and 2,500 scientific expert reviewers, goes on to review the evidence in great detail, including projections for the next century, likely risks, and the uncertainties involved. A great many scientists whom I know personally took time off from their research and devoted enormous effort to this enterprise whose sole aim is to provide information to people and their representatives.

In addition to the work of the IPCC, essentially all of the professional societies around the world that deal in any way with climate have issued strong statements drawing attention to the risks associated with anthropogenic climate change.

Now I want to speak to you not only as a scientist but as a citizen. I am appalled at the energetic campaign of disinformation being waged in the climate arena. I have watched good, decent, hard-working scientists savaged and whole fields of scholarship attacked without merit. Consider as an example the issues surrounding the email messages stolen from some climate scientists. I know something about this as I served on a panel appointed by the Royal Society of Great Britain, under the direction of Lord Oxburgh, to investigate allegations of scientific misconduct by the scientists working at the Climate Research Unit of the University of East Anglia. Neither we nor several other investigative panels found any evidence of misconduct. To be sure, we confirmed what was by then well known, that a handful of scientists had exercised poor judgment in constructing a figure for a non peer-reviewed publication. Rather than omitting the entire record of a particularly dubious tree-ring-based proxy, the authors of the figure only omitted that part of it that was provably false. If this was a conspiracy to deceive, though, it was exceedingly poorly conceived as anyone with the slightest interest in the subject could (and did) immediately find the whole proxy record in the peer-reviewed literature.

The true scandal here is the enormously successful attempt to elevate this single lapse of judgment on the part of a small number of scientists into a sweeping condemnation of a whole scholarly endeavor. When the history of this event is written, the efforts of those seeking to discredit climate science will be seen for what they are; why many cannot see it now is a mystery to me.

It falls to our generation to confront a global problem of potentially enormous implications. There are three aspects of this problem that make it particularly difficult to deal with:

1. It is global. All countries emit greenhouse gases to varying degrees, and it is therefore politically very difficult to regulate such emissions.

2. The risks, while potentially large, are still very uncertain, and in my view, the level of uncertainty is not likely to drop anytime soon.

3. While the costs of confronting these risks will fall largely to our generation, the primary beneficiaries of our actions will be our children and grandchildren, not us.

In facing this highly difficult problem, reasonable people will differ in what approaches to take. But citizens have a right to insist that their representatives confront this complex problem in an open and honest way. In soliciting advice, we should be highly skeptical of any expert who claims to be certain of the outcome. I include especially those scientists who express great confidence that the outcome will be benign; the evidence before us simply does not warrant such confidence. Likewise, beware those who deride predictive science in its entirety, for they are also making a prediction: that we have nothing to

worry about. And above all, do not shoot the messenger, for this is the coward's way out of openly and honestly confronting the problem.

Finally, let me emphasize what many others have pointed out before: Those nations that are first to develop sensible technology and policies to deal with climate change and pollution will likely attain great economic advantages. The market for clean energy in China alone is of staggering proportions. Nations that invest in energy research and in novel ideas in such fields as carbon sequestration and that foster enterprises that are in a position to sell such technologies to rapidly developing countries will prosper.

In her past, the U.S. helped the world confront such global problems as fascism and communism. As a citizen, I hope that my country will once again rise to the challenge and assume leadership in this arena too.

Summary of Written Testimony

1. The scientific basis for the existence of significant risks from anthropogenic climate change is solid and rests on principles established more than a century ago, as well as on records of the earth's climate as recorded by instruments and in the geologic record.
2. The conclusions of the scientific community that warming of the climate system is unequivocal, and that most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas rests on sound scientific research.
3. Historically, scientists have tended to underestimate risk.
4. Notwithstanding any of the above, there is universal agreement among scientists that current assessments of climate change risk are highly uncertain.
5. There is no scientific basis for the confidence expressed by some that the effects of climate change will be benign.
6. In respect to the stolen emails, while there is general agreement that the preparation of a particular graph by a few scientists shows poor judgment, there is no evidence for intent to deceive. Efforts by some to leverage this into a sweeping condemnation of a whole scholarly endeavor should be seen for what they are.
7. Dealing with the risks entailed in climate change will be extraordinarily difficult, and reasonable people will differ on questions of strategy. Citizens will expect their representatives to confront this issue in an open and honest way; making mascots of scientific mavericks or shooting the messengers are not rational options.
8. Nations that are first off the mark in developing new technologies and policies that address the climate issue, and selling these technologies to rapidly developing countries, will prosper.
9. We revere our forefathers for making material and mortal sacrifices for our benefit. One hopes that our descendents will hold us in similar regard.